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Abstract

Two models of learning-by-*exporting* are developed. Each addresses the rationale for a trade policy that protects infant domestic industries and shows that an export-led strategy for developing countries can reduce the optimal rate of subsidy. Furthermore, these models answer the question why the domestic price distortion in knowledge-spillover economies, such as that in Hong Kong and Singapore will be corrected faster than in economies with a large agricultural sector, such as that in Thailand and Indonesia.

JEL classification: F13, F43

Keywords: Learning-by-doing , learning-by-exporting , export-led growth

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1 Introduction

The existence of a learning industry has provided a theoretical basis for government intervention often called the infant industry argument. The basis for this is that competitive producers of a learning industry will produce less than the socially optimal output. However, this type of infant industry argument is passive, that is, there is little to tell us about the active policy that shapes the economy to be competitive. Furthermore, the recent history of economic growth of developing countries tells us that the sources of learning may be from export activity rather than industry output itself.

In this paper I have developed two simple dynamic models of learning-by-exporting in an open economy framework. One can be applied to an agrarian economy and the other to a relatively small open economy without a large agricultural sector. I will show that an export-led growth policy together with this type of learning can bring more favorable economic structure than that from a model of just learning-by-doing .

There is extensive empirical literature on learning-by-exporting . Cleridas, Lach and Tybout (1998) is an early empirical study applying Colombian data to test this hypothesis. Aw, Chung and Roberts (2000) tests and shows the positive correlation between export and firm productivity for Taiwanese industries. Aw,Roberts and Winston (2005) support the hypothesis that an export experiment is an important source of productivity growth for Taiwanese firms.[1]

The paper is organized as follows: Subsection 1 of Section 2 explains Bardhan's model while subsections 2 and 3 develop the two types of learning-by-exporting . Section 3 provides a conclusion for the paper.

2 Models

2.1 Learning-by-Doing : Bardhan's Model

In this section, I discuss Bardhan's (1971) learning-by-*doing* model in which there are two sectors; one is a learning sector while the other is not. The learning industry is an irreversible external economy for a single firm, that is, the industry-wide learning effects are completely external to each firm.

[1] See Trofimenko (2005), and Fernandes and Isgut (2005) for a recent survey.

The other assumptions include small open economy, balanced trade, perfect foresight, no capital accumulation, and no labor forth growth.

Bardhan's model is based on the standard two by two Heckscher-Ohlin-Samuelson (HOS) model.[2] A manufacturing sector benefits from learning-by-doing while the other sector (termed the agricultural sector here) does not. Learning-by-doing results from the accumulation of the manufacturing industry's total output.[3]

Technologies for these sectors are

$$Y_M = B(Q_M)F(K_M, L_M) \quad \textit{and} \quad Y_A = G(K_A, L_A). \tag{1}$$

Y_i is output and K_i,L_i are capital and labor required for the sector $i, i = M, A$. Production factors are assumed to have perfect employment and no factor growth.

$$K_M + K_A = \bar{K} \quad \textit{and} \quad L_M + L_A = 1 \tag{2}$$

The learning function is strictly concave, i.e., $B'(Q_M) > 0$ and $B''(Q_M) < 0$ and also satisfies Inada conditions. While Q_M is the cumulative output of the manufacturing industry

$$Q_M(t) = \int_0^t \{Y_M(\tau) - \delta Q_M(\tau)\} \, d\tau. \tag{3}$$

Knowledge resulting from learning-by-doing can depreciate, that is, the experiences may be forgotten at the rate of δ. Originally, Bardhan's model tried to capture the optimal subsidy of an infant industry (manufacturing sector in this paper) for developing countries. Hence, the learning function should have a ceiling and have the feature of the "catching-up" process of developing economies. In other words, Q_M cannot be above a finite positive level $\bar{Q}_M$, and $B(Q_M) = \bar{B}$ for $Q_M \geq \bar{Q}_M$. This means that the stock of experience

[2]Bardhan's paper is actually developed using capital-labor ratios in exactly the same way as with a traditional international trade model so that he can argue the comparative advantage based on the factor endowment theory. However, I describe his original model without arguing the comparative advantage of the economy just for simplification of the model. Nonetheless, this does not change the results.

[3]Industry learning is not under the control of any single firm, but is rather an irreversible external economy.

enhances productivity up to a point, and then a certain exogenous level of experience $\bar{Q}_M$ the economy catches up with the foreign efficiency level and there is no more learning. Under these assumptions, competitive solutions for the rate of return of capital and wage rates are respectively,

$$r = p^d B(Q_M) F_K = G_K \quad and \quad w = p^d B(Q_M) F_L = G_L.$$

Hence, the (relative) price of manufacturing goods given the price of agricultural goods as numeraire is

$$p^d = \frac{G_i}{B(Q_M) F_i}, \tag{4}$$

where F_i, G_i for $i = K, L$ represent derivatives with respect to each input, K and L.

