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A MODEL OF DUAL–INDUSTRIAL DEVELOPMENT IN A SEMI-INDUSTRIAL COUNTRY

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I. INTRODUCTION

DURING the past few decades, much theoretical attention in development economics has been given to development of a dual economy which focuses on the transition of a primarily agrarian economy into an industry-dominated one through sustained capital accumulation in industry.[1] However, during the same decades, many developing countries have managed to establish a sizable industrial sector which surpasses agriculture as the prime contributor to national output.[2] Hence, a *mere* shift of production from agriculture to industry is no longer the central issue in these countries. Yet the process of industrial development is by no means proceeding smoothly, even in relatively successful developing countries which are called semi-industrial countries. The typical current problem they face is the development of those sectors that produce major investment and intermediate goods using advanced technologies. However, the transition from an early stage of industrialization to later stages and the eventual maturity to a developed economy is not an easy one, and prospective candidates are still struggling with high import dependence of their industrial production, foreign exchange shortages, and staggering growth in their intermediate and capital goods industries.

The difficulties associated with industrial maturity are thus becoming an important development issue particularly for semi-industrial countries, but little

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1 The literature on dual economic development has evolved along two lines, the classical approach as represented by Lewis [9] [10] and Fei and Ranis [2], and the neoclassical approach attributable to Jorgenson [5] [6]. Both are concerned with the transitional growth of an economy from agriculture to industry, although they differ markedly in assuming and not assuming the existence of surplus labor.

2 The World Bank statistics show that, between 1965 and 1986, the average share of agriculture in GNP has fallen from 30 per cent to 22 per cent in the lower-middle income countries and from 18 per cent to 10 per cent in the upper-middle income countries, while the industry share (manufacturing and construction) has risen from 25 per cent to 30 per cent and from 37 per cent to 40 per cent, respectively, for the two groups of countries. These countries in all comprise about two-thirds of all the developing countries excluding major oil exporters and the East European nonmarket economies. See [13, pp. 226–27].

theoretical attention has so far been given to these problems and to policies that may facilitate smoother transition towards industrial maturity. The purpose of the present paper is to present a model of industrial development which focuses on the transition from early to later stages of industrialization, with particular emphasis on growth and interactions among different industrial sectors.

Past empirical research on industrial development has found distinct growth patterns for different industrial groups. A representative study along this line is that by Chenery and Taylor [1], who classified industrial branches into "early," "middle," and "late" industries according to the timing of their expansion relative to income growth. They found that growth patterns differ greatly not only among industries themselves but also among countries with different country characteristics.[3] The early industries use relatively simple technology and supply the essential needs of low-income countries, but do not increase their share in GNP after a fairly low level of per capita income. The middle industries double their share in the low income levels but show little rise during the later stage of industrialization. The late industries continue to expand faster than GNP up to the highest income levels and double their share in the later stage of industrialization. This group produces major intermediate and investment goods as well as income-elastic consumer goods. The country characteristics are classified by population size and resource endowments (as reflected in export orientation), yielding large (L), small primary-oriented (SP), and small manufacturing-oriented (SM) country groups.

We can derive two lessons from their finding. First, developing countries are so diverse that no one theory can hope to adequately describe the process of industrialization in different types of countries. Thus, in developing a model of industrialization, one needs to keep in mind a specific type of country to which the model addresses itself. Second, the observed growth patterns suggest that the problem of industrial maturity is largely related to the development of late and some middle industries. Thus, sectors such as basic metals, paper, machinery, transport equipment, and possibly chemicals play the key role in the later stage of industrialization. These sectors are distinct from early industries such as food processing, textiles, leather products, and clothing, in the ease of adopting required technologies and in the scale of operation at which efficient production is expected to be realized.

As for the type of countries on which we focus, we shall take the Republic of Korea as our reference case. Korea has achieved rapid industrial growth led by exports of labor-intensive manufactured products and is regarded as one of the representative semi-industrial economies along with Taiwan.[4] Its successful past

[3] The early industries include food processing, leather products, and textiles; the middle industries contain nonmetallic minerals, rubber products, wood products, chemicals, and petroleum refining; and the late industries include clothing, printing, basic metals, paper, and metal products (including machinery and transport equipment). An extension of Chenery and Taylor's analysis was carried out by Prakash and Robinson [11] who brought out similar conclusions based on substantially larger data, although the classification of the three industry groups is slightly different. In particular, clothing is grouped as middle rather than late, and wood products as late rather than middle.

[4] For an excellent description of Korean industrial development, see, for example, [12].

performance makes Korea an interesting case to model in the consideration of problems associated with industrial maturity. In doing so, we can benefit from a useful characterization of Korean development by Imaoka [3]. Examining various development indicators for Korea and Taiwan, Imaoka argues that Korea's (and Taiwan's) successful development was brought about not solely by the rapid growth of its export industries, but by the joint growth of export industries *and* the domestic intermediate and capital goods industries, the latter taking growth impetus from expanding export production in the form of increased intermediate and investment demands and in return providing cheaper products for use by the export sectors.[5] The reason for cheaper supply of intermediate and capital goods is sought in the realization of scale economies by directing much of intermediate and investment demands towards domestic industries through protective measures. Thus, Imaoka's thesis presupposes a policy package consisting of export promotion *and* protection of immature industries, which prompted him to call the growth pattern as "dual–industrial growth." From the policy point of view, Korea not only encouraged exports by all possible sectors but also provided selective protection for a number of sectors belonging to heavy industry,[6] so that Imaoka's characterization is appropriate as far as Korea is concerned.

Imaoka suspects that the concept of dual–industrial growth has relevance in other developing countries as well, but he has not elaborated. The present study uses Imaoka's thesis to develop a model of industrial growth in a semi-industrial country.[7] Specifically, we consider an economy with two industrial sectors, an export industry producing a consumer good and a heavy industry producing an intermediate/capital good. The export sector is assumed to be internationally competitive, but the heavy industry is assumed to be immature and shielded from foreign competition by policy. Hence, the heavy industry "monopolizes," as it were, the part of intermediate and investment demands from the two sectors which it can produce. As for technology, we assume constant returns to scale in the export industry and increasing returns to scale in the heavy industry. We also assume, for simplicity, that labor supply is unlimited at an institutionally determined wage rate. In the short run, producers in each sector choose the levels of variable inputs to maximize profits and reinvest the profit incomes into their own sector. Because of perfect tariff protection, the price of the heavy industrial product is determined by domestic demand and supply, which then affects the cost and profitability of the export industry.

