Austrian Model of Trade and Growth of a Developing Economy

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This paper develops a model of trade and growth for a developing economy based on the Austrian theory of capital. Two types of economies differ in terms of time preference rates. Each economy produces two capital goods, both of which provide services to consumers through their life periods. A human capital intensive capital good is produced by a relatively more roundabout method than less human capital intensive one. An economy with a low time preference rate exports a human capital intensive capital good to a high time preference rate economy. By importing a human capital intensive capital good and investing for a low vintage level of domestic human capital to the high vintage of the imported capital good, the growth rate of the high time preference rate economy increases. Another aspect of the Austrian trade model is to interpret the export of the consumer goods of a developing economy as the export of the domestic savings to finance the import of the capital good from the advanced economy. Trade contributes to the growth of the developing economy. Thus, the Austrian trade model exhibits the financial side of trade in the early stage of development.

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I. Introduction

Ever since Uzawa (1964) extended the growth model of Solow (1956) to an open economy, some issues remain unresolved for the model of trade and growth in the economics literature. The growth experiences of

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post-War world economy did not perceive every developing open economy to become a member of an advanced economy. International interactions between advanced and developing countries occur in several channels. The first channel involves bringing direct and indirect knowledge spillover effects from the advanced to the developing countries. Such channel, which carries over this spillover effect, could be the international trade of goods, international direct investments, or direct knowledge exchanges.

In the conventional neo-classical growth model of Solow type, the per capita capital stock of different economies converges with each other without reference to the interrelations between the two. Findlay (1996) pertains to this phenomenon as "trains on parallel tracks." International trade plays a role in connecting these two tracks.

Austrian approach emphasizes "individualistic approach" and "market adjustment process" in the market disequilibrium instead of equilibrium itself (Hong 2015). An advantage of the Austrian trade model is to provide the time framework in which the issue of market adjustment process is discussed. It covers the interactions or involvements of traders involved in the trade of the advanced and the developing economies. In this paper there are two markets in different time frameworks. One is the short-term rental markets and the other is the long-term financial markets, which require the investment decisions of the producers of capital goods. Savings take the form of bequests left to the succeeding generation in dynastic utility function. Being trade of the capital goods connected to the financial markets of trading economies, Austrian view sheds the light on the effect of trade on the growth of a developing economy.

Although one does not often find a trade and growth model in the Austrian perspective, an exception is the model of Findlay and Kierzkowski (1983). This model relates human capital formation to the time preference rate of an economy. International trade occurs between economies where human capital is abundant and low. A low time preference rate economy exports a human capital intensive good but imports a less human capital intensive good. Such trade pattern emerging out of the present model is consistent with Findlay and Kierzkowski.

On the part of the production of capital goods I take the Böhm-Bawerkian concept of the roundabout period of production (Hicks 1973; Faber 1979).[1] The "irreversibility of time" (Faber and Proops 1989) related

[1] The Austrian approach, which emphasizes the Böhm-Bawerkian roundabout period of production, is often referred to as "neo-Austrian" in the economics literature.

to the construction of a capital good is considered as well. In particular, I use Hayek's (1931) triangle of the time structure of production in which inputs at each point of time are differentiated by their distances from the primary input, that is, labor. In this regard, inputs are asymmetric.[2]

Another distinguishing aspect of Hayek's triangle is linking the reduction of present consumption with lengthening the time structure of inputs along the time axis of the inputs from the primary input. In this case, trade-off occurs between present and future consumption through the accumulation of capital. A reduction of consumption extends the initial period of the original inputs to a greater length of the period. This relationship is claimed to contribute to the growth of an economy.

One produces consumer goods in a relatively short period using simple labor as input, whereas the production of sophisticated services of capital goods requires a greater length of time that needs more human capital as input. This paper extends Hayek's triangle to an open economy from the viewpoint of a developing economy.

A trade pattern of a developing economy particularly displays the exports of consumer goods in exchange for the capital goods from advanced economies. A discussion on the effects of trade on the growth of a developing economy must address its trade pattern and its trading partners as argued by Lee (1995) and Keller (1996). A typical trade pattern of a developing economy shows that it exports consumer goods or light manufacturing goods and imports machinery and other intermediates. The international trade of consumer goods as against the capital goods or the intermediates amounts to trading present consumption for future consumption in the Austrian perspective. This study interprets the exports of consumer goods by a developing economy as exporting its savings instead of the conventional view of foreign investments and imports of capital goods as the extension of its time structure of production in Hayek's triangle.

In the conventional literature, the imports of capital goods bring the growth of a developing economy with them by the spillover effects of knowledge embodied with the goods. This paper puts more emphasis on the growth effects on the investments in the human capital side of the domestic economy to cope with the operation of the high-level human

[2] This aspect of Hayek's triangle contrasts with an endogenous growth model of variety-kind where inputs enter symmetrically into the assembly of the final good.

capital vintage of imported capital goods.

The capacity of the domestic economy to translate the high vintages of imported capital goods for the domestic production of capital goods depends on the "absorptive capacity" of domestic human capital. The growth performance of developing economies based on domestic human capital is already cited in Parente and Prescott's (1994) "barrier of an adoption to a new technique." "Absorptive capacity" is the inverse of the size of the barrier of an adoption of a new technique. Nelson and Phelps (1966) suggest that one of the determinants for the diffusion of technical progress is a different education level of human capital. Analogously, the presumption is that a human capital vintage gap between two trading economies explains the "absorptive capacity" of the domestic economy.

Consistent with the time horizon of the production of capital goods are the overlapped generations of their age cohorts. The life period of a capital good from its construction to its truncation should match that of an individual's life period. An individual family unit leaves bequests for the next generation. The more altruistic is the individual family unit, the greater amount of savings is available to the economy for the succeeding generation. This idea indicates that altruism proxies for the time preference rate of an individual family unit, and thus, a low time-preference rate economy is more altruistic toward forthcoming generations. The present model shows that a more altruistic economy, that is, a low time preference rate economy has a comparative advantage in a more time intensive (equivalently, human capital intensive) capital good and exports it to a high time preference rate economy, importing a less time intensive capital good.

Section II presents the model of the paper in which time is required for the production of a capital good. Specifically, this section discusses investment in time for the roundabout production period using simple labor. Section III describes a closed economy equilibrium of the model. Section IV focuses on the development of a basic trade model in light of the overlapping generations model and discusses a direction of the international trade of a capital good between an advanced and a developing country. Section V concludes the paper.

II. Model

Labor is a scarce primary factor of production. No change in the endowment of labor occurs given that death rate is offset by birth rate.

Every individual is given an expected life period T. Hence, the T number of generations overlaps at each period τ. The total endowment of labor in an economy is TL.

An individual acquires knowledge during early life period v. Individual productivity improves after the acquisition of knowledge and becomes human capital of vintage v. Productivity improves by a factor of $v>1$. The individual then spends the rest of life $(T-v)$ by providing services in association with the corresponding vintage of the capital good. A capital good producer manufactures a capital good of vintage v by embodying the knowledge acquired by an individual on freely given natural resources. This process captures the Austrian concept of a roundabout period of production in considering time period v for the construction of a capital good. Considering that a capital good provides services in conjunction with the corresponding incumbent human capital, service-life is also limited by utilization period $(T-v)$. A division of the time-horizon into the construction period and into the utilization period is inspired by Hicks's *Capital and Time* (1973).

