

Employment Gap, Wage Gap and Human Capital Migration

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Abstract: In this study, we construct a dual-sector economic growth model that explicitly incorporates both the commodity-producing sector and the service sector, and we rigorously analyze how cross-sectoral human capital migration shapes sectoral economic disparities. The model yields three central findings. First, human capital accumulation serves as a fundamental engine of steady-state growth: by enhancing labor productivity and fostering innovation capacity, it promotes sustained expansion not only within each individual sector but also at the aggregate economy level, thereby generating a mutually reinforcing dynamic between sectoral development and overall macroeconomic performance. Second, the direction of human capital flows matters critically for sectoral outcomes: the immigration of human capital into the service sector accelerates its output growth by raising skill intensity, improving service quality, and stimulating knowledge-based activities, whereas the emigration of human capital from the commodity sector constrains its growth potential by depleting the skilled workforce, dampening technological adoption, and reducing productive efficiency in goods production. Third, and most importantly, the interplay between human capital accumulation and cross-sectoral migration inevitably widens sectoral economic disparities: as skilled workers gravitate toward the service sector, the resulting divergence in skill endowments amplifies productivity gaps, output per worker differentials, and wage inequalities between the two sectors, creating a cumulative causation mechanism that perpetuates and deepens structural imbalance across the economy. These results underscore the pivotal role of human capital mobility in driving both aggregate prosperity and inter-sectoral inequality.

Keywords: Human Capital Migration;

Human Capital Accumulation; Sectoral Economic Disparities; SBGP; ABGP

1. Introduction

Human capital is a crucial driver of modern economic growth, and cross-sectoral disparities in human capital constitute an important source of sectoral economic inequality. Inter-sectoral differences in human capital primarily stem from sector-specific human capital accumulation and cross-sectoral human capital migration. Human capital theory incorporates the dynamic process of human capital accumulation into economic growth models [1], and analyzes the pivotal role of human capital as a determinant of productivity growth [2].

With the advancement of fundamental human capital theory, scholarly research on human capital migration has gained increasing depth. Recent literature has examined the significant interaction effects between technological innovation and human capital development [3]; analyzed human capital accumulation as a fundamental growth driver and its complementary effects with digital transformation [4]; and revealed the nonlinear growth effects of human capital across different economic cycles [5].

Another strand of literature focuses on the relationship between human capital migration and regional economic disparities. One view argues that human capital migration widens regional economic gaps. By developing a human capital accounting framework incorporating education, health, and population dynamics, this research reveals significant cross-country variations in human capital development and their amplifying effects on regional disparities [6], analyzes the key role of human capital in explaining development gaps across emerging economies [7], and further elucidates the core mechanism whereby biased human capital allocation leads to the persistent widening of spatial disparities [8].

A third strand of literature analyzes the

relationship between human capital and structural transformation. It argues that human capital quality is a key driver of sustainable structural transformation, and that the agglomeration of high-skilled human capital in the service sector accelerates sectoral structural change [9]; that human capital quality determines the efficiency of technology adoption and the pace of industrial upgrading [10]; that human capital and institutional quality constitute parallel pathways to structural transformation [11]; and further that there exists a long-term cointegration relationship among human capital, structural transformation, and energy transition, whereby human capital serves as the key transmission mechanism through which structural transformation affects energy efficiency [12].

Existing literature has primarily examined the economic effects of cross-country or cross-regional human capital flows, while research on inter-industry human capital mobility remains relatively scarce. Industrial upgrading is of vital importance for a country's economic growth, and the theory of economic structural transformation has also become a focal point in recent theoretical research. The first strand of literature approaches the issue from the demand side, introducing non-homothetic preferences into economic growth models to derive an economic pattern characterized by simultaneous dynamic structural change and stable aggregate growth [13]. The second strand analyzes the effects of inter-sectoral technology differences on economic structural change [14-15]. The third strand integrates both supply and demand dimensions to examine the impact of structural transformation on sectoral unbalanced changes [16]. The fourth strand analyzes the nature of structural change in an open economy [17-18].

While acknowledging that sectoral human capital accumulation affects economic disparities, this paper focuses on the key role of cross-sectoral human capital migration in structural change and sectoral disparities. The main manifestation of structural change is the change of the sectoral output share. The trend of structure change is due to the difference of sectoral growth rate, and the main reason for the difference of sectoral growth lies in the difference of sectoral human capital accumulation and cross-sectoral human capital migration. While acknowledging that the sectoral human capital accumulation has an

impact on economic disparities, this paper focuses on the key role of cross sectoral human capital migration on structural change and sectoral disparities.

The biggest difference between this paper and the existing literature is that this paper believes that the most critical factor affecting human capital migration is the sectoral employment gap, not the sectoral wage gap. The sectoral employment gap, that is, the sectoral human capital gap, reflects the difference in the supply of sectoral human capital, while the sectoral wage gap reflects the difference in the derivative demand of sectoral production for sectoral human capital. In some cases, wages in the service sector are lower than those in the commodity sector, while human capital still moves into the service sector, which is more common in contemporary developed countries. This means that the wage gap between sectors may not be the fundamental factor leading to migration. In developed countries, wages are generally high, unemployment insurance benefits are also high, and people who give up employment for higher unemployment insurance benefits are also everywhere, which means that the impact of sectoral wage gap on migration is minimal. The reason why workers are willing to give up their jobs in the commodity sector and enter the service sector is mainly because the jobs in the service sector are easier to obtain. These jobs have lower requirements on skills, easier skills acquisition and lower employment threshold, which have become the main incentive factors for migration. Whereas, the relocation policy of manufacturing industry in developed countries has also led to fewer and fewer jobs in the commodity sector, and more and more jobs in the service sector. It can be seen that the sector employment gap is the key factor leading to migration behavior.