Our question is whether a joint growth of the two sectors is possible under these circumstances and, if so, what are the conditions that are required for

5 The importance of interindustry linkages in industrial development has also been recognized in Kubo [7], but the mechanism that produces such a relationship has not been investigated.

6 Westphal shows that, in 1968, high effective protection was given to domestic sales of transport equipment, consumer durables, machinery, and intermediate products of relatively high fabrication, in that order, while those of other industrial categories and exports almost all had negative effective protection [12, p. 377, Annex Table 1].

7 The present model extends a two-sector model of Kubo [8] which in turn benefits from Inada [4]. However, incorporation of characteristic features of semi-industrial countries and Imaoka's dual growth hypothesis results in a much different model from its predecessors.

ensuring such a joint development. We will show below that there are certain requirements for the levels of capital accumulation in the two sectors and that if these requirements are met, the policy package of promoting exports of competitive industries *and* directing the intermediate and investment demands thereof to the immature heavy industries by protective means is a promising approach to enhance a smoother transition through different stages of industrialization. However, if the required conditions are not met, the above policy package will fail to lead to a joint growth of the two sectors, and alternative policies must be sought to achieve a better development performance.

The plan of the paper is as follows: Section II describes the model and Section III analyzes the temporary equilibrium. The dynamic growth of the economy is examined in Section IV and the implications for developing countries are discussed. Finally, Section V contains a brief conclusion.

II. THE MODEL

Our model of industrial development is built upon four characteristic features of a Korea-like semi-inlustrial economy as summarized by Imaoka [3]: (1) existence of an internationally competitive export industry; (2) existence of a large export market for this industry; (3) existence of an immature domestic intermediate/investment good industry whose technology is characterized by economies of scale; and (4) protection from foreign competition for this industry by governmental policy. The existence of a competitive export industry can be interpreted as the result of export promotion policies, although this aspect will not be explicitly treated in our model. Based on the above key features of a semi-industrial economy, we consider the following framework for our model.

(a) *Industrial sectors.* The economy we consider has two industrial sectors, one producing an exportable consumer good, X, and the other producing a different manufactured product, Y, usable for both investment and intermediate purposes. The consumer-good sector, called the X sector, is assumed to be sufficiently matured in the sense that it can compete in the international market. In semi-industrial countries, we can think of early industries such as food processing, textiles, and clothing. The second sector, the Y sector, is assumed to be immature; it cannot survive foreign competition unless protected by policy. In semi-industrial countries, this sector is typically represented by late or middle industries such as basic metals, machinery, transport equipment, and chemicals. Due to lack of competitiveness, its products are all used domestically and not exported.

(b) *Labor supply.* Following Lewis [9], we assume that labor supply is unlimited at an institutionally determined wage rate. Implicitly, we assume that there is a third sector in the economy containing a large amount of disguised unemployment. This sector is an informal sector whose economic activities are separated from the rest of the economy, except that it serves as an inexhaustible source of labor supply. Hence, the two industrial sectors can employ as much labor as they need without affecting the predetermined wage rate.

This, of course, is a simplification. While it is likely that labor supply is unlimited at an early stage of industrialization, as a country proceeds in the stages of development, the initially surplus labor will eventually get absorbed and the wage rate will begin to rise. However, we ignore this possibility here for the sake of simplicity and proceed by assuming unlimited supplies of labor, leaving other cases to future scrutiny.

(c) *Production.* We assume that production in both sectors uses labor (L) and capital (K) as inputs. In addition, the X sector uses intermediate inputs which are grouped into domestically produced (W_d) and imported (W_m) intermediates. Imported intermediates are assumed to be noncompetitive in the sense that they are as yet nonproducible domestically. The technology in the X sector is assumed to exhibit constant returns to scale. In fact, we assume that this sector's production function is of the Leontief type:

$$X=\min[K_x/k_x,\ L_x/l_x,\ W_d/a_d,\ W_m/a_m], \tag{1}$$

where k_x and l_x are capital and labor coefficients and a_m and a_d are imported and domestic input coefficients, all assumed technologically given.

We assume that the Y sector does not use intermediate inputs, but in order to reflect the advantages of industrial conglomeration and large scale operations of many heavy industrial production, we assume that its technology exhibits increasing returns to scale. Specifically, we assume that the production function of the Y sector is given by a homogeneous function of degree r ($r>1$) with respect to capital and labor:

$$Y=F_y(K_y,\ L_y)=K_y{}^r f_y(n_y), \tag{2}$$

where $n_y=L_y/K_y$ and $f_y(n_y)=F_y(1,\ n_y)$. We assume that F_y and f_y satisfy the following properties:

$$F_y(0,\ L_y)=F_y(K_y,\ 0)=0; \tag{3}$$

$$f_y'>0;\ f_y-n_y f_y'>0;\ \text{and}\ f_y''<0. \tag{4}$$

The scale economies assumed for the Y sector is interpreted as arising from Marshallian external economies of adjacent industrial locations. That is, we assume that the firms in the industry perceive constant-returns-to-scale technology, but their production activities entail external economies to other firms so that the resulting industry production exhibits increasing returns to scale. Since each firm in the industry perceives constant-returns technology, we may assume that, in the short run, the industry as a whole behaves as if maximizing the aggregate profits given the product and factor prices and the amount of capital. Of course, the realized profits will reflect the effects of scale economies. The profits thus generated are first distributed to a group of investors who are the owners of the firms, and they reinvest them for the expansion of their own sector. A similar consideration can be given to the X sector, except that the firms correctly perceive the technology in this case, since no aggregate scale economies exist in the X sector.

To summarize, the behavior of the two sectors can be described as follows. In the short run, the producers in each sector choose the levels of output and variable inputs so as to maximize short-run profits, given the output and input prices and the level of capital stock. The resulting profits are all reinvested for the expansion of their own sector.