Assume two capital goods, 1 and 2, are in the economy. The technology of production of each the capital good differs by the importance of human capital in the process. A relatively more human capital-intensive sector is more roundabout in the sense that production requires a longer period until the completion of the construction of a unit of a capital good.[3]

Capital good i provides services throughout its utilization period. Equation (1) indicates the amount of services provided by capital good i of vintage v_i during the utilization period of $\tau\in(T-v_i)$. This relationship is denoted by $Y_{v_i}(\tau)$ in a Cobb-Douglas form:

$$\begin{aligned} &Y_{v_i}(\tau) = A(t)K_{v_i}^{1-\alpha_i}(\tau)H_{v_i}^{\alpha_i}(\tau); \\ &i = 1, 2; \\ &\tau \in (0, T - v_i) \\ &A(t) > 1. \end{aligned} \tag{1}$$

Variable H_{v_i} refers to the amount of labor L_i employed for sector i in efficiency units: $H_{v_i}=v_iL_i$. Equation (1) is rewritten in a per capita form

[3] In this study, I use interchangeably "the roundabout period of production" and "the construction period." Two aspects in the production of a capital good are the labor acquisition of knowledge by the roundabout mode of production, and the construction of a physical unit of capital. A roundabout mode of production suggests the improvement of labor productivity. In this regard, a technique that is more roundabout is human capital intensive.

of the production:

$$y_{v_i}(\tau) = A(t)\left(k_{v_i} v_i\right)^{\alpha_i}$$
$$= A(t)\left(v_i\right)^{\alpha_i},$$

where k_{v_i} refers to the per capita capital stock defined as $k_{v_i} \equiv K_{v_i}/L_{v_i}$. One unit of labor complements one unit of a capital good $k_{v_i} \equiv 1$, and the first row of the per capita production function reduces to the form of the second row.

The greater importance of human capital for capital good 1 sector is represented by the larger exponent α on the roundabout production period: $\alpha_1 > \alpha_2$. This representation is related to the following passage from Hayek (1941, p. 270):

> "Yet it is the changes which are connected with this "heightening" or "deepening" of capital in which the special characteristics of a growth of capital are best seen, and for this reason this assumption actually helps to bring out an important point."

The time-intensive capital good of the present model can be interpreted as more "deepened" or a more "heightened" one in Hayek's terms.[4]

Coefficient $A(t)$ represents the expected productivity level of an economy for cohort t. The assumption is that the coefficient grows at the rate of the roundabout production period of the overall economy denoted by v multiplied by constant λ over the period from t to $t+T$.

$$\frac{A(t+T) - A(t)}{A(t)} = e^{\lambda v T};$$
$$0 < \lambda < \infty.$$

In its extreme, the importance of human capital is nil such that the roundabout period becomes zero. Then, $A(t+T) - A(t) = 0$ and the growth

[4] A later discussion will indicate that the increase of the roundabout production period related to the importance of human capital is primary for the explanation of the growth of the present model. In other words, Crusoe spending one more of a week for producing his net is more productive than having another Friday for catching fish. This analogy is comparable to the discussion of economic growth in terms of "intensive growth" or "extensive growth" in the economics profession.

rate is zero. The amount of output is a given constant in the amount of $A(0)$. No capital goods are produced in the economy, and the goods produced are considered consumer goods. In terms of the Hayek triangle, the distance of the intermediates from the primary factor is near zero.

A. Capital good producer's investment decision

A capital good producer has been given time period T. The producer decides on the process of dividing the given time period T between the construction period of capital good v and the utilization period for the accruals of rentals in the remaining period of $(T-v)$. For the construction of the capital good, the producer of the capital good employs labor. The wage rate the producer pays for a unit of labor is the amount of w_0 in terms of the rental units provided by the associated capital good. The following expression is producer i's present value function of the investment on a unit of labor in this decision problem at the initial period of 0:

$$\max_{v_i} \phi_i(v_i; 0, r, T) = -w_{0i}\int_0^{v_i} e^{-r_i s}ds + (A(0)-1)\int_{v_i}^{T} v_i^{\alpha_i} e^{-r_i s}ds;$$
$$i = 1, 2.$$

The present value function is evaluated by the interest rate in terms of the rentals of the capital good. The rental of the capital good i is denoted by p_i. The interest rate applied to the present value function of capital good r_i is obtained by dividing the interest rate prevailing over economy r by rental price p_i. This specification of the present value function suggests that the producer's subjective present value function varies with the rentals of the capital good, although the objective market rate of the interest remains constant.

A lengthening of the construction period of capital good i implies the increase in the roundabout production period in Austrian terms. Wage rate w_{0_i} in terms of its service units increases by lengthening the roundabout production period of capital good i. The value increases by the rate of $v_i^{\alpha_i}$. A unit of raw labor of sector i becomes a human capital of vintage v_i after the construction of capital good i.[5] Capital good producer i earns profits from the externality generated by the overall increase in

[5] In the increase in labor productivity, neither education nor learning-by-doing is involved. Knowledge given in nature is acquired by raw labor simply by lengthening the production period.

the roundabout production period represented by the term $(A(0)-1)$ in the bracket of the last term.[6] Finally, producer i employs the amount of labor L_i to meet the demand for rentals i in the market.

The first-order condition is as follows.

$$\varphi_i(v_i, r, T) = -w_{0i}a_i - (A(0)-1)\, v_i^{\alpha_i} + (A(0)-1)\, \alpha_i v_i^{\alpha_i - 1}\left(\frac{1-e^{-r(T-v_i)}}{r}\right) = 0 \qquad (2)$$

$i = 1, 2.$

The first-order condition is obtained by differentiating the present value function $\phi_i(\cdot)$ with respect to v_i, and then multiplying it by the term e^{rv_i}. This step suggests that first-order condition $\varphi_i(\cdot)$ is applied to the point of the end of the construction of capital good v_i.

The first two terms with the minus signs indicate the marginal costs of lengthening of the construction period, whereas the last term with the plus sign is its marginal benefits. Lengthening the construction period by a unit bears capital good producer i the wage rate in terms of the own units of its services of w_{oi}. A deferment of the utilization of the capital good incurs to the capital good producer the costs of $(A(0)-1)v_i^{\alpha_i}$. A unit increase of time raises the marginal productivity of labor by the amount of $(A(0)-1)\alpha_i v_i^{\alpha_i - 1}$. Capital good producer i earns the income during its utilization period of $(T-v_i)$. The capital good producer is on a trade-off between shortening the construction period of the capital good, having its longer servicing periods by lengthening the utilization period, and lengthening the construction period and having more efficient capital good services, although its life period is short. These two marginal effects are balanced by the first-order condition of $\varphi_i(\cdot)=0$.

The decision of a capital good producer on the choice of construction period v_i depends on the given market rate of interest r and the technology of production of capital good i for a given life period of an individual T. The first-order condition of $\varphi_i(\cdot)$ offers the responsiveness of construction period v_i with respect to the change in the rate of interest

[6] In a traditional Austrian example of a tree, externality comes from the benefits of nature in the growing of a tree by sunshine and rain. Similarly, the fermenting of grapes to wine by the lapse of time increases the value of wine. In this paper, the roundabout production period provides the acquisition of knowledge to the incumbent raw labor, and thus, yields externalities to the capital good producer.

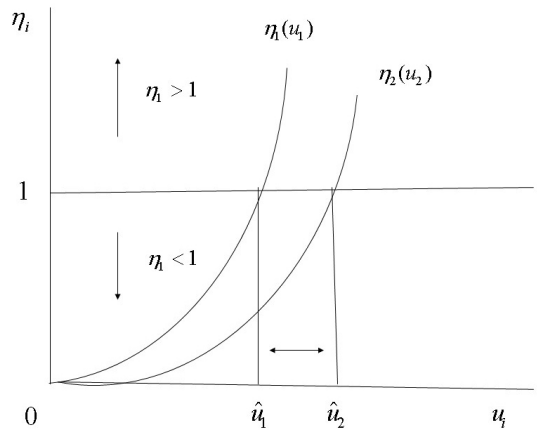

FIGURE 1
ELASTICITIES OF THE TWO CAPITAL GOODS AT THEIR UTILIZATION PERIODS

r in terms of its elasticity defined as $\eta_i(\cdot)$:

$$\eta_i(u_i, \alpha_i; r) \equiv -\left(\frac{r}{v_i}\frac{dv_i}{dr}\right) = -\frac{\left(e^{ru_i} - (1+ru_i)\right)}{(1-\alpha_i)\left(e^{ru_i}-1\right) + rv_i\left(e^{ru_i}+1\right)} = -\frac{n(u_i)}{m(u_i)} < 0, \tag{3}$$

