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R & D Sector Outsourcing, Human Capital Formation and Growth in the Context of Developed versus Developing Economies

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Abstract

A skill-biased endogenous growth has model has been considered where Research and Development (R & D) producer of the advanced economy outsource its R & D activity to a relatively technologically backward economy. R & D producer of the advanced economy endogenously determines the equilibrium proportion of R & D activity which takes an intermediate value. An advanced economy relies on the innovation activity for its technology improvement. Whereas a backward economy depends on both the imitation and the innovation activities – innovation being more skilled-intensive than imitation. This paper theoretically examines the impact of R & D outsourcing from an economy which is in the innovation-only regime to an economy which is in the imitation-innovation regime. It shows that dependence on the imitation activities rises and as a consequence of which proportion of skilled human capital falls and both skilled and unskilled human capital shift away from the innovation to the imitation activities in the backward economy. This also leads to a higher wage rate of both skilled and unskilled human capital in the backward economy. As a result proportion of outsourcing from advanced economy to backward economy falls. However, growth rate of the backward economy initially rises and eventually declines as time progresses. In the long run backward economy will get into a low equilibrium trap and gap from the world technology frontier widens.

Journal of Economic Literature Classifications: I24, J20, O30, O31, O33, O40.

Key Words: R & D activity, Outsourcing, Economic Growth, Endogenous Labor Composition, Imitation-Innovation, Convergence.

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1 Introduction

The WIR [2005] pointed out that due to the improvement of telecommunication services, the outsourcing of R & D activities to the developing countries, specifically to the Asian economies, has risen over time. WIR [2005] findings reveal that around 800 leading global transnational corporations are operating their R & D centers and R & D based firms in India and China, mainly in the information & communication technology, telecommunications, pharmaceuticals and automobile sectors. According to the ranking of R & D spending in 2002, China holds the sixth position in the world. Among the developing economies, South-East Europe and Common Wealth of Independent States, China, Korea, Russian Federation, India and Singapore respectively hold the first, second, fifth, sixth and eighth positions. In view of the growing importance of R & D outsourcing, one could study the impact of these phenomena on the growth rate and the convergence process in both the advanced and the backward countries.

In this respect, first, the consequences of the R & D outsourcing for the originating economy are analyzed.[1] On the one hand, attracted by cheap human capital in the relatively backward economy, an intermediate input producer of the advanced economy has the incentive to outsource its innovation activity, hence spurring technological change and economic growth. But on the other hand, innovation is skilled human capital intensive and the relative composition of skilled human capital is low in the backward economy, thus lowering the technological change and therefore the growth rate in the short run. So, by considering these two opposing effects, the optimal R & D outsourcing by the intermediate input producer in the advanced economy is endogenized in our research. Additionally, due to outsourcing, the demand for human capital decreases in the advanced economy, which may reduce wages and consequently, the income of the individuals in the advanced economy. Thus, it is possible that in the originating economy R & D outsourcing may increase the short run benefit of the intermediate input producers but may reduce the increment to technology level in the long run. In this context, the combined impacts of these opposing effects on the short run and the long run growth rate of the advanced economy is studied.

Next, the consequences of R & D outsourcing on growth in the destination economy are illustrated. Being a backward economy (that is, in the imitation-innovation regime) it would direct a proportion of its skilled and unskilled human capital in the R & D activity of the advanced economy (this one being in the innovation-only regime) instead of its own technology improvement, thus *lowering* its own economic growth rate. On the one hand, outsourcing might raise the relative composition of skilled human capital in

[1] Advanced economy which is in the innovation-only regime originates R & D outsourcing activity. So, orginating and advanced economies are used as synonyms. Similarly, a backward economy which is in the imitation-innovation regime is the destination source of the R & D activity. Thus, this part of research considers destination and backward economies as synonyms.

the backward economy and consequently may *increase* the technology level. Moreover, it may increase the income of skilled and unskilled human capital in the short run. On the other hand, in the long run, this may *increase the technology gap* between the destination economy and the originating economy. Seemingly, in the short run, outsourcing may increase the income level of the destination economy but in the long run it may be harmful for it. So, there is an intertemporal trade off in terms of the benefits of the different generations. This research incorporates a theoretical analysis of the impact of these two opposing effects on the growth rate and the convergence condition of the destination economy in a dynamic endogenous skill-bias growth framework. Furthermore, the analysis captures the effect of R & D outsourcing on the income, consumption and inequality paths of skilled and unskilled human capital in these two countries. To the best of our knowledge, this would be the first theoretical analysis of the economy-wide decision of outsourcing of R & D activity and the impact of that on growth, inequality and convergence condition for relatively advanced and backward economies.

The existing literature mainly concentrates on outsourcing of basic production, which is mostly unskilled labor-intensive. The existing studies largely focus on the rising inequality debate within these countries. The phenomenon of rising inequality is attributed to skilled-biased technical change[2] or to the increase in import competition from the low-wage countries.[3] Supporting the second view Feenstra and Hanson [1995] shows that if there is a shift in the production activities to the South any relative increment in the capital stock of the South or neutral technological progress in the South would raise the wage inequality in both the Northern and Southern economies.[4] This theoretical analysis of Feenstra and Hanson [1995] considers a single industrial output which is produced by a continuum of intermediate inputs. Intermediate inputs are produced by capital and by skilled and unskilled workers. Also, it is assumed that South is producing and exporting a certain range of intermediate inputs (up to a critical level of skilled to unskilled ratio) and North is producing the remaining. An increment in relative capital stock or neutral technological progress in the South raises the skilled intensive production/ export of South. This raises the relative demand for skilled workers in both the Northern and Southern countries, which leads to an increment in the relative wage rate of skilled workers in both the groups of countries. Their study also reveals that 31-51 percent increment in the relative wage rate of skilled worker during the period 1980's in United States of America (USA) is explained by the increasing trend of imports.

However, on the contrary, in a dynamic framework, Glass and Saggi [2001] shows that as an advanced economy outsources its unskilled intensive production goods to the South, there is a reduction in the cost

[2]See Davis and Haltiwanger [1991], Lawrence et al. [1993] and Berman et al. [1994].

[3]Leamer [1993], Leamer [1994], Borjas and Ramey [1995], Wood [1994] and Hijzen [2007] show that both the factors have significant impact.

[4]Feenstra and Hanson [1996] also postulates similar findings.

of production. This results in higher profitability and higher incentive for technology improvement. This increment in innovation can potentially create gains sufficient to offset the decline in the Northern wages. This leads to a fall in the relative wage gap between developed and developing economies. Instead of the assumption of Feenstra and Hanson [1995], that difference in capital stock is the driving factor behind outsourcing, Glass and Saggi [2001] assumes that technology difference in both the economies play this role. Glass and Saggi [2001] theoretically shows that outsourcing of the production activity lowers the wage gap between developing and developed economies.

Sayek and Şener [2006] considers that along with outsourcing, the basic production can shift to a less developed economy through imitation as well. Their study shows that outsourcing raises wage inequality in a technologically advanced economy and under certain conditions, a backward economy might face rising or declining trend in wage inequality.[5] Their analyses empirically show that in Mexico, foreign direct investment (FDI) raises the demand for skilled human capital and consequently, the relative wage rate. But none of these studies consider that an advanced economy can also outsource skilled-intensive activity and that a backward economy can also perform some R & D activity independently. So, the third research problem aims to shed light on these issues in the *distance-to-the-frontier* framework.

Instead of taking outsourcing as given, another strand of literature considers the firm level decision of choosing alternative production strategies of vertical integration at home, vertical integration at abroad, outsourcing, foreign sourcing, FDI or export. Using a general equilibrium framework Melitz [2003], Antras and Helpman [2004], Grossman and Helpman [2002] and Grossman et al. [2005], Helpman et al. [2004] show that in the absence of firm level heterogeneity, or increasing returns to matching between the firms (who engage in the outsourcing activity), all the firms will opt for the same production activity. Yet another strand of literature by Chen et al. [2004], Shy and Stenbacka [2003], Leahy and Montagna [2007] and Nickerson and Bergh [1999] show that in an oligopolistic setting when firms have significant market power, even if firms are ex-ante symmetric, their make or buy decision can vary depending upon their cost structure and the strategic policy. All of the above mentioned papers are talking about production shares. However, Lai et al. [2009] considers cost reducing R & D and shows that revenue sharing contract raises R & D outsourcing.

By considering a skill-biased endogenous growth frame work like Vandenbussche et al. [2006] and Basu and Mehra [2014] and also by endogenizing the outsourcing decision of the R & D producer of the originating economy, the following key findings of the research problem are obtained:

1. An economy in the innovation-only regime outsources its R & D activity to the imitation-innovation regime only if it yields a higher profit compared to the case of no outsourcing. The profit depends

[5] This is empirically supported by Feenstra and Hanson [1997], Geishecker and Görg [2005] and Geishecker and Görg [2013]

on three factors: relative wage gap between the destination and originating economies, relative skill difference between these two countries and the fixed cost of outsourcing. It is shown that, in equilibrium, the proportion of outsourcing takes an intermediate value. This implies that R & D producer of the advanced economy performs a certain part of R & D activity in his/ her own country and outsources the remaining part to an economy which is in the imitation-innovation regime. Thus, corner solutions are not equilibrium phenomena.

2. Given the structure of the model, when a backward economy is participating in the outsourcing activity, it carries out only imitation activity for the destination economy, but performs innovation activity for the world leader. As a consequence of this, the technology improvement in the backward economy (or destination) depends only on the imitation activity. However, besides the advantage of backwardness, there also exists a disadvantage of backwardness, as mentioned in Gerschenkron et al. [1962] and Howitt [2000]. Thus, going forward in time, the scope of imitation falls and the gap of the concerned economy from the world technology leader rises. This, in turn, implies that the distance of the backward economy from the world technology leader rises over time. The long run dynamics of the model show that the destination economy, which is in the imitation-innovation regime, remains stuck in a low equilibrium income trap.

3. As the destination economy moves away from the frontier, that is, as the gap of the concerned economy's technology level from the world technology leader rises, the dependency on the imitation activity rises and innovation activity falls. Given that innovation is skilled human capital intensive while imitation is unskilled human capital intensive (under a contant returns to scale (CRS) production structure), the, equilibrium proportion of unskilled human capital rises and skilled human capital falls as the time progresses for an economy which is in the imitation-innovation regime and is performing R & D activity for the advanced economy.

4. With an increase in the proportion of unskilled human capital in the destination economy, imitation attracts more unskilled human capital since this activity is unskilled human capital intensive. Due to the complementary effect, it attracts more skilled human capital as well. This further attracts unskilled human capital in the imitation activity and the process continues. Thus, both skilled and unskilled human capital shift from the innovation to the imitation activity as the time progresses.

5. Again, in the destination economy, with a fall in the proportion of skilled human capital, the wage rate of skilled workers rises. Moreover, the relative dependency on the imitation activity rises and on the innovation activity falls; consequently, the relative demand for unskilled human capital rises and

this raises the wage rate of unskilled workers as an economy diverges away from the world technology frontier. Thus, for a backward economy which is participating in the outsourcing activity, the wage rate of both skilled and unskilled workers rise. Additionally, the increment in the wage rate of skilled worker is so large that the relative gap of the wage rate of skilled workers between the backward and advanced economies tends to fall.

6. The proportion of skilled human capital falls and the relative wage gap of skilled worker between the backward and advanced economies falls as the time progresses. Consequently, in equilibrium, the proportion of R & D outsourcing tends to fall.

7. As the proportion of R & D outsourcing falls, the proportion of R & D activity that would be performed in the originating economy rises. This leads to a positive increment in the demand for skilled and unskilled workers in the advanced economy, which consequently, raises the wage rate of skilled and unskilled workers in that economy.

8. In the destination economy, the equilibrium proportion of skilled human capital falls and both skilled and unskilled human capital shift from the innovation to the imitation activity as an economy moves away from the frontier. As an economy regresses, the technological dependency on imitation rises and innovation falls. Given the assumption that imitation is unskilled human capital intensive, the relative increment in the technology level rises as an economy diverges from the world technology frontier. This implies that the growth rate initually rises in the diversified regime by participating in the R & D outsourcing activity. However, the scope of imitation also falls due to the disadvantage of backwardness. So, in equilibrium, initially the advantage of backwardness may dominate the disadvantage of backwardness. However, the situation may get reversed for a relatively backward economy. Consequently, its growth rate falls after a certain time. This implies that there exists an inverted U-shaped growth curve in the destination economy.

2 Economic Environment

In this section, the basic set up of the model is discussed. First, the production structure of the economy is illustrated. Followed by this, the dynamics of productivity growth implying technological progress are presented. After that, the consumption structure of the economy is described.

2.1 Production

Two differing economies are considered for analysis – one is technologically backward, which is in the imitation-innovation regime and the other is technologically advanced. In fact, the second type of economy is assumed to be the world technology leader.

The production structure is similar to the Aghion and Howitt [1992] framework of *creative destruction*. This implies that any improvement in the quality of an intermediate input renders the existing quality of the input obsolete. The production of the final output in a competitive market requires land whose value is normalized to one (for mathematical simplicity). This does not have any qualitative impact on the results. and a continuum of mass one unit of intermediate inputs. To produce one unit of intermediate input, one unit of final output is required. Each of the intermediate input producers in sector i is a monopolist who possesses the highest available technology in that particular sector in period t. The entire model is set up in discrete time. The production function is of Cobb-Douglas type:

$$Y_{\mathrm{t}} = l_{\mathrm{t}}^{1-\alpha} \int_0^1 A_{\mathrm{it}}^{1-\alpha} x_{\mathrm{it}}^{\alpha} di, \quad 0 < \alpha < 1, \tag{1}$$

where Y_{t} is the final output in period t, l_{t} is the total supply of land, $A_{\mathrm{i,t}}$ is the level of technology in sector i in period t, and $x_{\mathrm{i,t}}$ is the amount of intermediate input used in sector i in period t.

With the assumption that the final good sector is perfectly competitive, the price of each of the intermediate inputs is equal to its marginal product, that is,

$$p_{\mathrm{it}} = \frac{\partial Y_{\mathrm{t}}}{\partial x_{\mathrm{it}}} = \alpha A_{\mathrm{it}}^{1-\alpha} x_{\mathrm{it}}^{\alpha-1},$$

where p_{it} denotes the price of the intermediate input in sector i in period t. The monopolist chooses x_{it} by solving

$$\max_{x_{\mathrm{it}}} (p_{\mathrm{it}} x_{\mathrm{it}} - x_{\mathrm{it}}).$$

The monopolist produces the following amount of the intermediate good in sector i in period t

$$x_{\mathrm{it}} = \alpha^{\frac{2}{1-\alpha}} A_{\mathrm{it}}. \tag{2}$$

Accordingly, he/ she would earn the following level of profit in sector i in period t

$$\pi_{\mathrm{it}} = (p_{\mathrm{it}} - 1) x_{\mathrm{it}} = \left(\frac{1}{\alpha} - 1\right) \alpha^{\frac{2}{1-\alpha}} A_{\mathrm{it}} = \delta\ A_{\mathrm{it}} > 0,$$

where $\delta = \left(\frac{1}{\alpha} - 1\right) \alpha^{\frac{2}{1-\alpha}}$.

This implies that positive profits are reaped in the production of each of the intermediate inputs. This provides an incentive to undertake R & D activity to the intermediate input producers. Note that the technology adjusted intermediate inputs and the profit are same for all the sectors in every period.

2.2 Dynamics of Productivity

The R & D sector differs between the destination and originating economies. The improvement in technology depends on both the imitation and the innovation activities in the backward economy, whereas it depends only on the innovation activity in the advanced economy. This implies that the backward economy is in the diversified regime while the advanced economy is in the innovation-only regime. The production structure in the R & D sector is such that both skilled and unskilled human capital are required to undertake both the imitation and the innovation activities. The technology improvement specification for the backward economy in the absence of outsourcing is defined as:

$$A_{\text{it}} = A_{\text{it-1}} + \lambda \left[u_{\text{mit}}^{\sigma} \; s_{\text{mit}}^{1-\sigma} \; \frac{(\overline{A}_{\text{t-1}} - A_{\text{t-1}})}{\overline{A}_{\text{t}}} + \gamma \; u_{\text{nit}}^{\phi} \; s_{\text{nit}}^{1-\phi} \; A_{\text{t-1}} \right], \quad \lambda > 0, \gamma > 0, 0 < \phi < \sigma < 1,$$

where σ and ϕ respectively denote the elasticity of unskilled human capital in the imitation and innovation activities, λ measures the efficiency of the overall process of technological progress and γ measures the relative efficiency of innovation compared to imitation. As earlier, u_{mit} and s_{mit} respectively represent the level of unskilled and skilled human capital engaged in the imitation activity for the backward economy, u_{nit} and s_{nit} respectively represent the level of unskilled and skilled human capital engaged in the innovation activity for the backward economy. A_{t} measures the aggregate technology level of the concerned economy in period t, that is, $A_{\text{t}} = \int_0^1 \text{A}_{\text{it}} di$. Further, $\overline{A}_{\text{t-1}}$ measures the world leader's aggregate technology level in period $(t-1)$, where, $\overline{A}_{\text{t-1}} = \int_0^1 \overline{\text{A}}_{\text{i,t-1}} di$. Thus, $\left(\frac{\overline{A}_{\text{t-1}} - A_{\text{t-1}}}{\overline{A}_{\text{t}}} \right)$ captures the scope of imitation. Hence, imitation depends on the distance of an economy's technology level from the world technology leader, which captures the advantage of backwardness. Along with the advantage of backwardness there also exists a disadvantage of backwardness. Imitation becomes more challenging as the targeted technology level rises.[6] This is captured by $\overline{A}_{\text{t}}$, similar to Howitt [2000]. Innovation depends on the technology level of the concerned economy, that is, A_{t}. It is assumed that innovation is skilled human capital intensive. CRS technology implies that imitation is unskilled human capital intensive.