(d) *Prices.* We assume that the price of exportable consumer good, X, is determined in the international market and held constant at that level. That is, the present economy is assumed to be small as a supplier of X. We shall take X as *numéraire* and set its price equal to one. We also assume that the price of imported intermediate good is determined internationally and held fixed. On the other hand, the price of domestically produced intermediate/investment good, Y, is assumed to be determined by domestic demand and supply. This assumption can be justified if we postulate a governmental policy designed to protect the Y sector from foreign competition. For example, we may assume that the government levies high enough tariffs on competing foreign products so as to completely eliminate imports of those products. In fact, if we denote the international price of this group of products by $p_y{}^*$ and the domestic price of Y which prevails in the absence of foreign competition by $p_y{}^d$, both expressed in X, then imposition of tariffs at a rate slightly above $t_y{}^* \equiv (p_y{}^d - p_y{}^*)/p_y{}^*$ would eliminate all foreign competition for Y. Protective measures similar to this for immature domestic industries are often adopted in developing countries, so that its implication for the economy's growth is interesting to investigate. Note that, since the domestic and imported intermediates are not substitutable, the imported intermediates do not exert any direct influence in determining the price of Y.

We should note that, if the domestically determined price of Y is too high, the cost of producing X may exceed the international price of X, causing the sector to lose its competitiveness. That is, the price of Y must be kept within a certain range in order that the X sector can survive as an export industry. The competitiveness of the X sector depends not only on the prices of X and Y but also on the price of imported intermediates and the wage rate. Hence, we should carefully examine the relationship among these prices which ensures the international competitiveness of the X sector. This is one consistency requirement for the present model.

(e) *Output of X.* The short-run profit maximization assumed earlier determines the output and employment levels in the Y sector as usual, but those in the X sector remain undetermined as long as gross profit per unit of output is positive. The level of output in the X sector is determined either by the level of output demand or by the supply of inputs. The demand for the sector's output is the sum of domestic consumption demand and export demand. Here, we assume that there is a large export market for the X sector so that there is no shortage of demand. Hence, the output of X is constrained by supply side limitations. Since labor supply is assumed to be unlimited, the constraint is imposed either by the supply of intermediate goods or by the amount of capital. We assume that the X sector can import as much foreign-produced intermediates as it needs, so that there is no constraint from intermediate imports. The output of Y can be increased by employing more labor, so that domestic intermediates do not impose output constraint, either. Thus, we assume that the level of output of X is constrained by the amount of capital stock. That is, by (1),

$$X = K_x/k_x. \tag{5}$$

The requirements for other inputs are determined by multiplying this output level by respective input coefficients.

The assumption that the X sector can import as much foreign-produced intermediates as it needs corresponds to the generous import policy adopted by the Korean government to promote export production. We assume that such a policy is extended to the entire X production including production for domestic market because imported intermediates are assumed nonproducible domestically.

(f) *Employment and consumption.* Since labor supply is unlimited, sectoral employment equals sectoral labor demand. Hence, if we denote by L_x and L_y the labor demand in the two sectors, the total employment is $L_x + L_y$, and the total labor income becomes $w_0(L_x + L_y)$. We assume that wage incomes are all consumed on X, while no profit incomes are consumed. Then, total consumption demand for X becomes

$$C_x = w_0(L_x + L_y), \tag{6}$$

since the price of X is set equal to one.

(g) *Investment and capital accumulation.* We assume that both sectors reinvest profit incomes into their own sector. Denoting by p_m and p_y the price of imported and domestic intermediate goods expressed in terms of X, the profit of the X sector can be written as

$$\pi_x = X - p_m a_m X - p_y a_d X - w_0 l_x X. \tag{7}$$

By (5), X is determined as a function of K_x. Hence, the profit income of the X sector can be written as $\pi_x(K_x, p_m, p_y, w_0)$. On the other hand, the profit income in the Y sector is defined by

$$\pi_y = p_y Y - w_0 L_y, \tag{8}$$

where Y and L_y are the Y sector's profit-maximizing output and employment, which are in general determined as functions of capital stock and the output and input prices, that is, $Y(K_y, p_y, w_0)$ and $L_y(K_y, p_y, w_0)$. When these profit incomes are reinvested, they constitute demand for Y along with the intermediate demand from the X sector given by $a_d X$. Hence, the equilibrium condition for Y is written as:

$$\begin{aligned} Y(K_y, p_y, w_0) = a_d K_x/k_x + \pi_x(K_x, p_y, p_m, w_0)/p_y \\ + [Y(K_y, p_y, w_0) - w_0 L_y(K_y, p_y, w_0)/p_y]. \end{aligned} \tag{9}$$

From (9), the equilibrium price of Y can be solved in general as

$$p_y = p_y(K_x, K_y, p_m, w_0), \tag{10}$$

so that the equilibrium output and employment in the Y sector can be written as

$$Y = Y(K_x, K_y, p_m, w_0); \quad \text{and} \tag{11}$$

$$L_y = L_y(K_x, K_y, p_m, w_0). \tag{12}$$

Hence, if we ignore exogenous price variables, the short-run profits in the two sectors can be expressed as $\pi_x = \pi_x(K_x, K_y)$ and $\pi_y = \pi_y(K_x, K_y)$.

Let the rate of depreciation of capital in the two sectors be given by μ_x and μ_y, respectively. Since all profit incomes are reinvested into the two sectors, capital accumulation in the two sectors will proceed as follows:

$$\dot{K}_x = [\pi_x(K_x, K_y)/p_y] - \mu_x K_x; \text{ and} \tag{13}$$

$$\dot{K}_y = [\pi_y(K_x, K_y)/p_y] - \mu_y K_y. \tag{14}$$

This completes the description of the model. The important aspect of the above model is that the growth of the Y sector depends crucially on the size of the intermediate demand from the X sector and the investment demand from the two sectors. Since there are scale economies in the Y sector, its growth may accelerate once a certain amount of capital is accumulated. On the other hand, the existence of a large export market enables the X sector to operate at its full capacity, bringing forth a maximum growth impact on the Y sector through intermediate and investment demands. Thus the present model can be seen to embody the characteristic features of the Korea-like semi-industrial economy as described earlier.

