Journal of Development Economics 74 (2004) 393–410
JOURNAL OF Development ECONOMICS
www.elsevier.com/locate/econbase

Activation of a modern industry

Ping Wang[a], Danyang Xie[b,*]

[a] Vanderbilt University and NBER, USA
[b] International Monetary Fund, Asian Division, 700 19th Street N.W., Washington, DC 20431, USA

Received 1 July 2002; accepted 1 June 2003

Abstract

This paper constructs an integrated framework to disentangle the underlying economic mechanism of industrial transformation. We consider three essential elements for the analysis: skill requirements, industry-wide spillovers and degrees of consumption subsistence. We find that human and nonhuman resources, production factor matching and industrial coordination are all important for activating a modern industry. In the process of industrial transformation, job destruction may exceed job creation, and income distribution may get worse immediately following the activation of a modern industry. An array of policy prescriptions for advancing a poor country is provided.

JEL classification: D24; O14; D33
Keywords: Industrial transformation; Marshallian externality; Consumption subsistence; Factor matching

1. Introduction

Over the past four decades, several East Asian newly industrialized countries (NICs) have experienced rapid growth and drastic industrial transformation.[1] It is, however, often observed that some developing countries are always stuck with the traditional industries, unable to embark on modern industries that may spur economic advancement. What could be the barrier to activation of a modern industry? Are there any public policies that could

* Corresponding author. Tel.: +1-202-623-9655; fax: +1-202-623-6069.
E-mail address: dxie@imf.org (D. Xie).

[1] For an illustration of the industrial transformation experiences in Japan, (South) Korea, Taiwan and India, the reader is referred to Evans (1995). For micro patterns of job turnover and industrial productivity, see Robert and Tybout (1996).

0304-3878/$ - see front matter
doi:10.1016/j.jdeveco.2003.06.005

overcome this barrier to entry? While the recent economic growth literature largely ignores the underlying process of creating a modern industry, conventional economic development studies lack a formal model to explain such a process. Our paper intends to examine these important issues within an optimizing framework that accounts for a number of important features concerning the industrialization of a developing economy. It may help to understand why some less-developed countries stay poor for a long time and why some development aid programs fail to advance a low-income economy.[2]

Earlier contributions in the theory of economic take-off and transformation include pivotal works by Lewis (1955), Rostow (1960), Rosenstein-Rodan (1961) and Tsiang (1964). One of the most important recent developments along these lines is the big push theory revived by Murphy et al. (1989), Matsuyama (1991) and Chen and Shimomura (1998). In this literature, the existence of multiple equilibria imply that a big push may enable industrialization, moving from a bad to a good equilibrium, where the equilibrium selection process may depend on history and self-fulfilling prophecies. While these studies provide useful insight toward understanding why some countries took off successfully and some fell in the low-growth trap, an integrated framework that explicitly delineates the underlying microeconomic structure has not been fully developed. As a consequence, it is difficult to assess the various causes of failure to industrialize or to evaluate the effectiveness of a big push policy.

Generally speaking, industrial transformation features sectoral shifts (i) from low to high value-added goods, (ii) from agricultural and mining to manufacturing outputs (and services), and (iii) from labor intensive to capital, skill and technology intensive products. In the mid-1960s when Korean and Taiwanese economies began to take off, Balassa (1972) observed that there was a rapid industrial transformation from import substituting sectors to nontraditional exporting sectors, which has been believed a key to their success in economic development. In fact, the nontraditional exportables exhibited all three features mentioned above. Over the period from 1953 to 1968, the leading manufacturing sectors in Korea and Taiwan, has been shifted from processed food, to textile and plywood, to chemical and metal products, and to electronics and machine tools. Such a continual creation of new ventures replacing obsolete sectors has reflected not only the nimbleness of entrepreneurs but also the effectiveness of development strategies.[3]

The present paper emphasizes that industrialization is a process of reallocating labor and capital to sectors with external increasing returns. In a recent work, Kaneda (1995) focuses on labor reallocation in economic development, stressing that such a process is gradual due to a demographic constraint. In their cross-country study, Dowrick and Gemmell (1991) find that the speed of labor transfer from traditional to modern sectors has been slow in less developed countries, which lends empirical support to the important role

[2] In Morawetz (1981), an interesting case study is provided, illustrating why Colombian apparel producers failed in competition with East Asian economies. Easterly (2001) contains a wealth of examples of failed aid programs: Akosombo Dam in Ghana and Morogoro Shoe Factory in Tanzania. One of the worst examples is aid to Zambia. After US$2 billion in aid, Zambia today is poorer than in 1960.

[3] For detailed discussion of the development experiences in Korea and Taiwan, see Amsden (1989) and Kuo (1983), respectively. For a general discussion of the essential role of economic institutions in development, the reader is referred to a special issue edited by Adelman and Thorbecke (1989).

of labor reallocation in economic advancement. In our paper, the lack of education, investment funds and technology transfer is responsible for the failure to activate a modern sector. These factors help explain why poor countries are poor: the poor economic institutional environments discourage workers' incentive to self-select into a modern industry. These considerations are very different from those in Parente and Prescott (1999), where inferior technologies are used because a coalition of factor suppliers becomes the monopoly seller of input services. Our economic mechanism also differs from that in Peretto (1999) where the postponement of industrialization is due crucially to insufficient support for the expensive in-house R&D to enable the production in the modern sector. In addition, we incorporate the idea underlying the Stone–Geary utility function assuming that traditional sector outputs are essential for survival, but modern sector products are not. This enables the possibility that the modern sector may be non-operative at the early stage of development.[4]

Thus, the central features of our paper are three folds. First, production in the modern industry requires high-skilled labor. Even when new technologies are available, via joint venture, technology transfer or imitation, application of such technologies cannot be successful without sophisticated knowledge. This provides an essential role for human capital to play in the process of economic transformation. Second, modern sector needs industrial coordination, due to either vertical/horizontal integration or industry-wide networking. These factors can be simply captured by the presence of uncompensated spillovers in the modern industry. This form of the Marshallian externality implies naturally that the profitability of producing the modern good relies on operating at a good scale, which is difficult to be met in a poor economy. Third, modern goods are not necessary for survival. This reflects the realistic characteristic of advanced products, which ensures a lower marginal valuation of the outputs of a modern industry at the early stage of economic development.