Assuming concave instantaneous utility function, $U(C_M, C_A)$, and the balanced trade, $(Y_A - C_A) + \bar{p}^w (Y_M - C_M) = 0$, the social planner's problem is to maximize the intertemporal utility subject to the assumptions above and the small open economy assumption,

$$\max_{C_M \geq 0, C_A \geq 0} \quad \int_0^\infty \{U(C_M, C_A)\} e^{-\rho t} dt.$$

Defining $X_M = Y_M - C_M$, the corresponding current value Lagrange-Hamiltonian becomes

$$\begin{aligned} \tilde{H} = U(C_M, C_A) \quad &+ \quad \lambda \left[B(Q_M) F(K_M, L_M) - X_M - C_M \right] \\ &+ \quad \mu \left[G(\bar{K} - K_M, 1 - L_M) + \bar{p}^w X_M - C_A \right] \\ &+ \quad \gamma \left[B(Q_M) F(K_M, L_M) - \delta Q_M \right] \end{aligned}$$

It should be noted that if the learning-by-doing is bounded, γ is non-zero. The necessary conditions for optimality with respect to C_M, C_A, X_M, K_M, and L_M are

$$U_M \quad = \quad \lambda \tag{5}$$

$$
\begin{aligned}
U_A &= \mu && (6)\\
\bar{p}^w &= \frac{\lambda}{\mu} && (7)\\
\frac{\lambda+\gamma}{\mu} &= \frac{G_i}{B(Q_M)F_i}, \quad for \quad i = K, L, && (8)\\
\dot{\gamma} &= -\frac{\partial \tilde{H}}{\partial Q_M} + \rho\gamma. && (9)
\end{aligned}
$$

The first two conditions are the intertemporal envelope conditions that relate the marginal utility of consumption of the two goods to the shadow value of wealth. The third equation shows that the domestic marginal rate of substitution should equal the world's (given) terms of trade. The fourth equation defines the domestic relative price of two goods.

From the firm's profit maximization problem, the domestic relative price equals the left side of the optimal condition (8), which, in turn, is greater than the world terms of trade, i.e.,

$$
p^{\,d} = \frac{\lambda+\gamma}{\mu} \geq \frac{\lambda}{\mu} = \bar{p}^w. \tag{10}
$$

Unless the government intervenes, competitive production of the manufacturing industry will produce according to market price $\bar{p}^w(=\lambda/\mu)$ and there will be underproduction from a social point of view. Hence, the government should assure the production where a price equal to $p^{\,d}(=(\lambda+\gamma)/\mu)$. In this case, the optimal rate of subsidy (τ) is given by

$$
\bar{p}^w(1+\tau) = p^{\,d}, \quad where \quad \tau = \frac{\gamma}{\lambda} \tag{11}
$$

Now we have complete macroeconomic equilibrium conditions composed of resource constraints (2), static equilibrium conditions from equations (4) to (8), two dynamic equilibrium conditions, all together with the transversality condition

$$
\lim_{t\to\infty} \rho(t)Q_M(t)e^{-rt} = 0.
$$

Two dynamic equilibrium conditions are composed of the learning function (3) and the evolving path of shadow value of output accumulation of the manufacture sector. From the static conditions and resource constraints, K_M and L_M can be expressed by the functions of γ and Q_M. Thus, the following pair of differential equations describe the evolving pattern of the economy

$$\dot{Q}_M = B(Q_M)F(K_M(Q_M,\gamma), L_M(Q_M,\gamma)) - \delta Q_M \tag{12}$$

$$\dot{\gamma} = (\rho+\delta)\gamma - (\lambda+\gamma)B'(Q_M)F(K_M(Q_M,\gamma), L_M(Q_M,\gamma)). \tag{13}$$

Linearizing these differential equations around the steady state, we obtain

$$\begin{pmatrix} \dot{Q}_M \\ \dot{\gamma} \end{pmatrix} = \begin{pmatrix} \partial\dot{Q}_M/\partial Q_M & \partial\dot{Q}_M/\partial\gamma \\ \partial\dot{\gamma}/\partial Q_M & \partial\dot{\gamma}/\partial\gamma \end{pmatrix} \begin{pmatrix} Q_M - Q_M^* \\ \gamma - \gamma^* \end{pmatrix},$$

where,

$$\frac{\partial\dot{Q}_M}{\partial Q_M} = B'(Q_M)F(\cdot) + B(Q_M)\left(F_K\frac{\partial K_M}{\partial Q_M} + F_L\frac{\partial L_M}{\partial Q_M}\right) - \frac{B(Q_M)F(\cdot)}{Q_M} \tag{14}$$

$$\frac{\partial\dot{Q}_M}{\partial\gamma} = B(Q_M)\left(F_K\frac{\partial K_M}{\partial\gamma} + F_L\frac{\partial L_M}{\partial\gamma}\right) \tag{15}$$

$$\frac{\partial\dot{\gamma}}{\partial Q_M} = -B''(Q_M)(\lambda+\gamma)F(\cdot) - B'(\lambda+\gamma)\left(F_K\frac{\partial K_M}{\partial Q_M} + F_L\frac{\partial L_M}{\partial Q_M}\right) \tag{16}$$

$$\frac{\partial\dot{\gamma}}{\partial\gamma} = (\rho+\delta) - B'(Q_M)F(\cdot) - B'(Q_M)(\lambda+\gamma)\left(F_K\frac{\partial K_M}{\partial\gamma} + F_L\frac{\partial L_M}{\partial\gamma}\right). \tag{17}$$

Defining the "learning elasticity of output" of manufacturing industry as

$$\frac{\partial Y_M}{\partial Q_M}\frac{Q_M}{Y_M} = \frac{B'(Q_M)}{B(Q_M)}Q_M - \frac{Q_M}{F(\cdot)}\left(F_K\frac{\partial K_M}{\partial Q_M} + F_L\frac{\partial L_M}{\partial Q_M}\right).$$

If this elasticity is less than unity, equation (14) is negative.