III. TEMPORARY EQUILIBRIUM

The patterns of growth of the two-sector economy depend crucially on relative capital accumulation in the two sectors. In particular, the possibility of joint industrial growth and the conditions that enhance such growth must be examined on the basis of capital accumulation functions, (13) and (14). However, before proceeding to the dynamic analysis, we need to explore the properties of the temporary equilibrium.

(a) *Input demands.* The short-run decision of the two sectors is to choose the levels of variable inputs so as to maximize short-run profits, given the amount of capital stock, and the output and input prices. In the X sector, the level of output is determined by the amount of capital as in (5), so that the profit income is written, from (5) and (7), as

$$\pi_x = [(1 - p_m a_m - p_y a_d - w_0 l_x)/k_x] K_x, \tag{15}$$

where 1 represents the normalized price of X. Note that, in order that the X sector remain viable as an export industry, the gross profit per unit of output must be nonnegative. That is, $1 - p_m a_m - w_0 l_x - p_y a_d \geqq 0$, or

$$(1 - p_m a_m - w_0 l_x)/a_d \geqq p_y. \tag{16}$$

We shall refer to (16) as the *viability condition* of the export industry. Since a_d is technologically given, (16) requires that the domestically determined price of Y is sufficiently low. This in turn implies that capital accumulation in the Y sector must have proceeded to an adequate degree, since the technology in the Y sector exhibits economies of scale. The level of capital stock required for this purpose will be discussed later.

In the Y sector, labor is the only variable input, so that the short-run profit can be expressed, using (2) and (8), as

$$\pi_y = p_y K_y^r f_y(n_y) - w_0 n_y K_y, \tag{17}$$

where n_y is the labor-capital ratio in the Y sector. Since capital stock is fixed, maximizing (17) with respect to L_y is equivalent to maximizing

$$\pi_y/K_y = p_y K_y^{r-1} f_y(n_y) - w_0 n_y \tag{18}$$

with respect to n_y. By assumption, $f_y(n_y)$ is a strictly concave function that passes through the origin. As an additional requirement, we shall assume that f_y satisfies the Inada derivative conditions.[8] Then there is a unique labor-capital ratio that maximizes (18) for a given p_y and w_0. The necessary and sufficient condition for an optimum is given by

$$f_y'(n_y) = z_0, \tag{19}$$

where z_0 is defined by

$$z_0 = w_0/p_y K_y^{r-1}. \tag{20}$$

By assumption, $f_y'' < 0$, so that we can solve (19) for labor-capital ratio as

$$n_y = n_y(z_0), \tag{21}$$

where $n_y(z_0) = (f_y')^{-1}(z_0)$. We see that

$$dn_y/dz_0 = 1/f_y''(n_y(z_0)) < 0. \tag{22}$$

Hence, from (22) and (20), we obtain

$$\partial n_y/\partial p_y > 0; \ \partial n_y/\partial K_y > 0; \text{ and } \partial n_y/\partial w_0 < 0. \tag{23}$$

That is, the labor-capital ratio in the Y sector increases with its output price and capital stock and decreases with wage rate. Since the labor demand in the Y sector is given by $L_y = n_y K_y$, we also have

$$\partial L_y/\partial p_y = K_y \cdot \partial n_y/\partial p_y > 0; \tag{24}$$

$$\partial L_y/\partial K_y = n_y(z_0) + K_y \cdot \partial n_y/\partial K_y > 0; \text{ and} \tag{25}$$

$$\partial L_y/\partial w_0 = K_y \cdot \partial n_y/\partial w_0 < 0. \tag{26}$$

Hence, employment in the Y sector also increases with its output price and capital stock and decreases with wage rate.

The supply of Y is obtained by substituting (21) into (2):

$$Y = K_y^r f_y(n_y(z_0)). \tag{27}$$

Using the results in (23), we obtain the usual properties of a supply function:

$$\partial Y/\partial p_y = K_y^r f_y' \cdot \partial n_y/\partial p_y > 0; \tag{28}$$

[8] The Inada derivative conditions for f_y are: (i) $\lim_{n_y\to\infty} f_y'(n_y) = 0$; and (ii) $\lim_{n_y\to 0} f_y'(n_y) = \infty$. If f_y is strictly concave, these conditions guarantee the existence of an interior solution to profit maximization.

$$\partial Y/\partial K_y = rK_y^{r-1}f_y + K_y^r f_y' \cdot \partial n_y/\partial K_y > 0; \text{ and} \tag{29}$$

$$\partial Y/\partial w_0 = K_y^r f_y' \cdot \partial n_y/\partial w_0 < 0. \tag{30}$$

Finally, since labor supply is unlimited at w_0, total employment is the sum of sectoral labor demands. Hence, the total labor income becomes

$$I = w_0(L_x + L_y) = w_0[l_x(K_x/k_x) + n_y(z_0)K_y]. \tag{31}$$

(b) *Market for X.* By assumption, the workers spend all of their income on consumption of X, while no consumption is made out of profit income. Since incomes are expressed in X, the consumption demand for X is given by

$$C_x = I, \tag{32}$$

where I is defined by (31). From (24) to (26) and (31), consumption demand for X is seen to increase with capital stock in the two sectors and the price of Y, while the effect of an increase in wage rate is ambiguous.

