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PERMANENT vs. TEMPORARY INFANT

INDUSTRY ASSISTANCE

by

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ABSTRACT

This paper develops a two period model in which a dynamic external economy, in the form of learning-by-doing spillovers, provides the rationale for infant industry assistance. The incentive effects of permanent and temporary assistance are then examined by introducing owner/manager effort into the learning process. It is shown, under conditions of symmetric information, that temporary assistance is optimal. Under conditions of asymmetric information, it is shown that a form of permanent assistance is optimal if the policy maker can commit to a Period 1 per unit output subsidy and a Period 2 lump-sum subsidy contingent on Period 2 output.

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CONTENTS

1. Introduction

There seems to be general agreement, at least in the academic literature, that some form of dynamic external economy must exist for there to be a rationale for infant industry assistance, [Kemp (1960), Baldwin (1969), Krueger and Tuncer (1982), and Succar (1987)]. It is usually argued that this assistance should be temporary because of a technological assumption that the dynamic external economy disappears once the industry matures, [Corden (1974), p 256].

The dynamic external economy most often considered is learning-by-doing within a firm which has spillover effects to other firms and industries. Learning-by-doing is usually modelled through a relationship whereby a firm's current marginal cost is lower the greater is its cumulative output prior to the current period [Spence (1981) and Fudenburg and Tirole (1983)]. This paper continues in this tradition but adds a new element. Specifically, learning-by-doing only occurs if the firm's owner/manager expends some effort in the learning process.[1] It is assumed that owner/manager effort increases the probability that learning will occur, that is, a deterministic relationship between effort and learning does not exist.[2] It is also assumed that the firm can only obtain learning-by-doing in the first period, this eliminates problems of time consistency which have been investigated in Matsuyama (1990).[3] On the surface it might seem that this assumption is similar to the technological assumption made in the traditional infant industry literature which ensured only temporary assistance. However, given the externality, there may be a role for permanent assistance as this increases the long term profitability of the firm and increases the incentive for the firm

[1] This idea was alluded to in Baldwin (1969), p. 299.

[2] Wright (1990) models learning-by-doing in this way, but does not consider the question of permanent versus temporary infant industry assistance.

[3] Although not modelled, if the world price falls over time because of learning-by-doing abroad and the domesctic firm does not obtain learning-by-doing in the first period, then its future losses can be so large that it is optimal for the policy maker to give no assistance in the second period and essentially close the industry down. Rather than modelling foreign learning-by-doing, to simplify the analysis without losing any insight, it is assumed that the domestic firm can only obtain learning in the first period.

to obtain the socially optimal amount of learning. This might be especially so where the effort of the owner/manager is unobservable to the policy maker.

For a two period model, demand and cost conditions are outlined in Section 2. In Section 3, it is assumed that there is symmetric information in that the policy maker can observe owner/manager effort. As a result, the policy maker can directly subsidise this effort. It is shown that temporary assistance, in the form of Period 1 per unit output and effort subsidies, is optimal.

In Section 4, it is assumed that there is asymmetric information in that the policy maker can not observe the effort of the owner/manager. Where the policy maker is restricted to per unit output subsidies, once again it is shown that temporary assistance is optimal. This is despite the fact that Period 2 per unit output subsidies encourage the firm to obtain learning. Where the policy maker can commit to a Period 2 lump-sum payment contingent on Period 2 output as well as a Period 1 per unit output subsidy, it is shown that this particular form of permanent assistance is optimal. In fact, this form of permanent assistance duplicates the symmetric information solution. Section 5 provides some concluding remarks.

2. Demand and Cost Conditions

The domestic economy is assumed to be a small open economy. Therefore, domestic firms are price takers at the world price, p^w.