where u_i refers to the utilization period of a capital good i, $(T-v_i)$. The elasticity for the production of two capital goods is then compared. In the definition of elasticity, the utilization period of capital good i $(T-v_i)$ is denoted by u_i. For convenience of this comparison, numerator of $\eta_i(u_i)$ is $n(u_i)$, while the corresponding denominator is $m(u_i)$. The elasticity of the roundabout period with respect to the rate of interest is the ratio of term $n(u_i)$ to that of term $m(u_i)$. Elasticity varies with respect to the utilization period. The elasticity is zero when no more time is left for utilization, while elasticity is highest when the construction of a capital good merely starts. Figure 1 illustrates variability of elasticity with respect to utilization period of a capital good. The vertical axis represents the elasticity of sector i, whereas horizontal axis is the utilization period. An examination of the definition of the elasticity indicates that a crossing point $\hat{u}_i$ on the utilization period that divides the region into elastic and

inelastic and given by $e^{-rT} < \alpha_i$. The greater the importance of human capital, the higher is the rate of interest. The longer time period horizon T, the more likely is the critical range of $\hat{u}_i$ to divide the elastic and the inelastic regions.

The utilization period region above the critical level of $\hat{u}_i$ is elastic, $\eta_i(\cdot) > 1$, and the area below is inelastic, $\eta_i(\cdot) < 1$. The critical utilization period for capital good 1 for which human capital is relatively more important in providing its services is shorter than that for capital good 2, that is, $\hat{u}_1 < \hat{u}_2$. Hence, the critical roundabout period, which divides the elastic and the inelastic regions, is longer for capital good 1 than that for capital good 2: $\hat{v}_1 > \hat{v}_2$. In the succeeding parts of the study, the roundabout periods of the two capital goods are restricted to the region between two critical ones: $\hat{v}_2 < v < \hat{v}_1$.[7]

In this region of two critical roundabout periods, investment for human capital for capital good 1 rapidly decreases relative to that for capital good 2 by the increase in the interest rate. Conversely, the wage rate in the capital good 1 sector falls relatively fast to that on the capital good 2 sector. Consequently, the employment share for the capital good 1 sector falls. Result 1 summarizes the discussion of this section.

***Result* 1:** The roundabout period of the capital good 1 sector relative to that of the capital good 2 sector decreases (increases) by the increase (decrease) in the interest rate for the region of the roundabout periods of $\hat{v}_2 < v < \hat{v}_1$.

B. Shift of labor from low to a high vintage sector

The movement of labor between two sectors of the capital goods is considered at a given moment of time period τ. From this situation arises the adaptation cost in introducing the low vintage of the human capital of sector 2 to the higher level vintage of human capital in sector 1. Adapting the former to the latter requires capital good 1 investments in on-the-job education to ensure the operation of vintage 1 capital good. The cost depends on the gap in the vintages of labor of both sectors. The greater the gap in the vintages of labor between the two sectors,

[7] The restriction of research periods to this critical region recalls in part the 1966 QJE (Quarterly Journal of Economics) symposium on the capital controversy of re-switching debates of techniques. Hagemann and Kurz (1976) point out that re-switching is no longer an exception even in the Austrian capital theory.

the greater would be the cost. This cost side aspect captures Parente and Prescott's (1994) "barriers to technology adoption."[8] This cost is measured by the ratio of the human capital vintages of two sectors (v_2/v_1), which is inspired by Nelson and Phelps's (1966) human capital measure. The smaller the ratio, the higher will be the adaptation cost for given "barriers to technology adoption." Another factor that could be considered is economic environment, which renders the sector shift of labor either easier or harder than otherwise would be the case. For instance, subsidies to the movement of labor to sector 1 or other economic infrastructure could reduce the learning costs for vintage 1 labor.

Function $\tilde{\phi}_1(\cdot)$ expresses the producer's profit function of capital good 1 in terms of its own service units at time period τ with respect to the employment of labor from the capital good 2 sector. In this expression, the term $(v_2/v_1)^{1/\varsigma}$ captures the adaptation costs of low human capital vintage 2 to high human capital vintage 1 in terms of productivity. The exponent $1/\varsigma$ refers to the "barriers to technology adoption" and its inverse ζ represents "absorptive capacity" of human capital vintage 2 in the provision of capital good 1 services. The wider the vintage gap and the greater the "barriers to technology adoption," the larger is the adaptation cost of the migration of labor from low vintage sector 2 to high vintage sector 1. The second term on the employment ratio of the two sectors represents the migration costs of low vintage labor to high vintage sector. Exponent γ represents the parameter of the economic infrastructure.

$$\max_{v_2, L_2} \tilde{\phi}_1(v_2; v_1, \tau) = A(0)\left(\frac{v_2}{v_1}\right)^{1/\varsigma} v_1^{\alpha_1} L_{v_1} - w_{v_1}\left(\frac{L_{v_1}}{L_{v_2}}\right)^{\gamma} L_{v_2}$$

$$= w_{v_1} L_{v_1}\left\{A(0)\left(\frac{v_2}{v_1}\right)^{1/\varsigma} - \left(\frac{L_{v_1}}{L_{v_2}}\right)^{\gamma-1}\right\},$$

where $0 < \varsigma < 1; 1 < \gamma < \infty; 0 < v_2 < v_1$.

Parameter ξ, restricted by a positive number with the size smaller than 1, is consistent with its interpretation as "the barriers to technol-

[8] In this study, the parameter "barriers to technology adoption" is treated as a cause for the growth of a developing economy. This assumption is comparable to its role in Parante and Prescott's model as explaining for the relative income distribution of economies over a certain period.

ogy adoption." The higher the technology barrier, that is, the higher is $1/\zeta$, the less efficient is the operation of low vintage 2 labor in the high vintage capital good 1 sector given that $0<\upsilon_2<\upsilon_1$. Coefficient γ, being in the range of $1<\gamma<\infty$, reflects the increasing marginal cost of the supply of low vintage 1 labor to the high vintage 2 sector. The capital good 1 producer makes investment decisions in two respects. The first is the investment for the amount of employment from the low vintage capital 2 sector. This condition ensures the interior solution for labor market equilibrium. The second is investment for adaptation of low vintage 2 labor to high vintage 1. These decisions are the viable ones provided that the profit function of the capital good producer is positive, that is, $\tilde{\phi}_1(\cdot)>0$. Viability condition is expressed as:

$$A(0) > \frac{\left(L_{\upsilon_1} / L_{\upsilon_2}\right)^{\gamma-1}}{\left(\upsilon_2 / \upsilon_1\right)^{1/\varsigma}} \equiv \frac{\left(l_{12}\right)^{\gamma-1}}{\left(\upsilon_2 / \upsilon_1\right)^{1/\varsigma}}, \tag{4}$$

where the right-hand side of the inequality Equation (4) represents the ratio of the vintage efficiency units of the amount of employment of the capital good 1 sector to those of the amount of employment of the capital good 2 sector denoted by l_{12} and adjusted by the exponents of $\gamma-1$ and $1/\zeta$. If no differences exist in the labor employed in the two as well as in their vintages, then the ratio reduces to 1. Note that the ratio is equal to the necessary condition for the investment of the capital good 1 producer where no sector shift of labor is considered for profit function of $\phi_i(\cdot)$. In this respect, Equation (4) echoes "the catch-up effect" in the economic growth literature in the sense that the more lagged behind is the capital good 1 sector in its employment of labor relative to that of the capital good sector 2, a larger gap is left to be filled by the capital good 1 producer's adaptation investment.

The term on the right-hand side of the inequality rises as the employment of the high vintage capital good 1 sector relative to that of the low vintage capital good 2 sector increases. This process continues until the equality of Equation (4) is ensured. Another interpretation of Equation (4) is that adaptation investment is made for low vintage 2 labor to move from the capital good 1 sector. Result 2 provides a summary.