Since the X sector is internationally competitive and has a large export market, the output of X which is not domestically consumed will all be exported. Hence, export (E) of X is given by

$$E = X - C_x. \tag{33}$$

Using (5), (31), and (32), we can write

$$E = [(1 - w_0 l_x)/k_x]K_x - w_0 n_y(z_0)K_y. \tag{34}$$

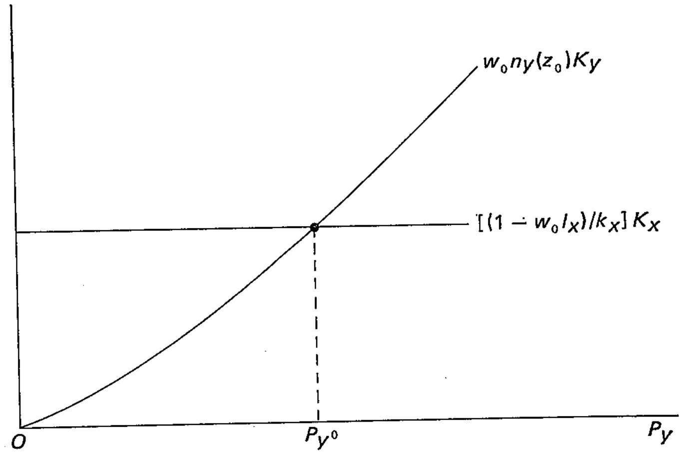
In order for the X sector to serve as an export industry as assumed, the volume of exports given by (34) must be strictly positive. The second term on the right-hand side (excluding the sign) is an increasing function of p_y in view of (23). Moreover, from the Inada derivative conditions, we can see that the labor-capital ratio, n_y, changes from 0 to infinite as p_y changes from 0 to infinite.[9] Hence, the second term on the right-hand side defines an upward-sloping curve through the origin in a space with p_y on the horizontal axis (Figure 1). The first term does not depend on p_y, so that it is shown as a horizontal line at the level of $[(1 - w_0 l_x)/k_x]K_x$ in Figure 1. The price p_y^o at which the two curves intersect defines the price of Y which makes exports of X equal to zero.

For the exports given by (34) to be positive, the price of Y must remain below p_y^o. On the other hand, p_y^o clearly increases with the X sector's capital stock for a given level of K_y, so that the above condition seems to suggest that the accumulated capital in the X sector must be sufficiently large compared to that in the Y sector. However, in order to clarify this point, we need to look into the determination of the price of Y.

(c) *Market for Y.* The demand for Y consists of intermediate demand from the X sector and investment demands from the two sectors. The intermediate

9 This can be shown as follows: Define $v \equiv n_y(z_0)$. Then, since $n_y(z_0) = (f_y')^{-1}(z_0)$, we have $z_0 = f_y'(v)$. Using the definition of z_0 given by (20), we obtain $w_0/(p_y K_y^{r-1}) = f_y'(v)$. Let $p_y \to 0$ for a fixed K_y. Then, $z_0 \to 0$. Hence, $\lim_{n_y \to 0} f_y'(v) = \infty$. By the Inada derivative condition, this implies that $n_y \to 0$. A similar argument shows that $p_y \to \infty$ implies $n_y \to \infty$.

Fig. 1. Upper Bound of p_y for Positive Export of X



demand is given by $W_d = a_d X$, where X is defined by (5). The amount of investment in each sector is equal to its profit income. The profit of the X sector is given by (15), and that of the Y sector is given by (17) with (21) substituted for n_y. These profit incomes are measured in X, so that investment demand for Y is given by the total profit income divided by p_y. Since the domestic market for Y is perfectly shielded from foreign competition, the equilibrium condition is given by

$$Y = [Y - (w_0/p_y)L_y] + a_d X + [1 - w_0 l_x - p_m a_m - p_y a_d)X]/p_y,$$

where X is given by (5). Cancelling terms and rearranging yields

$$w_0(L_x + L_y) = X - p_m a_m X. \tag{35}$$

The left-hand side of (35) equals domestic consumption of X. The second term on the right is the value of intermediate imports, which, since there are no other imports, equals total imports (M). That is, $M = p_m a_m X$. Hence, (35) can be rewritten as

$$X - C_x = M, \tag{36}$$

which, in view of (33), can be further rewritten as

$$E = M. \tag{37}$$

As long as the viability condition of the X sector is satisfied, the output of X and imports of intermediate goods will be positive, and (37) implies that exports (E) will also be positive. That is, when the domestic price of Y is determined at a level which satisfies the viability condition (16), the X sector does come out as an export industry. Moreover, (37) implies that the equilibrium price of Y ensures the balance-of-trade equilibrium. That is, even if imports of Y are completely eliminated by high tariffs, if the economy is linked to the rest of the world through exports of X, the equilibrium in the domestic market for Y implies the equilibrium in the balance of trade. This result is a manifestation of the Walras law in the present model.

How does the equilibrium in the Y-good market lead to the balance-of-trade equilibrium? To see this, rewrite (37) as

$$C_x = (1 - p_m a_m)X. \tag{38}$$

In the short run, the right-hand side of (38) is fixed since output of X is fixed at the level determined by its capital stock and so also is the required amount of intermediate imports. The consumption, C_x, equals total labor income, of which part originating in the X sector is fixed because output, wage rate, and the labor coefficient are fixed. Hence, the equality of (38) is achieved only through changes in employment in the Y sector. The capital stock in the Y sector is also fixed in the short run, so that employment can be changed only through changes in the price of Y. That is, the changes in the price of Y change the levels of employment and labor income in the Y sector, which results in changes in consumption demand for X, making exports of X to equal the fixed volume of intermediate imports.

The properties of the equilibrium price, p_y, can be explored by rewriting (36) as

$$w_0 n_y(z_0) K_y = [(1 - w_0 l_x - p_m a_m)/k_x] K_x, \tag{39}$$

where we used (34). Define

$$A \equiv (1 - w_0 l_x - p_m a_m)/(w_0 k_x). \tag{40}$$

Then, we can simplify (39) as

$$n_y(z_0) = AK_x/K_y, \tag{41}$$

and, since $n_y(z_0) = (f_y')^{-1}(z_0)$, we can solve (41) for z_0 as

$$z_0 = f_y'(AK_x/K_y). \tag{42}$$

Therefore, in view of (20), the equilibrium price of Y is expressed as

$$p_y = (w_0/K_y^{r-1})/[f_y'(AK_x/K_y)]. \tag{43}$$

Since $f_y'' < 0$, and $A > 0$ if the viability condition is satisfied, we have

$$\partial p_y/\partial K_x = (w_0/K_y^{r-1})(-Af_y''/K_y f_y'^2) > 0; \text{ and} \tag{44}$$

$$\partial p_y/\partial K_y = [(1-r)w_0/K_y^r f_y'] + (w_0/K_y^{r-1})(AK_x f_y''/K_y^2 f_y'^2) < 0. \tag{45}$$

Hence, the equilibrium price of Y increases with capital stock of the X sector and decreases with that of the Y sector. This implies that, when capital accumulation proceeds in the X sector, if the Y sector does not also accumulate capital at an appropriate speed, the price of Y will rise and the profitability and the rate of expansion of the X sector will be adversely affected. In other words, an expansion of an export industry which uses domestic intermediate goods calls for a joint growth of the sector which produces the goods in question; otherwise the growth of the export industry itself would be hampered. This point will be further examined in the dynamic analysis.