It is plausible to assume that the manufacturing sector's output is increasing function of the shadow value of cumulative volume of exports, that is,

$$\frac{\partial Y_M}{\partial \gamma} = B(Q_M)\left(F_K\frac{\partial K_M}{\partial \gamma} + F_L\frac{\partial L_M}{\partial \gamma}\right) > 0.$$

Hence, equation (15) is positive. This is assured if "learning elasticity" is less than unity and the additional condition [4] satisfying equation (16) is positive. However, it is difficult to determine the sign of equation (17). So following's Bardhan's logic, I also assume equation (17) is positive.

Combining all this information, we can draw phase diagram and can analyze the long-run properties of the economy around the steady state.

$$(Figure\ 1\ :\ Phase\ diagram\ of Bardhan's\ model)$$

Proposition 1 *(1) There exists rationale for the government to protect her manufacturing industry against the international competition. For this purpose, she needs to subsidize that industry by the difference between domestic and world market prices.*
(2) When initially the domestic price is relatively high, the subsidy will decrease along with the long-run equilibrium path and the domestic price will also go down.

Proof: (1) The proof is apparent from examination of equations (9) and (10). (2) The graphical analysis will suffice as sign conditions of equations from (14) to (17) tell us the system of two differential equations has a saddle path. If initially cumulative trade volume is less than the long-run optimal level

[4] $Q_M\frac{B'(Q_M)}{B(Q_M)} - Q_M\frac{B''(Q_M)}{B'(Q_M)} \geq 1.$

(this is the case in which we are interested), the shadow value of cumulative trade volume will decrease and cumulative trade volume will increase up to the steady state. From equation (9), as γ decreases price of manufacturing goods will also decrease, and approach to the world price level. While, from equation (10), the required subsidy will decrease.

However, note that this time path is deterministic. In other words, we cannot do anything to change this path. Even the optimal subsidy rate will be uniquely determined from the system. In spite of the title of his paper, there are few policy arguments in the model.

2.2 Learning-by-Exporting : Agrarian Economy

When we apply Bardhan's model to actual developing economies, mainly two defects will be apparent. First, many literature on the learning-by-doing assume that learning effects are produced by the activity of its whole industry[5]. However, the recent history of economic development in East Asian economies shows that the sources of the engine of growth have been their exports rather than industry output itself.[6] Second, in Bardhan's model, there is no knowledge spillover between industries. That is, the learning effects benefit the same lone industry in which learning takes place. However, again the recent economic development history tells us that the spillover effect is one of the most important sources of growth.

In this subsections as well as that following, I will develop two types of learning-by-exporting models. The first type is the learning-by-exporting model in which there is no spillover effects between sectors, suitable for a relatively large agrarian developing economy. It is plausible to assume that there is little or no positive spillover effect of technology between the manufacturing sector and agricultural sector. This model may explain the economic growth of Thailand, Indonesia, and Malaysia.

This agrarian economy is composed of manufacturing and agricultural sectors without externality between the two. The learning effect results from the export sector. Hence equations in (1) are modified

[5]Roughly speaking there are three types of learning sources in the literature: industry output, gross investment, and R&D and human capital sector.

[6]Clerides, et al.(1998) show there exists a positive association between export performance and the efficiency of the economy.

$$
\begin{aligned}
Y_M &= B(Q_H)\,[F((1-\alpha)K_M,(1-\alpha)L_M)+H(\alpha K_M,\alpha L_M)] \\
Y_A &= G(K_A,L_A).
\end{aligned}
\tag{18}
$$

H is the export sector so that if α equals 0, the manufacturing sector does not export at all (but it can still import at the given world price), and if α equals 1, the manufacturing sector provides its all quantity to export (and again it can still import). Of course in the real economy α exists somewhere between 0 and 1. Production functions for F and H can be different, so it is possible that the marginal products of each input for each sector are also different. In many developing countries, it is often observed that the exportable sector is more efficient than the domestic market oriented sector. I thus assume $H_i \geq F_i$ for $i = K, L$. Other variables are exactly the same as in the previous model. Resource constraint has the same assumptions before, so equation (2) is again applied.