On this basis, this paper introduces the migration process of human capital by taking the sectoral employment gap as the main influencing factor, and describes the migration behavior of human capital in the baseline model. The models include the goods and services sector. Each sector accumulates human capital separately, and the migration of human capital is affected by the migration cost and the employment gap between sectors. This paper deduces the human capital migration rate in equilibrium and analyzes its influencing factors. This paper further examines the nature of sectoral economic

growth and aggregate economic growth, and believes that cross sectoral human capital migration has a key impact on sectoral economic growth. The migration of human capital hinders the growth of the commodity sector, promotes the growth of the service sector, widens the sectoral economic gap and intensifies the imbalance of sector growth.

In the extended model, this paper introduces the sectoral wage gap and sectoral technology gap into the dynamic function of migration, and examines the comprehensive impact of various factors.

This rest of this paper is organized as follows. The second part establishes the baseline model and describes the basic economic situation. In the third part, the dynamic general equilibrium model of the cross-sectoral migration of human capital is introduced. In the fourth part, the sectoral economic equilibrium is described. The fifth part describes the aggregate economic equilibrium. In the sixth part, an extended model is established to investigate the impact of sectoral wage gap and sectoral technology gap. In the seventh part, conclusions are presented.

2. Product Market

In the baseline model, we establish an economic system includes two sectors, the commodity sector and the service sector, represented by M and S , respectively. The commodity sector and the service sector independently engage in good production. The production function of the goods of the two sectors as follows:

$$Y_M = H_{Y_M}^{1-\alpha} \int_0^{A_M} x(i)^\alpha di, \quad Y_S = A_S H_{Y_S} \quad (1)$$

Where Y_M and Y_S are goods produced by the commodity sector and the service sector, respectively, and H_{Y_M} and H_{Y_S} are the amounts of human capital invested in the production process by the two sectors, respectively. $x(i)$ denotes the quantities of the different types of machines in the commodity sector, the range of machines is $[0, A_M]$, then A_M and A_S indicate the technology levels of the two sectors. We also make a simple assumption about technological advances: technological advances in both sectors are exogenous with a rate of technological progress of $g_{A_i} = 0$ ($i = M, S$). The prices of goods in the two sectors are P_i , the actual gains of human capital are w_i , and the nominal gains

of human capital are $W_i = w_i P_i$ ($i = M, S$).

The final good is a combination of the goods from both the commodity sector and the service sector, taking the following form:

$$Y = Y_S^\alpha Y_M^{1-\alpha} \quad (2)$$

Where is the output of the final good. α and $1-\alpha$ are shares of the output of the two sectors in the production process of the final good, representing the importance of the outputs of the two sectors in the production of the final good, meeting $\alpha \in (0,1)$.

The equilibrium output of the commodity sector is:

$$Y_M = \Phi A_M H_{Y_M} \quad (3)$$

Where in the decentralized economy, $\Phi = \beta^{\beta/\alpha}$, whereas in the social planner economy, $\Phi = 1$.

Given the economy's production structure, the nominal wages of the two sectors are then obtained as

$$W_M = P_M \Phi A_M = \beta \frac{Y}{H_{Y_M}}, \quad W_S = P_S A_S = \alpha \frac{Y}{H_{Y_S}} \quad (4)$$

Further, the sectoral relative wage ratio, namely, the sectoral wage gap is:

$$\frac{W_S}{W_M} = \frac{P_S A_S}{P_M \Phi A_M} = \frac{\alpha}{\beta} \frac{H_{Y_M}}{H_{Y_S}} \quad (5)$$

The representative household maximizes the total lifetime utility in the infinite term. Assuming the instantaneous utility function of a representative household has a CRRA form of utility function, then the utility function of the representative household is as follows:

$$U = \int_0^\infty \frac{C^{1-\theta} - 1}{1-\theta} e^{-\rho t} dt \quad (6)$$

Where $\rho > 0$ is the subjective time preference rate, $\theta > 0$ is the reciprocal of the intertemporal elasticity of substitution. Because we assume the presence of a unique representative consumer in an economic system, there are no differences in sectoral preferences and consumption characteristics; this assumption is required so that the model can be simplified.

3. Human Capital Market

This paper focuses on the dynamic process of human capital, which mainly includes two aspects: the process of human capital accumulation and the process of cross-sectoral dynamic flow of human capital. Human capital accumulation is the main process for sectors to obtain new human capital, and the coordinated allocation effect of cross-sectoral human capital

flow on sectoral human capital investment can not be ignored.

3.1 Cross-sectoral Human Capital Migration

Cross-sectoral human capital migration is a dynamic process, during which the factors of production are reallocated among sectors, leading to dynamic changes in sectoral economic growth rates and in their relative importance throughout the economic system.

Because of the symmetry of the model, we can assume that human capital flows from the commodity sector to the service sector. Since the production structure of the model is completely symmetrical, this assumption will not affect the model analysis.

Next, we analyze the influencing factors of the dynamic flow of human capital.

First, migration costs and benefits rise in the process of cross-sectoral human capital migration. The migration costs are generally regarded as the social resources expended in the migration process. Furthermore, we attribute the benefits generated by the migration process to the wage difference between sectors. When the benefits of migration are higher than the costs of migration, the agent can make cross-sectoral migration decisions. When the cross-sectoral migration of human capital continues to occur, a dynamic process of human capital flow is formed. When the benefits obtained from migration can not make up for the costs of migration, the process of human capital migration stops.

Secondly, the sector human capital gap is expressed as the human capital ratio of the commodity sector and the service sector, which has an important impact on the migration of human capital. Moreover, this gap also indicates the sectoral relative employment, which represents the supply and demand relationship of human capital migration between sectors. The employment of human capital immigration sector (service sector) represents the demand of human capital migration, while the employment of human capital emigration sector (commodity sector) represents the supply of human capital migration. When there is continuous human capital migration, if the gap between service sector and commodity sector expands, it means that the demand for migrant human capital is higher than the supply, and the migration of human capital will accelerate; if the sectoral human capital gap is narrowed, it means that the

supply of migrant human capital is higher than the demand. At this time, the migration of human capital will slow down.