The main findings of our paper can be summarized as follows. First, we find that the activation of a modern sector requires not only resources of investment funding, skilled labor and new technology, but also appropriate matching between capital and labor, as well as industrial coordination to overcome the scale barrier. Second, our results suggest an array of plausible policy prescriptions for successful industrial transformation, including short-term foreign aids, technology transfer and immigration of skilled workers, as well as long-term saving incentives, education and R&D. Third, we illustrate the possibility of short-term rise in unemployment at the time of activating a modern industry or during the entire process of industrialization, depending crucially on the relative scarcity between capital and skilled workers.

The rest of the paper is organized as follows. Section 2 presents a simple illustration of why a country may not be able to enter a modern industry. Section 3 uses a more realistic model to study policies that help activate the modern industry and the effect of such an activation on income distribution. Section 4 asks what will happen to the unemployment situation if the production technologies are Leontief. Section 5 concludes with suggestions on future research.

[4] For empirical observations during the British industrialization, see Horrell (1996).

2. A simple illustration

In order to understand what could be the barrier to activating a modern industry, this section provide the basic intuition that drives the results in a simple model. We consider an economy that starts with a traditional industry employing capital and labor with a constant return to scale industry. A modern industry is then introduced, using an identical Cobb–Douglas technology except for the constant scaling factor. Under this simple setup, it is assumed that labor is homogeneous and capital is perfectly mobile between the two industries. Given limited human and nonhuman resources, we are asking under what conditions it is desirable to activate this modern industry. More realistic models that allow for departure from constant returns to scale and homogenous labor are delayed until Section 3 to deal with a richer set of questions such as, policies that help activate the modern industry and the effect of such an activation on income distribution. We further consider restricted factor substitution in Section 4 to discuss factor mismatch and unemployment issues in the process of industrial transformation.

More specifically, the production functions in the traditional industry (industry 1) and the modern industry (industry 2) are given by,

$$Y_i = A_i K_i^{\alpha} L_i^{1-\alpha}$$

where K_i, L_i and Y_i are the capital inputs, labor inputs, and final output in industry i ($i=1$, 2), respectively. At the moment, we assume that they share the same output elasticities α and $1-\alpha$ (or factor income shares), where $0<\alpha<1$. The sole difference between the technologies in the two industries is captured by the assumption that $A_2>A_1>0$, i.e., the modern industry uses an input saving technology. Letting p denote the relative price of good 2 in unit of good 1, the real GNP is thus given by $\mathrm{GNP}=Y_1+pY_2$.

Labor is homogenous and is supplied inelastically:

$$L_1 + L_2 \leq L. \tag{1}$$

where L is the total labor supply in the economy. The resource constraint for the homogeneous capital goods is given by

$$K_1 + K_2 \leq F, \tag{2}$$

where F is the total funding available for acquiring capital goods. The total funding is regarded as exogenous throughout the paper. This is made not only for simplicity but for flexibility to permit sources of funds that have been important in developing countries, such as via government allocation, foreign aid and direct foreign investment.[5]

The preferences on the two industrial outputs are different. In particular, it is assumed that the output of the traditional industry is a necessity good (say, processed food and clothing), whereas that of the modern sector is a luxury good (say, a manufacturing good such as telephone or TV). Thus, the utility function can be specified as:

$$\ln C_1 + \ln(C_2 + \theta)$$

[5] In the absence of capital accumulation (and hence endogenous saving), the total funding available in this economy is similar to the Arrow–Debreu endowment.

where $\theta>0$ indicates that C_2 is not a necessity good—it is a luxury good in the sense that its income elasticity is greater than one. During the process of economic development, one may capture the on-going increase in the standard of living by allowing the value of θ to decline over time. For example, while telephone and TV are luxurious in Korea and Taiwan 40 years ago, even automobile and computer are almost necessities nowadays in these economies.

In this simple model, the market equilibrium is the same as the social optimum, which is easier to deal with. In the absence of international trade, we have: $C_1=Y_1$ and $C_2=Y_2$. Given the specification of the production and the utility functions, let us proceed to find the social optimum allocation of capital and labor by solving the following maximization problem:

$$\max\ \ln[A_1K_1^{\alpha}L_1^{1-\alpha}]+\ln[A_2K_2^{\alpha}L_2^{1-\alpha}+\theta] \tag{P}$$

subject to constraints (1) and (2). If both industries are operative, the first-order conditions are standard and the assumption of common factor income shares implies equalization of capital labor ratio between the two industries, namely,

$$\frac{K_1}{L_1}=\frac{K_2}{L_2}=\frac{F}{L}. \tag{3}$$

The first-order condition on capital is,

$$\frac{\alpha}{K_1}=\frac{\alpha A_2K_2^{\alpha-1}L_2^{1-\alpha}}{A_2K_2^{\alpha}L_2^{1-\alpha}+\theta}. \tag{4}$$

which equalizes the marginal valuation of capital between the two industries. One can easily see that if $\theta=0$, total capital is divided equally between the two industries (as is the labor force).

In general, our specification yields full employment of both capital and labor, so both factor reallocation constraints (1) and (2), must hold for equality in equilibrium. Substituting Eq. (3) as well as Eqs. (1) and (2) with equality into Eq. (4), one obtains the solution for K_2:

$$\frac{1}{F-K_2}=\frac{A_2[F/L]^{\alpha-1}}{A_2K_2[F/L]^{\alpha-1}+\theta},$$

and the solution is:

$$K_2=\frac{1}{2}\frac{A_2F^{\alpha}L^{1-\alpha}-\theta}{A_2F^{\alpha-1}L^{1-\alpha}}.$$

We can now see that industry 2 will emerge if and only if

$$A_2F^{\alpha}L^{1-\alpha}-\theta>0. \tag{5}$$

It appears that given technological parameters A_2 and α, the developing country will be unable to enter the more advanced industry if the total funding and labor supply, adjusted by the technological factor, are insufficient to overcome the preference bias (i.e., if all the inputs are put in industry 2 and still unable to produce an output greater than θ). Again, in this simple model, if $\theta = 0$, industry 2 will always emerge.