It is assumed that production takes place in two periods. Period 1 is the learning phase and it is assumed that learning can only occur in this period. Period 2 is the mature phase where learning has ceased. In Period 1, a single domestic firm's cost function is given by $c_1(q_1)$, where q_1 is Period 1 output, $c_1'(q_1) > 0$, and $c_1''(q_1) > 0$. That is, marginal cost is increasing with output.[4]

As a result of learning-by-doing, in Period 2, a single firm's cost function is given by

$$c_2(q_2) = c_1(q_2) - \theta \cdot f(q_1) \cdot q_2, \tag{2.1}$$

[4] It is best to think of this increasing marginal cost arising from increases in factor prices as the industry expands rather than arising from diseconomies of scale.

where q_2 is Period 2 output, $f(q_1)$ encapsulates the traditional formulation of the learning curve with $f'(q_1) > 0$ and $f''(q_1) < 0$, and

$$\theta = \begin{cases} 1, & \text{with probability } \rho(a); \\ 0, & \text{with probability } (1-\rho(a)), \end{cases} \tag{2.2}$$

where a measures the effort expended by the firm's owner/manager to obtain learning, and $\rho'(a) > 0$, $\rho''(a) < 0$, $\rho(a) = 0$ if $a = 0$, and $\rho(a) < 1 \; \forall \; a$. The conditions on $\rho(a)$ capture the idea that the higher is effort expended by the owner/manager in the learning process, the higher is the probability that learning will occur. If $\theta = 1$, then Period 2 marginal cost is

$$c_2'(q_2) = c_1'(q_2) - f(q_1). \tag{2.3}$$

It is assumed that learning spills over from the industry being considered to other industries in the domestic economy and this externality provides the rationale for infant industry protection.[5] In the presence of learning-by-doing and the learning spillover, it is assumed that only one firm produces the product of interest in the domestic economy.[6]

3. Symmetric Information

The presence of the learning spillover means that in the absence of government policy welfare will not be maximised. As a result, both output and effort subsidies can be used to increase welfare. In this section, it is assumed that the policy maker can observe owner/manager effort and so can directly subsidise effort.

3.1. The Firm's Problem

In Period One, given s_1 and w_1, where s_1 is the Period 1 output subsidy and w_1 is the Period 1 effort subsidy, the firm maximises expected profit by choosing a and q_1. In

[5] Succar (1987) argues that inter-industry learning spillovers are as important as intra-industry spillovers, especially for developing countries.

[6] This assumption is the dynamic analogue of assuming natural monopoly in the presence of static economies of scale which are large relative to the size of the market. It maximises the opportunity of obtaining the learning.

Period Two, given s_2, where s_2 is the Period 2 output subsidy, and given the resolution of uncertainty and so the Period Two cost function, the firm chooses q_2 to maximise profit.

As is usual, this problem is solved backwards to guarantee optimal decisions are made at the start of each period.

3.1.1. Period Two

In Period 2, given the resolution of uncertainty and s_2, the firm maximises profit by choosing q_2. The firm's problem is

Problem 1:

$$\max_{q_2}\{\Pi_2(q_1, q_2, \theta, p^w, s_2) = p^w \cdot q_2 - (c_1(q_2) - \theta \cdot f(q_1) \cdot q_2) + s_2 \cdot q_2\}. \tag{3.1}$$

Assuming an interior solution, the first order condition for a maximum is

$$p^w - c_1'(q_2) + \theta \cdot f(q_1) + s_2 = 0. \tag{3.2}$$

Let the solution to this condition be given by $\hat{q}_2(q_1, \theta, p^w, s_2)$ and let maximised profit be given by $\hat{\Pi}_2(q_1, \theta, p^w, s_2)$.[7] Applying the implicit function theorem yields the following comparative static results

$$\frac{\partial \hat{q}_2}{\partial q_1} = \frac{\theta \cdot f'(q_1)}{c_1''(q_2)} > 0 \tag{3.3}$$

and

$$\frac{\partial \hat{q}_2}{\partial s_2} = \frac{1}{c_1''(q_2)} > 0. \tag{3.4}$$

3.1.2. Period One

In Period 1, given s_1 and w_1, the firm maximises expected profit by choosing a and q_1. The firm's problem is

[7] The second order condition for a maximum is satisfies because of the convexity of the cost function.