Cross-sectoral human capital flow is a continuous and dynamic process. The quantity of instantaneous migration can be calculated by adding all of the human capital from the commodity sector to the service sector at a given point in time. Therefore, the dynamic process of human capital migration can be expressed as follows:

$$\dot{H}_F = \delta_F Z_F \eta^\psi \quad (7)$$

Where $\delta_F > 0$ is the parameter of the resource consumption rate to characterize the efficiency of human capital migration. Z_F represents the amount of instantaneous costs associated with human capital. $\eta = H_D/H_L$ shows the influence of the sectoral human capital gap on human-capital migration behavior, and the impact is portrayed by ψ . H_M and H_S are the amounts of indigenous human capital in the two sectors, respectively. Furthermore, $\eta_D = H_F/H_D$ and $\eta_L = H_F/H_L$ represent the ratios of the migrant human capital to the human capital stocks in the two indigenous sectors, measuring the effect of human capital migration on human capital accumulation in the two sectors.

The costs of human capital migration can be expressed as:

$$Z_F = z_F Y \quad (8)$$

Where $z_F > 0$ is the costs consumed by human capital migration as a proportion of total social resources. Migration cost is also the input of agents in the process of migration. Because this paper establishes the aggregate economic model, the migrant human capital refers to a certain amount of human capital in the process of migration. This paper continues the basic assumption of economic growth theory, assuming that the migration cost of a single agent is fixed, so the larger the amount of migrant human capital, the greater the total migration cost. Therefore, Eq. (9) implies that when the unit migration cost and migration efficiency are fixed, and under the influence of the sectoral relative employment, the more social resources are invested in the migration process, the greater the total cost of migration, the greater the amount of migrant human capital will be.

This paper does not introduce the sectoral wage gap as an influencing factor into the migration

dynamic function. This is because in many countries, the wages in the services are not higher than those in the manufacturing. Especially in developed countries, the wages in the services have been lower than those in the manufacturing for a long time, while the employment in the services is much higher than that in the manufacturing. In addition, due to the high wages and unemployment benefits in developed countries, workers are even willing to receive unemployment benefits and do not work. It can be seen that the incentive effect of sectoral wage gap on human capital migration is very small. Therefore, this paper considers that it may be more appropriate to describe the migration behavior with the sectoral relative employment as the influencing factor.

3.2 Human Capital Accumulation

The process of accumulating scientific and technological knowledge and improving production skills is the process of human capital accumulation. Higher human capital can obtain higher remuneration, and the level of personal salary is closely related to the level of education received.

Given that human capital migration is primarily reflected in changes in the quantity of human capital, to maintain the unity of the concept of human capital within the framework of a model, the investigation into human capital accumulation also focuses on the characterization of the increase in human capital stock. This implies that human capital is homogeneous in this paper, and human capital accumulation refers to the increase in the number of individuals with high skills. In these settings, the job-search issue resulting from the heterogeneity of human capital is discarded and the role of human capital migration in numerical change can be understood.

Because this study focuses on the dynamic migration process of human capital, the human capital accumulation process is further simplified. Assuming human capital accumulation in two sectors is only limited by their respective amounts of human capital input while ignoring the labor time and inputs of other resources expended in the human capital accumulation process, the higher the amount of human capital investment in a sector, the greater the sector's advantage in accumulating human capital. The human capital accumulation processes of the commodity sector and the

service sector can be described as follows:

$$\dot{H}_M = \delta_M H_{HM}, \quad \dot{H}_S = \delta_S H_{HS} \quad (9)$$

Where H_{HM} and H_{HS} represent the two sectors' amounts of human capital allocated to training (human capital accumulation). $\delta_M, \delta_S \in (0,1)$ is the efficiency parameter of human capital accumulation.

The human capital constraints for the two sectors are as follows:

$$\bar{H}_M = H_{YM} + H_{HM}, \quad \bar{H}_S = H_{YS} + H_{HS} \quad (10)$$

Where H_{HM} and H_{HS} are the overall stocks of human capital of the commodity sector and the service sector, respectively.

Because human capital migration has a reallocation effect on the sector's human capital stock, the total amount of sectoral human capital includes not only the amount of indigenous human capital derived from autonomous accumulation but also the added amount of human capital derived from human capital migration. The relationships between migrated human capital and indigenous human capital can be expressed as follows:

$$\bar{H}_M = H_M - H_F, \quad \bar{H}_S = H_S + H_F \quad (11)$$

Where H_M and H_S are the amounts of indigenous human capital in the two sectors. Furthermore, assuming the amounts of human capital invested during the human capital accumulation process as a proportion of the total amounts of human capital in the two sectors are u_M and u_S , then $H_{HM} = u_M \bar{H}_M$ and $H_{HS} = u_S \bar{H}_S$.