***Result* 2:** On the equilibrium rate of investment is the adaptation investment for low vintage 2 labor to high vintage 1 labor, υ_2 is a monotonically increasing function of the ratio of the employment of high vintage

labor 1 to that of low vintage labor 2 as denoted by l_{12}.

Capital good 1 producer would invest as much as its marginal benefits to be greater than the wage rate. The expression of $(1/\zeta)(v_2/v_1)^{(1-\zeta)/\zeta} v_1^{\alpha_1}$ is the amount of marginal benefit, while the wage rate the producer needs to bear is in the amount of $v_1^{\alpha_1}$. The following expression shows the equilibrium condition for adaptation investment:[9]

$$\left(\frac{v_2}{v_1}\right)^{1/\zeta} = \frac{1}{v_1}\zeta^{\frac{1}{1-\zeta}}. \tag{5}$$

The first-order condition on profit function with respect to the employment of sector 1, L_{v_1}, suggests that the following expression is necessary for the employment of vintage 2 labor in the capital good 1 sector:

$$\left(\frac{v_2}{v_1}\right)^{1/\zeta} = \frac{\gamma\left(l_{12}(v_2)\right)^{\gamma-1}}{A(0)}. \tag{6}$$

The left side of the above expression is the vintage gap between the two sectors adjusted by "absorptive capacity" exponent ζ. Equations (5) and (6) yield the relationship between the "barriers to technology adoption" and the ratio of the employment of labor of the capital good 1 sector to that of the capital good 2 sector. Equation (7) expresses the relationship:

$$\zeta^{\frac{1}{1-\zeta}} = \frac{\gamma\left(l_{12}(v_2)\right)^{\gamma-1} v_1}{A(0)}. \tag{7}$$

The left-hand side of Equation (7) is a monotonically increasing function of ζ; thus, the ratio of the employment of the capital good 1 sector to that of the capital good sector 2 monotonically increases with the decrease in "barriers to technology adoption" for the given parameters of γ, $A(0)$ and for the given vintage v_1 of capital good 1. Hence, Result 2 with Equation (7) suggests Result 3.

[9] The term "adaptation investment" is suggested by one of the referees.

***Result* 3:** The lower the "barriers to technology adoption," the higher is the "adaptation investment" for low vintage 2 labor in the high vintage capital good 1 sector.

I will explain the implication of the Result 3 in the context of the open economy later on. It suggests that for a developing economy with a low "barriers to technology adoption" trade contributes to her growth through the increase of the "adaptation investment." Before discussing the effects of trade on the growth of the economy, the issue of whether a closed economy equilibrium exists in the proposed economy is examined.

Consider the rental market in the short term of a given time period of $\tau \in \min_i [T - v_i]$. The rental market is established after the construction of goods 1 and 2 is completed. Hence, the construction periods of the two capital goods are given in the market. Figure 2 illustrates the market equilibrium. The vertical axis is the price ratio of rental 1 to that of rental 2.[10] The horizontal axis is the relative employment for capital good 1 to that of capital good 2. The relative supply of rentals of capital good 1 to those of capital good 2 in terms of l_{12} is a monotonically increasing function. The line is drawn as an upward sloping aS curve, which is the short-run supply schedule in the sense that the construction periods of the capital goods are given by their ratio of (v_1/v_2). Market disequilibrium is adjusted in the short run in term of the utilization periods of the two capital goods. Together with a downward sloping relative demand for the rentals depicted as the DD curve, the relative supply schedule determines its equilibrium price. The equilibrium price and the relative employment at point a are respectively denoted by p^0 and l_{12}^0 in Figure 2.

Suppose the demand increases for the rentals of capital good 1. This situation is indicated by the rightward shift of the demand for the rentals from curve DD to curve $D'D'$ in Figure 2. The immediate response in the market is the rise of relative rentals to point p^1 as indicated by point b. With an increase in relative demand for rental 1, the wage rate in terms of its rental units rises in sector 1. Labor moves from sector 2 to sector 1 and continues along the $D'D'$ curve until the equilibrium is reached at point c. The movement of labor of sector 2 to sector 1 is limited by the "absorption capacity" of labor in the vintage 1 technique of capital

[10] Hereafter, the relative service prices of capital good 1 and capital good 2 are referred to as rental 1 and rental 2, respectively.

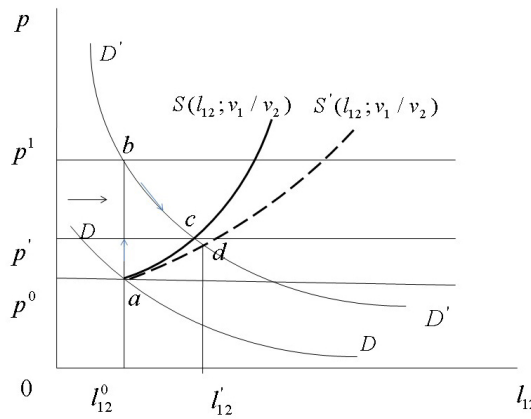

FIGURE 2
RENTAL MARKET IN THE SHORT RUN

good 1. Result 3 suggests that higher capacity results in a more elastic supply schedule as indicated by dotted line aS' in Figure 2. The low migration cost adds to make the supply schedule more elastic. In the more elastic case, the movement of labor continues until it reaches equilibrium at point d. The equilibrium in the increase of the relative demand for rental 1 reaches point l'_{12}, which corresponds to the relative price p' at point d. All of these adjustments occur during the short run period of $(T-v_1)$.

C. Austrian interpretation of market adjustment

A downward shift of the relative demand for the rental services of capital good 1 in the reverse direction indicates that the process of capital good 1 production that has already started needs to stop. In this situation, the sunk costs on the investments have been already committed for the production of capital good 1. Discussion on sunk costs in the Austrian approach goes further from the neo-classical one. The rise of sunk costs in the present model varies according to the point of the time at which the unexpected fall of the relative rental price of capital good 1 is realized by the producer.

At the initial investment commitment period of time 0, the prospective income stream of the producer of capital good 1 is zero: $\phi_1(v_1; 0, r, T) = 0$.[11] The unexpected fall of the price at period $\tau > 0$ may turn producer 1's prospective income streams negative, that is, $\phi_1(v_1; 0, r(\tau), T) < 0$, due

to the interest rate increase at time period τ denoted by $r(\tau)$ in terms of its service units.

Realizing the unexpected losses at the time period of τ in the income stream, producer 1 would reevaluate the present value function of the initial period as of the time period of τ. This value becomes negative with the interest rate increase, that is, $\phi_1(v_1; 0, r(\tau), T) < 0$. In view of Equation (3), one approach for producer 1 to adjust to the fall of the income stream would be to shorten the roundabout investment period from the initial plan to period v_1 to v_1^s: $v_1^s < v_1$. In other words, producer 1 restores the prospective income stream to zero, that is, $\phi_1(v_1^s; \tau, r(\tau), T) = 0$, by shortening the construction period. This outcome is consistent with the interest rate higher than the one initially foreseen.

Time τ may occur either before completing the construction of capital good 1 or during its utilization period. In the former case, the capital good 1 producer may avoid the losses by stopping production before the reach of the period v_1. The shortening of the construction period implies lengthening of utilization period. This decision increases the supply of rental services of the capital good 1, being compatible with the unexpected fall of the price.

In the case when producer 1 realizes the unexpected fall of its rental during the utilization period, capital losses (sunk costs in neo-classical terms) are unavoidable. In the present model, this case is represented by:

$$\int_{v_1^s}^{v_1} w_{01} e^{rs} ds.$$

An alternative way of producer 1's adjustment of this unforeseen circumstance would be to change his/her consumption plan to sustain the previous level of the consumption stream. To recuperate losses, producer 1 would need to increase savings. For the unexpected loss, Hayek in *Pure Theory of Capital* (1941, p. 308 footnote) states:

> "In the case of "windfall losses" it would, of course, often be possible gradually to recuperate the value of the capital originally invested. In order to do this the owner of the capital would have to decide, after the unfavorable change had occurred, to make the same allowance for depreciation as before

[11] In what follows, the producer of capital good 1 is simply referred as producer 1, and that of capital good 2 as producer 2.

and to reduce current consumption by the full amount of the loss. But this could hardly be discussed as "maintaining capital intact." It would mean that the owner would have to reduce consumption for a period below the level at which it could be permanently kept, in order to raise it later above that level."