Although the condition for entry (5) sends a clear message that the barrier results from a combination of both technological and preference parameters, it is nonetheless too simplistic.[6] In the real world, many components of the two sides matter. In the next section, we introduce external effects and differentiated labor into our model and give a more complete analysis of the entry condition and discuss normative policy issues.

3. External effects and differentiated labor

One of the important characteristic of the advanced industry is that its production function exhibits increasing returns to scale at the aggregate level. We model this aspect by resorting to the literature of Marshallian externality in new growth theory (Romer, 1986; Lucas, 1988; Benhabib and Farmer, 1994). In this section, we assume:

$$Y_1 = A_1 K_1^{\alpha_1} L_1^{1-\alpha_1}; \quad Y_2 = A_2 K_2^{\alpha_2} L_2^{1-\alpha_2} \bar{K}_2^{1-\alpha_2} \tag{6}$$

where K_2 is the capital input in a representative firm and $\bar{K}_2$ is the industry average and is treated by individual firms as exogenously given. This sector-specific Marshallian externality in firm capital captures learning from other entrepreneurs in production methods, in business management, as well as in marketing and networking,[7] While both sectors exhibit constant returns in private inputs, the modern industry has increasing social returns as a result of uncompensated spillovers from industry-specific capital. It is natural to assume that the modern industry uses capital more intensively than the traditional industry in the private sense (without accounting for the external effect), i.e., $\alpha_2 > \alpha_1$.

We further relax the homogeneous labor assumption allowing the economy to be populated by two types of workers, the low-skilled ones with mass N_1 and the high-skilled ones with mass N_2. While all workers can produce equally effectively in industry 1, only the high-skilled can handle work in industry 2. That is,

$$L_2 \leq N_2. \tag{7}$$

Additionally, in contrast to the previous section, we assume that the relative cost of establishing type-2 capital is greater than that of type-1. Namely, by normalizing the transformation rate from funds into type-1 capital as one, the transformation rate of type-2 capital is $q > 1$ (which is exogenously given). Thus, our funding constraint becomes,

$$K_1 + qK_2 \leq F. \tag{8}$$

[6] It is arguably difficult to assign cardinal comparisons between goods. To make the condition operational, we need a way to estimate the value of θ. One method is to infer the value of θ by looking at the trend of income shares of traditional and modern goods in developed countries.

[7] Alternatively, one may consider Marshallian externality in forms of human capital, as in Lucas (1988) or raw labor, as in Matsuyama (1991).

In fact, a reduction in this relative price measure may capture investment subsidies, investment tax rebates and reductions in tariff on imported capital goods.

3.1. Competitive equilibrium

Let us first look at the competitive equilibrium. In the presence of the Marshallian externality in industry 2, the competitive equilibrium can be obtained from solving a pseudo social planner's problem by regarding the external effect as given. Specifically, the optimization problem is to solve (P) modified for the new production technologies specified as in (Y), subject to labor reallocation constraints (1) and (7), as well as the capital reallocation constraint (8). Denote by MPK_i the marginal product of capital in sector i. If industry 2 is operative, the market allocation of capital must satisfy the equalization of the marginal valuation of capital:

$$\mathrm{MPK}_1 = \frac{p}{q}\mathrm{MPK}_2. \tag{9}$$

Note that from consumption allocation efficiency, the relative price must be equal to the marginal rate of substitution between good 2 and good 1: $p = \frac{\mathrm{MU}_2}{\mathrm{MU}_1} = \frac{C_1}{C_2+\theta}$, or,

$$p = \frac{A_1 K_1^{\alpha_1} L_1^{1-\alpha_1}}{A_2 K_2 L_2^{1-\alpha_2} + \theta}. \tag{10}$$

where MU_i is the marginal utility of consumption good i. In deriving Eq. (10), we have used the equilibrium condition that $\bar{K}_2 = K_2$. This ensures that at the equilibrium, the actual industry average of type-2 capital, which by definition equals the capital stock of the modern representative firm, is the same as what the firm thinks the average is.

Using Eq. (10), the capital allocation Eq. (9) can be re-arranged to yield:

$$\frac{\alpha_1}{K_1} = \frac{\alpha_2 A_2 L_2^{1-\alpha_2}}{q[A_2 K_2 L_2^{1-\alpha_2} + \theta]} \tag{11}$$

which reduces to the intuitive result: $K_2/K_1 = 1/q$ if $\theta = 0$ and $\alpha_1 = \alpha_2$.

To study under what parameter restriction industry 2 fails to emerge, we use the capital allocation constraint (8) with equality to rewrite Eq. (11) as:

$$\frac{\alpha_1}{K_1} = \frac{\alpha_2 A_2 L_2^{1-\alpha_2}}{A_2 (F - K_1) L_2^{1-\alpha_2} + q\theta}$$

which yields,

$$K_1 = \frac{\alpha_1}{(\alpha_1 + \alpha_2)}\left[F + \frac{q\theta}{A_2 L_2^{1-\alpha_2}}\right] \tag{12}$$

This suggests that the fraction of capital allocated to industry 1 (K_1/F) reduces as the total available funds (F) or the labor allocated to industry 2 (L_2) increases.

It is thus clear that industry 2 will remain non-operative if, $F-K_1 \leq 0$, or, utilizing Eq. (12) and setting Eq. (7) with equality,

$$\frac{\alpha_1}{F} \geq \frac{\alpha_2 A_2 N_2^{1-\alpha_2}}{q\theta}. \tag{13}$$

This states that the reasons for the developing country to be stuck with industry 1 could be: too little funding (small F), too few skilled labor (small N_2), imperfect copy of advanced technology (A_2 not sufficient high), too expensive the type-2 capital (high q) and too high the preference bias (high θ). This condition, however, is sufficient but not necessary, because it considers only capital but not labor reallocation—in other words, the country can be stuck with industry 1 even when Eq. (13) does not hold, if labor reallocation is taken into account.