For each fixed p_y, the locus of (K_x, K_y) satisfying (43) defines a curve in the (K_x, K_y) plane. We shall refer to this curve as the *iso-price curve*. Taking the derivative of (43) for a given p_y, we obtain

$$dK_y/dK_x = -(\partial p_y/\partial K_x)/(\partial p_y/\partial K_y) > 0,$$

where we used the results from (44) and (45). Hence, the iso-price curves are a family of upward-sloping curves in the (K_x, K_y) plane which, in view of (44) and (45), shift to the southeast as the level of price increases. Moreover, by applying the Inada derivative conditions to (42), it can be easily shown that the iso-price curves pass through the origin and extend to the northeast without limit. The concept of iso-price curves will prove to be useful in the dynamic analysis.

The remaining issue which need be resolved is whether the viability condition (16) is satisfied, given the equilibrium price of Y. Comparing (16) and (40), we see that (16) can be rewritten as

$$p_y \leqq A w_0 k_x / a_d. \tag{46}$$

Substituting (43) for p_y and rearranging, we obtain

$$K_y^{r-1} f_y'(AK_x/K_y) \geqq (a_d/Ak_x). \tag{47}$$

For each fixed K_x, the left-hand side of (47) is an increasing function of K_y and increases from 0 to infinite as K_y moves from 0 to infinite. Let K_y^o be the value of K_y which gives equality in (47). Then we can write

$$K_y^o = K_y^o(K_x; A, a_d, k_x), \tag{48}$$

and we see from (47) that $\partial K_y^o/\partial K_x > 0$ (see Figure 2). The value of K_y^o signifies the Y sector's minimum capital stock which makes the price of Y low enough so that the X sector's viability condition is satisfied, given the capital stock, K_x, in the X sector. We shall refer to K_y^o as the *critical capital stock* of the Y sector. If the initial capital stock of the Y sector falls below this level, the price of Y will be too high and the X sector will lose its international competitiveness.

In (48), the critical capital stock is expressed in general terms, but an example may be useful. Consider the Cobb-Douglas case. Let $F_y(L_y, K_y) = L_y^a K_y^b$, where $0 < a$, $b < 1$, and $r \equiv a + b > 1$. Then, $f_y(n_y) = n_y^a$, so that $f_y'(n_y) = a n_y^{a-1}$. Hence, the counterpart of (42) is

$$z_0 = a(AK_x/K_y)^{a-1}. \tag{49}$$

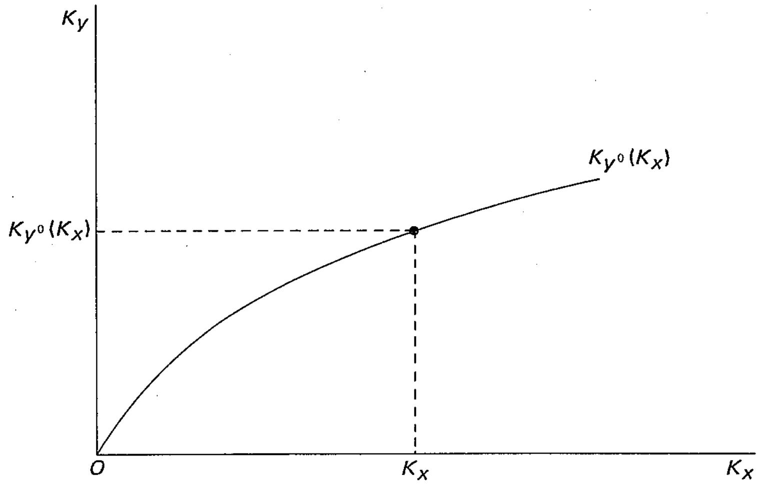
Solving (49) for p_y using the definition of z_0, (20), yields

$$p_y = (w_0/aK_y^{r-1})(AK_x/K_y)^{1-a}. \tag{50}$$

Substituting (50) into (16) and solving for K_y, we obtain the critical capital stock function as

$$K_y^o = [a_d/(ak_x A^a)]^{1/b} K_x^{(1-a)/b}.$$

Fig. 2. Y Sector's Critical Capital Stock



Clearly, this curve is upward-sloping, convex to above, and passes through the origin. For a given level of K_x, the critical capital is smaller, the smaller the input coefficients, l_x, a_m, a_d, and the price variables, w_0 and p_m, and the larger the capital coefficient, k_x.

IV. POSSIBILITY OF JOINT INDUSTRIAL GROWTH

We are now ready to examine the dynamic properties of the model using the capital accumulation functions, (13) and (14). The short-run profit of the X sector is given by (15), so that substituting it into (13) and making use of (40), we obtain

$$\dot{K}_x = [w_0 A K_x / p_y(K_x, K_y) - (a_d + \mu_x)](K_x/k_x), \tag{51}$$

where p_y is expressed as a function of K_x and K_y. Hence, $\dot{K}_x$ has the same sign as the term in the brackets, and the locus of $\dot{K}_x = 0$ is given by

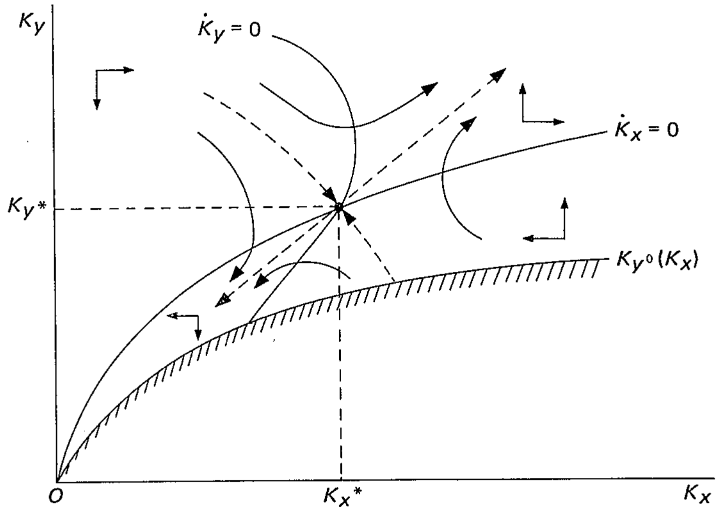
$$p_y(K_x, K_y) = w_0 A k_x / (a_d + \mu_x). \tag{52}$$