Since the export sector is the engine of the growth, equation (3) becomes

$$
Q_H(t) = \int_o^t \{B(Q_H)H(\tau) - \delta\, Q_H(\tau)\}\, d\tau. \tag{19}
$$

Under the assumption of perfect competition, the relative price between two sectors is defined

$$
p^{\,d} = \frac{G_i}{B(Q_H)\,[(1-\alpha)F_i + \alpha H_i]} \tag{20}
$$

where $i = K, L$.

While the consumer maximizes the same intertemporal utility subject to equations (2), (18), and (19) with the balanced trade condition, the first order necessary conditions are composed of equations (5), (6), (7) and

$$
\frac{\lambda}{\mu} + \frac{\gamma}{\mu}\phi = \frac{G_i}{B(Q_H)\,[(1-\alpha)F_i + \alpha H_i]}. \tag{21}
$$

for $i = K, L$, and where ϕ is the factor price ratio of export sector to manufacturing sector, i.e.,

$$
\phi(\alpha) = \frac{\alpha H_i}{B(Q_H)\,[(1-\alpha)F_i + \alpha H_i]}, \qquad i = K, L.
$$

The right hand side of equation (17) shows the ratio of factor share between two sectors and equals just p^d. The world given price is obtained from equation (7). By assuming α is less than or equal to 1, ϕ is greater than or equals 0. Hence the relation between the domestic factor price ratio and the world terms of trade is given by

$$p^{\,d} \equiv \frac{\lambda}{\mu} + \frac{\gamma}{\mu}\phi \geq \frac{\lambda}{\mu} = \bar{p}^{w}, \qquad 0 \leq \phi \leq 1. \tag{22}$$

If considering two polar cases of α and comparing equation (9) of Bardhan's model with equation (18), we find the following relation

1. Manufacturing sector is a perfect export sector: $\alpha = 1$

$$p^{\,d} = \frac{\lambda}{\mu} + \frac{\gamma}{\mu}\frac{1}{B(Q_H)} \geq \frac{\lambda}{\mu} = \bar{p}^{\,w}.$$

2. Manufacturing sector does not export at all: $\alpha = 0$

$$p^{\,d} = \frac{\lambda}{\mu} = \bar{p}^{\,w}.$$

The meanings of these findings are straightforward. When $\alpha = 1$, as $B(Q_H)$ approaches to $\bar{B}$, that is the catching-up process is gradually finishing, the domestic relative price also approaches to the minimum price when the export sector exists. On the other hand, $\alpha = 0$ means that there exists no other factors that make domestic relative price different from the world terms of trade (learning-by-exporting). Thus the domestic relative price is equalized with the world relative price.

Finally we can obtain the ratio of optimal subsidy under the learning-by-exporting case. Hence, the government should assure that the production a price equal to $p^{\,d}(= [\lambda + \gamma\,\phi]\,/\mu)$. The optimal rate of subsidy is given by

$$\bar{p}^{\,w}(1+\tilde{\tau}) = p^{\,d}, \qquad \textit{where} \;\; \tilde{\tau} = \frac{\gamma}{\lambda}\,\phi. \tag{23}$$

Together with the transversality condition

$$\lim_{t\to\infty} \rho(t)\, Q_H(t)\, e^{-rt} = 0,$$

we have a system of two differential equations describing the long-run properties of the economy

$$\dot{Q}_H = B(Q_H)H(\alpha K_M(Q_H,\gamma), \alpha L_M(Q_H,\gamma)) - \delta Q_H \tag{24}$$

$$\begin{aligned}\dot{\gamma} = {} & (\rho+\delta)\gamma \\ & - B'(Q_M)\lambda F((1-\alpha)K_M(Q_M,\gamma),(1-\alpha)L_M(Q_M,\gamma)) \\ & - B'(Q_M)(\lambda+\gamma)H(\alpha K_M(Q_M,\gamma), \alpha L_M(Q_M,\gamma)).\end{aligned} \tag{25}$$

To check their sign conditions, let us take partial derivatives of these differential equations with respect to Q_H and γ,

$$\begin{aligned}\frac{\partial \dot{Q}_H}{\partial Q_H} = {} & B'(Q_H)H(\cdot) \\ & + \alpha B(Q_H)\left(H_K\frac{\partial K_M}{\partial Q_H} + H_L\frac{\partial L_M}{\partial Q_M}\right) - \frac{B(Q_H)H(\cdot)}{Q_H}\end{aligned} \tag{26}$$

$$\frac{\partial \dot{Q}_H}{\partial \gamma} = \alpha B(Q_H)\left(H_K\frac{\partial K_M}{\partial \gamma} + H_L\frac{\partial L_M}{\partial \gamma}\right) \tag{27}$$

$$\begin{aligned}\frac{\partial \dot{\gamma}}{\partial Q_H} = {} & -B''(Q_H)(\lambda F(\cdot) + (\lambda+\gamma)H(\cdot)) \\ & - B'(Q_H)\lambda(1-\alpha)\left(F_K\frac{\partial K_M}{\partial Q_H} + F_L\frac{\partial L_M}{\partial Q_H}\right) \\ & - B'(Q_H)(\lambda+\gamma)\alpha\left(H_K\frac{\partial K_M}{\partial Q_H} + H_L\frac{\partial L_M}{\partial Q_H}\right)\end{aligned} \tag{28}$$

$$\begin{aligned}\frac{\partial \dot{\gamma}}{\partial \gamma} = {} & (\rho+\delta) - B'(Q_H)H(\cdot) \\ & - B'(Q_H)\lambda(1-\alpha)\left(F_K\frac{\partial K_M}{\partial \gamma} + F_L\frac{\partial L_M}{\partial \gamma}\right)\end{aligned}$$

$$-B'(Q_H)(\lambda+\gamma)\alpha\left(H_K\frac{\partial K_M}{\partial\gamma}+H_L\frac{\partial L_M}{\partial\gamma}\right). \qquad (29)$$