In Figure 2 a "capital gains" accrues to the capital good producer 1 by the rise of its relative rental service price, while on the capital good producer 2 falls the "capital losses." The construction period of the capital good 1 is lengthened and that of the capital good 2 is shortened. This is on the part of the demand for the investment due to the change of the rental service prices. How do the savings in the economy respond to the change in the rental prices? Considering that the "capital gains" of the capital good 1 producer be used for financing the lengthening of its construction period, it depends on the extent to which the capital good 2 producer would reduce consumption to recuperate his/her income losses. The greater is the amount of the reduction of consumption on the part of the capital good 2 producer, the lower becomes the rate of interest in the financial market. This would further contribute to the increase of the construction period of the capital good 1 to that of the capital good 2. As a result, the supply schedule aS in Figure 2 shifts to the rightward direction in the long run. Note that the supply curve of Figure 2 is drawn for a given construction periods of the two capital goods.

D. Average roundabout production period of the economy

This section discusses financial market equilibrium with respect to the average roundabout period of the economy. We define the average roundabout production period of an economy as the weighted average of the roundabout periods of the two sectors, the weight being the employment share of the labor of the sector. The average roundabout period v is in expression (8):

$$\begin{aligned} v(r) &= l_1(r)v_1(r) + l_2(r)v_2(r) \\ &= l_1(r)v_1(r) + \left(1 - l_1(r)\right)v_2(r) \\ &= l_1(r)\left(v_1(r) - v_2(r)\right) + v_2(r), \end{aligned} \tag{8}$$

where $l_i(\cdot)$ is an employment share of an i-sector, L_i/L. The relative wage rate of the two sectors explains the relative employment of the two. An individual worker selects a sector for which the wage rate is high. In

the present Austrian model, the relative wage rate is determined by the relative roundabout periods of the two sectors. The roundabout period of each sector decreases according to the interest rate increase in equation (3). Result 1 indicates that the relative roundabout period of capital good 1 decreases relatively greater than that of capital good 2. Hence, the relative wage rate for capital good 1 sector falls relatively in a greater amount by the increase in the interest rate. Consequently, the relative employment rate of capital good 1 sector falls compared to that of sector 2. In summary, all of these effects result in a monotonic decrease in the roundabout production period in the economy based on the interest rate increase, that is, $v'(r)<0$. This monotonic relationship shows the average roundabout period and the interest rate holds for range $\hat{v}_2<v<\hat{v}_1$. Demand for the roundabout production period or, in other words, demand for the construction of capital goods, can be translated into demand for loanable funds in the financial market. The downward sloping *DD* curve in Figure 3 depicts the demand for the roundabout period of the economy with respect to the interest rate.

E. Dynastic utility function

Individuals of $t\in[0, T]$ generations are overlapped, being consistent with the life period of capital goods. Periods for raising children and the education periods for them are abstracted away. We address the working periods of each individual as occurring when an individual arriving at time period t participates in the construction of capital goods and reaps his/her earnings working with the associated capital goods during the utilization periods. An individual earns wage rate w_t and leaves bequests s_t for his/her succeeding generation.

Individuals are divided into two groups. Members of the first group engage in the production of capital good 1, whereas those in the second group engage in the production of capital good 2. A representative individual of each group i of cohort t maximizes the dynastic utility function $V(c_{it})$ subject to his/her income constraint:

$$\max_{c_{it}} V_t(c_{it}) = u(c_{it}) + \theta V_{t+1}(c_{it+1}); \; 0 < \theta < 1$$
$$s.t.$$
$$c_{it} \leq w_{it} - r_{it}s_{it}$$
$$i = 1, 2.$$

Coefficient θ represents altruism for the consumption of the next generation, and r_{it} represents the interest rate in terms of the rental of capital good i to a member of group i of cohort t. Individual i's maximization problem is to select the amount of consumption c_{it} to maximize his/her dynastic utility function $V_i(c_{it})$. The consumption amount of an individual of group i for the next cohort $c_{i(t+1)}$ implies the savings of group i of cohort t, s_{it}. The utility function is of the following form of the log utility:

$$u(c_{it}) = \log c_{it}.$$

The first-order condition is:

$$\frac{s_{it}}{c_{it}} = \theta + r_{it}s; \quad i = 1, 2. \tag{9}$$

This equation suggests that the more altruistic is the current generation t to the consumption of the succeeding generation $t+1$, the greater is the amount of bequests bestowed on the next generation. In the financial market, the higher the interest rate, the greater is the savings amount of cohort t. We consider altruism parameter θ as an inverse of the time preference rate $0<\rho<1$, that is, $\theta=1/(1+\rho)$. In Equation (9), the decision to save of individual i who belongs to cohort t depends on the interest rate in terms of rentals r_{it}. Finally, the savings amount for cohort t as denoted by s_t is obtained by multiplying the amount of each individual savings by the size of employment associated with each sector i. The equation is as follows.

$$s_t = T\left(L_{1t}s_{1t} + L_{2t}s_{2t}\right);$$
$$L_{1t} + L_{2t} = L \forall t.$$

The savings amount of cohort t is a monotonically increasing function of interest rate r_t. Figure 3 presents the financial market of the economy in the long term for the given rentals of the two capital goods. Its vertical axis is the rate of interest r_t, whereas the horizontal axis represents the average roundabout period of the economy for the cohort $t+1$ of the succeeding generation. The greater the amount of bequests left

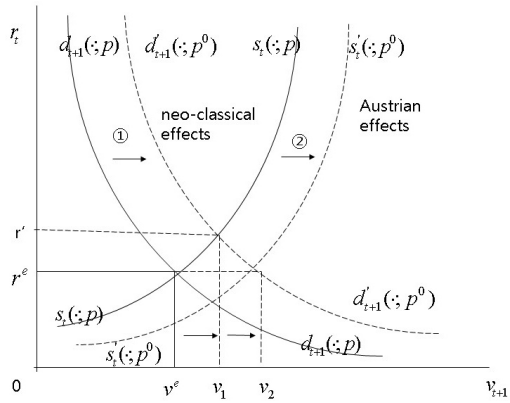

FIGURE 3
FINANCIAL MARKET IN THE LONG RUN

for the next generation by cohort t, the greater amount of savings is available for lengthening the roundabout period of the next generation $t+1$. The supply curve of the savings is drawn as an upward sloping curve $s_t(r_t; p)$ with respect to v_{t+1}. For a given interest rate of the previous generation r_t and for the given relative rentals of two capital goods p, the producer of capital good i of the current generation $t+1$ makes an investment decision. This monotonically decreasing function of interest rate r_t is drawn as a downward slope $d_t(r_t; p)$ in Figure 3.

A mismatch in cohorts is indicated with respect to the savings decisions of consumers and the investment decisions of producers of capital goods. The saving decision is made by the previous generation, whereas the current generation makes decisions on investments. This mismatch of the cohorts for the demand and the supply in the financial market creates complications as in the cob-web model. The elasticity of demand for investments of the current generation is simply assumed to be greater than that of the supply of savings of the previous one. This assumption ensures the equilibrium over the long run.

Figure 3 shows the interest rate and the average roundabout period of the economy indicated by r^e and v^e, respectively, and describes the closed economy equilibrium. The next section discusses the growth effects of trade with respect to its influence on the domestic financial market in the Austrian viewpoint.