We are now prepared to work out the necessary condition for industry 2 to remain inactive or the sufficient condition for industry 2 to start off. Denoting MPL_i as the marginal product of labor in sector i, we can analyze labor reallocation by examining the shadow wage ratio of the modern industry to the traditional industry (i.e., the ratio of the marginal valuation of labor):

$$\begin{aligned}\Omega(L_2) &= p\frac{\mathrm{MPL}_2}{\mathrm{MPL}_1} = \frac{\alpha_1(1-\alpha_2)}{(1-\alpha_1)\alpha_2} \times \frac{q[K_2/L_2]}{[K_1/L_1]} \\ &= \frac{\alpha_1(1-\alpha_2)}{(1-\alpha_1)\alpha_2} \times \left[\frac{L-L_2}{L_2}\right]\left[\frac{(\alpha_1+\alpha_2)A_2L_2^{1-\alpha_2}F}{\alpha_1[A_2L_2^{1-\alpha_2}F+q\theta]} - 1\right]\end{aligned} \tag{14}$$

where the second equality makes use of Eq. (9) and the third equality makes use of Eq. (12). The last expression shows that the shadow wage ratio between the two industries is inversely related to the relative capital-intensity measure (the first term) and the relative labor abundance (the second term), but positively related to the relative capital abundance (the last term) Notice that in the absence of skill differentiation and the Marshallian externality in industry 2, factor price equalization holds and the capital–labor ratio would then depend solely on the relative price.

From Eq. (14), we can see that the shadow wage ratio is negative for low level of L_2 and will initially rise when L_2 increases but will eventually approach zero when L_2 approaches L. In other words, $\Omega(L_2)$ is increasing in L_2 if $\sup_{L2\in(0,\ L)} \Omega(L_2)=0$; it becomes hump-shaped if $\sup_{L2\in(0,\ L)} \Omega(L_2)>0$.

If $\sup_{L2\in(0,\ L)} \Omega(L_2)<1$, industry 2 will never emerge. In this case, a policy that increases the number of skilled workers (with L fixed) will not jump start industry 2. Thus, at the early stage of development when the economy is extremely poor, policy instrument selection is crucial in the sense that accumulation of investment funds, rather than education, is necessary for a successful industrial transformation.

A more interesting case arises when F and A_2 are high enough so that $\sup_{L2\in(0,\ L)} \Omega(L_2)>1$ (as depicted in the top panel of Fig. 1). From the arguments above, the

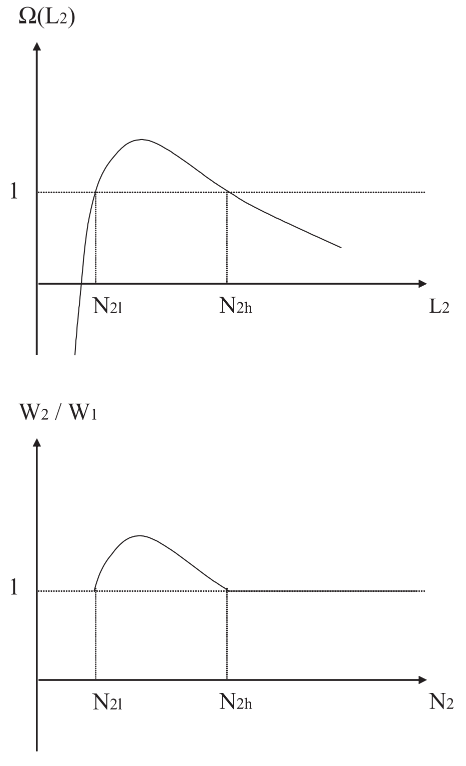

Fig. 1. $\Omega(L_2)$ and wage ratio W_2/W_1.

relative wage $\Omega(L_2)$ must now be hump-shaped. We can show that there exist $N_{2l} < N_{2h}$ such that $\Omega(N_{2l}) = \Omega(N_{2h}) = 1$. Recall that while unskilled workers are only capable of producing good 1, skilled workers can produce both goods. Thus, whenever industry 2 is operative, the market wage ratio must be greater than or equal to one. For a given pair of market wages $\{W_1, W_2\}$, a skilled worker's job selection rule is given as follows. In the degenerate case when $W_1 = W_2$, we assume without loss of generality that a skilled worker will always choose industry 2 as long as there is a vacancy. In the nondegerate case when $W_1 < W_2$, the shadow wage ratio equals the market wage ratio: $\Omega(N_2) = W_2/W_1$, under which all skilled workers are employed in the modern industry. In general, the equilibrium market wage ratio satisfies (see the bottom panel of Fig. 1):

$$\frac{W_2}{W_1} = \begin{cases} \text{undefined} & \text{if } N_2 < N_{2l} \\ \Omega(N_2) & \text{if } N_{2l} \leq N_2 < N_{2h} \\ 1 & \text{if } N_2 \geq N_{2h} \end{cases}. \tag{15}$$

3.2. Equilibrium characterization

Given Eqs. (14) and (15), the competitive equilibrium has the following properties:

(i) when $N_2 < N_{2l}$, industry 2 remains non-operative thus skilled workers all work in industry 1;
(ii) when $N_2 = N_{2l}$, industry 2 is activated and skilled workers all work in industry 2 but wages are equal across the two industries;
(iii) when $N_{2l} < N_2 < N_{2h}$, skilled workers all work in industry 2, earning a wage greater than that in industry 1;
(iv) when $N_2 = N_{2h}$, wage differential vanishes as in case (ii);
(v) when $N_2 > N_{2h}$, we must have $L_2 = N_{2h}$ and skill mismatch occurs as the surplus skilled labor, $N_2 - N_{2h}$, work in industry 1 with wages equalized between the two industries.

Of course, if case (v) occurs, the country should be contemplating the activation of a third and more advanced industry.