Note that (52) is an expression for one of the iso-price curves. From the previous analysis, we know that iso-price curves are upward-sloping curves in the (K_x, K_y) plane which pass through the origin and extend towards the northeast direction. Moreover, the iso-price curves for higher prices of Y locate to the southeast of the curves for lower prices.

The definition of the Y sector's critical capital stock is given by (46) with equality, and it also coincides with one of the iso-price curves:

$$p_y(K_x, K_y) = w_0 A k_x / a_d. \tag{53}$$

Fig. 3. Growth of the Two-Sector Economy



Clearly, the right-hand side of (53) is greater than the right-hand side of (52). Hence, by the property of the iso-price curves, the curve defined by (52) locates to the northwest of the curve defined by (53). In other words, the $\dot{K}_x = 0$ curve is an upward-sloping curve which locates to the northwest of the critical capital stock curve. Moreover, from (44) and (45), $\dot{K}_x < 0$ to the southeast of $\dot{K}_x = 0$ and $\dot{K}_x > 0$ to the northwest. These results are shown in Figure 3 by arrows.

The Y sector's capital accumulation function, (14), can be rewritten, using (18), as

$$\dot{K}_y = [K_y{}^{r-1} f_y(n_y) - w_0 n_y/p_y - \mu_y]K_y. \tag{54}$$

In equilibrium, p_y and n_y are given as functions of K_x and K_y. However, since K_x appears only through p_y, we can write (54) as

$$\dot{K}_y = \phi[K_y, p_y(K_x, K_y)]K_y. \tag{55}$$

The sign of $\dot{K}_y$ is the same as that of ϕ, and the locus of $\dot{K}_y = 0$ coincides with that of $\phi = 0$. Differentiating $\phi(K_y, p_y(K_x, K_y))$ with respect to K_x and K_y and using (19), we obtain

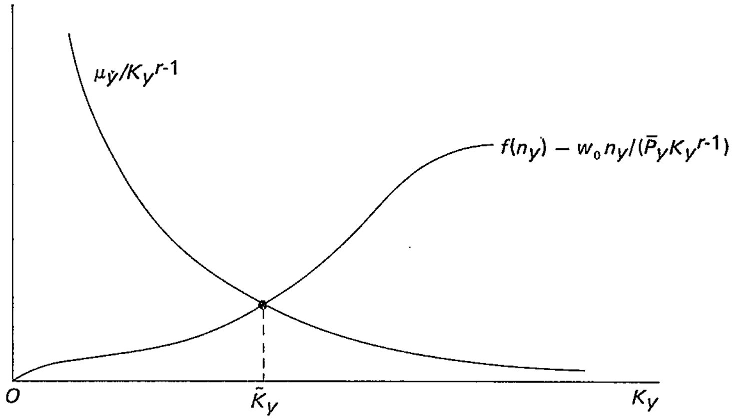
$$\partial\phi/\partial K_x = (w_0 n_y/p_y{}^2)\cdot\partial p_y/\partial K_x > 0; \text{ and} \tag{56}$$

$$\partial\phi/\partial K_y = (r-1)K_y{}^{r-2} f_y(n_y) + (w_0 n_y/p_y{}^2)\cdot\partial p_y/\partial K_y \gtreqless 0. \tag{57}$$

Thus, the sign of the derivative of ϕ with respect to K_y is indeterminate. However, if we focus on one of the iso-price curves, say $p_y = \bar{p}_y$, then

$$\partial\phi(K_y, \bar{p}_y)/\partial K_y = (r-1)K_y{}^{r-2} f_y(n_y) > 0. \tag{58}$$

Fig. 4. Existence of K_y Satisfying $\phi(K_y, \bar{p}_y)=0$



That is, as K_y is increased along an iso-price curve, $\dot{K}_y$ also increases unambiguously. Since $\bar{p}_y$ is arbitrary, this result implies that, if the $\dot{K}_y = 0$ curve exists, it intersects with each iso-price curve exactly once. To the right of this intersection, $\dot{K}_y > 0$, and to the left, $\dot{K}_y < 0$.

The existence of the $\dot{K}_y = 0$ (or $\phi = 0$) curve can be seen as follows: For a fixed $\bar{p}_y$, write

$$\phi(K_y, \bar{p}_y)=K_y^{r-1}\{[f_y(n_y)-w_0n_y/(\bar{p}_yK_y^{r-1})]-\mu_y/K_y^{r-1}\}. \quad (59)$$

The term μ_y/K_y^{r-1} is a variant of rectangular hyperbola and has both axes as asymptotes. The term in the brackets increases with K_y:

$$\partial[f_y(n_y)-w_0n_y/(\bar{p}_yK_y^{r-1})]/\partial K_y=(r-1)w_0n_y/(\bar{p}_yK_y^{r})>0. \quad (60)$$

Moreover, by the Inada derivative conditions, (19) and (20) imply that, for a fixed $\bar{p}_y$, n_y goes to zero as K_y goes to zero. Hence, the term in the brackets also goes to zero. Thus, we have Figure 4, which shows that, for each fixed $\bar{p}_y$, there is a unique K_y which makes $\phi(K_y, \bar{p}_y)$ equal to zero, or $\dot{K}_y=0$. As $\bar{p}_y$ rises, the term in the brackets of (59) increases, while μ_y/K_y^{r-1} is unchanged. Hence, in view of (60), the value of K_y that defines the intersection of the $\dot{K}_y = 0$ curve with the iso-price curve must be smaller, the higher the price p_y.