If the backward economy participates in the R & D outsourcing of the advanced economy, then it has to perform three activities: first, imitation for the backward economy, second, innovation for the backward economy and third, innovation for the advanced economy. The dynamics of technology improvement for the destination economy are defined as:

$$A_{\text{it}} = A_{\text{it-1}} + \lambda \left[u_{\text{mit}}^{\sigma} \; s_{\text{mit}}^{1-\sigma} \; \frac{(\overline{A}_{\text{t-1}} - A_{\text{t-1}})}{\overline{A}_{\text{t}}} + \gamma \; u_{\text{nit}}^{\phi} \; s_{\text{nit}}^{1-\phi} \; A_{\text{t-1}} + \gamma \; \tilde{u}_{\text{nit}}^{\phi} \; \tilde{s}_{\text{nit}}^{1-\phi} \; \mu(a_{\text{t-1}}) \overline{A}_{\text{t-1}} \right], \tag{3}$$

where $\tilde{u}_{\text{nit}}^{\phi}$ and $\tilde{s}_{\text{nit}}^{\phi}$ respectively measure the level of unskilled and skilled human capital engaged in the innovation activity for the advanced economy. Further, $a_{\text{t-1}} = \frac{A_{\text{t-1}}}{\overline{A}_{\text{t-1}}}$. $a_{\text{t-1}}$ measures inverse distance of an

[6] As mentioned by Gerschenkron et al. [1962].

economy's technology level from the world technology frontier. $\mu(a_{\text{t-1}})$ measures the proportion of R & D outsourcing undertaken by the advanced economy. The productivity of the outsourcing activity depends on the interaction of the technology level of the advanced economy and the proportion of the outsourcing. According to eq. (3) either an increment in the technology level of the advanced economy or an increment in the proportion of outsourcing raises the productivity of the outsourcing activity.

Next, the technology improvement process of the advanced economy is specified. It is assumed that the advanced economy is the technology leader. Technology improvement of the world leader depends on how efficiently skilled and unskilled human capital are innovating upon the country's own technology level, that is,

$$A_{\text{it}} = A_{\text{i,t-1}} + \lambda\gamma U_{\text{Fit}}^{\phi} S_{\text{Fit}}^{1-\phi} \overline{A}_{\text{t-1}}, \tag{4}$$

where U_{Fit} and S_{Fit} respectively denote the level of unskilled and skilled human capital in the advanced economy .

To satisfy the basic assumption that innovation is relatively skilled human capital intensive than imitation, the following assumption is made:

A1. *The elasticity of skilled human capital is higher in the innovation activity than in the imitation activity, that is, $\sigma > \phi$. In the same vein, in the innovation-only regime, innovation is skilled human capital intensive, which implies that $\phi < \frac{1}{2}$.*[7]

A2. *World technology frontier is growing at a constant exogenous rate $\bar{g}$.*

2.3 Consumption

A one period overlapping generation model is considered. There is heterogeneity among the individuals in terms of their cognitive ability. Cognitive ability of an individual is assumed to be uniformly distributed over the interval $[0, 1]$. A binary education system like Galor and Zeira [1993] has been considered. By acquiring education an individual can become skilled otherwise he/ she can work as unskilled worker. If an individual decides to opt for acquiring education, then he/ she spends (1 - θ) fraction of life on education and works as a skilled worker for the remaining θ fraction of life. This implies that individuals with high cognitive ability spend lesser time on education and work as skilled workers for a higher proportionate time of life. Cost of education rises as cognitive ability of an individual falls. Thus, the cost of education has one-to-one inverse mapping with the cognitive ability of an individual. Utility depends on the consumption

[7]In the diversified regime this research does not require any assumption on the absolute intensity of skilled or unskilled human capital in the imitation or innovation activities. Hence, this parametric restriction pertains only to the specialized economy.

level of the k^{th} individual. The utility function of the k^{th} individual will be:

$$\mathbb{W}_{\text{kt}} = c_{\text{kt}}, \tag{5}$$

where $\mathbb{W}_{\text{kt}}$ and c_{kt} respectively denote life time utility and consumption of k^{th} individual in period t. The budget constraint of a skilled worker will be:

$$c_{\text{kt}} = \theta \ w_{\text{st}}; \tag{6}$$

and the budget constraint of unskilled will be:

$$c_{\text{kt}} = w_{\text{ut}}, \tag{7}$$

where w_{st} and w_{ut} respectively denote wage rate of skilled and unskilled worker.

It is assumed that the backward economy is a small open economy. It can purchase final output at an exogenously given world price. Individuals have perfect foresight. The total population of an economy is normalized to one. There is no population growth. Each parent has one child. The labor market is perfectly competitive. At the end of $(t-1)^{\text{th}}$ generation, the next generation appears.

3 Key Analytical Results

In this section, the key analytical results of the model pertaining to the R & D outsourcing from the advanced to the backward economy are derived. First the condition under which the R & D producer of the destination economy participates in the R & D outsourcing activity is determined. We next ascertain the condition under which R & D producer of the advanced economy participates in the outsourcing activity. This helps in determining the profit maximizing proportion of outsourcing by an intermediate input producer in the advanced economy to the backward economy. Following this, the post outsourcing maximization exercise of the R & D producer is solved which entails the post outsourcing wage rate of skilled and unskilled workers in the originating economy. Subsequently, in the presence of R & D outsourcing, the maximization exercise of the R & D producer of the diversified regime has been determined. This helps to derive the demand curve for both skilled and unskilled human capital as well as the allocation of these in the imitation and the innovation activities. Next, from the utility maximization exercise of individuals, one is able to derive the supply curves of both skilled and unskilled human capital. Moreover, by interacting the demand and supply curves, the equilibrium proportions of skilled and unskilled human capital and the allocation of these in both the imitation and the innovation activities are determined. Additionally, the dynamics of the equilibrium proportion of outsourcing and the growth path of the backward economy is derived. Followed by this, the long run dynamics of the backward economy are examined. Finally, the production and consumption paths of the destination and originating economy are analyzed.

3.1 Condition for Participating in the Outsourcing Activity – for the Destination Economy

We begin by analyzing the condition under which an R & D producer in the backward economy chooses to participate in the R & D activity of the advanced economy. The R & D producer of the backward economy has to perform three activities if he/ she is engaged in the outsourcing activity: imitation for the backward economy, innovation for the backward economy and innovation for the advanced economy. So, the maximization programme of R & D producer of the backward economy can be set up as:

$$\max_{u_{\mathrm{mit}}, s_{\mathrm{mit}}, u_{\mathrm{nit}}, s_{\mathrm{nit}}, \tilde{u}_{\mathrm{nit}}, \tilde{s}_{\mathrm{nit}}} A_{\mathrm{it\text{-}1}} + \lambda\delta \left[u_{\mathrm{mit}}^{\sigma}\ s_{\mathrm{mit}}^{1-\sigma}\ \frac{(\overline{A}_{\mathrm{t\text{-}1}} - A_{\mathrm{t\text{-}1}})}{\overline{A}_{\mathrm{t}}} + \gamma\ u_{\mathrm{nit}}^{\phi}\ s_{\mathrm{nit}}^{1-\phi}\ A_{\mathrm{t\text{-}1}} + \gamma\ \tilde{u}_{\mathrm{nit}}^{\phi}\ \tilde{s}_{\mathrm{nit}}^{1-\phi}\ \overline{A}_{\mathrm{t\text{-}1}}\ \mu(a_{\mathrm{t\text{-}1}}) \right]$$
$$- w_{\mathrm{ut}}\ (u_{\mathrm{mit}} + u_{\mathrm{nit}} + \tilde{u}_{\mathrm{nit}}) + w_{\mathrm{st}}\ (s_{\mathrm{mit}} + s_{\mathrm{nit}} + \tilde{s}_{\mathrm{nit}}). \tag{8}$$

From eq. (8), the first order conditions of the maximization exercise of the R & D producer of the backward economy are:

$$\begin{aligned}
\frac{\partial\ \mathbb{L}^{\nVdash}}{\partial\ u_{\mathrm{mit}}} &= \lambda\delta\sigma u_{\mathrm{mit}}^{\sigma-1}\ s_{\mathrm{mit}}^{1-\sigma}\ \frac{(\overline{A}_{\mathrm{t\text{-}1}} - A_{\mathrm{t\text{-}1}})}{\overline{A}_{\mathrm{t}}} - w_{\mathrm{ut}} \ = \ 0;\\
\frac{\partial\ \mathbb{L}^{\nVdash}}{\partial\ s_{\mathrm{mit}}} &= \lambda\delta(1-\sigma) u_{\mathrm{mit}}^{\sigma}\ s_{\mathrm{mit}}^{-\sigma}\ \frac{(\overline{A}_{\mathrm{t\text{-}1}} - A_{\mathrm{t\text{-}1}})}{\overline{A}_{\mathrm{t}}} - w_{\mathrm{st}} \ = \ 0;\\
\frac{\partial\ \mathbb{L}^{\nVdash}}{\partial\ u_{\mathrm{nit}}} &= \lambda\delta\gamma\phi\ u_{\mathrm{nit}}^{\phi-1}\ s_{\mathrm{nit}}^{1-\phi}\ A_{\mathrm{t\text{-}1}} - w_{\mathrm{ut}} \ = \ 0;\\
\frac{\partial\ \mathbb{L}^{\nVdash}}{\partial\ s_{\mathrm{nit}}} &= \lambda\delta\gamma(1-\phi)\ u_{\mathrm{nit}}^{\phi}\ s_{\mathrm{nit}}^{-\phi}\ A_{\mathrm{t\text{-}1}} - w_{\mathrm{st}} \ = \ 0;\\
\frac{\partial\ \mathbb{L}^{\nVdash}}{\partial\ \tilde{u}_{\mathrm{nit}}} &= \lambda\delta\gamma\phi\ \tilde{u}_{\mathrm{nit}}^{\phi-1}\ \tilde{s}_{\mathrm{nit}}^{1-\phi}\ \overline{A}_{\mathrm{t\text{-}1}}\ \mu(a_{\mathrm{t\text{-}1}}) + \lambda\delta\gamma\ \tilde{u}_{\mathrm{nit}}^{\phi}\ \tilde{s}_{\mathrm{nit}}^{1-\phi}\ \overline{A}_{\mathrm{t\text{-}1}}\ \frac{d\ \mu(a_{\mathrm{t\text{-}1}})}{d\ \tilde{u}_{\mathrm{nit}}} - w_{\mathrm{ut}} \ = \ 0;\\
\frac{\partial\ \mathbb{L}^{\nVdash}}{\partial\ \tilde{s}_{\mathrm{nit}}} &= \lambda\delta\gamma(1-\phi)\ \tilde{u}_{\mathrm{nit}}^{\phi}\ \tilde{s}_{\mathrm{nit}}^{-\phi}\ \overline{A}_{\mathrm{t\text{-}1}}\ \mu(a_{\mathrm{t\text{-}1}}) + \lambda\delta\gamma\ \tilde{u}_{\mathrm{nit}}^{\phi}\ \tilde{s}_{\mathrm{nit}}^{1-\phi}\ \overline{A}_{\mathrm{t\text{-}1}}\ \frac{d\ \mu(a_{\mathrm{t\text{-}1}})}{d\ \tilde{s}_{\mathrm{nit}}} - w_{\mathrm{st}} \ = \ 0.
\end{aligned} \tag{9}$$

Given that all the intermediate input producers face the same maximization problem, in equilibrium we have,

$$u_{\mathrm{mit}} = u_{\mathrm{mt}}, \qquad u_{\mathrm{nit}} = u_{\mathrm{nt}}, \qquad \tilde{u}_{\mathrm{nit}} = \tilde{u}_{\mathrm{nt}}, \qquad s_{\mathrm{mit}} = s_{\mathrm{mt}}, \qquad s_{\mathrm{nit}} = s_{\mathrm{nt}}, \qquad \tilde{s}_{\mathrm{nit}} = \tilde{s}_{\mathrm{nt}}. \tag{10}$$

The total population is normalized to one, which implies that,

$$\begin{aligned}
&U_{\mathrm{t}} = u_{\mathrm{mt}} + u_{\mathrm{nt}} + \tilde{u}_{\mathrm{nt}} \quad \Rightarrow \widehat{U}_{\mathrm{t}} = U_{\mathrm{t}} - \tilde{u}_{\mathrm{nt}} = u_{\mathrm{mt}} + u_{\mathrm{nt}};\\
&S_{\mathrm{t}} = s_{\mathrm{mt}} + s_{\mathrm{nt}} + \tilde{s}_{\mathrm{nt}} \quad \Rightarrow \widehat{S}_{\mathrm{t}} = S_{\mathrm{t}} - \tilde{s}_{\mathrm{nt}} = s_{\mathrm{mt}} + s_{\mathrm{nt}};\\
&U_{\mathrm{t}} + S_{\mathrm{t}} = 1,
\end{aligned}$$

where $\widehat{U}_{\rm t}$ and $\widehat{S}_{\rm t}$ respectively measure the proportion of unskilled and skilled human capital engaged in the R & D activity of the backward economy.

From eqs. (9) and (10), one can derive the following expression for the wage rates of skilled and unskilled workers in the event that the R & D producer performs all of these three activities.

$$\begin{aligned}
w_{\rm ut} &= \lambda\delta\sigma u_{\rm mt}^{\sigma-1}\ s_{\rm mt}^{1-\sigma}\ \frac{(\overline{A}_{\text{t-1}} - A_{\text{t-1}})}{\overline{A}_{\rm t}} = \lambda\delta\gamma\phi\ u_{\rm nt}^{\phi-1}\ s_{\rm nt}^{1-\phi}\ A_{\text{t-1}} \\
&= \lambda\delta\gamma\phi\ \tilde{u}_{\rm nt}^{\phi-1}\ \tilde{s}_{\rm nt}^{1-\phi}\ \overline{A}_{\text{t-1}}\ \mu(a_{\text{t-1}}) + \lambda\delta\gamma\ \tilde{u}_{\rm nt}^{\phi}\ \tilde{s}_{\rm nt}^{1-\phi}\ \overline{A}_{\text{t-1}}\ \frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{u}_{\rm nt}}; \\
w_{\rm st} &= \lambda\delta(1-\sigma)u_{\rm mt}^{\sigma}\ s_{\rm mt}^{-\sigma}\ \frac{(\overline{A}_{\text{t-1}} - A_{\text{t-1}})}{\overline{A}_{\rm t}} = \lambda\delta\gamma(1-\phi)\ u_{\rm nt}^{\phi}\ \tilde{s}_{\rm nt}^{-\phi}\ A_{\text{t-1}} \\
&= \lambda\delta\gamma(1-\phi)\ \tilde{u}_{\rm nt}^{\phi}\ \tilde{s}_{\rm nt}^{-\phi}\ \overline{A}_{\text{t-1}}\ \mu(a_{\text{t-1}}) + \lambda\delta\gamma\ \tilde{u}_{\rm nt}^{\phi}\ \tilde{s}_{\rm nt}^{1-\phi}\ \overline{A}_{\text{t-1}}\ \frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{s}_{\rm nt}}.
\end{aligned} \tag{11}$$

From eq. (11), the relative wage rate of skilled and unskilled workers in the backward economy, when it participates in the R & D activity of the advanced economy is obtained as follows:

$$\begin{aligned}
\frac{w_{\rm ut}}{w_{\rm st}} &= \frac{\sigma}{1-\sigma}\frac{s_{\rm mt}}{u_{\rm mt}} = \frac{\phi}{(1-\phi)}\frac{s_{\rm nt}}{u_{\rm nt}} \\
\Rightarrow \quad \psi\frac{s_{\rm mt}}{u_{\rm mt}} &= \frac{s_{\rm nt}}{u_{\rm nt}} = \frac{(1-\phi)}{\phi}\frac{\tilde{s}_{\rm nt}}{\tilde{u}_{\rm nt}}\frac{\left[\phi\mu(a_{\text{t-1}}) + \tilde{u}_{\rm nt}\frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{u}_{\rm nt}}\right]}{\left[(1-\phi)\mu(a_{\text{t-1}}) + \tilde{s}_{\rm nt}\frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{s}_{\rm nt}}\right]},
\end{aligned} \tag{12}$$

where $\psi = \frac{\sigma(1-\phi)}{\phi(1-\sigma)} > 1$ by **A1**. The demand for skilled and unskilled human capital in the imitation and the innovation activities in the R & D activity of the backward economy respectively turn out to be:

$$\begin{aligned}
s_{\rm mt} &= \frac{h(a_{\text{t-1}})\ \widehat{U}_{\rm t} - \widehat{S}_{\rm t}}{\psi - 1}; & s_{\rm nt} &= \frac{\psi\ \widehat{S}_{\rm t} - h(a_{\text{t-1}})\ \widehat{U}_{\rm t}}{\psi - 1}; \\
u_{\rm mt} &= \frac{\psi[h(a_{\text{t-1}})\ \widehat{U}_{\rm t} - \widehat{S}_{\rm t}]}{(\psi-1)\ h(a_{\text{t-1}})}; & u_{\rm nt} &= \frac{\psi\widehat{S}_{\rm t} - h(a_{\text{t-1}})\ \widehat{U}_{\rm t}}{(\psi-1)\ h(a_{\text{t-1}})}; \\
\frac{s_{\rm mt}}{u_{\rm mt}} &= \frac{h(a_{\text{t-1}})}{\psi}; & \frac{s_{\rm nt}}{u_{\rm nt}} &= h(a_{\text{t-1}}).
\end{aligned} \tag{13}$$

where $h(a_{\text{t-1}}) = \left[\frac{(1-\sigma)\psi^{\sigma}(1-a_{\text{t-1}})}{\gamma(1-\phi)a_{\text{t-1}}(1+\bar{g})\overline{A}_{\text{t-1}}}\right]^{\frac{1}{(\sigma-\phi)}}$. Note that $h(a_{\text{t-1}})$ is a decreasing function of the distance to the world technology frontier (that is, $a_{\text{t-1}}$). This implies that as an economy bridges the gap from the world technology frontier, the proportion of skilled to unskilled human capital falls in the imitation as well as in the innovation activities.