In case (i) where industry 2 remains inactive, there are two separate reasons. When $\Omega(N_2)0$, the condition is equivalent to Eq. (13) and in this case, limited resources from capital funding, labor and the modern technology result in lower marginal valuation of capital in industry 2. When $0 < \Omega(N_2) < 1$, there are enough resources to enable equalization of the marginal valuation of capital, though it leads to a shadow wage ratio which is too low for skilled workers to participate in industry 2. Summarizing, the activation of a modern industry requires not only sufficient resources of capital funds, skilled labor and new technologies, but also appropriate matches between capital and labor to ensure profitability of every factor reallocation in a competitive fashion.

It may be noted that even for moderate F and A_2, a reduction in the price of type-2 capital, q, as a result of learning from advanced economies, can also help kick start the modern industry in developing countries. This is easily seen from Eq. (14) since the reduction in q can raise the shadow wage ratio $\Omega(N_2)$ and hence the market wage ratio W_2/W_1 to exceed 1.

Another observation we can make from Fig. 1 is that as N_2 increases above N_{2l} as the modern industry begins to operate, the income distribution gets worse initially. To understand this phenomenon, note that the output of the modern sector is a luxury good. An increase in N_2 generates a positive wealth effect, thus raising the relative demand for the modern good and encouraging capital reallocation from the traditional to the modern sector. As a result of capital–labor complementarity (in the Pareto sense), the relative wage rises (which can be seen from the second square bracket in Eq. (14)).

As N_2 increases further toward N_{2h}, income distribution improves eventually as the skilled labor becomes sufficiently abundant (which can be seen from the first square bracket in Eq. (14)). If industry 3 is not activated when N_2 continues to increase, some skilled labor has to work in industry 1 and the wage differential disappears. That is, skill mismatch may occur as a consequence of over-education without an appropriate industrial policy. Real world examples include the cases of Macao and Philippines, whose educational attainments have been comparable to Hong Kong and Taiwan, though experiencing significantly lower levels of development over the past four decades (based on data from Penn World Tables 5.6).

The existence of external effect implies that although an individual firm has no incentive to embark on a type-2 goods production unilaterally, the society as a whole may find such activity welfare enhancing. To see this possibility, note that for the society as a whole, the marginal product of type-2 capital is $A_2 L_2^{1-\alpha_2}$. Hence, if

$$\frac{A_2 N_2^{1-\alpha_2}}{q\theta} > \frac{\alpha_1}{F} > \frac{\alpha_2 A_2 N_2^{1-\alpha_2}}{q\theta},$$

an output subsidy to type-2 goods production at the rate of $1/\alpha_2 - 1$, financed by a lump-sum tax, may activate industry 2 and raise the representative agent's welfare. Of course, if this rate of subsidy required to artificially jumpstart industry 2 is excessively high, the welfare need not improve due to the distortions created. In this case, the short-term solutions include (i) receiving external assistance from international organizations to raise F (e.g., European Investment Bank loans and the U.S. Aid), (ii) obtaining technological transfer from developed countries to advance A_2, and (iii) attracting immigrants of high skills to increase N_2. The long-term solutions are (i) better education to raise the mass of skilled workers, (ii) greater saving incentives to increase available funds, and (iii) more R&D investments to improve new technologies. The radical measure may be to advertise the modern way of life, which reduces θ by turning a luxury good to a necessity good.

Many of these aforementioned programs have been implemented by some rapidly industrialized economies. For example, in the volume edited by Thorbecke and Wan (1999), extensive discussions can be found on some successful development programs that have fostered the take-off of the Taiwanese economy and led to the 'Taiwan Miracle'. These include the US$1.2 billion U.S. aid from 1951 to 1965 allocated to infrastructure, as well as the high interest rate and light taxation policies in inducing a growing supply of funds (F). Moreover, the outstanding education and training programs have assisted the structural changes in Taiwan's labor force (by shifting from N_1 to N_2) to accommodate rapid industrial transformation.[8] Furthermore, the presence of uncompensated modern sector-specific externality implies that the marginal private benefit of allocating capital to the modern sector is less than the marginal social benefit. In recognizing this problem, Taiwan established several public enterprises (in steel, utility and transportation industries) in the 1970s to help internalize such positive externalities (see Chen and Ku, 1999; Wan, 2003).

Similar arguments have been made concerning the development experiences of Hong Kong and Korea. In particular, Thorbecke et al. (2002) elaborates on the importance of organizing sufficient funds for productive industries in the case of Hong Kong, whereas Adelman (1999) stresses that Korean government has played a positive role in funds matching and investment subsidy in the 1960s and 1970s. On the contrary, as discussed in Morawetz (1981), the failure to modernize in Columbia has been due partly to the inability

[8] See Lucas (1993) for an alternative explanation on how to make a miracle. In particular, on-the-job learning and reverse engineering may raise the level of skills and provide a necessary human capital stock to modernize.

of domestic firms to upgrade their production plants via technological transfer from developed countries (A_2).

What can we say about the behavior of relative price, p? Can our theory lend support to the observed price trend? Focusing on the most relevant case when the modern industry is operating and there is no skill mismatch ($N_{2l} < N_2 < N_{2h}$), all skilled workers are employed in the modern industry. From Eqs. (10)–(12), the formula determining the relative price p is given by,

$$p = \frac{q\alpha_1 A_1 (L - N_2)^{1-\alpha_1}}{\alpha_2 A_2^{\alpha_1} N_2^{\alpha_1(1-\alpha_2)} \left[\frac{\alpha_1}{\alpha_1 + \alpha_2}\left(q\theta + FA_2 N_2^{1-\alpha_2}\right)\right]^{1-\alpha_1}}. \tag{16}$$

Obviously, as A_2 rises or q declines, the supply of goods 2 increases and hence the relative price decreases. More interestingly, as more skilled labor is available, through the Rybczynski magnification effect goods 2 becomes more abundant, thus lowering the relative price. This finding is consistent with both time series and cross-section evidence that relative price of luxury goods falls during the process of development.