These results imply that the $\dot{K}_y = 0$ curve has the form shown in Figure 3. It may be sloped upward or downward in the (K_x, K_y) plane, but it intersects with each iso-price curve exactly once. Since the $\dot{K}_x = 0$ curve coincides with one of the iso-price curves, the $\dot{K}_x = 0$ and $\dot{K}_y = 0$ curves have a unique intersection, (K_x^*, K_y^*), where $K_x^* > 0$ and $K_y^* > 0$.

The directions of changes in K_x and K_y are also shown in Figure 3 by arrows. As can be seen from the diagram, the intersection (K_x^*, K_y^*) of the $\dot{K}_x = 0$ and $\dot{K}_y = 0$ curves is a stationary state and, in fact, it turns out to be a saddle point.

Hence, the growth of the economy starting from various initial combinations of sectoral capital stock will follow the movements shown in the diagram.

Let us examine the possibility of joint industrial growth based on Figure 3. If the initial capital stock of the two sectors is below the stationary-state capital stocks, the joint growth of the two sectors is not possible. One necessary condition for such joint industrial growth is that either the X sector's or the Y sector's initial capital stock exceed the corresponding stationary-state capital stock. However, since we are assuming that the Y sector is an immature industry, we would not expect its capital stock to be initially very large. Hence, a more relevant requirement is that the X sector's initial capital exceed the level given by K_x^*. Another necessary condition is that the Y sector's initial capital stock exceed the critical level determined by the X sector's initial capital stock. The two conditions together still do not constitute a sufficient condition for joint industrial growth. There is a path starting from a point on the critical capital stock curve, with $K_x > K_x^*$, which approaches the stationary state. If the initial combination of sectoral capital stock locates to the right of this path, the two sectors will grow jointly under the policy package of export expansion and protection of the immature industry. If the initial point lies to the left of this path, the adoption of protective policy for the immature industry will result in contraction of both sectors, even if the export industry is initially competitive internationally. The above two conditions are not sufficient for the success of joint industrial growth but can be viewed as the necessary preconditions which must be met before launching into the export promotion-cum-protection policy aiming at further industrial development.

Unsuccessful industrial growth will arise in the present model when the price of the domestic intermediate good is too high to make the export industry adequately profitable to create enough demands for the immature industry, a kind of vicious circle. To avoid such an undesirable outcome, a country should first expand the export industry adequately and in addition apply a big-push type expansion policy for the immature target industry. Alternatively, a policy to provide production subsidies to the export industry can be used, which will shift the $\dot{K}_x = 0$ curve downward. Then, the stationary-state capital stock of both sectors will be reduced, so that the initial capital required for successful joint growth becomes smaller. However, one should note that the subsidy must be financed from outside the model, either by external government funds or by support from overseas.

The success of joint industrial development depends also on the technological and price parameters. General conclusions are hard to derive but, for the Cobb-Douglas case discussed earlier,[10] the following results are obtained. The Y sector's critical capital stock curve and the $\dot{K}_x = 0$ curve shift downward as k_x increases or l_x, a_d, a_m, p_m, or w_0 decreases. The $\dot{K}_x = 0$ curve also shifts downward as μ_x decreases. The $\dot{K}_y = 0$ curve shifts upward as l_x, k_x, a_m, p_m, w_0, or μ_y decreases.

10 In the Cobb-Douglas case, the $\dot{K}_y = 0$ curve is upward-sloping if $b < 1$ and downward-sloping if $b > 1$. The description in the text is for $b < 1$ but the results are essentially unchanged even if $b > 1$.

These results imply that the following changes in price and technology parameters bring forth a *higher possibility* of joint industrial growth in the Cobb-Douglas case:

(1) Reduction in intermediate input coefficients (a_d and a_m);
(2) Reduction in labor coefficient (l_x);
(3) Reduction in the price of imported intermediate good (p_m);
(4) Reduction in the wage rate (w_0); and
(5) Reduction in the rates of depreciation (μ_x and μ_y).

Thus, increases in the efficiency of factor utilization and reduction in the wage rate and the price of imported intermediates increase the possibility of joint industrial growth. An increase in the durability of capital goods reduces the rates of depreciation and contributes to better development of the two sectors. The effect of changes in capital coefficient, k_x, cannot be ascertained even for the Cobb-Douglas case.

V. CONCLUSION

We have constructed a model of industrial development in a semi-industrial country incorporating Imaoka's [3] dual-industrial growth hypothesis, in order to examine whether the joint growth of a competitive export industry and an immature intermediate/investment good industry is possible through a policy package of export promotion plus protection of the immature industry. The main conclusion is that, for a country which satisfies certain conditions, such a policy package can in fact lead to joint growth of the two industrial sectors, but that without a parallel growth in the domestic industry which supplies intermediate inputs to the export industry, the growth of the export industry itself may be hampered. The basic requirements for successful joint growth are that the export industry's capital stock exceeds a certain level determined by technological conditions and input prices, and that the capital accumulation of the immature industry exceeds a certain critical level determined by the size of the export industry and the technological and price parameters. These are not sufficient conditions but they provide a rough benchmark for a successful adoption of the above policy package. The requirements will be easier met the more efficient the use of inputs in the export industry, the lower the wage rate and the price of imported intermediate goods, and the lower the rate of depreciation. If these conditions are not met, joint industrial growth based on the above policy package is difficult. In such cases, some supplementary policy is necessary, such as a big-push policy to accelerate capital accumulation in the two sectors or production subsidies to the export industry. If such supplementary policies cannot be adopted, the use of export promotion cum protection policy as adopted by successful semi-industrial economies such as Korea and Taiwan would not be advisable.

The present analysis confined itself to a simplified model of a semi-industrial economy. We have made a number of assumptions which are preferably relaxed, such as the unlimited supply of labor and the non-use of intermediate goods in the production of intermediate/investment goods. These refinements need to be carried out to examine the validity of our results in a more general setting, but they are left for future scrutiny. Another point is that the preconditions for successful joint industrial development has been left vague in this theoretical analysis. An empirical extension of the analysis to obtain an order-of-magnitude feel for the minimum capital stock of the export sector and the critical capital stock of the immature industry would be extremely valuable.

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