Problem 2:

$$\max_{a,q_1}\{\Pi^E(a, q_1, p^w, s_1, s_2, w_1) = p^w \cdot q_1 - c_1(q_1) + s_1 \cdot q_1 + \rho(a) \cdot \hat{\Pi}_2(1) + (1 - \rho(a)) \cdot \hat{\Pi}_2(0) - v(a) + w_1 \cdot a, \tag{3.5}$$

where $\hat{\Pi}_2(1)$ and $\hat{\Pi}_2(0)$ denote maximised Period 2 profit where $\theta = 1$ and 0 respectively and $v(a)$ is the cost of owner/manager effort with $v'(a) > 0$ and $v''(a) > 0$. Assuming an interior solution, after applying the envelope theorem and noting that $\frac{\partial \hat{\Pi}_2(0)}{\partial q_1} = 0$,

the first order conditions for a maximum are

$$\frac{\partial \Pi^E(\cdot)}{\partial a} = \rho'(a) \cdot (\hat{\Pi}_2(1) - \hat{\Pi}_2(0)) - v'(a) + w_1 = 0 \tag{3.6}$$

and

$$\frac{\partial \Pi^E(\cdot)}{\partial q_1} = p^w - c_1'(q_1) + s_1 + \rho(a) \cdot f'(q_1) \cdot \hat{q}_2(1) = 0. \tag{3.7}$$

It is assumed that the second order conditions for a maximum are satisfied.

Let the solution to the first order conditions be given by $\hat{q}_1(p^w, s_1, s_2, w_1)$ and $\hat{a}(p^w, s_1, s_2, w_1)$ and let maximised expected profit be given by $\hat{\Pi}^E(p^w, s_1, s_2, w_1)$.

Applying the implicit function theorem yields the following comparative static results

$$\frac{\partial \hat{q}_1}{\partial s_1} = \frac{-\rho''(\hat{a}) \cdot (\hat{\Pi}_2(1) - \hat{\Pi}_2(0)) + v''(\hat{a})}{|J|} > 0, \tag{3.8}$$

$$\frac{\partial \hat{a}}{\partial s_1} = \frac{\rho'(\hat{a}) \cdot \hat{q}_2(1) \cdot f'(\hat{q}_1)}{|J|} > 0, \tag{3.9}$$

$$\frac{\partial \hat{q}_1}{\partial s_2} = \frac{\left(\rho(\hat{a}) \cdot f'(\hat{q}_1)\frac{\partial \hat{q}_2(1)}{\partial s_2}\right) \cdot \left(-\rho''(\hat{a}) \cdot (\hat{\Pi}_2(1) - \hat{\Pi}_2(0)) + v''(\hat{a})\right)}{|J|} > 0, \tag{3.10}$$

$$\frac{\partial \hat{a}}{\partial s_2} = \frac{(\rho'(\hat{a}) \cdot \hat{q}_2(1)f'(\hat{q}_1)) \cdot \left(\rho(\hat{a}) \cdot f'(\hat{q}_1) \cdot \frac{\partial \hat{q}_2(1)}{\partial s_2}\right)}{|J|} > 0, \tag{3.11}$$

$$\frac{\partial \hat{q}_1}{\partial w_1} = \frac{\rho'(\hat{a}) \cdot f'(\hat{q}_1) \cdot \hat{q}_2(1)}{|J|} > 0, \tag{3.12}$$

$$\frac{\partial \hat{a}}{\partial w_1} = \frac{-\left(-c_1''(\hat{q}_1) + \rho(\hat{a}) \cdot f''(\hat{q}_1) - \rho(\hat{a}) \cdot f'(\hat{q}_1) \cdot \frac{\partial \hat{q}_2(1)}{\partial q_1}\right)}{|J|} > 0, \tag{3.13}$$

where $|J|$ is the Jacobian determinant which by the second order conditions for a maximum is greater than zero.

These comparative static results are what one would expect. An increase in s_1 increases $\hat{q}_1$, in turn, this increases the marginal expected profit of a and causes $\hat{a}$ to rise. An increase in s_2 also increases both $\hat{q}_1$ and $\hat{a}$ because it increases the marginal expected profit of a and q_1. Finally, an increase in w_1 increases $\hat{a}$, in turn, this increases the marginal expected profit of q_1 and causes $\hat{q}_1$ to rise.