3.3. Further discussion

A noticeable omission of the model economy established in previous sections is the role played by international trade in industrial transformation. This is particularly relevant because many developing economies discussed above are of the small open nature with high trade dependence. Thus, this subsection is devoted to elaborating on whether our results can be generalized to an open economy.

For illustrative purposes, we restrict our attention to a small open, less developed country (LDC) without international labor mobility where p is determined by the prevailed world price, denoted p^*. Let π denote the shadow price determined in the home country, given by the righthand side of Eq. (16). Consider first the case with only capital flows but without international goods trading. This is straightforward as we only need to augment the total funding available F by foreign direct investment (assuming net capital inflows as in most developing countries). Thus, an increase in foreign direct investment is likely to lead to a successful activation of a modern industry.

The conventional Heckscher–Ohlin setup features international goods trading without capital mobility. Since this case is more difficult to analyze, we focus only on a particular environment in which the LDC does not have sufficient skilled labor/capital to export modern goods even if such an industry is established. Denote the tariff rate on imported modern goods as τ, so $p=(1+\tau)p^*$ by construction under the small open economy setting. In this case, international trade permits consumption of the modern product without activation of a modern industry as long as $\pi>(1+\tau)p^*$—this is due to barriers from preferences and domestic technologies, as illustrated in the closed economy case. Thus, at the early stage of development, international trade may reduce the incentive for an LDC to activate modern industries as domestic firms have comparative advantage to specialize in the production of traditional goods. This finding corroborates with the result in Young (1991) where international trade may harm economic development when it encourages resource reallocation towards less sophisticated sectors. Our conclusion also suggests it may not be entirely unjustified for an LDC to impose high tariff (higher τ) accompanied by an investment subsidy to modern capital (lower q) in view of a successful industrial transformation.[9] This is in sharp contrast with Bond et al. (in press) where reduction in tariff may enable the activation of modern industry as a result of learning from exporting.

4. Unemployment

In previous sections, factor substitutability is assumed to function so that there is never any unemployment. Skill mismatch—high-skilled workers work in low-skilled industry—is possible when the modern industry does not operate (or when skilled workers are abundant but short of activating a third industry). In the real world, however, developing countries may have massive unemployment. This led us to conduct an analysis of industrial transformation in an environment where full employment may break down. The conventional literature of unemployment usually departs from the Walrasian setup, such as to consider search frictions or incomplete labor contract. For comparison purposes, we prefer to address the issue within the perfect competition framework under fixed proportion production technologies.

In particular, we assume the production technologies to take the Leontief forms:

$$Y_i = A_i \min\{K_i, \gamma_i L_i\}, i = 1,\ 2$$

where $A_2 > A_1$ and $\gamma_2 < \gamma_1$. In other words, type-2 capital is more productive and industry 2 production is more capital intensive. For simplicity, we abstract from the consideration of the external effect in the modern sector.

A model with Leontief technology is cumbersome to handle. But since our focus is on developing countries, we can safely restrict our attention to the case that

$$\min\{K_1, \gamma_1 L_1\} = K_1.$$

That is, unskilled labor is abundant and capital is relatively scarce in industry 1. We cannot make the same assumption for industry 2, however, because skilled labor may be more scarce than type-2 capital. Thus, we need to study two separate cases, while the equilibrium solution is an appropriate selection from the two cases, depending on the availability of investments funds and skilled workers.

4.1. Capital scarcity in the modern industry

When capital binds in the modern industry, we have $\min\{K_2, \gamma_2 L_2\} = K_2$. In the absence of distortions or externalities, the competitive equilibrium is the same as the social optimum. The central planner's problem is given by,

$$\max\ \ln(A_1 K_1) + \ln[A_2 K_2 + \theta]$$

[9] More precisely, as long as $p^* < \pi < (1+\tau)p^*$, the LDC may activate the modern industry but is unable to export modern goods to the world market in the absence of export subsidy.

subject to Eq. (8). Utilizing Eq. (8) with equality, we can manipulate the first-order condition to obtain:

$$\frac{1}{F-qK_2}=\frac{A_2}{q[A_2K_2+\theta]},$$

which leads to,

$$K_1=\frac{A_2F+q\theta}{2A_2};\quad K_2=\frac{A_2[F/q]-\theta}{2A_2}. \tag{17}$$

Thus in order for industry 2 to emerge, the condition we need is,

$$A_2[F/q]>\theta, \tag{18}$$

which has the same flavor and interpretation as condition (5).

When the above condition is met, the fixed proportion production technologies imply:

$$L_1=\frac{A_2F+q\theta}{2A_2\gamma_1};\quad L_2=\frac{A_2[F/q]-\theta}{2A_2\gamma_2}.$$

Thus, in order to support this case where capital is relatively scarce in both industries, we need:

$$N_1\geq\frac{A_2F+q\theta}{2A_2\gamma_1}\ \text{and}\ N_2\geq\frac{A_2[F/q]-\theta}{2A_2\gamma_2}.$$

In this case, unemployment may occur:

$$u_1=N_1-\frac{A_2F+q\theta}{2A_2\gamma_1};\quad u_2=N_2-\frac{A_2[F/q]-\theta}{2A_2\gamma_2} \tag{19}$$

where u_1 and u_2 are unemployment of unskilled and skilled, respectively. Total unemployment u is therefore given by,

$$u=L-\frac{1}{2}\left[F\left(\frac{1}{\gamma_1}+\frac{1}{q\gamma_2}\right)-\frac{\theta}{A_2\gamma_1\gamma_2}(\gamma_1-q\gamma_2)\right] \tag{20}$$

Let us run a thought experiment. Suppose at the beginning the developing country falls a little short of enough funding to activate the modern industry. The unemployment is then given by $L-F/\gamma_1$. If an aid, G, is received so that industry 2 barely goes into existence, the unemployment will rise because industry 2 creates less employment than industry 1 loses, for two reasons: (i) industry 2 is more capital intensive; and (ii) type-2 capital is more expensive. Both imply that there must be sufficiently large amount of capital moved out of industry 1, thus inducing substantial job destruction in the traditional sector. This can be referred to as the creative destruction effect of industrialization. Only when the aid is substantially high to allow the developing country to operate industry 2 at a good scale will the unemployment fall.