From eqs. (12) and (13), we get that,

$$\frac{(1-\phi)}{\phi}\frac{\tilde{s}_{\rm nt}}{\tilde{u}_{\rm nt}}\frac{\left[\phi\mu(a_{\text{t-1}}) + \tilde{u}_{\rm nt}\frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{u}_{\rm nt}}\right]}{\left[(1-\phi)\mu(a_{\text{t-1}}) + \tilde{s}_{\rm nt}\frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{s}_{\rm nt}}\right]} = h(a_{\text{t-1}}). \tag{14}$$

This gives us the relative productivity of unskilled to skilled human capital in the R & D activity of the innovation sector in the destination and the originating economies. It is assumed that the R & D producer of the backward economy is performing the innovation activity for both the backward and the advanced economies. In equilibrium, the productivity would be the same in both the activities if the condition in eq. (14) is satisfied. However, the R & D producer of the backward economy would not participate in the outsourcing activity if the productivity of innovation activity is higher in the backward economy than the advanced economy. The condition for the absence of outsourcing is captured by:

$$\frac{(1-\phi)}{\phi}\frac{\tilde{s}_{\mathrm{nt}}}{\tilde{u}_{\mathrm{nt}}}\frac{\left[\phi\mu(a_{\mathrm{t\text{-}1}})+\tilde{u}_{\mathrm{nt}}\frac{d\ \mu(a_{\mathrm{t\text{-}1}})}{d\ \tilde{u}_{\mathrm{nt}}}\right]}{\left[(1-\phi)\mu(a_{\mathrm{t\text{-}1}})+\tilde{s}_{\mathrm{nt}}\frac{d\ \mu(a_{\mathrm{t\text{-}1}})}{d\ \tilde{s}_{\mathrm{nt}}}\right]}<h(a_{\mathrm{t\text{-}1}}).$$

In the opposite case, the R & D producer of the backward economy would not perform the innovation activity for the backward economy. This implies that if the above condition holds with strict equality, then he/ she would be indifferent between performing innovation activity for the backward economy and the advanced economy. It is **assumed** that if the equality holds, the R & D producer of the backward economy performs imitation activity only for the backward economy and innovation activity only for the advanced economy.[8]

Remark 1 *The backward economy participates in the outsourcing activity and performs imitation activity for the destination economy and executes innovation activity for the origination economy if the following condition holds:*

$$\frac{(1-\phi)}{\phi}\frac{\tilde{s}_{nt}}{\tilde{u}_{nt}}\frac{\left[\phi\mu(a_{t\text{-}1})+\tilde{u}_{nt}\frac{d\ \mu(a_{t\text{-}1})}{d\ \tilde{u}_{nt}}\right]}{\left[(1-\phi)\mu(a_{t\text{-}1})+\tilde{s}_{nt}\frac{d\ \mu(a_{t\text{-}1})}{d\ \tilde{s}_{nt}}\right]}=h(a_{t\text{-}1}).$$

To get an intuitive understanding of the above condition, one simplification can be introduced.[9] Let us assume that there be no change in the proportion of outsourcing even when there is a change in the allocation of skilled and unskilled human capital in the outsourcing activity $\left(\text{that is, } \frac{d\ \mu(a_{\mathrm{t\text{-}1}})}{d\ \tilde{u}_{\mathrm{nt}}}=0 \text{ and } \frac{d\ \mu(a_{\mathrm{t\text{-}1}})}{d\ \tilde{s}_{\mathrm{nt}}}=0\right)$. This implies that the proportion of skilled and unskilled human capital engaged in the outsourcing activity has no impact on the proportion of outsourcing. From eq. (12), we get the ratio of wage rate to be:

$$\psi\frac{s_{\mathrm{mt}}}{u_{\mathrm{mt}}}=\frac{s_{\mathrm{nt}}}{u_{\mathrm{nt}}}=\frac{\tilde{s}_{\mathrm{nt}}}{\tilde{u}_{\mathrm{nt}}}=h(a_{\mathrm{t\text{-}1}}). \tag{15}$$

[8]The analysis focuses on the impact of the R & D Outsourcing on the backward economy. This analysis concentrates on that parametric condition where outsourcing occurs in the backward economy.

[9]This simplification is not required for the future analysis.

By utilizing eq. (15) in eq. (11), one gets that:

$$w_{\mathrm{ut}} = \lambda\delta\sigma\psi^{\sigma-1}h^{1-\sigma}(a_{\text{t-1}})\ \frac{(1-a_{\text{t-1}})}{(1+\bar{g})} = \lambda\delta\gamma\phi\ h^{1-\phi}(a_{\text{t-1}})\ A_{\text{t-1}} = \lambda\delta\gamma\phi\ h^{1-\phi}(a_{\text{t-1}})\ \overline{A}_{\text{t-1}}\ \mu(a_{\text{t-1}});$$

$$\begin{aligned} w_{\mathrm{st}} &= \lambda\delta(1-\sigma)\psi^{\sigma}h^{-\sigma}(a_{\text{t-1}})\ \frac{(1-a_{\text{t-1}})}{(1+\bar{g})} = \lambda\delta\gamma(1-\phi)\ h^{-\phi}(a_{\text{t-1}})\ A_{\text{t-1}} \\ &= \lambda\delta\gamma(1-\phi)\ h^{-\phi}(a_{\text{t-1}})\ \overline{A}_{\text{t-1}}\ \mu(a_{\text{t-1}}). \end{aligned} \tag{16}$$

Eq. (16) implies that the productivity of the innovation activity for the backward economy and for the advanced economy would be the same if

$$A_{\text{t-1}} = \overline{A}_{\text{t-1}}\ \mu(a_{\text{t-1}}) \qquad \Rightarrow \qquad a_{\text{t-1}} = \mu(a_{\text{t-1}}). \tag{17}$$

The condition in eq. (17) implies that if there is no technology gap between destination and originating economies, the advanced economy would be indifferent between performing R & D activity in its own country and oursourcing it. If outsourcing weighted technology level of advanced economy is identical to that in the backward economy, then the R & D producer of the backward economy would be indifferent between performing innovation activity for the backward economy and for the advanced economy. If instead $a_{\text{t-1}} > \mu(a_{\text{t-1}})$, then he/ she prefers not to participate in the outsourcing activity otherwise participates in the outsourcing activity, that is, the proportion of skilled and unskilled human capital engaged in the imitation activity would be as follows:

$$\begin{aligned} s_{\mathrm{mt}} &= \frac{h(a_{\text{t-1}})\ \widehat{U}_{\mathrm{t}} - \widehat{S}_{\mathrm{t}}}{\psi - 1}, && \text{if}\ \ a_{\text{t-1}} \geq \mu(a_{\text{t-1}}); \\ &= 0, && \text{if}\ \ a_{\text{t-1}} < \mu(a_{\text{t-1}}); \\ u_{\mathrm{mt}} &= \frac{\psi[h(a_{\text{t-1}})\ \widehat{U}_{\mathrm{t}} - \widehat{S}_{\mathrm{t}}]}{(\psi-1)\ h(a_{\text{t-1}})}, && \text{if}\ \ a_{\text{t-1}} \geq \mu(a_{\text{t-1}}); \\ &= 0, && \text{if}\ \ a_{\text{t-1}} < \mu(a_{\text{t-1}}). \end{aligned}$$

Similarly, the proportion of human capital engaged in the innovation activity in the backward economy will be as follows:

$$\begin{aligned} s_{\mathrm{nt}} &= \frac{\psi\ \widehat{S}_{\mathrm{t}} - h(a_{\text{t-1}})\ \widehat{U}_{\mathrm{t}}}{\psi - 1}, && \text{if}\ \ a_{\text{t-1}} > \mu(a_{\text{t-1}}); \\ &= 0, && \text{if}\ \ a_{\text{t-1}} < \mu(a_{\text{t-1}}); \\ u_{\mathrm{nt}} &= \frac{\psi\widehat{S}_{\mathrm{t}} - h(a_{\text{t-1}})\ \widehat{U}_{\mathrm{t}}}{(\psi-1)\ h(a_{\text{t-1}})}, && \text{if}\ \ a_{\text{t-1}} > \mu(a_{\text{t-1}}); \\ &= 0, && \text{if}\ \ a_{\text{t-1}} < \mu(a_{\text{t-1}}). \end{aligned}$$

As opposed to this, the proportion of human capital engaged in the innovation activity in the advanced economy will be:

$$\tilde{s}_{\text{nt}} = \frac{\psi\ \widehat{S}_{\text{t}} - h(a_{\text{t-1}})\ \widehat{U}_{\text{t}}}{\psi - 1}, \qquad \text{if}\ \ a_{\text{t-1}} < \mu(a_{\text{t-1}});$$

$$= 0, \qquad \text{if}\ \ a_{\text{t-1}} > \mu(a_{\text{t-1}});$$

$$\tilde{u}_{\text{nt}} = \frac{\psi\widehat{S}_{\text{t}} - h(a_{\text{t-1}})\ \widehat{U}_{\text{t}}}{(\psi - 1)\ h(a_{\text{t-1}})}, \qquad \text{if}\ \ a_{\text{t-1}} < \mu(a_{\text{t-1}});$$

$$= 0, \qquad \text{if}\ \ a_{\text{t-1}} > \mu(a_{\text{t-1}}).$$

3.2 Condition for Outsourcing for the Originating Economy

We next derive the condition under which the R & D producers of the advanced economy outsource their R & D activity to the backward economy. Assuming that the condition in **Remark 1** holds, R & D producers of the backward economy would not perform any innovation activity for the backward economy. That is, if they participate in the outsourcing activity, they would **only imitate for the backward economy and only innovate for the advanced economy**.

First, the R & D intermediate input producers of the advanced economy decide whether to engage in the outsourcing activity. What wil be there incentive to do so? They will outsource only if their profit is higher from outsourcing than in the absence of it. It is known that the technology leader relies only on innovation activity for further technological improvement. By **A1**, innovation is skilled human capital intensive. However, the proportion of skilled worker is lower in the backward than in the advanced economy so that the increment in technology level may also be low in the presence of outsourcing. However, the wage rate of skilled worker is lower in the backward than in the advanced economy, which implies a lowering of the cost of innovation for the advanced economy if it outsources. Thus, there is a trade off between the increment to technology and cost. Also, it is assumed that there is a fixed cost of outsourcing. Therefore, an intermediate input producer of the advanced economy outsources if

$$(N_{\text{OD}} - w_{\text{OD}}) + (N_{\text{OO}} - w_{\text{OO}}) - F \geq N_{\text{WOO}} - w_{\text{WOO}}, \tag{18}$$

where N_{OD} is the amount of innovation that occurs in the backward economy if the advanced economy outsources, w_{OD} is the cost of innovation in the backward economy if the advanced economy outsources, N_{OO} is the amount of innovation that occurs in the advanced economy if the advanced economy outsources and w_{OO} is the cost of innovation in the advanced economy if the advanced economy outsources. Further, N_{WOO} is the amount of innovation that occurs in the advanced economy if advanced economy does not outsource, w_{WOO} is the cost of innovation in the advanced economy if the advanced economy does not outsource and F

is the fixed cost of outsourcing. Thus, the benefits from outsourcing and without outsourcing are captured by the following expressions:

$$N_{\text{OD}} - w_{\text{OD}} = \left[\lambda\delta\gamma\ \tilde{u}_{\text{nit}}^{\phi}\ \tilde{s}_{\text{nit}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{ut}}\ \tilde{u}_{\text{nit}} + w_{\text{st}}\ \tilde{s}_{\text{nit}})\right] \mu(a_{\text{t-1}});$$

$$N_{\text{OO}} - w_{\text{OO}} = \left[\lambda\delta\gamma\ U_{\text{Fit}}^{\phi}\ S_{\text{Fit}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{Fut}}\ U_{\text{Fit}} + w_{\text{Fst}}\ S_{\text{Fit}})\right] (1 - \mu(a_{\text{t-1}}));$$

$$N_{\text{WOO}} - w_{\text{WOO}} = \lambda\delta\gamma\ U_{\text{Fit}}^{\phi}\ S_{\text{Fit}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{Fut}}\ U_{\text{Fit}} + w_{\text{Fst}}\ S_{\text{Fit}}). \tag{19}$$

Here, $(N_{\text{OD}} - w_{\text{OD}})$ and $(N_{\text{OO}} - w_{\text{OO}})$ respectively measure the profit/ gain of the intermediate input producer of the advanced economy that he/ she gains after outsourcing from the backward and advanced economy. This implies that $(N_{\text{OD}} - w_{\text{OD}}) + (N_{\text{OO}} - w_{\text{OO}})$ measures the total gross profit of the intermediate input producer of the advanced economy after outsourcing. After deducting the fixed cost of outsourcing (that is, F), net profit of the intermediate input producer of the **advanced economy after outsourcing** is derived. In comparison $(N_{\text{WOO}} - w_{\text{WOO}})$ measures the net profit of the intermediate input producer of the **advanced economy in the absence of outsourcing**. By substituting eq. (19) in eq. (18), we get the following condition for outsourcing:

$$\begin{aligned}
&\left[\lambda\delta\gamma\ U_{\text{Fit}}^{\phi}\ S_{\text{Fit}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{Fut}}\ U_{\text{Fit}} + w_{\text{Fst}}\ S_{\text{Fit}})\right] (1 - \mu(a_{\text{t-1}})) \\
&\qquad + \left[\lambda\delta\gamma\ \tilde{u}_{\text{nit}}^{\phi}\ \tilde{s}_{\text{nit}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{ut}}\ \tilde{u}_{\text{nit}} + w_{\text{st}}\ \tilde{s}_{\text{nit}})\right] \mu(a_{\text{t-1}}) - F \\
&\qquad \geq \lambda\delta\gamma\ U_{\text{Fit}}^{\phi}\ S_{\text{Fit}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{Fut}}\ U_{\text{Fit}} + w_{\text{Fst}}\ S_{\text{Fit}})
\end{aligned}$$

$$\mu(a_{\text{t-1}}) \geqslant \frac{F}{\left[\underbrace{\left\{\lambda\delta\gamma\ \tilde{u}_{\text{nit}}^{\phi}\ \tilde{s}_{\text{nit}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{ut}}\ \tilde{u}_{\text{nit}} + w_{\text{st}}\ \tilde{s}_{\text{nit}})\right\}}_{(1)} - \underbrace{\left\{\lambda\delta\gamma\ U_{\text{Fit}}^{\phi}\ S_{\text{Fit}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{Fut}}\ U_{\text{Fit}} + w_{\text{Fst}}\ S_{\text{Fit}})\right\}}_{(2)}\right]}. \tag{20}$$