The expenditure of social resources by migration will affect the constraints of social resources and lead to the reduction of consumption. The resource constraints of the aggregate economy at time t can be expressed as follows:

$$C + Z_F \leq Y \quad (12)$$

3.3 Equilibrium Migration Conditions

The solution of the maximization of the profits in the process of human capital migration is the free entry conditions, which is shown as follows:

$$W_S - W_M = \frac{1}{\delta_F} \left(\frac{H_M}{H_S} \right)^w \quad (13)$$

Eq. (13) implies a positive correlation between nominal wage difference and sectoral relative employment. Combining Eq. (4) with Eq. (9), we obtain the following relationships:

$$W_S = \frac{\delta_F \left(\frac{H_S}{H_M} \right)^{\psi}}{1 - \frac{\beta}{\alpha} \left(\frac{1 - g_{H_S}}{\delta_S} \right) H_S + H_F} \quad (14)$$

$$W_M = \frac{\delta_F \left(\frac{H_S}{H_M} \right)^{\psi}}{\frac{\alpha}{\beta} \left(\frac{1 - g_{H_M}}{\delta_M} \right) H_M - H_F - 1} \quad (15)$$

Where g_{H_M} and g_{H_S} are the human-capital accumulation rates of the two sectors, respectively. Eq. (15) implies that the higher the nominal wage of the labor-immigration sector, the greater the incentive for the labor migration to this sector; whereas the lower the nominal wage of the labor-emigration sector, the greater the incentive for labor to move out of this sector. In this case, labor migration is faster.

4. Sectoral Economic Equilibrium

With a continuous cross-sectoral flow of human capital, economic resources are reallocated among sectors and as a result, the two sectoral economies gradually achieve the BGP equilibrium. When sectoral economies achieve equilibrium, the aggregate economy also achieves dynamic equilibrium. The current-value Hamiltonian is constructed as follows:

$$\begin{aligned} H &= \ln C + I_{H_M} \dot{H}_M + I_{H_S} \dot{H}_S + I_{H_F} \dot{H}_F \\ &\text{s.t.} \end{aligned} \quad (16)$$

$$C = (1 - z_F) [A_S (1 - u_S) H_{S_A}]^{\eta} [A_M (1 - u_M) H_{M_A}]^{\beta}$$

Where C , u_M , u_S and z_F are control variables; H_M , H_S and H_F are state variables; λ_{H_M} , λ_{H_S} and λ_{H_F} are Hamilton multipliers; , and are shown in Eqs. (6) and (8) and constrained by Eqs. (7), (9) and (11). By solving this Hamiltonian system, we see that the main characteristics of both the sectoral economy and the aggregate economy are on the equilibrium growth path.

Sectoral economic equilibrium refers to the equilibrium allocation achieved under the conditions that a sector's market elements are all clear and its consumers achieve intertemporal optimization. The sectoral balanced growth path (SBGP) is a path formed by all of the sector's equilibrium allocations; it allows the sector's interest rate to remain constant in SBGP. The aggregate economic equilibrium refers to the

equilibrium allocation achieved under the conditions that the market elements of all of the economic system's sectors are clear and that intertemporal optimization is achieved for aggregate consumption. The aggregate balanced growth path (ABGP) is a path formed by the equilibrium allocation of the aggregate economy, which is characterized by an aggregate economy interest rate that remains constant. By solving the dynamic optimization problem shown in Eq. (12), the growth rate of each of the major variables of SBGP and ABGP can be obtained and individually analyzed through the following propositions.

4.1 Affiliations

By solving the Hamiltonian system shown in Eq. (16), the equilibrium human-capital migration rate can be obtained as shown in the following proposition.

Proposition 1: In the cross-sectoral human capital migration model, there is a unique SBGP economic equilibrium for the commodity sector and the service sector, respectively. When the commodity sector and the service sector are on their respective SBG paths, the aggregate economy is also on the ABG path. In addition, the human-capital migration rate that meets the requirements of the ABGP equilibrium and the SBGP equilibrium is the equilibrium human capital migration rate, represented by the constant in the following equation:

$$g_{H_F} = \frac{[\theta \delta_F \eta^{\psi} (W_S - W_M) - \rho] - (\theta - 1) [\alpha \delta_S + \beta \delta_M]}{\theta + \frac{\psi(\theta - 1)}{\delta_F \eta^{\psi}} \left[\frac{\alpha \eta_S \delta_S}{W_S} - \frac{\beta \eta_M \delta_M}{W_M} \right]} \quad (17)$$

Proposition 1 shows that the migration of human capital will not only affect human capital accumulation in both sectors but also have an impact on economic growth in both sectors. Therefore, the equilibrium human capital migration rate is the equilibrium rate that can ensure that the sectoral economy will follow the SBG path. In addition, human capital migration closely links the two interdependent sectors and promotes that the entire economic system reaches the ABGP equilibrium. Therefore, the equilibrium human capital migration rate is also a human capital migration rate that is consistent with the ABGP equilibrium. The effects of the influencing factors are as follows.

4.2 Human Capital Migration Efficiency

The higher the efficiency of human capital migration, the more favorable the cross-sectoral

economic systems and environments are for that migration. A higher efficiency of human capital migration is associated with a highly efficient immigration system, convenient traffic conditions and living conditions, along with a weaker constraint on factors such as the household registration system. These factors will provide institutional and environmental guarantees for human capital migration and can increase the human-capital migration rate.

4.3 Human Capital Accumulation Efficiency

There should be a negative correlation between the human capital accumulation efficiency and the human capital migration rate. When human capital accumulation efficiency is higher, the supply of human capital in the service sector is increasing, and the demand for new migration of human capital is decreasing. Whereas the increase in the human capital in the commodity sector implies a rapid growth in this sector, and this will reduce the migration of human capital.

4.4 Sectoral Human Capital Gap

The effect of human capital gap is primarily seen in the form of direct and indirect roles. The sectoral human capital gap's direct role in human capital migration can be investigated for the items that contain h and y . The larger the sectoral human capital gap (h) and the sensitivity of human capital migration to the human capital gap (y), the faster the human capital migration rate. Individuals tend to migrate to the service sector to achieve higher social status. The human capital gap also reflects the sectoral gaps in sectoral development prospects and each individual's career development. Therefore, human capital groups in the service sector can attract human capital in the commodity sector, thus accelerating the process of human capital migration.