F. Price of a capital good

In perfect competition, the cost of a capital good is equal to its discounted stream of profits, such that the following is the expression of the price of a capital good of vintage v_i denoted by $q_{v_{it}}$:

$$q_{v_i} = w_{0_i} \int_0^{v_i} e^{rs} ds = (A(0) - 1) \int_0^{T-v_i} p_i v_i^{\alpha_i} e^{-rs} ds.$$

The first term of the price is the amount of the investment for the production of capital good i in terms of its own service units over its construction period per unit of labor, whereas the second term is also its value in terms of its price p_i.

Hence, the relative price of the two capital goods in terms of their own prices is represented as:

$$q(r) \equiv \frac{q_{v_1}(r)}{q_{v_2}(r)} = \frac{w_{0_1} \int_0^{v_1} e^{rs} ds}{w_{0_2} \int_0^{v_2} e^{rs} ds} = \frac{p_1 w_0 \int_0^{v_1} e^{rs} ds}{p_2 w_0 \int_0^{v_2} e^{rs} ds} \equiv p\Gamma(r). \tag{10}$$

The next point of interest is the variation in the relative price of capital goods price q with respect to the interest rate. The variation depends on the change in the relative roundabout periods of two sectors for a given relative price p. The amount of investments is relatively greater to the sector for which its roundabout production period becomes longer. Based on Result 1, $\Gamma'(r) < 0$. Hence, the amount of investment is relatively greater for capital good 1, suggesting that the amount of rentals provided by good 1 is relatively greater for the economy with a lower interest rate. Good 1 will become more efficient relative to good 2 in an economy with a lower interest rate, and in the sense that a relatively greater amount of rentals is provided by the former.

III. Equilibrium of a Closed Economy

The equilibrium of a closed economy is the one that satisfies Equations (2), (7), (9), and (10) for a given endowment of labor $0 < L < \infty$ with its given lifetime period $0 < T < \infty$ and for a given time preference rate 0

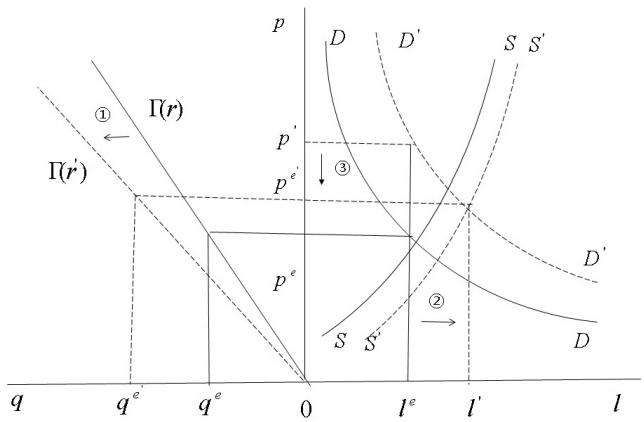

FIGURE 4
ADJUSTMENT OF THE INVESTMENT TO THE RENTAL MARKET DISEQUILIBRIUM

$<\rho<1$ of an individual in the economy. The equilibrium shows the producer's profit maximizing condition for investment, condition for labor's choice of the sector to engage with, and individual's choice of the consumption over his/her life period. These factors are consistent with the producer's zero profit condition in the production of capital goods. These conditions are not simultaneously fulfilled at a given time period of τ. They are fulfilled over a given long run life period of cohort t. Figure 4 illustrates the short-run rental market as well as the long-run investment.

The vertical axis represents the relative price ratio of rental 1 to rental 2. The right-hand side of the horizontal axis represents the relative employment of the two, and its left-hand side is the relative price of the two capital goods. The right-hand quadrant of Figure 4 shows the relative demand and supply curve of rentals. Its equilibrium price is denoted by p^e, and the employment ratio of the two sectors is denoted by l^e. The left-hand quadrant of Figure 4 links the relative price of two capital goods to the rentals by the efficiency units of term $\Gamma(\cdot)$ in equation (10). The lower is the rate of interest, the steeper becomes the slope. The relative equilibrium price of capital goods q^e follows on the left-hand side horizontal line.

I consider a new equilibrium by the increase of the relative demand for the rental services 1. It is shown as the shift of the curve DD to the rightward direction $D'D'$ in the right hand quadrant. It will result in the

rise of the relative price to p' on the vertical axis. The producer 1 revises his/her investment plan to extend the construction period, while the producer 2 to shorten it. This revision of their plans contribute to the increase of the average roundabout period of the economy in view of equation (8). On the other hand, there occurs capital gains to the producer 1 and the capital losses to the producer 2. This affects the average roundabout period of the economy through the change in the rate of interest in the financial market by a Hayek's "recuperation effect." The fall of the efficiency schedule from $\Gamma(r)$ to a dotted line $\Gamma(r')$ as indicated by the arrow ① in Figure 2 reflects the fall of the rate of interest. Adding this to the neo-classical allocation effect finally gives the shift of the supply schedule on the rightward direction to the $S'S'$ schedule in the right hand quadrant, resulting in the increase of the relative employment of the capital good 1 sector to l' indicated by the arrow ②. The arrow ③ shows the reach to the final equilibrium price of $p^{e'}$. The extent to which the supply schedule shifts to the rightward direction depends on by the reduction of the rate of interest. The greater is the amount of the rate of reduction, the greater is the amount of the shift of the supply schedule, yielding the greater amount of the rate of the employment in the capital good 1 sector.

The time lag between the provisions of the rentals and construction of capital goods might trigger over-investments or under-investments based on the wrong expectations on future rentals. Suppose that the investment commitment by producer 1 was wrong in the sense that over-investments occurred from the high expectations on relative rental 1 at the price level of p' instead of p^e. This is the case in which the time preference rate ρ being lower than the market rate of interest r. On the realization of the excess supply of rentals at price p', producer 1 lays off labor. The released labor from sector 1 would seek employment in sector 2. From the viewpoint of producer 2, investments for labor are unnecessary given that labor from sector 1 is of a higher vintage of human capital than its human capital vintage level. The change in the rate of employment goes in the reverse direction from the previous case. The producer 1 witnesses the "irreversibility" of time in investment. In order to avoid "the sunk costs" the producer 1 would adjust the time preference rate ρ to the market rate of interest r.

Adjustment of the rental market in its disequilibrium is not on a conventional "Walrasian tatônnement." In this case, adjustments on the initial commitments on investments are necessary. The process starts from the withdrawal or the expansion of investments by the producers

of the capital goods. Then, the reallocation of employment follows. The final step considers minimizing the excess supply of or excess demand for rental 1 or rental 2 in the rental market. For the case of under-investments by producer 1, the opposite sequences follow. The investment for capital good 1 increases relative to that for capital good 2. In the short run, labor moves to the capital good 1 sector by investments for the adaptation of the low vintage human capital of the capital good 2 sector to the high vintage of the human capital of sector 1. The supply of labor to sector 1 will become more elastic as forthcoming cohorts participate in the supply of labor to sector 1. For this under-investment case, however, no sunk costs arise on the side of producer 1.

The Austrian perspective on market disequilibrium is more than just simple adjustments to the excess supply and demand for the rental markets. A capital good producer may not only change the commitments on the investments but may also review his/her previous plan on maintaining a constant income stream. Under the circumstances of losses or gains in income streams, the capital good producer may increase or decrease his/her savings. As in the previous discussion on Figure 2, producer 1's review of his/her consumption plan on the ignorance of the impending fall of the rental price suggests that he/she would adjust the attitude according to the time preference rate to equalize the latter with the interest rate.[12] This approach restores the rental market equilibrium.

Alternatively, producer 1 would abstain from the consumption and raise the amount of bequests bestowed on the succeeding generation in view of Equation (9). These steps would contribute to the shift in supply schedule $S(\cdot)S(\cdot)$ in Figure 4 to the rightward direction over the long run. Hence, equilibrium is reached once again. The adaptation of producer 1 to these unforeseen situations with respect to his/her future consumption stream links the disequilibrium in the rental market with the adjustments in the financial market.[13]

[12] In a similar vein, I have discussed the behavior of an entrepreneur of the capital good production on Hicks's Traverse in a neo-Austrian framework (Kim 1994).