Expression (1) in eq. (20) denotes the post outsourcing profit of the intermediate input producer of the originating economy from the destination economy. However, expression (2) in eq. (20) represents the post outsourcing profit of the originating economy from its own country. Therefore, it implies that the proportion of outsourcing depends on the profit gap of the originating and the destination economies and the fixed cost of outsourcing. As the profit from the destination economy increases in comparison with that of the originating economy, the bounding constraint for the proportion of outsourcing falls. If the condition in eq. (20) is satisfied, the advanced economy will engage in the outsourcing of its R & D activity. This implies that if the outsourcing occurs, its proportion will be at least as much as indicated by the r.h.s of the condition in eq. (20). If the condition in eq. (20) holds with a strict inequality then it implies that the profit from outsourcing is strictly higher than the profit in the absence of outsourcing. In this case, the intermediate input producer of advanced economy will outsource all its R & D activity to the backward economy, that is, $\mu(a_{\text{t-1}}) = 1$. The reversal of the strict inequality sign implies $\mu(a_{\text{t-1}}) = 0$. The focus of this analysis is on the case an interior solution, where the condition in eq. (20) holds with a strict equality.[10]

Remark 2 *The originating economy outsources the following proportion of R & D activity, if it is participating in the outsourcing activity*

$$\mu(a_{t\text{-}1}) = \frac{F}{\left[\left\{\lambda\delta\gamma\ \tilde{u}_{nit}^{\phi}\ \tilde{s}_{nit}^{1-\phi}\ \overline{A}_{t\text{-}1} - (w_{ut}\ \tilde{u}_{nit} + w_{st}\ \tilde{s}_{nit})\right\} - \left\{\lambda\delta\gamma\ U_{Fit}^{\phi}\ S_{Fit}^{1-\phi}\ \overline{A}_{t\text{-}1} - (w_{Fut}\ U_{Fit} + w_{Fst}\ S_{Fit})\right\}\right]}.$$

3.3 Maximization Problem of the Intermediate Input Producer of the Originating Economy

This subsection discusses the post outsourcing optimization exercise of the advanced economy. This helps us to analyze the post outsourcing wage rate of skilled and unskilled workers. From eq. (4), the maximization exercise of the advanced economy will be:

$$\max_{U_{\text{Fit}}, S_{\text{Fit}}} \lambda\delta\gamma\ U_{\text{Fit}}^{\phi}\ S_{\text{Fit}}^{1-\phi}\ \overline{A}_{\text{t-1}}(1-\mu(a_{\text{t-1}})) - (w_{\text{Fut}}\ U_{\text{Fit}} + w_{\text{Fst}}\ S_{\text{Fit}}), \tag{21}$$

where $w_{\text{Fut}}$and w_{Fst} represent wage rate of unskilled and skilled worker in the advanced economy in period t. Post outsourcing, the wage rate of skilled and unskilled workers in the advanced economy will be:

$$\begin{aligned} w_{\text{Fut}} &= \lambda\delta\gamma\phi\ U_{\text{Fit}}^{\phi-1}\ S_{\text{Fit}}^{1-\phi}\overline{A}_{\text{t-1}}(1-\mu(a_{\text{t-1}})); \\ w_{\text{Fst}} &= \lambda\delta\gamma(1-\phi)\ U_{\text{Fit}}^{\phi}\ S_{\text{Fit}}^{-\phi}\ \overline{A}_{\text{t-1}}(1-\mu(a_{\text{t-1}})). \end{aligned} \tag{22}$$

Accordingly, eq. (22), as the proportion of outsourcing increases, the wage rates of both skilled and unskilled workers fall in the advanced economy. Intuitively, an increment in R & D outsourcing implies a reduction of the level of the R & D activity in the advanced economy. This reduces the demand for both skilled and unskilled workers and, consequently, lowers the wage rate of both types of workers in the advanced economy.

Given that all the intermediate input producers face the same maximization problem, in equilibrium, we have,

$$U_{\text{Fit}} = U_{\text{Ft}}, \qquad S_{\text{Fit}} = S_{\text{Ft}}. \tag{23}$$

Substituting eqs. (22) and (23) in eq. (20), the proportion of outsourcing is derived to be:

$$\begin{aligned} \mu(a_{\text{t-1}}) &= \frac{F}{-\lambda\delta\gamma\ U_{\text{Fit}}^{\phi}\ S_{\text{Fit}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{ut}}\ \tilde{u}_{\text{nit}} + w_{\text{st}}\ \tilde{s}_{\text{nit}}) + \lambda\delta\gamma\ \tilde{u}_{\text{nti}}^{\phi}\ \tilde{s}_{\text{nti}}^{1-\phi}\ \overline{A}_{\text{t-1}}} \\ \Rightarrow\ \lambda\delta\gamma\ U_{\text{Ft}}^{\phi}\ S_{\text{Ft}}^{1-\phi}\ \overline{A}_{\text{t-1}}\ \mu^2(a_{\text{t-1}}) &+ \left[(w_{\text{ut}}\ \tilde{u}_{\text{nit}} + w_{\text{st}}\ \tilde{s}_{\text{nit}}) - \lambda\delta\gamma\ \tilde{u}_{\text{nit}}^{\phi}\ \tilde{s}_{\text{nit}}^{1-\phi}\ \overline{A}_{\text{t-1}}\right]\mu(a_{\text{t-1}}) + F = 0. \end{aligned} \tag{24}$$

[10]Later in Subsection 3.3 on page 17 and in eq. 35 in Subsection 3.4 on page 19, it has been shown that the equilibrium proportion of outsourcing indeed takes an intermediate value.

Now, let us introduce some notations. Let $A = \lambda\delta\gamma\ U_{\text{Ft}}^{\phi}\ S_{\text{Ft}}^{1-\phi}\ \overline{A}_{\text{t-1}} > 0$, $B = \left[(w_{\text{ut}}\ \tilde{u}_{\text{nit}} + w_{\text{st}}\ \tilde{s}_{\text{nit}}) - \lambda\delta\gamma\ \tilde{u}_{\text{nit}}^{\phi}\ \tilde{s}_{\text{nit}}^{1-\phi}\ \overline{A}_{\text{t-1}}\right]$ and $C = F > 0$. Therefore, the solution to the $\mu(a_{\text{t-1}})$ is $\frac{-B\pm\sqrt{B^2-4AF}}{2A}$.Given that $A > 0$ and $C > 0$, $\mu(a_{\text{t-1}}) > 0 \Rightarrow B < 0$. The condition $B < 0$ implies that the post outsourcing profit from the backward economy should be positive (that is, $(N_{\text{OO}} - w_{\text{OO}})$ in eq. (19)). Otherwise, the R & D producer of the advanced economy does not have any incentive to outsource its R & D activity to the backward economy.

3.4 Maximization Exercise of the Intermediate Input Producer of the Destination Economy

Post outsourcing maximization exercise of the R & D producer of the backward economy is set up as:

$$\max_{u_{\text{mit}},s_{\text{mit}},\tilde{u}_{\text{nit}},\tilde{s}_{\text{nit}}} A_{\text{it-1}} + \lambda\delta\left[u_{\text{mit}}^{\sigma}\ s_{\text{mit}}^{1-\sigma}\ \frac{(\overline{A}_{\text{t-1}} - A_{\text{t-1}})}{\overline{A}_{\text{t}}} + \gamma\ \tilde{u}_{\text{nit}}^{\phi}\ \tilde{s}_{\text{nit}}^{1-\phi}\ \overline{A}_{\text{t-1}}\ \mu(a_{\text{t-1}})\right]$$
$$- w_{\text{ut}}\ (u_{\text{mit}} + \tilde{u}_{\text{nit}}) - w_{\text{st}}\ (s_{\text{mit}} + \tilde{s}_{\text{nit}}).$$

From eq. (21), the first-order conditions of the maximization exercise are:

$$\begin{aligned}
\frac{\partial\ \mathbb{L}_{\mathbb{H}}}{\partial\ u_{\text{mit}}} &= \lambda\delta\sigma u_{\text{mit}}^{\sigma-1}\ s_{\text{mit}}^{1-\sigma}\ \frac{(\overline{A}_{\text{t-1}} - A_{\text{t-1}})}{\overline{A}_{\text{t}}} - w_{\text{ut}} = 0;\\
\frac{\partial\ \mathbb{L}_{\mathbb{H}}}{\partial\ s_{\text{mit}}} &= \lambda\delta(1-\sigma) u_{\text{mit}}^{\sigma}\ s_{\text{mit}}^{-\sigma}\ \frac{(\overline{A}_{\text{t-1}} - A_{\text{t-1}})}{\overline{A}_{\text{t}}} - w_{\text{st}} = 0;\\
\frac{\partial\ \mathbb{L}_{\mathbb{H}}}{\partial\ \tilde{u}_{\text{nit}}} &= \lambda\delta\gamma\phi\ \tilde{u}_{\text{nit}}^{\phi-1}\ \tilde{s}_{\text{nit}}^{1-\phi}\ \overline{A}_{\text{t-1}}\ \mu(a_{\text{t-1}}) + \lambda\delta\gamma\ \tilde{u}_{\text{nit}}^{\phi}\ \tilde{s}_{\text{nit}}^{1-\phi}\ \overline{A}_{\text{t-1}}\ \frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{u}_{\text{nit}}} - w_{\text{ut}} = 0;\\
\frac{\partial\ \mathbb{L}_{\mathbb{H}}}{\partial\ \tilde{s}_{\text{nit}}} &= \lambda\delta\gamma(1-\phi)\ \tilde{u}_{\text{nit}}^{\phi}\ \tilde{s}_{\text{nit}}^{-\phi}\ \overline{A}_{\text{t-1}}\ \mu(a_{\text{t-1}}) + \lambda\delta\gamma\ \tilde{u}_{\text{nit}}^{\phi}\ \tilde{s}_{\text{nit}}^{1-\phi}\ \overline{A}_{\text{t-1}}\ \frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{s}_{\text{nit}}} - w_{\text{st}} = 0.
\end{aligned} \tag{25}$$

Thus, the wage rates of skilled and unskilled workers depend on their respective marginal productivities in the technology improvement activity in both the originating and destination economies. Given that there is mass 1 of intermediate firms, the labor market equilibrium condition will be:

$$S_{\text{t}} = s_{\text{mt}} + \tilde{s}_{\text{nt}}, \qquad U_{\text{t}} = u_{\text{mt}} + \tilde{u}_{\text{nt}}.$$

From eq. (25), the relative wage rate of skilled and unskilled workers in the imitation activity in period t will be:

$$\frac{w_{\text{st}}}{w_{\text{ut}}} = \frac{(1-\sigma)}{\sigma}\frac{u_{\text{mt}}}{s_{\text{mt}}}. \tag{26}$$

We next try to figure out the relative wage rate of unskilled and skilled human capital in the innovation activity in period t. For this one needs to first re-express the proportion of outsourcing in a somewhat different way. This expression will also be used later in the analysis. Rewriting the solution of eq. (24) we get,

$$\mu(a_{\text{t-1}}) = \frac{-B \pm \sqrt{B^2 - 4AF}}{2A}$$

$$\Rightarrow \quad \pm \left[\left[(w_{\text{ut}}\ \tilde{u}_{\text{nit}} + w_{\text{st}}\ \tilde{s}_{\text{nit}}) - \lambda\delta\gamma\ \tilde{u}_{\text{nti}}^{\phi}\ \tilde{s}_{\text{nti}}^{1-\phi}\ \overline{A}_{\text{t-1}} \right]^2 - 4AF \right]^{\frac{1}{2}}$$

$$= 2A\ \mu(a_{\text{t-1}}) - \left[\lambda\delta\gamma\ \tilde{u}_{\text{nti}}^{\phi}\ \tilde{s}_{\text{nti}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{ut}}\ \tilde{u}_{\text{nit}} + w_{\text{st}}\ \tilde{s}_{\text{nit}}) \right]. \tag{27}$$

To interpret the first-order conditions of maximization of the intermediate input producer of the backward economy, one needs to understand the change in the proportion of outsourcing due to a change in the allocation of unskilled human capital in the innovation activity $\left(\text{that is, } \frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{u}_{\text{nt}}}\right)$. It is also important to determine the change in the proportion of outsourcing due to a change in the allocation of skilled human capital in the innovation activity $\left(\text{that is, } \frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{s}_{\text{nt}}}\right)$. We first analyze the change in the proportion of outsourcing due to a change in the allocation of unskilled human capital in the innovation activity. Differentiating eq. (24) w.r.t $\tilde{u}_{\text{nt}}$ and using eqs. (10) and (27), we get,

$$\frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{u}_{\text{nt}}} = \frac{\underbrace{\mu(a_{\text{t-1}})}_{1} \left[\underbrace{\lambda\delta\gamma\phi\ \tilde{u}_{\text{nt}}^{\phi-1}\ \tilde{s}_{\text{nt}}^{1-\phi}\ \overline{A}_{\text{t-1}} - w_{\text{ut}}}_{2} \right]}{2\ \underbrace{A}_{3}\ \underbrace{\mu(a_{\text{t-1}})}_{1} - \left[\underbrace{\lambda\delta\gamma\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{ut}}\ \tilde{u}_{\text{nt}} + w_{\text{st}}\ \tilde{s}_{\text{nt}})}_{4} \right]}. \tag{28}$$

Next, the change in the proportion of the outsourcing due to a change in the allocation of skilled human capital in the innovation activity (that is, $\frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{u}_{\text{nt}}}$) is ascertained. Differentiating eq. (24) w.r.t $\tilde{s}_{\text{nt}}$ and using eqs. (10) and (27), we get,

$$\frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{s}_{\text{nt}}} = \frac{\underbrace{\mu(a_{\text{t-1}})}_{1} \left[\underbrace{\lambda\delta\gamma(1-\phi)\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{-\phi} \overline{A}_{\text{t-1}} - w_{\text{st}}}_{2} \right]}{2\ \underbrace{A}_{3}\ \underbrace{\mu(a_{\text{t-1}})}_{1} - \left[\underbrace{\lambda\delta\gamma\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{ut}}\ \tilde{u}_{\text{nt}} + w_{\text{st}}\ \tilde{s}_{\text{nt}})}_{4} \right]}. \tag{29}$$

Therefore, the change in the proportion of outsourcing due to the change in the allocation of unskilled as well as skilled workers in the outsourcing activity depends on the following factors: proportion of outsourcing (denoted as (1) in eqs. (28) and (29)), productivity of the R & D activity of the advanced economy (represented as (3) in eqs. (28) and (29)), post outsurcing profit of the originating economy from the destination economy (symbolized as (4) in eqs. (28) and (29)) and also on the partial change in the productivity of unskilled as well as skilled workers due to endogenous determination of the proportion of outsourcing (denoted as (2) in eqs. (28) and (29)). Substituting eqs. (28) and (29), in eq. (25), one can derive the wage rates of skilled and unskilled workers in the innovation activity of the backward economy. The wage rate of unskilled workers turns out to be:

$$\frac{w_{\rm ut} - \lambda\delta\gamma\phi\ \tilde{u}_{\rm nt}^{\phi-1}\ \tilde{s}_{\rm nt}^{1-\phi}\ \overline{A}_{\rm t\text{-}1}\ \mu(a_{\rm t\text{-}1})}{\Big[\lambda\delta\gamma\phi\ \tilde{u}_{\rm nt}^{\phi-1}\ \tilde{s}_{\rm nt}^{1-\phi}\ \overline{A}_{\rm t\text{-}1} - w_{\rm ut}\Big]} = \frac{\lambda\delta\gamma\ \tilde{u}_{\rm nt}^{\phi}\ \tilde{s}_{\rm nt}^{1-\phi}\ \overline{A}_{\rm t\text{-}1}\mu(a_{\rm t\text{-}1})}{2A\ \mu(a_{\rm t\text{-}1}) - \Big[\lambda\delta\gamma\ \tilde{u}_{\rm nt}^{\phi}\ \tilde{s}_{\rm nt}^{1-\phi}\ \overline{A}_{\rm t\text{-}1} - (w_{\rm ut}\ \tilde{u}_{\rm nt} + w_{\rm st}\ \tilde{s}_{\rm nt})\Big]}. \tag{30}$$

and that of skilled worker will be:

$$\frac{w_{\rm st} - \lambda\delta\gamma(1-\phi)\ \tilde{u}_{\rm nt}^{\phi}\ \tilde{s}_{\rm nt}^{-\phi}\ \overline{A}_{\rm t\text{-}1}\ \mu(a_{\rm t\text{-}1})}{\Big[\lambda\delta\gamma(1-\phi)\ \tilde{u}_{\rm nt}^{\phi}\ \tilde{s}_{\rm nt}^{-\phi}\ \overline{A}_{\rm t\text{-}1} - w_{\rm st}\Big]} = \frac{\lambda\delta\gamma\ \tilde{u}_{\rm nt}^{\phi}\ \tilde{s}_{\rm nt}^{1-\phi}\ \overline{A}_{\rm t\text{-}1}\mu(a_{\rm t\text{-}1})}{2A\ \mu(a_{\rm t\text{-}1}) - \Big[\lambda\delta\gamma\ \tilde{u}_{\rm nt}^{\phi}\ \tilde{s}_{\rm nt}^{1-\phi}\ \overline{A}_{\rm t\text{-}1} - (w_{\rm ut}\ \tilde{u}_{\rm nt} + w_{\rm st}\ \tilde{s}_{\rm nt})\Big]}. \tag{31}$$