The indirect role of the human capital gap on human capital migration is primarily reflected in the ratios of η_M and η_S , the migrant human capital on the indigenous human capital in the two sectors, meeting the requirements of $\partial g_{H_F} / \partial \eta_M > 0$ and $\partial g_{H_F} / \partial \eta_S < 0$. This indicates that the higher the proportion of the migrant human capital in relation to the indigenous human capital in the service sector, the more crowded the human capital is, and the greater the obstacle to immigration. The higher

the proportion of the migrant human capital in relation to the indigenous human capital in the commodity sector, the greater the incentive for human capital emigration and the more easily the human capital migrates out of the commodity sector.

4.5 Sectoral Nominal Wage

The human capital gap also has an indirect effect on human capital migration through the two sectors' nominal wages. It is noteworthy that $\partial g_{H_F} / \partial W_S > 0$ and $\partial g_{H_F} / \partial W_M < 0$, which mainly manifest the incentive of sectoral wage gap to human capital migration. The increase of wages in the service sector will stimulate the inflow of human capital, while the wage increase in the commodity sector will hinder the outflow of human capital. Eq.(17) intuitively reveals the mechanism that nominal wages affect the migration of human capital.

5. SBGP Human Capital Accumulation Rate

In the Hamiltonian system shown in Eq.(16), the equilibrium human-capital accumulation rates of the two sectors can be solved, as shown in the following proposition.

Proposition 2: In the cross-sectoral human capital migration model, when the commodity sector and the service sector are on their respective SBG paths, human capital accumulation behaviors also achieve SBGP equilibrium. The SBGP human-capital accumulation rates of the two sectors are as follows:

$$g_{H_S} = \delta_S(1 + \eta_S) + \frac{\alpha\eta_S\delta_S}{W_S} \{ \theta g_{H_F} - \delta_F \eta^w (W_S - W_M) + \rho - \psi(\theta - 1) [\delta_S(1 + \eta_S) - \delta_M(1 - \eta_M)] \} \quad (18)$$

$$g_{H_M} = \delta_M(1 - \eta_M) - \frac{(1 - \alpha)\eta_M\delta_M}{W_M} \{ \theta g_{H_F} - \delta_F \eta^w (W_S - W_M) + \rho - \psi(\theta - 1) [\delta_S(1 + \eta_S) - \delta_M(1 - \eta_M)] \} \quad (19)$$

5.1 Human Capital Accumulation Efficiency

Eq. (18) shows that the human capital accumulation rate in the service sector is higher by a factor of $(1 + \eta_S)$ compared to the case without migration. This means that human capital accumulation in the service sector needs to change from the base volume of human

capital at the time of the absence of human capital migration to continuously accelerated growth of the base volume at the time of human capital migration. Therefore, Eq. (18) demonstrates that human capital migration increases the service sector's stock of human capital and improves the economic effect of the human capital accumulation in the service sector.

Accordingly, Eq. (19) implies that the human capital accumulation rate in the commodity sector needs to decrease by $(1-\eta_M)$ times based on the sector's human-capital accumulation efficiency parameter, indicating that the outflow of human capital reduces the commodity sector's stock of human capital to $\bar{H}_M$. With the continuous outflow of human capital, $\bar{H}_M$ keeps decreasing, therefore, the human capital accumulation in the commodity sector has a continuously decelerated growth.

5.2 Human Capital Accumulation Gap

By solving the Hamiltonian in Eq. (16) and combining Proposition 2, the cross-sectoral gap in human capital accumulation can be obtained, as shown in the following proposition.

Proposition 3: In the cross-sectoral human capital migration model, the gap in SBGP human capital accumulation rate between the two sectors is as follows:

$$g_{H_S} - g_{H_M} = \frac{\theta g_{H_F} - [\delta_F \eta^\psi (W_S - W_M) - \rho]}{\psi(\theta - 1)} \quad (20)$$

This implies that both human capital migration and human capital accumulation are interdependent. The faster human capital moves out of the commodity sector and into the service sector, the faster the human capital accumulation in the service sector, the slower the accumulation of human capital in the commodity sector, and the greater the sectoral human capital gap will be, which will attract human capital to further move out of the commodity sector and improve the migration speed of human capital.

Human capital migration and human capital accumulation in the service sector exhibit an interactive positive externality, whereas human capital migration and human capital accumulation in the commodity sector exhibit an interactive negative externality. The interactive externalities are the primary form of interaction between human capital migration and human capital accumulation.

5.3 The SBGP Economic Growth Rate

By solving the Hamiltonian system in Eq. (16), the SBGP economic growth rates of the two sectors can be obtained, as shown in the following proposition.

Proposition 4: in the cross-sectoral human-capital flow model, when the commodity sector and the service sector are on their respective SBG paths, the economic growth in the two sectors achieves the SBGP equilibrium. The SBGP economic growth rates of the two sectors are as follows:

$$g_{Y_S} = (\delta_S - \rho) + \left(1 + \frac{\psi \eta_S \delta_S}{\delta_F \eta^\psi W_S}\right) g_{H_F} - [\delta_F \eta^\psi (W_S - W_M) - \rho] \quad (21)$$

$$g_{Y_M} = (\delta_M - \rho) + \left(1 - \frac{\psi \eta_M \delta_M}{\delta_F \eta^\psi W_M}\right) g_{H_F} - [\delta_F \eta^\psi (W_S - W_M) - \rho] \quad (22)$$

5.4 The Gap in SBGP Growth Rate

Human capital migration can influence economic growth either directly or indirectly. Eqs. (13) and (14) can also be presented in the following forms:

$$g_{Y_S} = (\delta_S - \rho) + \frac{\psi \eta_S \delta_S}{\delta_F \eta^\psi W_S} g_{H_F} - (\theta - 1)[g_{H_F} - \psi(g_{H_S} - g_{H_M})] \quad (23)$$

$$g_{Y_M} = (\delta_M - \rho) - \frac{\psi \eta_M \delta_M}{\delta_F \eta^\psi W_M} g_{H_F} - (\theta - 1)[g_{H_F} - \psi(g_{H_S} - g_{H_M})] \quad (24)$$