Following the same method, as in the previous subsection, I define the "learning elasticity of export" of the manufacturing industry as

$$\frac{\partial B(Q_H)H(\cdot))}{\partial Q_H}\frac{Q_H}{B(Q_H)H(\cdot)}=\frac{B'(Q_H)}{B(Q_H)}Q_H-\frac{Q_H}{H(\cdot)}\left(H_K\frac{\partial K_M}{\partial Q_H}+H_L\frac{\partial L_M}{\partial Q_H}\right).$$

If this elasticity is less than unity, equation (26) is negative.

It is plausible to assume that the manufacturing sector's output is an increasing function of the shadow value of cumulative volume of exports, that is,

$$\frac{\partial B(Q_H)H(\cdot)}{\partial\gamma}=\alpha B(Q_H)\left(H_K\frac{\partial K_M}{\partial\gamma}+H_L\frac{\partial L_M}{\partial\gamma}\right)>0.$$

Hence, equation (27) is positive. If we make the same assumptions with equations (16) and (17) as with equations (28) and (29), we can draw the phase diagram and find that the system of the two differential equations has the saddle path.

Now we have a new policy instrument to change the long-run equilibrium and its path. Changes in α will modify the long-run equilibrium situation in the way stated in Proposition 2(3).

(*Figure* 2 : *Phase diagram of Agrarian Economy*)

Proposition 2 *(1) There exits rationale for the government to protect her manufacturing industry against the international competition. For this purpose it needs to subsidize that industry with the difference between domestic and world market prices. Required subsidy is now less than that of Bardhan's economy.*
(2) When the domestic price is initially relatively high, the subsidy will decrease with the long-run equilibrium path as well as the domestic price.
(3) If the learning function performs effectively, that is, there is little forgotten information, export-led strategy makes domestic relative price closer to the world terms of trade in the long-run.

Proof: (1) It is apparent from equations (20), (21) and (22). Thus, when comparing equations (10) and (22), we obtain the desired result.
(2) Identical to the proof of proposition 1 (2)
(3) If learning is performed effectively, δ must be small. From equations (26) and (27), an increase in α makes $\dot{Q}_H = 0$ line slope downward. Leaving the $\dot{\gamma} = 0$ line unchanged it leads to higher Q_H and lower γ in the steady state. This finally leads to the domestic price approaching closer to the world price in equation (22).

2.3 Learning-by-Exporting : Knowledge Spillover

In this subsection, I explain the learning-by-exporting model with the spillover effect which is suitable for a relatively small economy such as Singapore and Hong Kong that do not have a large agricultural sectors. Instead they have relatively large domestic market oriented sectors such as their service sectors. In these cases, it becomes plausible to assume that the exporting sector produces a positive externality to the non-tradable sector. This can explain the economic growth of Singapore and Hong Kong (The economic growth of Korea and Taiwan may be explained by the combination of both models).

The production functions of the two sectors, manufacturing and service, are

$$\begin{aligned} Y_M &= B(Q_H)\left[F((1-\alpha)K_M,(1-\alpha)L_M) + H(\alpha K_M, \alpha L_M)\right] \\ Y_S &= E(Q_H)G(K_S, L_S). \end{aligned} \qquad (30)$$

The production function of manufacturing sector is the same as in the previous model. But the service sector's production will increase as the manufacturing exports increase. That is, there exists knowledge spillover from manufacturing exports to service output. This externality function is assumed greater than unity (positive externality). This change makes it possible to analyze two kinds of spillover effects through international trade: one is international spillovers captured by $B(\cdot)$, while the other is domestic spillovers among industries captured by $E(\cdot)$. Although service sectors (i.e., leisure industry, telecommunications, etc.) are actually tradable, many literatures assume they are non-tradable. In this subsection, I develop a model with tradable service sectors. By this assumption, I can compare the degree of policy effects with the previous two models. A model based on a non-tradable service sector is developed in the appendix.

$$p^d = \frac{E(Q_H)G_i}{B(Q_H)\left[(1-\alpha)F_i + \alpha H_i\right]} \tag{31}$$

where $i = K, L$.

While the consumer maximizes the same intertemporal utility subject to equations (2), (18), and (19) with the balanced trade condition, the first order necessary conditions are composed of equations (5), (6), (7) and

$$\frac{\lambda}{\mu} + \frac{\gamma}{\mu}\phi = \frac{E(Q_H)G_i}{B(Q_H)\left[(1-\alpha)F_i + \alpha H_i\right]}. \tag{32}$$

for $i = K, L$, and where ϕ is defined as same as before.