From eqs. (30) and (31) we get,

$$\frac{w_{\rm ut}}{w_{\rm st}} = \frac{\phi}{(1-\phi)}\frac{\tilde{s}_{\rm nt}}{\tilde{u}_{\rm nt}}. \tag{32}$$

Given that skilled and unskilled workers are perfectly mobile between imitation and innovation activities, the relative demand for skilled and unskilled human capital in the innovation activity has been derived. That is, from eqs. (26) and (32), we get that:

$$\psi\frac{s_{\rm mt}}{u_{\rm mt}} = \frac{\tilde{s}_{\rm nt}}{\tilde{u}_{\rm nt}} \quad \Rightarrow \quad \frac{\tilde{s}_{\rm nt}}{\tilde{u}_{\rm nt}} = \frac{\psi S_{\rm t} - (\psi-1)\tilde{s}_{\rm nt}}{U_{\rm t}}. \tag{33}$$

Next, an implicit function of the demand for skilled human capital in the innovation activity has been obtained. Substituting eq. (29) in eq. (25), we get,[11]

$$\lambda\delta(1-\sigma)u_{\rm mt}^{\sigma}\ s_{\rm mt}^{-\sigma}\ \frac{(\overline{A}_{\rm t\text{-}1} - A_{\rm t\text{-}1})}{\overline{A}_{\rm t}} = \lambda\delta\gamma(1-\phi)\ \tilde{u}_{\rm nt}^{\phi}\ \tilde{s}_{\rm nt}^{-\phi}\ \overline{A}_{\rm t\text{-}1}\ \mu(a_{\rm t\text{-}1}) + \lambda\delta\gamma\ \tilde{u}_{\rm nt}^{\phi}\ \tilde{s}_{\rm nt}^{1-\phi}\ \overline{A}_{\rm t\text{-}1}\ \frac{d\ \mu(a_{\rm t\text{-}1})}{d\ \tilde{s}_{\rm nt}}$$

$$\Rightarrow \quad 2A\mu(a_{\rm t\text{-}1})\left[\frac{z(a_{\rm t\text{-}1})\ U_{\rm t}^{\sigma-\phi}}{[\psi S_{\rm t} - (\psi-1)\tilde{s}_{\rm nt}]^{\sigma-\phi}} - \mu(a_{\rm t\text{-}1})\right] - \frac{\lambda\delta\gamma\ z(a_{\rm t\text{-}1})\ U_{\rm t}^{\sigma}\ \tilde{s}_{\rm nt}\ \overline{A}_{\rm t\text{-}1}}{[\psi S_{\rm t} - (\psi-1)\tilde{s}_{\rm nt}]^{\sigma}}\left[1 - \frac{z(a_{\rm t\text{-}1})\ U_{\rm t}^{\sigma-\phi}}{[\psi S_{\rm t} - (\psi-1)\tilde{s}_{\rm nt}]^{\sigma-\phi}}\right] = 0. \tag{34}$$

where $z(a_{\rm t\text{-}1}) = \frac{(1-\sigma)\psi^{\sigma}}{\gamma(1-\phi)}\ \frac{(\overline{A}_{\rm t\text{-}1} - A_{\rm t\text{-}1})}{\overline{A}_{\rm t}\ \overline{A}_{\rm t\text{-}1}} = \frac{(1-\sigma)\psi^{\sigma}}{\gamma(1-\phi)}\ \frac{(1-a_{\rm t\text{-}1})}{(1+\bar{g})\ \overline{A}_{\rm t\text{-}1}}$.

$$\text{Therefore,}\ \ B < 0 \ \Rightarrow\ \frac{z(a_{\rm t\text{-}1})\ U_{\rm t}^{\sigma-\phi}}{[\psi S_{\rm t} - (\psi-1)\tilde{s}_{\rm nt}]^{\sigma-\phi}} < 1.$$

$$\text{Therefore, from eq. (34), we get,}\ \frac{z(a_{\rm t\text{-}1})\ U_{\rm t}^{\sigma-\phi}}{[\psi S_{\rm t} - (\psi-1)\tilde{s}_{\rm nt}]^{\sigma-\phi}} - \mu(a_{\rm t\text{-}1}) > 0$$

$$\Rightarrow\ \mu(a_{\rm t\text{-}1}) < \frac{z(a_{\rm t\text{-}1})\ U_{\rm t}^{\sigma-\phi}}{[\psi S_{\rm t} - (\psi-1)\tilde{s}_{\rm nt}]^{\sigma-\phi}} < 1$$

$$\Rightarrow\ \mu(a_{\rm t\text{-}1}) < 1. \tag{35}$$

[11] Detailed mathematical derivations are provided in the cluster of eqs. (50) - (55) in Appendix on pages 37- 39.

Remark 3 *In equilibrium, the R & D producer of the advanced economy outsources a fraction of its R & D activity to the backward economy.*

3.5 Labor Supply of the Destination Economy

In this section, the supply curve of skilled and unskilled human capital in period t will be derived. Individuals have different cognitive ability and the cost of education varies accordingly. An individual opts for education if his/ her lifetime income as skilled worker is higher than as unskilled worker. Therefore, from eqs. (5), (6) and (7), the cut off level of cognitive ability above which an individual opts for education is given by:

$$\mathbb{W}_{\text{st}} \geq \mathbb{W}_{\text{ut}} \qquad \Rightarrow \quad \theta_{\text{t}} \equiv \hat{\theta} \geq \frac{w_{\text{ut}}}{w_{\text{st}}}. \tag{36}$$

An individual whose cognitive ability is below $\hat{\theta}$ works as unskilled worker and otherwise, he/ she works as skilled worker. So, $\hat{\theta}$ measures the cut off cognitive ability above which an individual opts for education. Intuitively, as wage inequality rises, the supply of the proportion of unskilled workers falls and skilled workers rises. The higher wage gap between skilled and unskilled workers provides the incentive to become skilled.

3.6 Labor Market in Equilibrium in the Destination Economy

It is the interaction of the demand and supply curves of skilled and unskilled human capital in the imitation and the innovation activities that determines the equilibrium proportions of skilled and unskilled human capital in period t in the backward economy. These, in turn, determine the equilibrium allocation of skilled and unskilled human capital in the imitation and the innovation activities.

From eqs. (32), (33) and (36), the proportion of the supply of unskilled workers in the economy is given by:

$$U_{\text{t}} = \frac{\phi}{(1-\phi)} \frac{[\psi\ S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]}{U_{\text{t}}} \qquad \Rightarrow \quad U_{\text{t}}^2 = \frac{\phi}{(1-\phi)} \left[\psi\ S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}\right]. \tag{37}$$

Accordingly, since an individual who works as skilled, works for θ fraction of his/ her life after spending (1-θ) fraction on education, the proportion of the supply of skilled worker by using eq. (37) will be:

$$S_{\text{t}} = \int_{\hat{\theta}_{\text{t}}}^{1} \theta_{\text{t}}\ \mathrm{d}\theta = \frac{1-\hat{\theta}_{\text{t}}^{\,2}}{2}$$

$$\Rightarrow \quad S_{\text{t}} = \frac{1-U_{\text{t}}^2}{2} = \frac{1}{2} - \frac{\phi}{2(1-\phi)} \left[\psi\ S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}\right]. \tag{38}$$

The dynamics of skilled and unskilled workers show that there exists a negative relation between the equilibrium proportions of skilled and unskilled human capital. By using eq. (38), the condition will be as follows:

$$S_{\mathrm{t}} = \frac{1 - U_{\mathrm{t}}^2}{2} \qquad \Rightarrow \quad \frac{d\ S_{\mathrm{t}}}{d\ U_{\mathrm{t}}} = -U_{\mathrm{t}} < 0. \tag{39}$$

Remark 4 *As the equilibrium proportion of unskilled human capital rises it entails a reduction in the equilibrium proportion of skilled human capital.*

Next, the relation between the equilibrium proportion of skilled human capital and allocation of it in the innovation activity is derived. From eqs. (38) and (39), we get,

$$\frac{dS_{\mathrm{t}}}{d\tilde{s}_{\mathrm{nt}}} = \frac{(\sigma - \phi)}{(1-\phi)(2-\sigma)} > 0. \tag{40}$$

Intuitively, by **A1**, innovation is skilled human capital intensive. Therefore, innovation attracts more skilled human capital as the equilibrium proportion of skilled human capital rises.

Remark 5 *As the equilibrium proportion of skilled human capital rises, it results in a higher equilibrium proportion of skilled human capital allocation to the innovation activity.*

Next, the implicit function for the equilibrium proportion of skilled human capital in the innovation activity is derived. By substituting eq. (37) in eq. (34), we get,

$$\begin{aligned} 2A\mu(a_{\mathrm{t\text{-}1}}) &\left[\frac{z(a_{\mathrm{t\text{-}1}})\ \Phi^{\sigma-\phi}}{U_{\mathrm{t}}^{\sigma-\phi}} - \mu(a_{\mathrm{t\text{-}1}})\right] \\ &- \lambda\delta\gamma\ z(a_{\mathrm{t\text{-}1}})\ \frac{\Phi^{\sigma}}{U_{\mathrm{t}}^{\sigma}}\ \tilde{s}_{\mathrm{nt}}\ \overline{A}_{\mathrm{t\text{-}1}} \left[1 - \frac{z(a_{\mathrm{t\text{-}1}})\ \Phi^{\sigma-\phi}}{U_{\mathrm{t}}^{\sigma-\phi}}\right] = 0, \end{aligned} \tag{41}$$

where $\Phi = \frac{\phi}{(1-\phi)}$. From eqs. (35) and (37), we get the following regularity conditions:

$$\begin{aligned} &\frac{z(a_{\mathrm{t\text{-}1}})\ \Phi^{\sigma-\phi}}{U_{\mathrm{t}}^{\sigma-\phi}} < 1 \\ \text{and } &\frac{z(a_{\mathrm{t\text{-}1}})\ \Phi^{\sigma-\phi}}{U_{\mathrm{t}}^{\sigma-\phi}} > \mu(a_{\mathrm{t\text{-}1}}). \end{aligned} \tag{42}$$

We now try to show that there exists an equilibrium proportion of skilled and unskilled human capital, so that the participations in both – imitation and innovation – activities are positive. This amounts to proving that $0 < \tilde{s}_{\text{nt}} < S_{\text{t}}$ and $0 < \tilde{u}_{\text{nt}} \ < U_{\text{t}}$. By using eq. (41), let us assume that

$$k_1(\tilde{s}_{\text{nt}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}}) = 2A\mu(a_{\text{t-1}}) \left[\frac{z(a_{\text{t-1}}) \ \Phi^{\sigma-\phi}}{U_{\text{t}}^{\sigma-\phi}} - \mu(a_{\text{t-1}}) \right];$$

$$\text{and } k_2(\tilde{s}_{\text{nt}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}}) = \lambda\delta\gamma \ z(a_{\text{t-1}}) \ \frac{\Phi^{\sigma}}{U_{\text{t}}^{\sigma}} \ \tilde{s}_{\text{nt}} \ \overline{A}_{\text{t-1}} \left[1 - \frac{z(a_{\text{t-1}}) \ \Phi^{\sigma-\phi}}{U_{\text{t}}^{\sigma-\phi}} \right]. \tag{43}$$

First, the sign of the curve $k_1(\tilde{s}_{\text{nt}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}})$ has been ascertained for the two extreme possible values (that is, $\tilde{s}_{\text{nt}}$ takes a value either 0 or S_{t}). We get that,

$$k_1(0, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}}) = 0; \text{ and}$$

$$k_1(S_{\text{t}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}}) \gtreqless 0, \text{ according as } \frac{z(a_{\text{t-1}}) \ \Phi^{\sigma-\phi}}{U_{\text{t}}^{\sigma-\phi}} - \mu(a_{\text{t-1}}) \gtreqless 0.$$

$k_1(0, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}})$ takes a value zero since $\mu(a_{\text{t-1}}) = 0$, if no skilled worker is engaged in the innovation activity (that is, $\tilde{s}_{\text{nt}} = 0$). The value of $k_1(S_{\text{t}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}})$ is indeterminate since the value of $\mu(a_{\text{t-1}})$ is not determined at $\tilde{s}_{\text{nt}} = S_{\text{t}}$.

Next, the sign of the curve $k_2(\tilde{s}_{\text{nt}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}})$ has been determined for the two extreme possible values. That is,

$$k_2(0, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}}) = 0, \text{ and}$$

$$k_2(S_{\text{t}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}}) > 0, \text{ From eq. (42).}$$

Given that $k_1(0, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}}) = k_2(0, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}}) = 0$ and $k_2(S_{\text{t}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}}) > 0$, if $k_1(S_{\text{t}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}}) > 0$, then there may exist positive value of the equilibrium proportion of skilled human capital in the innovation activity irrespective of whether $k_1(s_{\text{nt}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}})$ and $k_2(s_{\text{nt}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}})$ are monotonic or non-monotonic. However, if $k_1(S_{\text{t}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}}) < 0$, then the positive value of the equilibrium proportion of skilled human capital in the innovation activity exists only if either one of the $k_1(s_{\text{nt}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}})$ or $k_2(s_{\text{nt}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}})$ are non-monotonic.

Lemma 1 *The technology improvement of the destination economy via imitation as well as the outsourcing activity exists*

- *only if either one of the $k_1(s_{nt}, a_{t\text{-}1}, U_t, S_t)$ or $k_2(s_{nt}, a_{t\text{-}1}, U_t, S_t)$ are non-monotonic, when $k_1(S_t, a_{t\text{-}1}, U_t, S_t) < 0$;*
- *irrespective of whether $k_1(s_{nt}, a_{t\text{-}1}, U_t, S_t)$ and $k_2(s_{nt}, a_{t\text{-}1}, U_t, S_t)$ are monotonic or non-monotonic, when $k_1(S_t, a_{t\text{-}1}, U_t, S_t) > 0$.*

Now, the monotonicity of the functions $k_1(\tilde{s}_{\text{nt}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}})$ and $k_2(\tilde{s}_{\text{nt}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}})$ are ascertained. To do that, the curvature of the above mentioned functions needs to be derived. First, the curvature of $k_1(\tilde{s}_{\text{nt}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}})$ has been determined. From eq. (43), we get,

$$k_1(\tilde{s}_{\text{nt}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}}) = 2A\mu(a_{\text{t-1}})\left[\frac{z(a_{\text{t-1}})\ \Phi^{\sigma-\phi}}{U_{\text{t}}^{\sigma-\phi}} - \mu(a_{\text{t-1}})\right]$$

$$= \underbrace{2A\left[\frac{z(a_{\text{t-1}})\ \Phi^{\sigma-\phi}}{U_{\text{t}}^{\sigma-\phi}} - 2\mu(a_{\text{t-1}})\right]}_{\substack{(1)\\ indeterminate}}\underbrace{\frac{d\mu(a_{\text{t-1}})}{d\tilde{s}_{\text{nt}}}}_{\substack{(2)\\ \gtreqless 0}} + \underbrace{2A\mu(a_{\text{t-1}})\frac{(\sigma-\phi)^2}{(1-\phi)(2-\sigma)}\frac{z(a_{\text{t-1}})\ \Phi^{\sigma-\phi}}{U_{\text{t}}^{\sigma-\phi+2}}}_{\substack{(3)\\ +ve}}. \tag{44}$$

For mathematical tractability, the signs of the three parts in the r.h.s of eq. (44) (which are symbolized as (1), (2) and (3)) are analyzed separately. As for the first part, from eq. (42), we have,

$$\frac{z(a_{\text{t-1}})\ \Phi^{\sigma-\phi}}{U_{\text{t}}^{\sigma-\phi}} - \mu(a_{\text{t-1}}) > 0$$

$$\Rightarrow \quad \frac{z(a_{\text{t-1}})\ \Phi^{\sigma-\phi}}{U_{\text{t}}^{\sigma-\phi}} - 2\mu(a_{\text{t-1}}) > -\mu(a_{\text{t-1}}).$$

Therefore, the sign of the first part in the r.h.s of eq. (44) is indeterminate. It can be either positive or negative. We next, try to determine the sign of the second part in the r.h.s of eq. (44). From eq. (29), we get,

$$\frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{s}_{\text{nt}}} = \frac{\mu(a_{\text{t-1}})\left[\lambda\delta\gamma(1-\phi)\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{-\phi}\overline{A}_{\text{t-1}} - w_{\text{st}}\right]}{2\ A\ \mu(a_{\text{t-1}}) - \left[\lambda\delta\gamma\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{ut}}\ \tilde{u}_{\text{nt}} + w_{\text{st}}\ \tilde{s}_{\text{nt}})\right]}$$

$$= \frac{\mu(a_{\text{t-1}})\left[\lambda\delta\gamma(1-\phi)\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{-\phi}\overline{A}_{\text{t-1}} - w_{\text{st}}\right]}{\pm\sqrt{B^2-4AF}}, \qquad \text{[From eq. (27)]}. \tag{45}$$

From eq. (54), it is known that the numerator of eq. (45) is positive. The denominator of eq. (45) takes a positive or a negative value respectively depending on whether the denominator takes a positive or a negative square root. Therefore,

$$\frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{s}_{\text{nt}}} > 0, \qquad \text{if } \mu(a_{\text{t-1}}) = \frac{-B+\sqrt{B^2-4AF}}{2A};$$

$$\frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{s}_{\text{nt}}} < 0, \qquad \text{if } \mu(a_{\text{t-1}}) = \frac{-B-\sqrt{B^2-4AF}}{2A}.$$

Further, it is obvious that the third part in the r.h.s of eq. (44) is positive. Therefore, it is difficult to ascertain the sign of the derivative in eq. (44). It depends on the sign of the first and the second parts of eq. (44) and also on their magnitude. Thus, monotonicity or non-monotonicity of the $k_1(\tilde{s}_{\text{nt}}, a_{\text{t-1}}, U_{\text{t}}, S_{\text{t}})$ cannot be proved unambiguously.