[13] A windfall loss of producer 1 might be offset by the capital gains of producer 2. I consider the former as more influential on the financial market than the latter, given that the construction period of capital good 1 is longer, whereas the latter is not too distant from the primary input of labor in Hayek's time structure of production.

IV. International Trade

A developing economy trades capital goods with an advanced economy. The two economies have an identical production technology of the two capital goods. They differ in their time preference rates. I assume that time preference rate of an advanced economy denoted by ρ^* is smaller than that of a developing economy denoted by ρ.[14] Considering that the services of capital goods themselves are not tradable, the trade of capital goods takes the place of service trade. The trade of capital goods between the two economies occurs through the difference in the domestic rental service prices between the two.

The more efficient is human capital involved in the provision of the service by the capital good would result in cheaper prices because of the availability of a greater amount of services. Coefficient $\Gamma(r)$ in equation (10) represents the relative efficiency of two capital goods in providing their services. Result 1 suggests that the coefficient is higher for the low time preference rate economy: $\Gamma(\rho^*) > \Gamma(\rho)$. Hence, for a given relative service price of two capital goods, the low time preference rate economy supplies a relatively greater amount of the services of the capital good 1 to the domestic economy. The domestic price of the service price of capital good 1 in low time preference rate economy will be lower than that in the high time preference rate economy. This consideration spurs the establishment of the trade of capital goods between two economies. Figure 5 illustrates the closed economy equilibrium of two economies. The relative supply schedule of capital good 1 service for the low time preference rate economy is represented by the dotted line $S^*(l; \rho^*)$ on the right-hand quadrant. I denote the relative rental price s of capital good 1 with respect to the price of capital good 2 in their respective efficiency units by $\tilde{q}$, which is defined as $q/\Gamma(\cdot)$. The relative price of capital goods adjusted by their respective efficiency units is on the left-hand side of quadrant 2 of Figure 5. It is found by translation of the vertical axis by the 45^0 line on the horizontal axis.

Figure 5 shows the slope with respect to the relative rental price of capital good 1 is lower than that of the high time preference rate economy due to Result 1. This relationship implies that the relative supply of rental service 1 is greater in the low time preference rate economy as indicated by its supply schedule of $S^*(l; \rho^*)$. Consequently, the relative rental price of capital good 1 is lower in the low time preference rate

[14] The variables with the asterisk are the ones of the advanced economy.

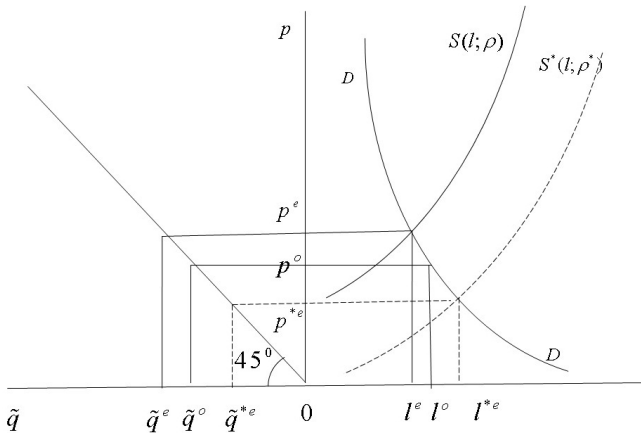

FIGURE 5
TRADE EQUILIBRIUM OF THE CAPITAL GOOD MARKET

economy. Equivalently, the relative price of capital good 1 in its efficiency units is lower in the low time preference rate economy. Given $p^* < p$, the inequality of $q^*/\Gamma(\rho^*) < q/\Gamma(\rho)$ follows. Hence, $\tilde{q}^* < \tilde{q}$ and trade of capital goods are established between the two economies. Trade is established on the international price of $\tilde{q}^0$ with the relative employment ratio of l^0 and the rental service price of p^0. The low time preference rate economy exports capital good 1 and imports capital good 2. Proposition 1 summarizes the direction of trade.

***Proposition* 1:** A low time preference rate economy of a longer average roundabout period of an economy (human capital abundant economy) exports time intensive capital good 1 (human capital intensive good) and imports a less time intensive capital good 2 (less human capital intensive good) for the region of roundabout period $\hat{v}_2 < v < \hat{v}_1$.

The international price of capital good 1 in terms of capital good 2 in their efficiency units denoted by $\tilde{q}^0$ will be in the range of the domestic prices of two economies, that is, $\tilde{q}^* < \tilde{q}^0 < \tilde{q}$.

Thus far, the lack of a difference is assumed in the individual lifetime periods of two economies. Suppose no difference in their time preference rates occurs, but an individual's lifetime period of the advanced economy is longer than that of the developing economy. This case raises a question on the direction of trade between the two economies whose demography

varies. Equation (9) suggests that the relative efficiency of capital good 1 to that of capital good 2 will be greater for an economy with an individual longer life period than for one with a shorter life period, that is, $\Gamma^*(T^*) > \Gamma(T); T^* > T$, being the same time preference rate for the two economies. The efficiency adjusted relative capital good price 1 will be lower at the advanced economy of the longer life demography. Proposition 1 offers that the direction of trade by the economy of a long age demography exports a time intensive (human capital intensive) capital good and imports a less time intensive (less human capital intensive) capital good.

Findlay and Kierzkowski's low time preference rate economy is the one whose average roundabout period of the economy is longer in terms of the present model. Proposition 1 can be translated to the proposition of the relative human capital endowment of the two trading economies being the cause of trade. The amount of human capital of sector i is the amount of labor multiplied by its efficiency units of v_i. Considering that the roundabout production period of capital good i measures the efficiency of labor engaged with its production, the human capital abundance of an economy is expressed by the average roundabout period of an economy:

$$\frac{H}{L} = \frac{v_1 L_1 + v_2 L_2}{L} = v_1 l_1 + v_2 l_2 = v,$$

where H represents the total amount of human capital stock in the economy. In the previous discussion, the average roundabout period of the low time preference rate economy is longer than that of the high time preference rate economy. The production of capital good 1, which takes a relatively more roundabout period, is incumbent with a relatively more human capital-intensive labor such that it is considered human capital intensive. Similarly, capital good 2, which is produced in a relatively shorter roundabout period, is produced by a relatively less human capital-intensive labor. Hence, proposition 1 is consistent with Findlay and Kierzkowski's model.

A. Trade and growth

Free trade improves the welfare of both trading partners as indicated in the conventional trade proposition. This section considers the impli-

cation of trade on growth for two trading economies. Recall that the average roundabout period of an economy explains the growth rate of an economy. The allocation of labor toward the capital good 1 sector contributes to the increase in the average roundabout period. The allocation to the capital good 2 sector reduces the said period.

By free trade, the advanced economy with the low time preference rate specializes in the production of capital good 1. The average roundabout period of the economy increases and contributes to its growth rate. On the contrary, the developing economy with the high time preference rate specializes in the production of capital good 2. The average roundabout period of the economy decreases and its growth rate falls by the specialization of the production of capital good 2.

The Austrian view on the effect of trade on growth goes further than the traditional static allocation effect. This perspective comes from a developing economy with the high time preference rate. A lowering of the rental of capital good 1 will induce the negative value of producer 1's present value of the investment in the developing economy. Producer 1 has two means of adjusting to free trade. In the case of the closed economy, first, the producer could shorten the construction period of capital good 1, and second, the producer could reduce the current consumption level to sustain the consumption in the future by Hayek's "recuperation effect."

First, we discuss the effects from the viewpoint of the investments of producers and compare these effects with the previous closed economy case in the change of rentals. In contrast to the case of the closed economy, the imported capital good with a high vintage provides domestic producer 1 with opportunities to invest for the adaptation of the domestic human capital of vintage 1 to the high vintage of the imported capital good. Suppose that the "barriers to the technology adoption" of domestic human capital are low. Result 3 suggests that lengthening the construction period is possible for producer 1. This lengthening effect is reinforced for the economy where the migration costs of the labor from the production of capital good 1 to that of capital good 2 are low, as discussed in Result 2. In conclusion, the opening of trade in the Austrian perspective allows domestic producer 1 to meet the new challenges of adapting the domestic human capital to the imported capital good. This approach contributes to lengthening the construction period of capital good 1. The positive growth effect of free trade follows.