From Eqs. (23) and (24), the gap in sectoral economic growth rate at equilibrium can be obtained as follows:

$$g_{Y_S} - g_{Y_M} = \delta_S - \delta_M + \frac{\psi}{\delta_F \eta^\psi} \left(\frac{\eta_S \delta_S}{W_S} + \frac{\eta_M \delta_M}{W_M} \right) g_{H_F} \quad (25)$$

Human capital investment efficiency directly restricts the human capital accumulation rate, and the cross-sectoral migration behavior of human capital also affects the stock and accumulation rate of human capital, both of which affect the sectoral economy through the output effect and the growth effect. The gap in sectoral human capital investment efficiency and cross-sectoral human capital migration behavior are key factors that cause both unbalanced sectoral economic development and changes in sectoral economic disparities.

When the service sector always maintains a high investment efficiency of human capital, or

human capital keeps moving into the service sector, then cross-sectoral economic disparity gradually expands. Changes in cross-sectoral economic disparity lead to changes in cross-sectoral economic status and cross-sectoral competitiveness, situating the sectoral economies within dynamic unbalanced changes.

5.5 The Influencing Factors of the SBGP Economic Growth

The first items of Eqs. (21) and (22) imply that the SBGP economic growth rates of the two sectors depend primarily on their human capital accumulations, in which the higher the human capital accumulation efficiencies of and , the faster the economic growth rates of the two sectors.

Eq. (25) implies that the second terms in Eqs. (23) and (24) measures the difference of the economic growth rate and the human capital investment efficiency in the commodity sector and the service sector. Eq. (23) also shows that the economic growth rate in the service sector would have some increase based on the effect of human capital inflow. While human capital migration would also result in an expanding gap between human capital stocks, which could have an adverse effect on the sector's economic growth. This adverse effect can be expressed by the item $\psi\eta_S\delta_S / (\delta_F\eta^\psi W_S)$. Ultimately, the economic growth rate in the service sector increases by $g_{H_F}\psi\eta_S\delta_S / (\delta_F\eta^\psi W_S)$ based on the term $(\delta_S - \rho)$ in Eq. (23).

Similarly, human capital outflow will result in economic slowdown in the commodity sector. This slowdown effect is partially offset by the negative effect resulting from the widening sectoral human capital gap, represented by the term $\psi\eta_M\delta_M / (\delta_F\eta^\psi W_M)$. Ultimately, the economic growth rate in the commodity sector decreases by $g_{H_F}\psi\eta_M\delta_M / (\delta_F\eta^\psi W_M)$ based on the term $(\delta_M - \rho)$.

The third terms in Eqs. (23) and (24), $g_{H_F} - \gamma(g_{H_S} - g_{H_M})$, can be regarded as the difference of the change rate of H_F and η^ψ . The human capital migration effect caused by the human capital gap (η) is only a part of the total effect of human capital migration, thus g_{H_F} is greater than $\psi(g_{H_S} - g_{H_M})$. The gap between

H_F and $\psi(g_{H_S} - g_{H_M})$ measures the effect of human capital migration caused by the social resources invested in the process of human capital migration (Z_F). Because Z_F is an expenditure of the total resources of society, the effect of human capital migration caused by Z_F is negatively correlated with the sectoral economic growth rate g_{Y_S} and g_{Y_M} .

6. The ABGP Equilibrium

By solving the Hamiltonian system in Eq. (16), the ABGP growth rate of the aggregate economy can be obtained, as shown in the following proposition.

Proposition 5: In the cross-sectoral human capital migration model, when the commodity sector and the service sector are on their respective SBG paths, the aggregate economy achieves its unique ABGP equilibrium, and the ABGP growth rate of the aggregate economy is as follows:

$$g_Y = \frac{1}{\theta - 1} \left[[\delta_F \eta^\psi (W_S - W_M) - \rho] - g_{H_F} \right] \quad (26)$$

In this study, although the SBGP growth rates of sectoral economies are different from each other, the aggregate economy can achieve a long-term growth at a stable and constant growth rate. This implies that although the sectors are experiencing unbalanced economic growth, the aggregate economy achieves balanced growth. Human capital migration behavior dynamically links the two sectors to make it possible for economic resources and factors to flow dynamically between them and achieve the optimal allocation so that the two sectors become a unified economy and as the two sectors travel along their respective SBG paths, the aggregate economy also reaches the ABGP equilibrium.

6.1 ABGP Growth and SBGP Growth

Proposition 5 explicitly shows that the relationship between the ABGP growth rate of the aggregate economy and the SBGP growth rate of the sectoral economy, as well as the relationship with the difference in sectoral economic growth rate, shown as follows:

$$g_Y = \frac{\delta_F \eta^\psi [(\delta_S - \delta_M) - (g_{Y_S} - g_{Y_M})]}{\psi(\theta - 1) \left(\frac{\eta_S \delta_S}{W_S} + \frac{\eta_M \delta_M}{W_M} \right)} + \frac{\delta_F \eta^\psi (W_S - W_M) - \rho}{\theta - 1} \quad (27)$$

Eq. (27) implies a negative correlation between ABGP growth rate and the gap in SBGP growth rate. Due to the weighted average relation between ABGP growth rate and SBGP growth rates, the widening gap in SBGP growth rate implies more unbalance sectoral development, thus ABGP economic growth will be hindered.