Next, the curvature of the $k_2(\tilde{s}_{nt}, a_{t\text{-}1}, U_t, S_t)$ has been derived. From eq. (43), we get,

$$k_2(\tilde{s}_{nt}, a_{t\text{-}1}, U_t, S_t) = \lambda\delta\gamma\ z(a_{t\text{-}1})\ \frac{\Phi^{\sigma}}{U_t^{\sigma}}\ \tilde{s}_{nt}\ \overline{A}_{t\text{-}1}\left[1 - \frac{z(a_{t\text{-}1})\ \Phi^{\sigma-\phi}}{U_t^{\sigma-\phi}}\right]$$

$$\Rightarrow \quad \frac{dk_2(\tilde{s}_{nt}, a_{t\text{-}1}, U_t, S_t)}{d\tilde{s}_{nt}} = \underbrace{\lambda\delta\gamma\ z(a_{t\text{-}1})\ \frac{\Phi^{\sigma}}{U_t^{\sigma}}\ \overline{A}_{t\text{-}1}\left[1 - \frac{z(a_{t\text{-}1})\ \Phi^{\sigma-\phi}}{U_t^{\sigma-\phi}}\right]}_{\substack{(1)\\ +ve}}$$

$$- \underbrace{\lambda\delta\gamma\ z(a_{t\text{-}1})\ \frac{\Phi^{\sigma}}{U_t^{\sigma+1}}\ \tilde{s}_{nt}\ \overline{A}_{t\text{-}1}}_{\substack{(2)\\ +ve}}\ \underbrace{\frac{dU_t}{d\tilde{s}_{nt}}}_{\substack{(3)\\ -ve}}\ \underbrace{\left[\sigma - (2\sigma-\phi)\ z(a_{t\text{-}1})\ \frac{\Phi^{\sigma-\phi}}{U_t^{\sigma-\phi}}\right]}_{\substack{(4)\\ indeterminate}}. \tag{46}$$

To understand the slope of eq. (46), one needs to ascertain first the slope of the eqs. represented as (1), (2), (3) and (4) in that equation. From the regularity conditions in the cluster of eqs. (42), one gets that (1) in eq. (46) is positive. Moreover, it is obvious that (2) in the eq. (46) is also always positive. From **Remarks 4** and **5**, the third part (resp. (3)) of eq. (46) is negative. Now, one needs to evaluate the sign of the fourth part (that is, (4)) in eq. (46). If it is positive then $k_2(\tilde{s}_{nt}, a_{t\text{-}1}, U_t, S_t)$ is a increasing monotonic function. From eq. (42), we get that,

$$\frac{z(a_{t\text{-}1})\ \Phi^{\sigma-\phi}}{U_t^{\sigma-\phi}} > \mu(a_{t\text{-}1})$$

$$\Rightarrow \quad \sigma - (2\sigma-\phi)\ z(a_{t\text{-}1})\ \frac{\Phi^{\sigma-\phi}}{U_t^{\sigma-\phi}} < \sigma - (2\sigma-\phi)\mu(a_{t\text{-}1})$$

$$\text{Now, if } \mu(a_{t\text{-}1}) = 0, \qquad \sigma - (2\sigma-\phi)\ z(a_{t\text{-}1})\ \frac{\Phi^{\sigma-\phi}}{U_t^{\sigma-\phi}} < \sigma;$$

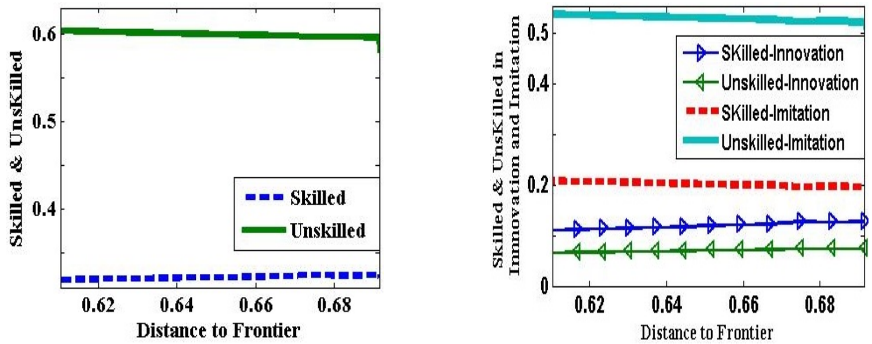
$$\text{and, if } \mu(a_{t\text{-}1}) = 1, \qquad \sigma - (2\sigma-\phi)\ z(a_{t\text{-}1})\ \frac{\Phi^{\sigma-\phi}}{U_t^{\sigma-\phi}} < -(\sigma-\phi). \tag{47}$$

Therefore, (4) in eq. (46) can take either positive or negative values depending on the value of $\mu(a_{t\text{-}1})$. Again, from eq. (42), we get that,

$$\frac{z(a_{t\text{-}1})\ \Phi^{\sigma-\phi}}{U_t^{\sigma-\phi}} < 1$$

$$\Rightarrow \quad \sigma - (2\sigma-\phi)\ z(a_{t\text{-}1})\ \frac{\Phi^{\sigma-\phi}}{U_t^{\sigma-\phi}} > -(\sigma-\phi). \tag{48}$$

Therefore, both the conditions in eqs. (47) and (48) imply that $\sigma - (2\sigma-\phi)\ z(a_{t\text{-}1})\ \frac{\Phi^{\sigma-\phi}}{U_t^{\sigma-\phi}} \gtreqless 0$. Thus, one cannot derive a definitive sign for the slope of $k_2(\tilde{s}_{nt}, a_{t\text{-}1}, U_t, S_t)$. Thus, $k_2(\tilde{s}_{nt}, a_{t\text{-}1}, U_t, S_t)$ can be either monotonic or non-monotonic.



(a) Skilled and Unskilled Human Capital

(b) Skilled and Unskilled Human Capital in Imitation and Innovation Activities

Figure 1: Skilled-Unskilled Human Capital and Allocation of these in Imitation and Innovation Activities

Remark 6 *It cannot be unambiguously proved whether* $k_1(\tilde{s}_{nt}, a_{t\text{-}1}, U_t, S_t)$ *and* $k_2(\tilde{s}_{nt}, a_{t\text{-}1}, U_t, S_t)$ *are monotonic or non-monotonic functions.*

Therefore, analytically it is difficult to ascertain the existence of skilled and unskilled human capital in the imitation and innovation activities. Thus, numerical simulation had to be resorted to. The findings for the simulation exercise are now discussed. The specific parameter values considered for our analysis are as follows:[12]

Parameters	λ	γ	δ	σ	ϕ	$\bar{g}$	F	U_F	$a(1)$	$\overline{A}(1)$
Values	0.8	1	0.4	0.6	0.3	0.02	0.1	0.4	0.7	10

Table 1: Parameter Values for Numerical Simulation

The parametric values imply that to start with the outsourcing activity backward economy is sufficiently advanced, which is captured by a high value of a(1). It is considered that the backward economy needs to be sufficiently technologically advanced. To satisfy **A1**, a higher value is assigned to σ than ϕ. It is assumed that there exists a fixed composition of skilled and unskilled human capital in the originating economy. The world technology frontier is growing at a constant rate. These parameter values satisfy all the required regularity conditions given in cluster of eqs. (42). One can now analyze the dynamics of the composition of human capital as the time progresses. To do this, eqs. (34) and (38) have

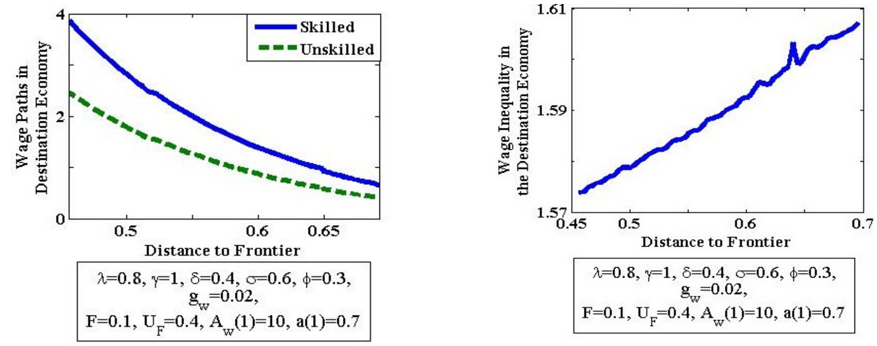
[12]Numerical solution has been done for the case where $\mu(a_{t\text{-}1}) = \frac{-B+\sqrt{B^2-4AF}}{2A}$.

been simultaneously solved by using numerical simulations. Post outsourcing, the backward economy undertakes imitation activity for its own country and performs innovation activity for the advanced economy. However, as the time progresses, the technology level of the world leader rises. Consequently, due to the disadvantage of backwardness, imitation becomes more challenging for the destination economy. This leads to a lower increment of technology level. Eventually, the technology gap of the backward economy widens vis-a-vis the world technology leader. Thus, as the time progresses, the backward economy regresses in terms of the relative technology from the world technology frontier. Therefore, by participating in the R & D outsourcing activity, the backward economy diverges away from the world technology frontier. Subsequently, its dependence on imitation rises and innovation falls. By **A1**, imitation is unskilled human capital intensive. Thus, as an economy moves away from the frontier, the proportion of unskilled human capital rises and skilled human capital falls, as is illustrated in Fig. 1a on page 25. . This finding contrasts with Vandenbussche et al. [2006], Aghion et al. [2009], Di Maria and Stryszowski [2009] and Basu and Mehra [2014]. In the absence of outsourcing, their studies show that without outsourcing as the time progresses skilled human capital rises and unskilled human capital falls, which is opposed to our findings.

Lemma 2 *Under* **A1***, for the country which is in the imitation-innovation regime and which is performing R & D activity for the advanced economy, the proportion of skilled human capital decreases and unskilled human capital increases as an economy moves away from the world technology frontier, even as the aggregate stock of human capital remains unchanged.*

Next, the focus is on the equilibrium allocation of skilled and unskilled human capital in the imitation and the innovation activities in the backward economy as the time progresses. By **Lemma 2**, and **A1**, as an economy regresses, the proportion of unskilled human capital rises. Since imitation is unskilled intensive, imitation attracts more unskilled human capital. Due to the complementary effect, imitation also attracts skilled human capital. As an outcome of this process, unskilled human capital again moves to the imitation activity and the process continues. Consequently, both skilled and unskilled human capital shift from innovation activity to imitation activity, as is shown in Fig. 1b on page 25. This finding is also different from that of Vandenbussche et al. [2006], Aghion et al. [2009], Di Maria and Stryszowski [2009] and Basu and Mehra [2014]. Their studies show that (without outsourcing) as the time progresses, both skilled and unskilled human capital shift from imitation to innovation (resp. imitation) activity, which is exactly opposite of this finding with outsourcing.

Lemma 3 *Under* **A1***, for the country which is in the diversified regime and participating in the R & D*



(a) Wage Paths (b) Wage Inequality

Figure 2: Wage Paths and Wage Inequality in the Destination Economy

outsourcing activity, the equilibrium proportions of skilled and unskilled human capital employment levels increase in the imitation activity and decrease in the innovation activity, as an economy moves further away from the world technology frontier.

3.7 Wage Paths of the Destination Economy

In this subsection, the dynamics of the wage paths and wage inequality of skilled and unskilled workers in the backward economy have been characterized. First, the focus is on the wage paths differentiated by composition of human capital. By **Lemma 2**, the proportion of skilled human capital falls and unskilled human capital rises as the backward economy diverges away from the world technology frontier. With the fall in the proportion of skilled human capital, the demand for skilled human capital rises which induces a rise in the wage rate of skilled workers as an economy moves away from the frontier. Further, as the backward economy regresses, the scope of imitation rises. By **A1**, since imitation is unskilled intensive, it raises the demand for unskilled human capital and, consequently, increases the wage rate of unskilled workers in the destination economy. This implies that the wage paths of both skilled and unskilled workers rise as an economy, which is participating in the R & D outsourcing activity, regresses in the imitation-innovation regime (this is demonstrated in Fig. 2a on page 27). In comparison, Basu and Mehra [2014] shows that without outsourcing as the economy progresses, the wage rate of skilled workers rises and unskilled workers falls.

Furthermore, the wage inequality between skilled and unskilled workers in the diversified regime has been analyzed. Inequality is defined as

$$win_{\mathrm{t}} = \frac{w_{\mathrm{st}}}{w_{\mathrm{ut}}},$$

where win_{t} measures the wage inequality between skilled and unskilled workers in the backward economy.

From eqs. (26) and (32), the wage inequality depends on the relative intensity of unskilled-skilled human capital in the imitation and the innovation activities. While it is analytically difficult to derive the nature of these curves, through numerical simulations it is shown that wage inequality between skilled and unskilled workers falls as the gap form the world technology frontier rises (this is illustrated in Fig. 2b on page 27). Intuitively, as the scope of imitation rises, the relative demand for unskilled to skilled human capital rises and so does the relative wage rate of unskilled to skilled as the time progresses. This finding is not in line with Basu and Mehra [2014] which shows that wage inequality between skilled and unskilled workers rises in the diversified regime as the time progresses.