A similar explanation applies to the producer of capital good 2. The relative rise of rental 2 raises its present value of investment. Domestic

producer 2 lengthens its construction period by this favorable effect of trade. Together with the increase in the roundabout production period of capital good 1 by domestic producer 1, this situation contributes to the average roundabout period of the economy. In the economy where the level of "the barriers to technology adoption" is low and the migration costs of labor moving from the production of capital good 1 to that of capital good 2 are not high, growth rate could increase. By free trade, both the export and the import sectors could grow in parallel with each other in the present Austrian view of trade. This result contrasts with the conventional static trade model. A sector, which is in comparative advantage expands, whereas the sector, which is in comparative disadvantage, shrinks after trade.

This supply side effect of trade on growth does not differ from the neo-classical argument of trade in the endogenous growth model of various types. The difference is that it is involved with intermediates distinguished by the distance from the primary factors of production and labor in Hayek's triangle.[15]

The effect of trade on growth rate is considered from the supply side with respect to the average roundabout period of the economy. Suppose that producer 1 committed investment not knowing of the impending change of free trade. He/she realizes "windfall losses" after opening up the trade. To recuperate the losses, producer 1 adjusts the amount of bequests to the forthcoming generation.

Rental 1 falls due to the import of capital good 1. This outcome raises the rate of interest in terms of rental 1 for producer 1. In equation (8), the parties involved in the production of capital good 1 leave a greater amount of bequests. The rise of rental 2 by the export of capital good 2 lowers the interest rate in terms of rent 2 to producer 2. In contrast to the case of sector 1, the parties engaged in the production of capital good 2 would intend to leave a lower amount of bequests in the case of the closed economy and would thus, increase consumption.

Given that rental 1 becomes low relative to rental 2 by trade, the individuals of sector 2 would increase consumption of rental 1.[16] The

[15] Considering that the intermediates involved in the production of a capital good are differentiated by the distance from the original input, the present model suggests the importance of the SITC digit number associated with the import structure of a developing economy. The intermediates of capital good 1 would expand in terms of their sub-digit numbers in the SITC classification as development proceeds.

[16] In the closed economy, this condition would revert the relative fall of rental

importance of human capital in the production of capital good 2 is assumed to be almost nil, and no roundabout production period occurs. Hence, sector 2 is considered as a sector for the production of consumption goods.[17] Those individuals of sector 1 who obtain consumer goods would instead tend to import capital good 1 given that they intend to increase savings.

The behavior of savings of the two groups applies analogously to the advanced economy. Equation (11) expresses the amount of bequests to be left by the two groups for the next generation in the advanced economy:

$$\frac{s^*_{it}}{c^*_{it}} = \theta + r^*_{it} s^*_{it}; \quad i = 1, 2. \tag{11}$$

By trade, rental 1 of the advanced economy falls and group 1 leaves a lower amount of bequests and increases consumption. Group 2 would decrease consumption given the rise in rental 2. However, the increase in consumption in the open economy is matched by its import from the developing economy.

In conclusion, the increase in savings by group 1 of the developing economy converts into the import of capital good 1 from the advanced economy. This outcome relieves the constraint, which is often referred to as "foreign exchange constraint" in the economic development literature.

Figure 3 is a self-explanatory illustration of the Austrian effect of trade on growth. The increase in the supply of savings contributing to the average roundabout period of an economy is shown by the rightward direction from supply schedule $s_t s_t$ to schedule $s'_t s'_t$ as noted by ②. The shift of the aggregate demand for the average roundabout period by the neo-classical growth effect of trade shifts the $d_{t+1} d_{t+1}$ schedule to the rightward direction of $d'_{t+1} d'_{t+1}$ as indicated by the direction of ①. The increase in the average roundabout period of the economy from the closed-economy equilibrium of v^e to v_1 represents the neo-classical effect, whereas the increase in the period from v_1 to v_2 is attributed to the Austrian effect. This outcome relieves financial strains of the "adaptation

1 and bring the economy back to the equilibrium.

[17] In other words, service to a consumer is provided by a consumer's direct consumption not via the use of capital goods. This observation is consistent with the trade pattern of a developing economy as presented in the introduction for the background of the Austrian trade model.

investment" for the import vintage of capital good 1 sector. A trade structure of a developing economy characterized by the export of the consumer goods and the import of the capital goods reflects a Hayek's "recuperation effect" of the capital good sector. The present model of the Austrian trade and growth is by no means competing with the neo-classical growth models. The former rather complements the latter approach.

V. Conclusion

This paper extends Hayek's triangle to an open economy. An abstinence of the present consumption contributes to the growth of an economy by stretching the intermediates starting from the original inputs down to the final goods. The abstinence of the present consumption is related to the time-preference rate of the economy. In an economy that values more of the future consumption against the present consumption, a greater amount of savings is available for extension of the intermediates down to the final goods. This extension causes the economy to grow.

However, the growth experiences of developing economies suggest a close link between trade structure and growth performances. Light consumer goods are on the exports of a developing economy at the initial stage of development, whereas imports largely consist of machinery and intermediates. This trade structure indicates that a country could extend its time structure of the economy by importing intermediates in exchange for consumer goods. In this regard, a Hayek's triangle is extended along the time axis by trade.

A time extension of Hayek's triangle is represented by the time intensity of the production of a capital good in the present model. The production technology of capital goods is distinguished by the importance of time in their production. A time intensive capital good considers production time as more important for its manufacture compared with a less time intensive capital good. A high time preference rate economy is considered a developing economy, and an advanced economy is one that has a low time preference rate economy. A low time preference rate economy exports time intensive capital goods and imports less time intensive capital goods. This trade structure favorably affects the growth of the low time preference rate economy through the specialization of time intensive capital goods.

A specialization of the less time intensive good is unfavorable to the growth of the high time preference rate economy. This unfavorable growth

effect could be counteracted by the investments for the adaptation of low vintage human capital to the high vintage of the imported capital good. The rate of investments depends on the domestic human capital's "absorptive capacity" of the high vintage technique on the imported capital good. The extent of this adaptation investment outweighs the unfavorable composition effects of trade, which contributes to the growth performance of a developing economy. The adaptation investment allows the human capital of the less time intensive capital good sector to move to a time intensive one. This migration adds a favorable growth effect to the developing economy. The growth effects are limited by the domestic human capital's "absorptive capacity" as well as by the migration cost of moving human capital from the low vintage of the export sector to the high vintage of the import sector. In conclusion, the growth effect of trade for a developing economy depends on the domestic human capital's "absorptive capacity" and the migration cost of moving human capital from the export sector to the import sector.

The present model has several limitations. First, the time horizon of the capital good production is limited by an individual's lifetime period. Its truncation is concurrent with the individual's life period in the long run. Although this presumption facilitates the analysis of this study, a problem remains in how far this concurrence between the time horizon of capital good production and the individual's lifetime period matches with the short-run reality. Despite this shortcoming, proposition 1 predicts a direction of trade between the economies whose demography varies.

Second, the existence of freely available natural resources, which become a capital good on the application of labor, as in a simple Crusoe's economy, is another limitation of the present model. Accumulation of capital goods erodes the natural resources and induces environmental problems, which are left out.

This paper leaves open the determination of the "absorptive capacity" of the domestic human capital. One of the possible determinants might be the distance of the vintage level between the domestic human capital and that of the human capital of the advanced economy. This aspect can be matched by research on the trade and growth model of a developing economy.

In the transition from a closed to an open economy co-exists the old domestic capital good with the new imported capital good. The effect of the growth rate of the economy in the present model by the co-existence of the two capital goods due to free trade is one of the topics that merit

further examination.[18]

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[18] I have considered this problem in relation to Hicks's traverse (Kim 2008).

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