Even though this additional spillover effect will not change the model structure greatly, it will change the effect of the government policy. Social planner would solve the same problem as seen in an agrarian economy. Thus, we obtain the same domestic price and optimal subsidy. Although nothing changes in the learning function, we have a slightly different evolving equation of γ

$$\begin{aligned} \dot{\gamma} &= (\rho+\delta)\gamma \\ &\quad - B'(Q_M)\lambda F((1-\alpha)K_M(Q_M,\gamma),(1-\alpha)L_M(Q_M,\gamma)) \\ &\quad - B'(Q_M)(\lambda+\gamma)H(\alpha K_M(Q_M,\gamma),\alpha L_M(Q_M,\gamma)) \\ &\quad - \mu E'(Q_H)G(\cdot). \end{aligned} \tag{33}$$

Thus, equations (28) and (29) become

$$\begin{aligned} \frac{\partial\dot{\gamma}}{\partial Q_H} &= -B''(Q_H)(\lambda F(\cdot) + (\lambda+\gamma)H(\cdot)) - E''(Q_H)G(\cdot) \\ &\qquad - B'(Q_H)\lambda(1-\alpha)\left(F_K\frac{\partial K_M}{\partial Q_H} + F_L\frac{\partial L_M}{\partial Q_H}\right) \\ &\qquad - B'(Q_H)(\lambda+\gamma)\alpha\left(H_K\frac{\partial K_M}{\partial Q_H} + H_L\frac{\partial L_M}{\partial Q_H}\right) \end{aligned}$$

$$+ E'(Q_H)\mu \left(G_K \frac{\partial K_M}{\partial Q_H} + G_L \frac{\partial L_M}{\partial Q_H} \right) \quad (34)$$

$$\begin{aligned} \frac{\partial \dot{\gamma}}{\partial \gamma} &= (\rho + \delta) - B'(Q_H) H(\cdot) \\ &\quad - B'(Q_H)\lambda(1-\alpha) \left(F_K \frac{\partial K_M}{\partial \gamma} + F_L \frac{\partial L_M}{\partial \gamma} \right) \\ &\quad - B'(Q_H)(\lambda+\gamma)\alpha \left(H_K \frac{\partial K_M}{\partial \gamma} + H_L \frac{\partial L_M}{\partial \gamma} \right) \\ &\quad + E'(Q_H)\mu \left(G_K \frac{\partial K_M}{\partial \gamma} + G_L \frac{\partial L_M}{\partial \gamma} \right). \end{aligned} \quad (35)$$

$(Figure\ 3\ :\ Phase\ diagram\ of\ Knowledge\ Spillover)$

Proposition 3 *(1) and (2): Same as in Proposition 2.*
(3): If the learning function performs effectively, that is, there is little forgotten information, the export-led strategy makes domestic relative price closer to that of the world terms of trade in the long-run. Furthermore, export-led growth makes the subsidy small and adjustment speed faster in the knowledge spillover case than the case of an agrarian economy.

Proof: (1) and (2): Same as the proof of proposition 1 (1) and (2).
(3): If learning is effective, δ must be small. From equations (26) and (27), an increase in α makes $\dot{Q}_H = 0$ line slope downward. And if marginal effects of Q_H and γ on factor inputs (K_M and L_M) are equivalent, the slope of the $\dot{\gamma} = 0$ line becomes steeper (equations (34) and (35)). As a result, the effect of an increase in α will bring lower steady state value of γ. Further, from equation (32), the steady state value of domestic price approaches the world price, and from equation (23), the subsidy will become small and the adjustment speed becomes faster than in the case of the agrarian economy.

3 Conclusions

To summarize the findings in propositions (1), (2) and (3), for developing countries who have an infant but learning industry, there exists rationale for the government intervention. Without government intervention, the infant industry will disappear because of the penetration of foreign goods.

In this case, it is possible to know the optimal rate of subsidy. However, this tells us nothing about the active policy intervention for development. By introducing the idea of export-led growth into the model, we can obtain an active, non-passive policy tool to attain the faster growth.

This export-led growth policy has different effects according to the type of the economy. The economy with knowledge spillover can achieve a competitive structure faster than an economy without spillover between industries. The former is likely to apply to the export-led growth of economies such as Hong Kong and Singapore. And the latter is likely to explain the economic growth with relatively large agricultural sector, such as Thailand, Indonesia, and Malaysia. In these countries, it is plausible to assume that there is no technological spillover between manufacturing and agricultural sectors.

Although the degree of policy effect is different with various types of the economies, with a few assumptions, one finds that this active export-led policy tool has a strong effect on economic structure in the long-run.

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Appendix

In this appendix I briefly explain the knowledge spillover model with a non-tradable service sector. This leads to a model without trade balance assumption. However, only changes in budget constraints of manufacturing sector is needed for describing the model. Many articles on international macroeconomic models assume the existence of non-tradable sectors so as to analyze the terms of trade between domestic and international prices.[7]

This new budget constraint therefore becomes

$$\dot{b} = \bar{p}^{\,w} Y_M - \bar{p}^{\,w} C_M + rb.$$

That is, the consumer can borrow or lend freely through the international (bond) market.