3.8 Proportion of Outsourcing

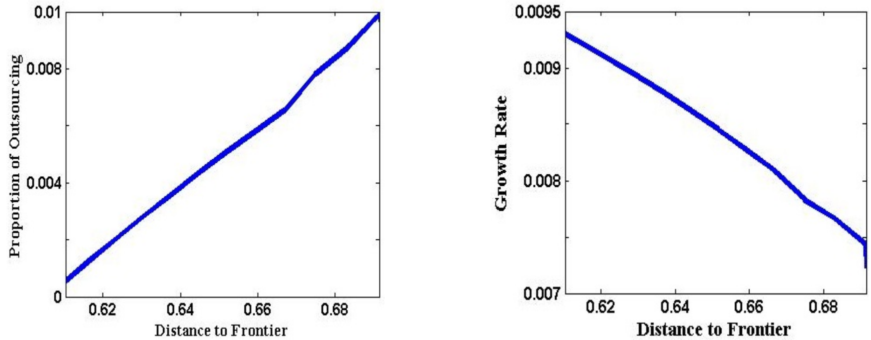
The dynamics of the equilibrium proportion of R & D outsourcing are discussed in this subsection. From eqs. (24) and (53), the equilibrium proportion of R & D outsourcing from the originating to the destination economy is captured by the following expression:

$$\lambda\delta\gamma\, U_{\mathrm{Ft}}^{\phi}\, S_{\mathrm{Ft}}^{1-\phi}\, \overline{A}_{\mathrm{t-1}}\, \mu^2(a_{\mathrm{t-1}}) + \left[(w_{\mathrm{ut}}\, \tilde{u}_{\mathrm{nit}} + w_{\mathrm{st}}\, \tilde{s}_{\mathrm{nit}}) - \lambda\delta\gamma\, \tilde{u}_{\mathrm{nit}}^{\phi}\, \tilde{s}_{\mathrm{nit}}^{1-\phi}\, \overline{A}_{\mathrm{t-1}}\right] \mu(a_{\mathrm{t-1}}) + F = 0$$

$$\Rightarrow \quad \lambda\delta\gamma\, U_{\mathrm{Ft}}^{\phi}\, S_{\mathrm{Ft}}^{1-\phi}\, \overline{A}_{\mathrm{t-1}}\, \mu^2(a_{\mathrm{t-1}})$$

$$- \lambda\delta\gamma \frac{U_{\mathrm{t}}^{\phi}}{[\psi S_{\mathrm{t}} - (\psi-1)\tilde{s}_{\mathrm{nt}}]^{\phi}}\, \tilde{s}_{\mathrm{nt}}\, \overline{A}_{\mathrm{t-1}} \left[1 - \frac{z(a_{\mathrm{t-1}})\, U_{\mathrm{t}}^{\sigma-\phi}}{[\psi S_{\mathrm{t}} - (\psi-1)\tilde{s}_{\mathrm{nt}}]^{\sigma-\phi}}\right] \mu(a_{\mathrm{t-1}}) + F = 0. \qquad (49)$$

From eq. (49), the equilibrium proportion of R & D outsourcing is a function of skilled human capital engaged in the outsourcing activity. However, the existence of skilled human capital employed in the innovation activity has not been shown through analytical analysis. Therefore, to find out the dynamics of the equilibrium proportion of R & D outsourcing one needs to resort to numerical simulations. Intuitively, attracted by the cheaper workforce of the backward economy, the intermediate input producers of the advanced economy outsource their R & D activity to the backward economy. The skill composition of human capital is also lower in the destination economy. By **A1**, the R & D activity of the advanced economy is skilled intensive, and by **Lemma 2**, as the time progresses, the proportion of skilled workers falls in the backward economy. Moreover, as discussed in Subsection 3.7 on page 27, the wage rate of skilled workers rises in the diversified regime as the time progresses. Additionally, in the upcoming Subsection 3.11 on page 31, it is shown that the wage gap of skilled workers between the backward and advanced economies falls as the time progresses. Consequently, the profit of the intermediate input producer of the advanced economy falls when the destination economy worsens in terms of the relative technology level. This leads to an absolute reduction in the proportion of outsourcing as the time progresses in the destination economy. This is also demonstrated through numerical simulations in Fig. 3a on page 29.



(a) Proportion of Outsourcing

(b) Growth Path

Figure 3: Proportion of Outsourcing and Growth Path in the Destination Economy

Proposition 1 *Under* **A1***, as the time progresses, the equilibrium level of R & D outsourcing falls which is in the backward economy (imitation-innovation regime), which is participating in the R & D activity of the advanced economy.*

3.9 Growth Path of the Destination Economy

In this subsection the growth path of the backward economy depending on its distance to frontier has been characterized. It is assumed that the R & D producer of the backward economy is performing imitation activity for its own country and innovating for the advanced economy. This implies that the growth rate of the backward economy depends only on the imitation activity of the backward economy. By rearranging the technological progress as in eq. (3) and summing up over all the intermediate goods sectors i, one can define the growth rate of a decentralized backward economy in period t as

$$g_t = \int_0^1 \frac{A_{it} - A_{t-1}}{A_{t-1}} di = \lambda\ u_{\mathrm{mt}}^{\sigma}\ s_{\mathrm{mt}}^{1-\sigma}\ \frac{(\overline{A}_{\mathrm{t\text{-}1}} - A_{\mathrm{t\text{-}1}})}{\overline{A}_{\mathrm{t}} A_{\mathrm{t\text{-}1}}} = \lambda\ u_{\mathrm{mt}}^{\sigma}\ s_{\mathrm{mt}}^{1-\sigma}\ \frac{(1 - a_{\mathrm{t\text{-}1}})}{(1+\bar{g}) a_{\mathrm{t\text{-}1}} \overline{A}_{\mathrm{t\text{-}1}}}.$$

The growth rate of the destination economy depends on the allocation of skilled and unskilled human capital in the imitation activity and its relative distance from the frontier. Since the explicit analytical solutions of these (that is, u_{mt} and s_{mt}) could not be obtained, we have to again resort to numerical simulations. Fig. 3b on page 29 shows that as an economy regresses its growth rate initially rises and thereafter falls. Intuitively, this is how it works. As an economy's distance from the world technology frontier rises, the scope of imitation rises and that of innovation falls. By **A1**, imitation is unskilled intensive. By **Lemma 2** and **Lemma 3**, the proportion of unskilled human capital rises and both skilled and unskilled human capital shift away from innovation to imitation activity, as an economy moves away from the frontier. This induces a relatively higher increment of technological progress as well as the growth rate of the economy,

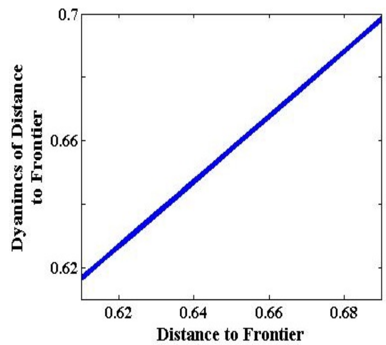


Figure 4: Dynamics of Distance to Frontier

which is in the imitation-innovation regime and performing R & D activity for the advanced economy. But, along with the advantage of backwardness, there exists the disadvantage of backwardness. As the relative gap of the economy from the world technology frontier rises, imitation becomes more challenging. As a consequence of this, the relative increment of the technology level falls as well as the growth rate. This implies that there exists an inverted U-shaped growth curve with respect to the time. This finding is very different from Basu and Mehra [2014]. Their studies reveal that (in the absence of R & D outsourcing) the growth rate of an economy which is in the diversified regime rises as an economy progresses. However, Di Maria and Stryszowski [2009] shows that even in the absence of outsourcing growth rate of the backward economy which is in the diversified regime falls as an economy progresses.

Proposition 2 *Under* **A1** *and* **A2***, for the backward economy, which is in the imitation-innovation regime and is participating in the R & D outsourcing, there exists an inverted U-shaped growth curve as its distance from the world technology frontier increases.*

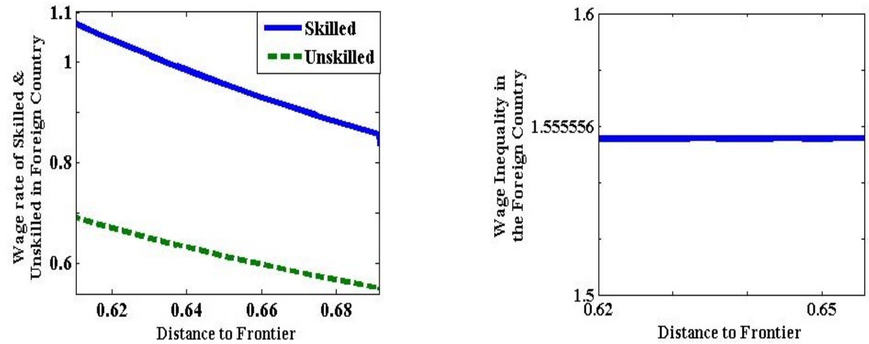
3.10 Dynamics of Distance to Frontier of the Destination Economy

Furthermore, the analysis has been done for the long run dynamics of an economy which is in the imitation-innovation regime and which is participating in the R & D activity of the advanced economy. The definition of growth rate can be specified as:

$$g_{t+1} = \frac{A_{t+1} - A_t}{A_t} = \frac{A_{t+1}}{A_t} - 1 = \frac{A_{t+1}}{\overline{A}_{t+1}}\frac{\overline{A}_t}{A_t}(1+\bar{g}) - 1 = \frac{a_{t+1}(1+\bar{g})}{a_t} - 1$$

$$\Rightarrow \quad a_{t+1} = \frac{(1+g_{t+1})}{(1+\bar{g})}a_t.$$

If the growth rate of the destination economy is higher than the growth rate of the world leader, then the economy will be able to converge to the frontier, and in the long run, would be able to catch up with the frontier technology level. Otherwise, the destination economy will remain stuck in a low equilibrium



(a) Wage Paths (b) Wage Inequality

Figure 5: Wage Paths and Wage Inequality in the Originating Economy

technology as well as income trap. From Fig. 4 on page 30, as the time progresses, the distance of the economy from the world technology frontier rises. From **Proposition 2**, the growth rate initially rises after that falls as the time progresses. However, this increment in growth rate is lower than the growth rate of the world technology leader. As a consequence of this, the distance of the backward economy from the world frontier increases as the time progresses and in the long run, the backward economy is stuck in a low equilibrium technology trap. This finding is not in line with Basu and Mehra [2014] and Di Maria and Stryszowski [2009]. Their studies show that without outsourcing, in the long run, all the economies will converge to the world technology frontier. Hence,

Proposition 3 *Under* **A1**, *and* **A2**, *due to outsourcing, in the long run, the backward economy will get stuck into a low equilibrium income trap.*

3.11 Wage Paths and Wage Inequality of the Originating Economy

In this subsection, the post outsourcing wage rates of skilled and unskilled workers and wage inequality path in the advanced economy are discussed. From eq. (22), it is known that the post outsourcing wage paths of the advanced economy depends on the equilibrium proportion of R & D outsourcing. Since, an explicit analytical solution of the level of R & D outsourcing is hard to get, we again had to rely on numerical simulations. From **Proposition 1**, the equilibrium proportion of outsourcing falls as an economy diverges away from the frontier. This implies that the proportion of R & D activity that would be undertaken in the advanced economy rises as the time progresses. This leads to an increment in the demand for skilled and unskilled workers. Consequently, the wage rates of both skilled and unskilled workers rise in the advanced economy, as is also illustrated in Fig. 5a on page 31.

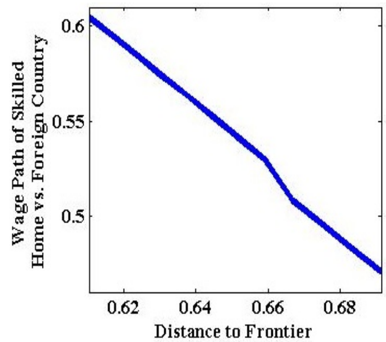


Figure 6: Skilled Wage Inequality Between Backward and Advanced Economies

The wage inequality between skilled and unskilled workers in the advanced economy is now discussed. The wage inequality between skilled and unskilled workers in the foreign country, denoted as win_{Ft}, will be:

$$win_{\mathrm{Ft}} = \frac{w_{\mathrm{Fst}}}{w_{\mathrm{Fut}}} = \frac{\phi}{(1-\phi)}\frac{S_{\mathrm{Ft}}}{U_{\mathrm{Ft}}}.$$

An exogenously given composition of human capital has been assumed in the advanced economy. Therefore, there exists a constant wage inequality in the destination economy. Numerical simulations also corroborate this findings; see Fig. 5b on page 31.

Next, the wage inequality of skilled workers between the backward and advanced economies is demonstrated. The aim is to capture as to whether skilled wage gap between backward and advanced economies is converging or not. The relative wage ratio is given by:

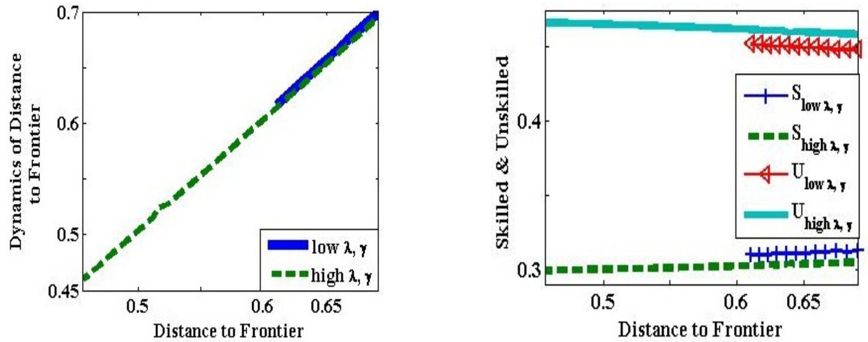
$$win_{\mathrm{HFt}} = \frac{w_{\mathrm{st}}}{w_{\mathrm{Fst}}},$$

where win_{HFt} measures relative skilled wage gap between the backward and advanced economies. Again numerical simulations demonstrate that the wage gap of skilled human capital between the backward and advanced economies falls (see Fig. 6 on page 32). This implies that the wage rate of skilled worker rises at a higher rate in the backward economy than the advanced economy. Thus, as the time progresses, the cost advantage of the backward economy falls. As mentioned in Subsection 3.8 on page 28, this also provides an incentive for a lower absolute proportion of R & D outsourcing from the originating to the destination economy. Thus,

Proposition 4 *Under* **A1***,*

- *Due to outsourcing, in the imitation-innovation regime, the wage rates of both skilled and unskilled workers increase as the backward economy moves away from the world technology frontier.*

- *In the advanced economy the wage rates of skilled and unskilled workers rise as the technology level rises.*



(a) Dynamics of Distance to Frontier

(b) Skilled and Unskilled Human Capital

Figure 7: Comparative Static: Dynamics of Distance to Frontier and Skilled and Unskilled Human Capital

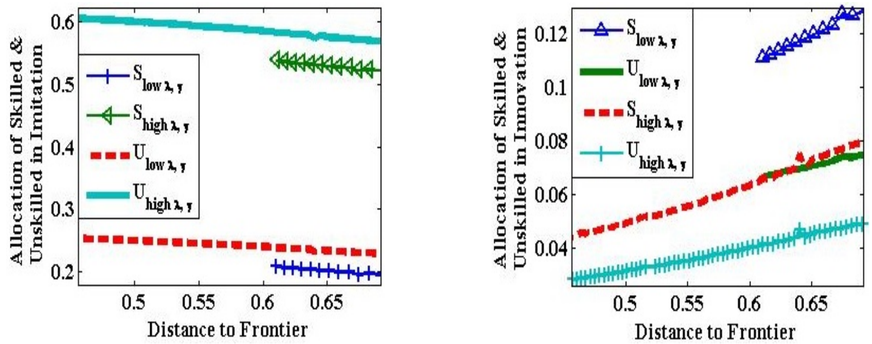
- *There exists a falling wage inequality between skilled and unskilled workers in the imitation-innovation regime as the backward economy participates in the R & D outsourcing activity.*
- *A constant wage inequality between skilled and unskilled workers prevails in the advanced economy, in the post outsourcing scenario.*
- *Skilled wage gap between the originating and destination economies falls as the time progresses.*

3.12 Production and Consumption Paths of both the Economies

In this subsection, the aggregate production and consumption paths of both the originating and destination economies have been analyzed. From eqs. (1) and eq. (2), one can obtain the production path of the aggregate economy to be:

$$Y_t = \alpha^{\frac{2}{(1-\alpha)}} A_t.$$

This implies that aggregate production is a linear function of the technology level of the concerned economy. That is, the technology adjusted final output is the same in every time period. Since A_t is an increasing function with respect to time, it implies that aggregate production rises in both the advanced and backward economies as the time progresses. Next, the consumption paths of both the economies are characterized. Each individual lives for one period only. No one saves. Also, no one has altruistic preferences. This implies that the consumption of an individual is exactly equal to the income of that individual. From **Proposition 4**, the wage rates of both skilled and unskilled workers rise as the time progresses in both the destination and originating economies. This implies that the consumption of both skilled and unskilled human capital as well as the aggregate consumption of the economy rises as the time progresses. The



(a) Skilled and Unskilled Human Capital in Imitation Activity

(b) Skilled and Unskilled Human Capital in Innovation Activity

Figure 8: Comparative Static: Allocation of Skilled and Unskilled Human Capital in Imitation and Innovation Activities

aggregate consumption of the economy, denoted as C_t, is defined as:

$$C_t = \frac{w_{ut}U_t + \theta w_{st}S_t}{U_t + S_t}.$$

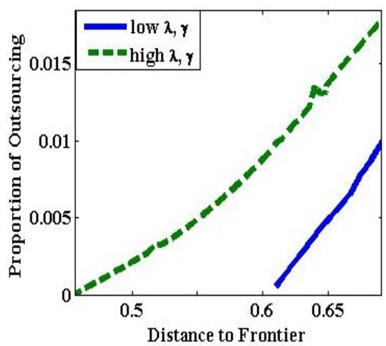
If there is a mismatch between the production and consumption of the aggregate economy, the backward economy can purchase/ sell final good at an exogenously given world price.