3.2. The Policy Maker's Problem

The policy maker's problem is to maximise welfare by choosing s_1, s_2, and w_1, subject to the constraint that if it is optimal for the domestic firm to produce, then the domestic firm must make at least zero economic profit. It is assumed that the policy maker can commit to s_2 in Period 1, otherwise, after the learning-by-doing has occurred it is optimal for the policy maker to set $s_2 = 0$ as a positive s_2 reduces Period 2 net profit. The measure of welfare used is the sum of expected profit and the expected external benefit of learning-by-doing minus the sum of all expected per unit subsidies. This welfare measure ignores distribution considerations and also ignores consumer surplus because the price in the domestic economy is fixed at the world price.

The constraint can be satisfied by making a lump sum payment to the firm. This payment has no welfare significance becaues distribution considerations are being ignored. As a result, this constraint will be ignored in the formal analysis of the policy maker's problem as it has no operational consequence other than requiring a lump sum payment.

The policy maker's problem is

Problem 3:

$$\max_{s_1, s_2, w_1} \{W^E = \hat{\Pi}^E(\cdot) + B^E - s_1 \cdot \hat{q}_1 - w_1 \cdot \hat{a} - s_2 \cdot \left(\rho(\hat{a}) \cdot \hat{q}_2(1) + (1 - \rho(\hat{a})) \cdot \hat{q}_2(0)\right)\}, \quad (3.14)$$

where B^E denotes the expected external benefit and $\hat{q}_1$ and $\hat{a}$ are shortened version of $\hat{q}_1(p^w, s_1, s_2, w_1)$ and $\hat{a}(p^w, s_1, s_2, w_1)$ respectively. It is assumed that the external benefit

is an increasing function of the amount of learning-by-doing obtained in the industry of concern and is given by $B = B(\theta \cdot f(q_1))$, where $B'(\cdot) > 0$ and $B(\theta \cdot f(q_1)) = 0$ if $\theta = 0$. As a result,

$$B^E = \rho(\hat{a}) \cdot B(f(\hat{q}_1)). \quad (3.15)$$

After applying the envelope theorem, the first order conditions for a maximum to this problem are

$$\begin{aligned}\frac{\partial W^E}{\partial s_1} &= \left(\rho(\hat{a}) \cdot B'(\cdot) \cdot f'(\cdot) - s_1 - s_2 \cdot \rho(\hat{a}) \cdot \frac{\partial \hat{q}_2(1)}{\partial q_1}\right) \cdot \frac{\partial \hat{q}_1}{\partial s_1} \\ &\quad + \left(\rho'(\hat{a}) \cdot B(\cdot) - w_1 - s_2 \cdot \left(\rho'(\hat{a}) \cdot \left(\hat{q}_2(1) - \hat{q}_2(0)\right)\right)\right) \cdot \frac{\partial \hat{a}}{\partial s_1} = 0,\end{aligned} \quad (3.16)$$

$$\begin{aligned}\frac{\partial W^E}{\partial s_2} &= \left(\rho(\hat{a}) \cdot B'(\cdot) \cdot f'(\cdot) - s_1 - s_2 \cdot \rho(\hat{a}) \cdot \frac{\partial \hat{q}_2(1)}{\partial q_1}\right) \cdot \frac{\partial \hat{q}_1}{\partial s_2} \\ &\quad - s_2 \cdot \left(\rho(\hat{a}) \cdot \frac{\partial \hat{q}_2(1)}{\partial s_2} + (1 - \rho(\hat{a})) \cdot \frac{\partial \hat{q}_2(0)}{\partial s_2}\right) \\ &\quad + \left(\rho'(\hat{a}) \cdot B(\cdot) - w_1 - s_2 \cdot \left(\rho'(\hat{a}) \cdot \left(\hat{q}_2(1) - \hat{q}_2(0)\right)\right)\right) \cdot \frac{\partial \hat{a}}{\partial s_2} = 0,\end{aligned} \quad (3.17)$$

and

$$\begin{aligned}\frac{\partial W^E}{\partial w_1} &= \left(\rho(\hat{a}) \cdot B'(\cdot) \cdot f'(\cdot) - s_1 - s_2 \cdot \rho(\hat{a}) \cdot \frac{\partial \hat{q}_2(1)}{\partial q_1}\right) \cdot \frac{\partial \hat{q}_1}{\partial w_1} \\ &\quad + \left(\rho'(\hat{a}) \cdot B(\cdot) - w_1 - s_2 \cdot \left(\rho'(\hat{a}) \cdot \left(\hat{q}_2(1) - \hat{q}_2(0)\right)\right)\right) \cdot \frac{\partial \hat{a}}{\partial w_1} = 0.\end{aligned} \quad (3.18)$$