Eqs. (21) and (22) also show that

$$g_Y = \frac{1}{\theta} \left[(\delta_S - \rho) + \frac{\psi \eta_S \delta_S}{\delta_F \eta^W W_S} g_{H_F} - (g_{Y_S} - g_Y) \right] \quad (28)$$

$$g_Y = \frac{1}{\theta} \left[(\delta_M - \rho) - \frac{\psi \eta_M \delta_M}{\delta_F \eta^W W_M} g_{H_F} + (g_Y - g_{Y_M}) \right] \quad (29)$$

Eq. (28) implies that $g_{Y_S} > g_Y > g_{Y_M}$. Consider the scenario that the gap in SBGP growth rate remain unchanged. Consider a scenario where the gap in SBGP growth rates remains unchanged. If the ABGP growth rate is pulled downward toward the lower sectoral growth rate, the gap between the ABGP growth rate and the service sector's growth rate widens, and the ABGP growth rate declines. Thus, a negative correlation exists between the ABGP growth rate and the growth rate of the service sector. Conversely, if the ABGP growth rate is pulled upward toward the commodity sector's growth rate, the gap with the commodity sector's growth rate widens, and the ABGP growth rate increases, implying a positive correlation.

6.2 ABGP Growth and Human Capital

Eq. (26) implies that the relationship between the ABGP growth rate and the human capital migration rate is as follows:

$$g_Y = g_{H_F} - \psi(g_{H_S} - g_{H_M}) \quad (30)$$

Eq. (30) implies that the gap between the human capital migration rate and the ABGP growth rate is $\psi(g_{H_D} - g_{H_L}) > 0$, thus $g_Y < g_{H_F}$. This is because human capital migration is only one of the dynamic behaviors that drive the ABGP economic growth, and human capital accumulation plays a more important role in the ABGP economic growth.

Proposition 4 and Eq. (30) show the relationship between the ABGP growth rate of the aggregate economy and the gap in human capital migration rates, shown as follows:

$$g_Y = \frac{\delta_F \eta^W (W_S - W_M) - \rho - \psi(g_{H_S} - g_{H_M})}{\theta} \quad (31)$$

Eqs. (32) and (33) show that the greater the gap in sectoral human capital accumulation rate, the slower the ABGP economic growth. The ABGP

economic growth is the weighted average of sectoral economic growth, and human capital accumulation is the main reason for the sectoral economic disparity. Whereas the widening gap in sectoral human capital accumulation means that sectoral economic development is more unbalance, which will reduce the ABGP economic growth.

7. The Impact of Technological Gap and Wage Gap on Migration

In this section, we establish an extended model to discuss the impact of sectoral wage gap and sectoral technological gap on human capital migration.

Sectoral wage gap is another important factor affecting migration. Because agents are profit seeking, they tend to migrate to higher wage sectors. If the wage of the service sector is higher than that of the commodity sector, it will form an incentive for migration. Moreover, the sectoral wage gap represents the benefits of migration to a certain extent, and the social resources consumed in migration can be regarded as the cost of migration. When the benefit of migration is greater than the cost, the migration behavior will continue.

Eq. (3) implies that the sectoral wage gap is negatively correlated with the sectoral employment gap. To some extent, the sectoral wage gap represents the demand of the service sector for the migrated human capital, while the sectoral employment gap represents the supply of the commodity sector for the migrated human capital. Therefore, the role of sectoral wage gap and sectoral employment gap on migration is opposite.

In the early stage of migration, the wages in the service sector are higher and the stock of human capital is lower, so the incentive effects of sectoral wage gap and sectoral employment gap on migration are both positive. This situation represents the situation of developing countries in the early stage of structural change. In the late stage of migration, the human capital stock of the service sector is high, which may depress the per capita wage for employment, and even cause the wage of the service sector to be lower than that of the commodity sector. At this time, the incentive effect of the sectoral wage gap on migration is negative. However, due to the rapid development of the service sector, it can still provide jobs for the newly migrated human capital, so the incentive effect of the sectoral

employment gap on migration is still positive. This situation is similar to that in the basic model of this paper, which also represents the situation of developed countries in the late stage of structural change.

Sectoral technology gaps also have an important impact on migration. The sectoral technology gap represents the gap in the level of development between sectors, and also has an impact on the sectoral wage gap. Therefore, it is meaningful to consider the impact of sectoral technology gap on migration.

Based on the above considerations, we establish the following extended model, and rewrite the dynamic process of human capital migration as:

$$\dot{H}_F = \delta_F z Y \eta^\psi \left(\frac{A_S}{A_M} \right)^\varepsilon \left(\frac{W_S}{W_M} \right)^\phi \quad (32)$$

Solving the current-value Hamiltonian shown in Eq. (16) under the constraint of Eq. (34), we obtain the following proposition.

Proposition 6: In the extended model, there is a unique SBGP economic equilibrium for the commodity sector and the service sector, respectively. When the commodity sector and the service sector are on their respective SBG paths, the aggregate economy is also on the ABG path. In addition, the human-capital migration rate that meets the requirements of the ABGP equilibrium and the SBGP equilibrium in the extended model is as follows:

$$\begin{aligned} g_{H_F} &= [\Theta \delta_S + \delta_M - (1 + \Theta) \Gamma_F] \\ &\quad \left\{ \frac{\psi}{\frac{\delta_F \eta^\psi}{\varepsilon + \alpha} \left(\frac{A_S}{A_M} \right)^\varepsilon \left(\frac{W_S}{W_M} \right)^\phi} \left[\frac{\eta_M \delta_M}{(\varepsilon + \phi)(1 - \alpha) W_M} \right. \right. \\ &\quad \left. \left. - \frac{\eta_S \delta_S}{\alpha W_S} \frac{\Theta}{\alpha - \phi - \frac{\alpha(\varepsilon - \beta)}{\beta}} \right] - \Lambda \right\} \\ \Theta &= \frac{\alpha + \psi(1 + \eta_S) - \phi}{\beta - \psi(1 - \eta_M) + \phi}, \\ \Lambda &= \frac{2\psi\eta_M\Theta}{\alpha + \psi(1 + \eta_S) - \phi} \end{aligned} \quad (33)$$