Since capital is scarce in this case, it is clear that once the modern sector is operative, additional increases in investment funds always result in less unemployment, as it can be seen from Eq. (20). That is, once the modern industry is operative, there will be no more creative destruction in jobs. Consider now only the case where industry 2 is operative. When γ_2 increases, i.e., production of the modern good uses capital more intensively, capital scarcity becomes more severe. As a consequence, both the unemployment in industry 2 and the total unemployment rise, but the unemployment rate in the traditional sector remains unchanged (see Eq. (19)). This explains, in part, why in many socially planned economies, misallocation of funds to some heavy industries may be a costly and painful process.[10] In this case, a sector-specific investment tax credit that decreases q is likely a successful industrial policy, leading to modernization.

When θ decreases, i.e., what used to be the luxury good becomes less so, it encourages capital reallocation from the traditional sector, industry 1, to the modern sector, industry 2 (see Eq. (17)). Under the fixed proportion technologies, demand for unskilled workers decreases, whereas demand for skilled workers rises, thereby leading to higher unemployment in industry 1 but less in industry 2. Its effect on total unemployment is ambiguous, depending on the sign of $(\gamma_1 - q\gamma_2)$. In particular, recall that $\gamma_2 < \gamma_1$ and $q > 1$. Total unemployment rises (falls) as θ decreases if the difference in capital intensity is small (large) and the capital cost differential is large (small). Thus, to accomplish a successful industrial transformation, one must take into account the transitional cost of unemployment during the process of sector shifts. The above result provides a clear-cut analysis in evaluating such a cost.

4.2. Skilled labor scarcity in the modern industry

We next turn to the case where skilled labor binds in the modern industry and hence we have $\min\{K_2, \gamma_2 L_2\} = \gamma_2 L_2$. In this case, skilled labor is relatively scarce in industry 2. The central planner's problem now becomes,

$$\max \ \ln(A_1 K_1) + \ln[A_2 \gamma_2 L_2 + \theta]$$

subject to Eq. (7) and the capital reallocation constraint,

$$K_1 + q\gamma_2 L_2 \le F. \tag{21}$$

Since the skilled labor binds in industry 2, monotonicity of the preferences implies the equilibrium level of industry 2 employment must be at $L_2 = N_2$, which can then be substituted into Eq. (21) with equality to yield:

$$K_1 = F - q\gamma_2 N_2 \tag{22}$$

$$L_1 = (F - q\gamma_2 N_2)/\gamma_1 \tag{23}$$

This is an equilibrium if the solution fulfils the presumption that unskilled labor is relative abundant, i.e., $\gamma_1 (L - N_2) \ge K_1$. Using Eq. (23), this condition becomes:

$$\gamma_1 L \ge F + (\gamma_1 - q\gamma_2) N_2 \tag{24}$$

[10] For example, see a discussion of the case of China over the period 1952–1980 by Chow (1993).

In this case, industry 2 reaches full employment and unemployment may occur only in industry 1, which is given by,

$$u = L - N_2 - L_1 = L - F/\gamma_1 - (\gamma_1 - q\gamma_2)N_2/\gamma_1. \tag{25}$$

Three points deserve further elaboration. First, as long as $N_2>0$ and condition (24) is met, industry 2 always operates, yet its scale is limited due to the scarcity of skilled workers. Second, if the difference in capital intensity is sufficiently small and the capital cost differential is sufficiently large such that $\gamma_1 - q\gamma_2 < 0$, an increase in the skilled labor may suck too much capital to industry 2 so that the loss of employment in industry 1 is larger than jobs created in industry 2, leading to a higher unemployment rate. In contrast to the previous case where capital funding is scarcer than the skilled labor, this creative destruction effect occurs even when the modern industry is operative. In this case, foreign aid programs may become essentially ineffective, as in several African examples studied by Easterly (2001). Instead, educational and training programs (including subsidy to education) may better suit the need, raising the critical mass of skilled workers (N_2) to result in a successful modernization.

Finally, while an increase in F or a decrease in γ_2 still reduce unemployment unambiguously, the effect of θ disappears. This is in stark contrast to previous case when capital is binding in the modern industry. Intuitively, since the skilled labor is scarce in production of the modern good, capital is always employed at a fixed proportion to the supply of skilled workers. This removes the potential trade-off in the reallocation of capital. As a result, whether the modern good is more necessary for survival does not matter to capital allocation or employment in the traditional industry, thus generating no effect on the unemployment rate.

5. Conclusions

In this paper, we have proposed an integrated framework to disentangle the underlying economic mechanism of industrial transformation. We have concluded that human and nonhuman resources, production factor matching and industrial coordination are all important for activating a modern industry. We have provided an array of short-term and long-term policy prescriptions for achieving a successful process of industrial evolution. Inappropriate implementation of development policy programs may fail to work and a poor country may stay backward.

Along these lines, a natural extension is to examine industrial evolution by allowing investment funds to accumulate. This enables a full characterization of the pattern of transitional growth of an economy in the process of industrialization. In particular, one may incorporate the dynamic aspects of Goodfriend and McDermott (1995) and Matsuyama (2002) to help explain not only the failure to modernize but the time delay in industrialization.

Another extension is to construct an n-sector model, where industries are ranked by the degrees of consumption subsistence and the measures of capital intensity. This can help understand the pattern of emergence and decline of industries. From a normative point of view, it may be useful to consider endogenous trade-off between investment funds and skilled workers in the sense that by allocating funds to education or retraining, one may increase the fraction of skilled workers. Under that framework, one can study more thoroughly the welfare implications of public education programs.

There are several other avenues that may be interesting for future research. For brevity, we only mention two. On the one hand, one may incorporate a mechanism considered by Laitner (2000) that an economy's average propensity to save rises endogenously in the process of industrialization. In this case, growth can be sustained in the modern sector in which the perpetually growing funds enable perpetual accumulation of the capital stock. On the other hand, one may also follow Jovanovic (1998) or Wan (2001) to allow workers matched with high-quality capital or more profitable firms to have greater incentive to acquire marketable skills. This will then endogenize the evolution of human capital, leading to further industrialization.