The optimal condition for the supply side yields

$$p^{\,d} = \frac{E(Q_H)G_i}{B(Q_H)\left[(1-\alpha)F_i + \alpha H_i\right]} \tag{36}$$

for $i = K, L$.

Under these assumptions, the representative consumer would maximize the same utility as the previous models, and the corresponding current-value Hamiltonian is

$$\begin{aligned} H \equiv U(C_M, C_S) \quad &+ \quad \lambda\left[\bar{p}^{\,w} B(Q_H)\{F + H\} - \bar{p}^{\,w} C_M + rb\right] \\ &+ \quad \mu\left[E(Q_H)G - C_S\right] \\ &+ \quad \gamma\left[H - \delta Q_H\right]. \end{aligned}$$

From the optimality conditions of this problem,

$$\bar{p}^{\,w} = \frac{\partial U(C_M, C_S)}{\partial C_M} \Big/ \eta = \frac{U_M}{\eta}. \tag{37}$$

[7] Brief literature review is found in Turnovsky (1997).

From the optimum conditions with respect to K_M and L_M and defining $p^{\,d}$ as equation (21) with equation (22), we obtain

$$p^{\,d} = \frac{\gamma}{\mu}\,\phi + \frac{U_M}{\mu} = \frac{\gamma}{\mu}\phi + \frac{U_M}{U_S}, \tag{38}$$

where ϕ is already defined in the previous subsection.

Optimal rate of subsidy for this case therefore becomes

$$\bar{p}^{\,w}(1+\hat{\tau}) = p^{\,d}, \quad \textit{where} \;\; \hat{\tau} = \frac{\eta\,\gamma}{\mu\,U_M}\,\phi + \frac{\eta-\mu}{\eta}. \tag{39}$$

Unfortunately, however, from equations (37), (38),and (39), we cannot conclude that the subsidy is needed. We can no longer identify the optimal rate of subsidy, because from equation (39), subsidy τ can be negative depending on the values of μ and η, which exactly equal the marginal utilities of service and manufacturing goods.