The intutition behind each of these conditions is similar. Increases in s_1, s_2, and w_1 increase $\hat{q}_1$ and $\hat{a}$. In turn, increases in $\hat{q}_1$ and w_1 have two counteracting effects on expected welfare. The first is that expected welfare tends to rise because the expected learning spillover increases and the second is that expected welfare tends to fall because the expected total subsidy payment rises. At the solution to the first order conditions, these counteracting effects are balanced at the margin. Let the solution to Problem 3 be given by $\hat{s}_1$, $\hat{s}_2$, and $\hat{w}_1$.

Proposition 1: *The symmetric information solution to the policy maker's problem involves $\hat{s}_2 = 0$. The optimal Period 1 output subsidy is set equal to the expected marginal externality of output, at the optimal solution, and the optimal Period 1 effort subsidy is set equal to the expected marginal externality of effort, at the optimal solution.*

Proof: Rearranging (3.16) yields

$$\left(\rho(\hat{a}) \cdot B'(\cdot) \cdot f'(\cdot) - s_1 - s_2 \cdot \rho(\hat{a}) \cdot \frac{\partial \hat{q}_2(1)}{\partial q_1}\right) = - \frac{\left(\rho'(\hat{a}) \cdot B(\cdot) - w_1 - s_2 \cdot \left(\rho'(\hat{a}) \cdot \left(\hat{q}_2(1) - \hat{q}_2(0)\right)\right)\right) \cdot \frac{\partial \hat{a}}{\partial s_1}}{\frac{\partial \hat{q}_1}{\partial s_1}}. \tag{3.19}$$

Substituting this into (3.17) and rearranging gives

$$\left(\rho'(\hat{a}) \cdot B(\cdot) - w_1 - s_2 \cdot \left(\rho'(\hat{a}) \cdot \left(\hat{q}_2(1) - \hat{q}_2(0)\right)\right)\right) \cdot \left(\frac{\partial \hat{a}}{\partial s_2} - \frac{\frac{\partial \hat{a}}{\partial s_1} \cdot \frac{\partial \hat{q}_1}{\partial s_2}}{\frac{\partial \hat{q}_1}{\partial s_1}}\right) = s_2 \cdot \left(\rho'(\hat{a}) \cdot \left(\hat{q}_2(1) - \hat{q}_2(0)\right)\right). \tag{3.20}$$

From the comparative static results

$$\left(\frac{\partial \hat{a}}{\partial s_2} - \frac{\frac{\partial \hat{a}}{\partial s_1} \cdot \frac{\partial \hat{q}_1}{\partial s_2}}{\frac{\partial \hat{q}_1}{\partial s_1}}\right) = 0, \tag{3.21}$$

so $\hat{s}_2 = 0$.

Given $\hat{s}_2 = 0$, and combining (3.18) and (3.16) yields

$$-\left(\rho'(\hat{a}) \cdot B(\cdot) - w_1\right) \cdot \left(\frac{\partial \hat{a}}{\partial w_1} - \frac{\frac{\partial \hat{a}}{\partial s_1} \cdot \frac{\partial \hat{q}_1}{\partial w_1}}{\frac{\partial \hat{q}_1}{\partial s_1}}\right) = 0. \tag{3.22}$$

From the comparative static results

$$\left(\frac{\partial \hat{a}}{\partial w_1} - \frac{\frac{\partial \hat{a}}{\partial s_1} \cdot \frac{\partial \hat{q}_1}{\partial w_1}}{\frac{\partial \hat{q}_1}{\partial s_1}}\right) \neq 0, \tag{3.23}$$

which implies that

$$\hat{w}_1 = \rho'(\hat{a}) \cdot B(\cdot), \tag{3.24}$$

and

$$\hat{s}_1 = \rho(\hat{a}) \cdot B'(\cdot) \cdot f'(\cdot). \tag{3.25}$$

(Q.E.D.)