The human capital accumulation rates of SBGP in service sector and commodity sector in the extended model are as follows:

$$\begin{aligned} g_{H_S} &= (1 + \eta_S) \delta_S + (\eta_S + \Gamma_S) g_{H_F} \\ &\quad - \left\{ (1 + \eta_S) \frac{\delta_F \eta^\psi}{\varepsilon + \alpha} \left(\frac{A_S}{A_M} \right)^\varepsilon \left(\frac{W_S}{W_M} \right)^\phi \right. \\ &\quad \left. \left[W_S \left(1 - \frac{\phi}{\alpha} - \frac{\varepsilon - \beta}{\beta} \right) - W_M \frac{\varepsilon + \phi}{\beta} \right] \right\} \end{aligned} \quad (34)$$

$$\begin{aligned} g_{H_M} &= (1 - \eta_M) \delta_M + (2 - \eta_M - \Gamma_M) g_{H_F} \\ &\quad - \left\{ (1 - \eta_M) \frac{\delta_F \eta^\psi}{\varepsilon + \alpha} \left(\frac{A_S}{A_M} \right)^\varepsilon \left(\frac{W_S}{W_M} \right)^\phi \right. \\ &\quad \left. \left[W_S \left(1 - \frac{\phi}{\alpha} - \frac{\varepsilon - \beta}{\beta} \right) - W_M \frac{\varepsilon + \phi}{\beta} \right] \right\} \end{aligned} \quad (35)$$

The SBGP economic growth rate of service sector and commodity sector in the extended model are as follows:

$$\begin{aligned} g_{Y_S} &= \delta_S - \frac{\delta_F \eta^\psi}{\alpha} \left(\frac{W_S}{W_M} \right)^\phi \left[W_S \left(2 - \frac{\phi}{\alpha} \right) - W_M \frac{\phi}{\beta} \right] \\ &\quad + \left[1 + \frac{\psi \eta_S \delta_S}{(2\alpha - \phi) \delta_F \eta^\psi W_S \left(\frac{W_S}{W_M} \right)^\phi} \right] g_{H_F} \end{aligned} \quad (36)$$

$$\begin{aligned} g_{Y_M} &= \delta_M - \frac{\delta_F \eta^\psi}{\alpha} \left(\frac{W_S}{W_M} \right)^\phi \left[W_S \left(2 - \frac{\phi}{\alpha} \right) - W_M \frac{\phi}{\beta} \right] \\ &\quad + \left[1 - \frac{\psi \eta_M \delta_M}{\phi \delta_F \eta^\psi W_M \frac{\beta}{\alpha} \left(\frac{W_S}{W_M} \right)^\phi} \right] g_{H_F} \end{aligned} \quad (37)$$

The ABGP growth rate of the aggregate economy in the extended model is as follows:

$$\begin{aligned} g_Y &= \frac{\frac{\delta_F \eta^\psi}{\alpha} \left(\frac{W_S}{W_M} \right)^\phi \left[W_S \left(2 - \frac{\phi}{\alpha} \right) - W_M \frac{\phi}{\beta} \right] - g_{H_F}}{\theta - 1} \\ \Gamma_F &= \frac{\delta_F \eta^\psi}{\varepsilon + \alpha} \left(\frac{A_S}{A_M} \right)^\varepsilon \left(\frac{W_S}{W_M} \right)^\phi \\ &\quad \left[W_S \left(1 - \frac{\phi}{\alpha} - \frac{\varepsilon - \beta}{\beta} \right) - W_M \frac{\varepsilon + \phi}{\beta} \right] \\ \Gamma_S &= \frac{\psi}{\alpha - \phi - \frac{\alpha(\varepsilon - \beta)}{\beta}} \frac{\eta_S (1 + \eta_S) \delta_S}{\frac{\alpha \delta_F \eta^\psi W_S}{\varepsilon + \alpha} \left(\frac{A_S}{A_M} \right)^\varepsilon \left(\frac{W_S}{W_M} \right)^\phi} \\ \Gamma_M &= \frac{\psi}{\varepsilon + \phi} \frac{\eta_M (1 - \eta_M) \delta_M}{\frac{\beta \delta_F \eta^\psi W_M}{\varepsilon + \alpha} \left(\frac{A_S}{A_M} \right)^\varepsilon \left(\frac{W_S}{W_M} \right)^\phi} \end{aligned} \quad (38)$$

The human capital migration rate of the extended model is generally smaller than that of the baseline model, because the extended model incorporates additional frictions (e.g., wage and technology gaps) that may slow migration.

8. Conclusions

In this study, a macroeconomic model including human capital accumulation and human capital migration is constructed. Both the economic mechanism of the interaction between cross-sectoral human capital migration and human

capital accumulation and the mechanism of the unbalanced sectoral economic growth and sectoral economic gap are systematically analyzed. The nature of the aggregate economy on the ABGP is further examined, and the theory of cross-sectoral human capital migration has been substantially developed from the macro perspective of dynamic general equilibrium.

The study concludes that whereas human capital accumulation is an essential factor causing sectoral economic disparities, human capital migration leads to cross-sectoral reallocation of human capital and further aggravates the unbalanced growth of sectoral economies. Under normal circumstances, the outflow of human capital from the commodity sector deteriorates its economic development, whereas the inflow of human capital to the service sector will promote its development. Under the action of the market mechanism, the free allocation of human capital leads to a prosperous economy in the service sector and a relatively stagnant economy in the commodity sector, expanding sectoral economic disparities.

Finally, our model could be further extended in several directions, including by considering more complex factors affecting human capital migration, and considering the influence of human capital migration on sectoral technological progress and urbanization.

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