Figure 1: Bardhan's Model

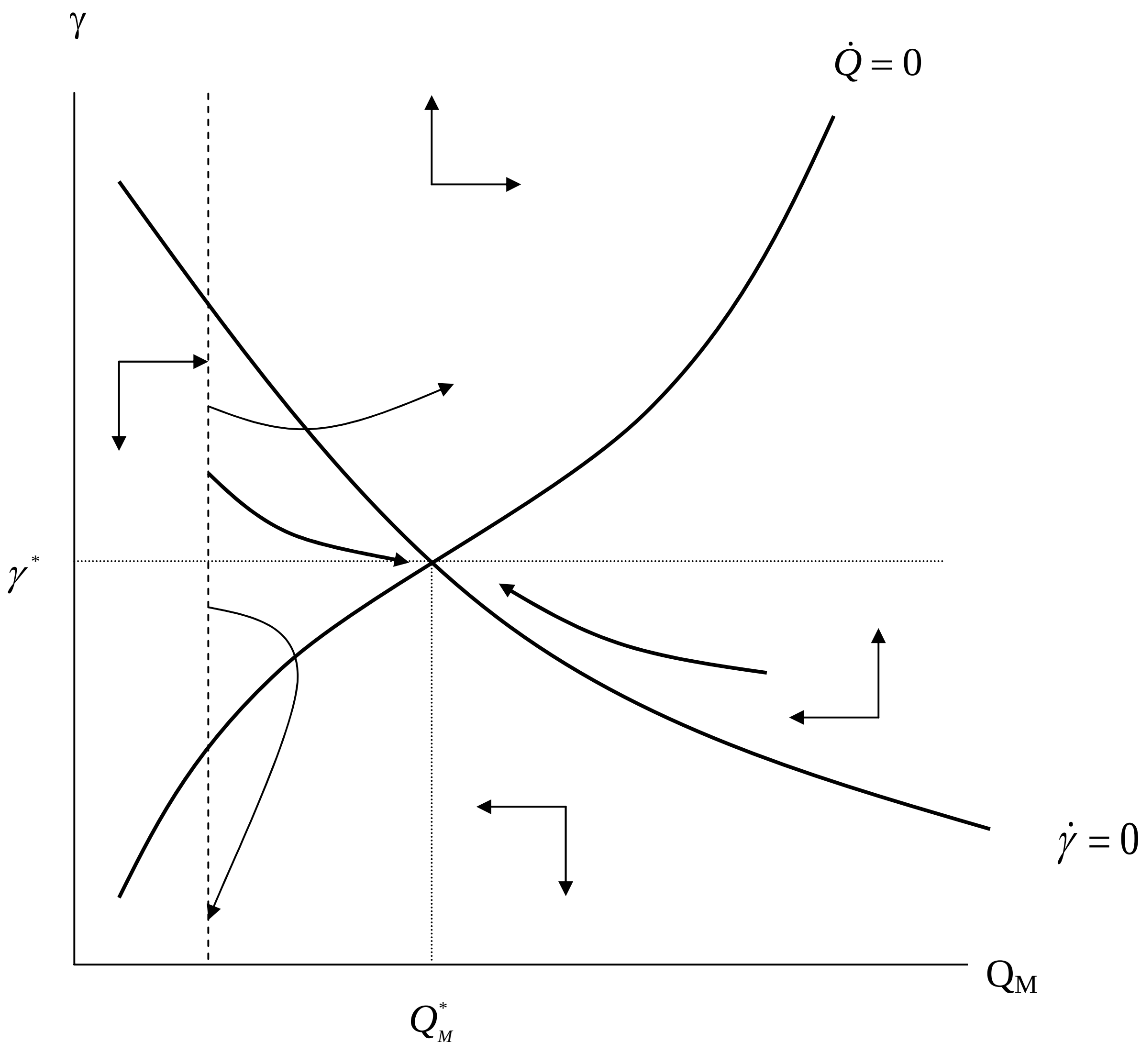

Figure 2: Agrarian Model

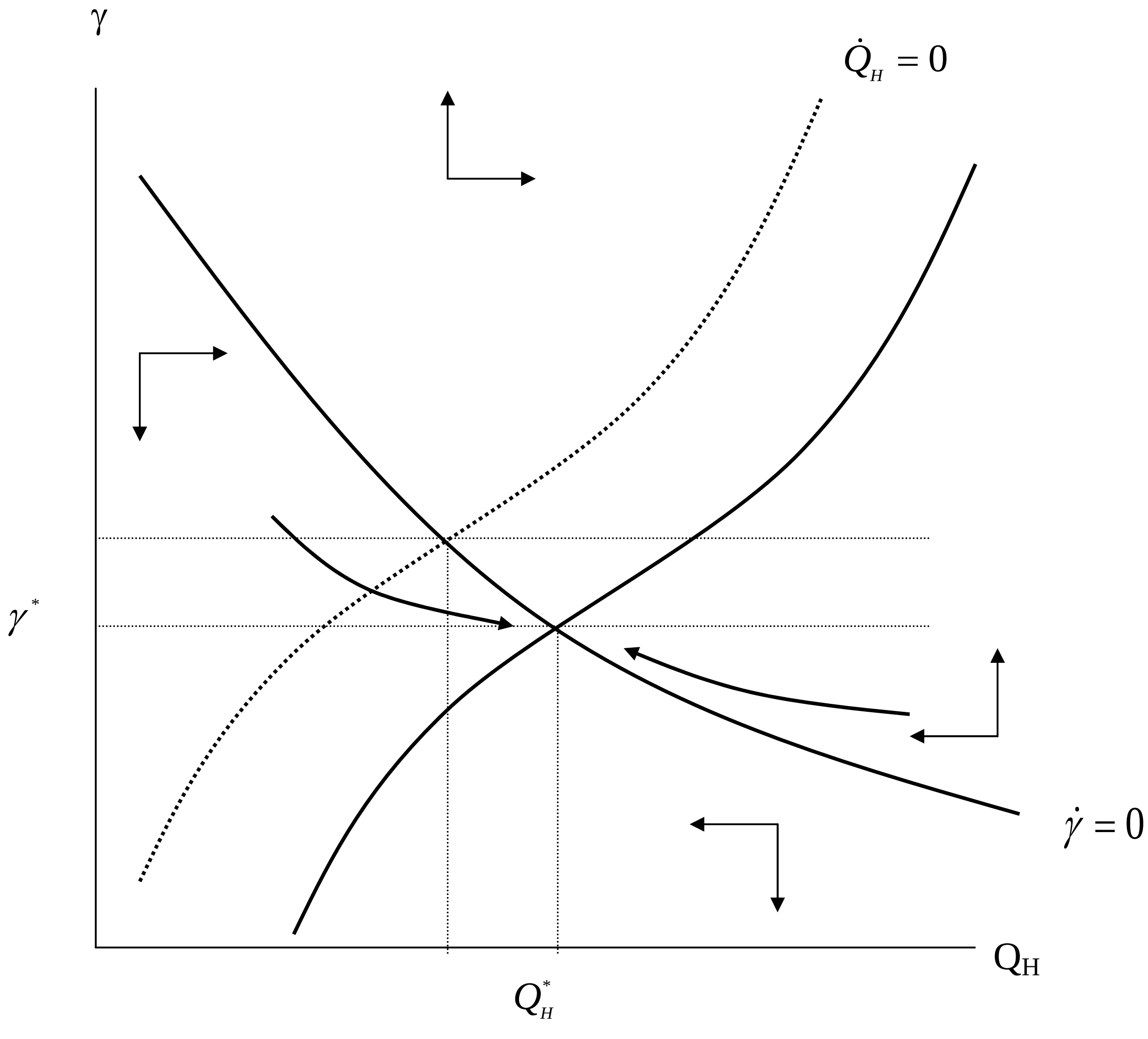

Figure 3: Spillover Model