Acknowledgements

We have benefited from Bob Driskill, Andrew Feltenstein, Peter Howitt, Reza Vaez-Zadeh, two anonymous referees, as well as participants of the 2002 ASSA Meetings in Atlanta, the 2002 International Conference held at City University of Hong Kong, SUNY-Binghamton and the authors' own institutions. Needless to say, the views expressed here are those of the authors and do not necessarily represent those of the IMF or IMF policy, while any remaining errors are solely the authors' responsibility.

References

Adelman, I., 1999. State and market in the economic development of Korea and Taiwan. In: Thorbecke, E., Wan Jr., H. (Eds.), Taiwan's Development Experience: Lessons on Roles of Government and Market. Kluwer Academic Publishing, Norwell, MA, pp. 289–326.

Adelman, I., Thorbecke, E., 1989. The role of institutions in economic development. World Development (special issue).

Amsden, A.H., 1989. Asia's Next Giant: South Korea and Late Industrialization. Oxford Univ. Press, Oxford, UK.

Balasa, B., 1972. Industrial Policies in Taiwan and Korea. In: Di Marco, L. (Ed.), International Economics and Development. Academic Press, New York, NY, pp. 159–180.

Benhabib, J., Farmer, R., 1994. Indeterminacy and increasing returns. Journal of Economic Theory 63, 19–41.

Bond, E., Jones, R., Wang, P., 2004. Economic Take-offs in a Dynamic Process of Globalization. Review of International Economics (in press).

Chen, T.-J., Ku, Y.-H., 1999. Second-stage import substitution. In: Ranis, G., et al. (Eds.), The Political Economy of Taiwan into the 21st Century. Edward Elgar, Cheltenham, UK, pp. 79–108.

Chen, B.-L., Shimomura, K., 1998. Self-fulfilling expectations and economic growth: a model of technology adoption and industrialization. International Economic Review 39 (1), 151–170.

Chow, G.C., 1993. Capital formation and economic growth in China. Quarterly Journal of Economics 108 (3), 809–842.

Dowrick, S., Gemmell, N., 1991. Industrialisation, catching up and economic growth: a comparative study across the world's capitalist economies. Economic Journal 101 (1), 263–275.

Easterly, W., 2001. The Elusive Quest for Growth. MIT Press, Cambridge, MA.

Evans, P., 1995. Embedded Autonomy: States and Industrial Transformation. Princeton Univ. Press, Princeton, NJ.

Goodfriend, M., McDermott, J., 1995. Early development. American Economic Review 85 (1), 116–133.
Horrell, S., 1996. Home demand and British industrialization. Journal of Economic History 56 (3), 561–604.
Jovanovic, B., 1998. Vintage capital and inequality. Review of Economic Dynamics 1 (2), 497–530.
Kaneda, M., 1995. Industrialization under perfect foresight: a world economy with a continuum of countries. Journal of Economic Theory 66 (2), 437–462.
Kuo, S.W.Y., 1983. The Taiwan Economy in Transition. Westview Press, Boulder, CO.
Laitner, J., 2000. Structural change and economic growth. Review of Economic Studies 67 (3), 545–561.
Lewis, A., 1955. The Theory of Economic Growth. Allen and Unwin, London, UK.
Lucas Jr., R.E., 1988. On the mechanics of economic development. Journal Monetary Economics 22 (1), 3–42.
Lucas Jr., R.E., 1993. Making a miracle. Econometrica 61 (2), 251–272.
Matsuyama, K., 1991. Increasing returns, industrialization and indeterminacy of equilibrium. Quarterly Journal of Economics 106 (2), 617–650.
Matsuyama, K., 2002. The rise of mass consumption societies. Journal of Political Economy 110 (5), 1035–1070.
Morawetz, D., 1981. Why the Emperor's New Clothese are not Made in Colombia: A Case Study of Latin American and East Asian Manufacturing Exports. Oxford Univ. Press, New York, NY.
Murphy, K.M., Shleifer, A., Vishny, R.W., 1989. Industrialization and the big push. Journal of Political Economy 97 (5), 1003–1026.
Parente, S.L., Prescott, E.C., 1999. Monopoly rights: a barrier to riches. American Economic Review 89 (5), 1216–1233.
Peretto, P.F., 1999. Industrial development, technological change and long-run growth. Journal of Development Economics 59 (2), 389–417.
Robert, M.J., Tybout, J.R. (Eds.), 1996. Industrial Evolution in Developing Countries: Micro Patterns of Turnover, Productivity and Market Structure. Oxford Univ. Press, Oxford, UK.
Romer, P., 1986. Increasing returns and long-run growth. Journal of Political Economy 94 (6), 1002–1037.
Rosenstein-Rodan, P.N., 1961. Notes on the theory of the 'Big Push'. In: Ellis, H.S. (Ed.), Economic Development for Latin America. Macmillan, London, UK, pp. 57–66.
Rostow, W.W., 1960. The Stage of Economic Growth. Cambridge Univ. Press, Cambridge, UK.
Thorbecke, E., Tung, A., Wan Jr., H.Y., 2002. Industrial Targeting: Lessons from Past Errors and Successes of Hong Kong and Taiwan. World Development 25 (8), 1047–1061.
Thorbecke, E., Wan Jr., H. (Eds.), 1999. Taiwan's Development Experience: Lessons on Roles of Government and Market. Kluwer Academic Publishers, Norwell, MA.
Tsiang, S.C., 1964. A model of economic growth in Rostovian stages. Econometrica 32 (4), 619–648.
Wan Jr., H.Y., 2001. Endogenous Growth Theory and Industrial Policy, Working Paper. Cornell University.
Wan Jr., H.Y., 2003. Industrial Policy under Globalization: East Asian Evidence, Working Paper. Cornell University.
Young, A., 1991. Learning by doing and the dynamic effects of international trade. Quarterly Journal of Economics 106 (2), 369–406.