Proposition 5 *Under* **A1***,*

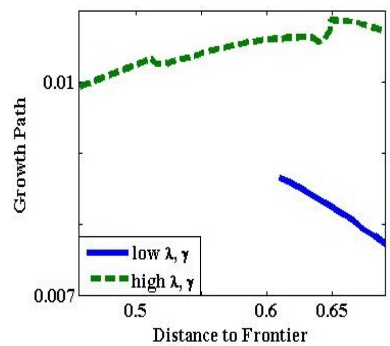
- *The aggregate production levels of both the originating and destination economies rise as the time progresses.*
- *The consumption paths of skilled and unskilled workers as well as the aggregate consumption of the economy rise in both the originating and the destination economies.*

4 Comparative Statics

We now attempt some comparative static analysis. A relatively technologically inefficient scenario is considered. Keeping other parameter values same, a relatively lower values of λ and γ have been assumed. These two parameters measured the overall technological efficiency and the efficiency of the innovation compared to the imitation. New parameter values are postulated to be $\lambda = 0.5$ and $\gamma = 0.7$. It is found that, findings are qualitatively similar except the growth path of an economy which is in the diversified regime and engaged in the outsourcing activity; as is shown in Fig. 9b on page 35. The growth rate of the destination economy rises as the time progresses. If the economy is not sufficiently technologically efficient,

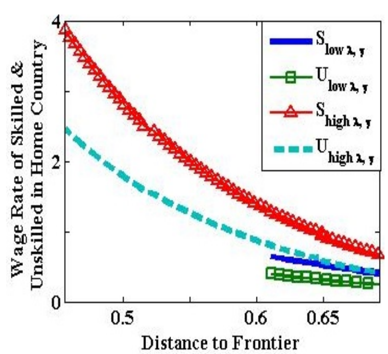


(a) Proportion of Outsourcing

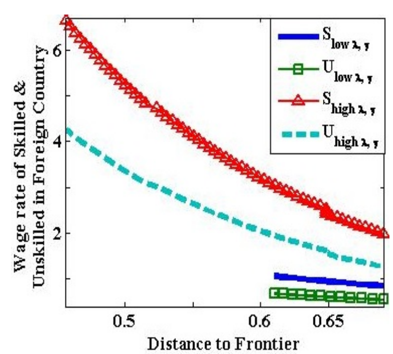


(b) Growth Path

Figure 9: Comparative Static: Proportion of Outsourcing and Growth Path



(a) Wage Paths of Destination Economy



(b) Wage Paths of Originating Economy

Figure 10: Comparative Static: Wage Paths of Destination and Originating Economies

the advanced economy brings to an end the R & D outsourcing activity even if the destination economy is not sufficiently technologically backward. Therefore, the falling growth curve for the destination economy does not happen in this scenarios. All other findings are same as in **Lemma 2**, **Lemma 3**, **Proposition 1**, **Proposition 3** and **Proposition 4** as is shown respectively in fig 7b on page 33, 8a on page 34, 8b on page 34, 9a on page 35, 7a on page 33, 10a on page 35 and 10b on page 35.

5 Conclusion

In general, an economy can adopt two strategies for technology improvement – imitation and innovation. A backward country can improve its technology level by imitating from the frontier or by innovating new knowledge if it is not participating in the outsourcing activity. An advanced economy relies on innovation activity only for technology improvement. It is assumed that different types of human capital are efficient in different activities – that is, imitation and innovation. This study hypothesises a situation where technology leader is outsourcing a proportion of its R & D activity to a backward economy. Consequently, the backward economy is performing imitation activity for its own technology improvement and innovation activity for the advanced economy. This is a limitation of this analysis. It is shown that the proportion of unskilled human capital rises and skilled human capital falls as the time progresses in the destination economy. As an associated outcome, both skilled and unskilled human capital shift away from innovation to imitation activity. Due to a rising opportunity of imitation activity and falling proportion of skilled workers, the wage rates of both skilled and unskilled workers rise as an economy moves away from the frontier. These lead to a reduction in the proportion of outsourcing from the advanced economy to a backward economy. Consequently, the growth rate of the backward economy initially rises and, after a certain time, falls as the time progresses. In the long run, the backward economy gets stuck into a low equilibrium income trap and does not converge to the world technology leader in terms of technology level and growth.

Appendix

Maximization Exercise of the Intermediate Input Producer of the Backward Economy

Next, the implicit function of the equilibrium level of skilled human capital in the innovation activity has been derived. Substituting eq. (29) in eq. (25), we get,

$$\lambda\delta(1-\sigma)u_{\text{mt}}^{\sigma}\ s_{\text{mt}}^{-\sigma}\ \frac{(\overline{A}_{\text{t-1}}-A_{\text{t-1}})}{\overline{A}_{\text{t}}} = \lambda\delta\gamma(1-\phi)\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{-\phi}\ \overline{A}_{\text{t-1}}\ \mu(a_{\text{t-1}}) + \lambda\delta\gamma\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{1-\phi}\ \overline{A}_{\text{t-1}}\ \frac{d\ \mu(a_{\text{t-1}})}{d\ \tilde{s}_{\text{nt}}}$$

$$\Rightarrow \left[\underbrace{(1-\sigma)u_{\text{mt}}^{\sigma}\ s_{\text{mt}}^{-\sigma}\ \frac{(\overline{A}_{\text{t-1}}-A_{\text{t-1}})}{\overline{A}_{\text{t}}} - \gamma(1-\phi)\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{-\phi}\ \overline{A}_{\text{t-1}}\ \mu(a_{\text{t-1}})}_{(1)}\right] \left[2A\mu(a_{\text{t-1}}) - \left\{\underbrace{\lambda\delta\gamma\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{ut}}\ \tilde{u}_{\text{nt}} + w_{\text{st}}\ \tilde{s}_{\text{nt}})}_{(2)}\right\}\right]$$
$$= \gamma\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{1-\phi}\ \overline{A}_{\text{t-1}}\mu(a_{\text{t-1}})\left[\underbrace{\lambda\delta\gamma(1-\phi)\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{-\phi}\overline{A}_{\text{t-1}} - w_{\text{st}}}_{(3)}\right]. \tag{50}$$

For mathematical tractability the above three expressions of eq. (50) (which are denoted as (1), (2) and (3)) have been derived separately. First, we determine the first expression of eq. (50).

$$(1-\sigma)u_{\text{mt}}^{\sigma}\ s_{\text{mt}}^{-\sigma}\ \frac{(\overline{A}_{\text{t-1}}-A_{\text{t-1}})}{\overline{A}_{\text{t}}} - \gamma(1-\phi)\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{-\phi}\ \overline{A}_{\text{t-1}}\ \mu(a_{\text{t-1}})$$
$$= (1-\sigma)\ \psi^{\sigma}\ \frac{U_{\text{t}}^{\sigma}}{[\psi S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]^{\sigma}}\frac{(\overline{A}_{\text{t-1}}-A_{\text{t-1}})}{\overline{A}_{\text{t}}} - \gamma(1-\phi)\frac{U_{\text{t}}^{\phi}}{[\psi S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]^{\phi}}\ \overline{A}_{\text{t-1}}\ \mu(a_{\text{t-1}}) \qquad \text{[From eq. (33)]}$$
$$= \frac{\gamma(1-\phi)\ U_{\text{t}}^{\phi}\overline{A}_{\text{t-1}}}{[\psi S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]^{\phi}}\left[\frac{z(a_{\text{t-1}})\ U_{\text{t}}^{\sigma-\phi}}{[\psi S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]^{\sigma-\phi}} - \mu(a_{\text{t-1}})\right], \tag{51}$$

where $z(a_{\text{t-1}}) = \frac{(1-\sigma)\psi^{\sigma}}{\gamma(1-\phi)}\ \frac{(\overline{A}_{\text{t-1}}-A_{\text{t-1}})}{\overline{A}_{\text{t}}\ \overline{A}_{\text{t-1}}} = \frac{(1-\sigma)\psi^{\sigma}}{\gamma(1-\phi)}\ \frac{(1-a_{\text{t-1}})}{(1+\bar{g})\ \overline{A}_{\text{t-1}}}$.

To determine the second part of eq. (50), one needs to define the wage bill of the outsourcing activity.

$$w_{\text{ut}}\ \tilde{u}_{\text{nt}} + w_{\text{st}}\ \tilde{s}_{\text{nt}}$$
$$= \lambda\delta\sigma u_{\text{mt}}^{\sigma-1}\ s_{\text{mt}}^{1-\sigma}\ \frac{(\overline{A}_{\text{t-1}}-A_{\text{t-1}})}{\overline{A}_{\text{t}}}\ \tilde{u}_{\text{nt}} + \lambda\delta(1-\sigma)u_{\text{mt}}^{\sigma}\ s_{\text{mt}}^{-\sigma}\ \frac{(\overline{A}_{\text{t-1}}-A_{\text{t-1}})}{\overline{A}_{\text{t}}}\tilde{s}_{\text{nt}} \qquad \text{[From eq. (25)]}$$
$$= \lambda\delta\psi^{\sigma}\frac{(1-\sigma)}{(1-\phi)}\ \tilde{s}_{\text{nt}}\frac{U_{\text{t}}^{\sigma}}{[\psi S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]^{\sigma}}\ \frac{(\overline{A}_{\text{t-1}}-A_{\text{t-1}})}{\overline{A}_{\text{t}}}, \qquad \text{[From eq. (33)].} \tag{52}$$

Next, the second expression of eq. (50) has been derived.

$$
\begin{aligned}
&\lambda\delta\gamma\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{ut}}\ \tilde{u}_{\text{nt}} + w_{\text{st}}\ \tilde{s}_{\text{nt}}) \\
=&\lambda\delta\gamma \frac{U_{\text{t}}^{\phi}}{[\psi S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]^{\phi}}\ \tilde{s}_{\text{nt}}\ \overline{A}_{\text{t-1}} - \lambda\delta\psi^{\sigma}\frac{(1-\sigma)}{(1-\phi)}\ \tilde{s}_{\text{nt}} \frac{U_{\text{t}}^{\sigma}}{[\psi S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]^{\sigma}}\ \frac{(\overline{A}_{\text{t-1}} - A_{\text{t-1}})}{\overline{A}_{\text{t}}}
\end{aligned}
$$

[From eq. (33) and eq. (52)]

$$
=\lambda\delta\gamma \frac{U_{\text{t}}^{\phi}}{[\psi S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]^{\phi}}\ \tilde{s}_{\text{nt}}\ \overline{A}_{\text{t-1}} \left[1 - \frac{z(a_{\text{t-1}})\ U_{\text{t}}^{\sigma-\phi}}{[\psi S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]^{\sigma-\phi}}\right]\ >\ 0, \quad [\text{since } B\ <\ 0]. \tag{53}
$$

Therefore, $B\ <\ 0\ \Rightarrow\ \frac{z(a_{\text{t-1}})\ U_{\text{t}}^{\sigma-\phi}}{[\psi S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]^{\sigma-\phi}}\ <\ 1$.

Subsequently, the third expression of eq. (50) has been determined.

$$
\begin{aligned}
&\lambda\delta\gamma(1-\phi)\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{-\phi}\overline{A}_{\text{t-1}} - w_{\text{st}} \\
&= \lambda\delta\gamma(1-\phi)\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{-\phi}\overline{A}_{\text{t-1}} - \lambda\delta(1-\sigma)u_{\text{mt}}^{\sigma}\ s_{\text{mt}}^{-\sigma}\ \frac{(\overline{A}_{\text{t-1}} - A_{\text{t-1}})}{\overline{A}_{\text{t}}} \quad [\text{From eq. (25)}] \\
&= \lambda\delta\gamma(1-\phi)\ \frac{U_{\text{t}}^{\phi}}{[\psi S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]^{\phi}}\overline{A}_{\text{t-1}} \\
&\qquad\qquad - \lambda\delta(1-\sigma)\psi^{\sigma}\ \frac{U_{\text{t}}^{\sigma}}{[\psi S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]^{\sigma}}\ \frac{(\overline{A}_{\text{t-1}} - A_{\text{t-1}})}{\overline{A}_{\text{t}}} \quad [\text{From eq. (33)}] \\
&= \lambda\delta\gamma(1-\phi)\ \frac{U_{\text{t}}^{\phi}}{[\psi S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]^{\phi}}\overline{A}_{\text{t-1}} \left[1 - \frac{z(a_{\text{t-1}})U_{\text{t}}^{\sigma-\phi}}{[\psi S_{\text{t}} - (\psi-1)\tilde{s}_{\text{nt}}]^{\sigma-\phi}}\right]\ >\ 0.
\end{aligned} \tag{54}
$$

Substituting eq. (51), eq. (53), eq. (54) and eq. (33) in eq. (50), we get the implicit demand function of the skilled human capital in the innovation activity.

$$
\begin{aligned}
&\left[(1-\sigma)u_{\text{mt}}^{\sigma}\ s_{\text{mt}}^{-\sigma}\ \frac{(\overline{A}_{\text{t-1}} - A_{\text{t-1}})}{\overline{A}_{\text{t}}} - \gamma(1-\phi)\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{-\phi}\ \overline{A}_{\text{t-1}}\ \mu(a_{\text{t-1}})\right] \\
&\qquad \left[2A\mu(a_{\text{t-1}}) - \left[\lambda\delta\gamma\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{1-\phi}\ \overline{A}_{\text{t-1}} - (w_{\text{ut}}\ \tilde{u}_{\text{nt}} + w_{\text{st}}\ \tilde{s}_{\text{nt}})\right]\right] \\
&\qquad\qquad = \gamma\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{1-\phi}\ \overline{A}_{\text{t-1}}\mu(a_{\text{t-1}}) \left[\lambda\delta\gamma(1-\phi)\ \tilde{u}_{\text{nt}}^{\phi}\ \tilde{s}_{\text{nt}}^{-\phi}\overline{A}_{\text{t-1}} - w_{\text{st}}\right]
\end{aligned}
$$

$$
\begin{aligned}
\Rightarrow \quad & \frac{\gamma(1-\phi)\ U_{\mathrm{t}}^{\phi}\overline{A}_{\text{t-1}}}{[\psi S_{\mathrm{t}}-(\psi-1)\tilde{s}_{\mathrm{nt}}]^{\phi}}\ \left[\frac{z(a_{\text{t-1}})\ U_{\mathrm{t}}^{\sigma-\phi}}{[\psi S_{\mathrm{t}}-(\psi-1)\tilde{s}_{\mathrm{nt}}]^{\sigma-\phi}}-\mu(a_{\text{t-1}})\right] \\
& \qquad \left[2A\mu(a_{\text{t-1}})-\left\{\frac{\lambda\delta\gamma\ U_{\mathrm{t}}^{\phi}\ \tilde{s}_{\mathrm{nt}}\ \overline{A}_{\text{t-1}}}{[\psi S_{\mathrm{t}}-(\psi-1)\tilde{s}_{\mathrm{nt}}]^{\phi}}\ \left[1-\frac{z(a_{\text{t-1}})\ U_{\mathrm{t}}^{\sigma-\phi}}{[\psi S_{\mathrm{t}}-(\psi-1)\tilde{s}_{\mathrm{nt}}]^{\sigma-\phi}}\right]\right\}\right] \\
& \qquad = \frac{\lambda\delta\gamma^{2}(1-\phi)\ U_{\mathrm{t}}^{2\phi}}{[\psi S_{\mathrm{t}}-(\psi-1)\tilde{s}_{\mathrm{nt}}]^{2\phi}}\tilde{s}_{\mathrm{nt}}\ \overline{A}_{\text{t-1}}^{2}\mu(a_{\text{t-1}})\ \left[1-\frac{z(a_{\text{t-1}})U_{\mathrm{t}}^{\sigma-\phi}}{[\psi S_{\mathrm{t}}-(\psi-1)\tilde{s}_{\mathrm{nt}}]^{\sigma-\phi}}\right] \\
\Rightarrow \quad & 2A\mu(a_{\text{t-1}})\left[\frac{z(a_{\text{t-1}})\ U_{\mathrm{t}}^{\sigma-\phi}}{[\psi S_{\mathrm{t}}-(\psi-1)\tilde{s}_{\mathrm{nt}}]^{\sigma-\phi}}-\mu(a_{\text{t-1}})\right] \\
& \qquad -\frac{\lambda\delta\gamma\ z(a_{\text{t-1}})\ U_{\mathrm{t}}^{\sigma}\ \tilde{s}_{\mathrm{nt}}\ \overline{A}_{\text{t-1}}}{[\psi S_{\mathrm{t}}-(\psi-1)\tilde{s}_{\mathrm{nt}}]^{\sigma}}\left[1-\frac{z(a_{\text{t-1}})\ U_{\mathrm{t}}^{\sigma-\phi}}{[\psi S_{\mathrm{t}}-(\psi-1)\tilde{s}_{\mathrm{nt}}]^{\sigma-\phi}}\right]=0. \qquad (55)
\end{aligned}
$$

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