The intutition behind Proposition 1 is quite simple. There are three choice variables for the policy maker, s_1, s_2, and w_1, but only two target variables, q_1 and a. Therefore, one of the choice variables is redundant and since s_1 and w_1 have a more direct effect on the target variables than s_2, the theory of distortions [Corden (1974) and Bhagwati (1971)] suggests that s_2 be made redundant.

One implication of Propostion 1 is that temporary assistance, in the form of Period 1 subsidies on output and effort, is optimal rather than permanent assistance, in the form of output subsidies in both periods. This is despite the fact that a Period 2 output subsidy gives the firm an incentive to increase learning, as can be seen from the comparative static results.

Another implication of Proposition 1 is that the assumption regarding the policy maker being able to commit to a Period 2 subsidy in Period 1 is not operational, as $\hat{s}_2 = 0$ at the solution to the policy maker's problem.

4. Asymmetric Information

In this section, it is assumed that the policy maker is unable to observe the effort of the owner/manager and as a result is unable to directly subsidise effort. That is, w_1 is no longer a choice variable for the policy maker. The policy maker can only give per unit subsidies on variables it can observe. One question addressed in this section, is whether under these information conditions it is still optimal to set $\hat{s}_2 = 0$, especially since the comparative static results imply that s_2 and w_1 have similar effects on Period 1 output and effort.

Three cases will be considered. The first is where the policy maker can commit to a Period 2 output subsidy in Period 1. The second is where no such commitment is possible and the third is where the policy maker can commit to a Period 2 lump-sum subsidy which is contingent on Period 2 output.

4.1. Committment to Period 2 Output Subsidy

In this section, it is assumed that the policy maker can commit to a Period 2 output subsidy in Period 1.

4.1.1. The Firm's Problem.

The firm's problem is identical to Problem 2 of Section 3 except the term associated with w_1 does not appear in the objective function. Let the solution to the firm's problem be given by $q_2(q_1, \theta, p^w, s_2)$, $\bar{q}_1(p^w, s_1, s_2)$, and $\bar{a}(p^w, s_1, s_2)$, and let maximised Period 2 profit and expected profit be respectively given by $\bar{\Pi}_2(q_1, \theta, p^w, s_2)$ and $\bar{\Pi}^E(p^w, s_1, s_2)$.

The comparative static results are qualitatively the same as (3.8) to (3.13) in Section 3, except they are calculated at $\bar{a}$, $\bar{q}_1$, $\bar{\Pi}_2(1)$, $\bar{\Pi}_2(0)$, and $\bar{\Pi}^E$. The intuition for these results is the same as in Section 3.

4.1.2. The Policy Maker's Problem

The policy maker's problem is identical to Problem 3 of Section 3, except the term associated with w_1 does not appear in the objective function and w_1 is no longer a choice variable. The first order conditions for a maximum are qualitatively the same as (3.16) and (3.17) in Section 3, except they are calculated at $\bar{q}_2(1)$, $\bar{q}_2(0)$, $\bar{q}_1$, and $\bar{a}$.

Proposition 2: *The asymmetric information solution to the policy maker's problem, where the policy maker can commit to a Period 2 output subsidy in Period 1, involves $\bar{s}_2 = 0$. The optimal Period 1 output subsidy is set greater than the expected marginal externality of output at the optimal solution.*

Proof: Combining the first order conditions of the policy maker's problem yields a qualitatively similar condition to (3.20) in Section 3. Namely,

$$\rho'(\bar{a})\cdot\Big(B(\cdot)-s_2\cdot\big(\bar{q}_2(1)-\bar{q}_2(0)\big)\Big)\cdot\left(\frac{\partial\bar{a}}{\partial s_2}-\frac{\frac{\partial\bar{a}}{\partial s_1}\cdot\frac{\partial\bar{q}_1}{\partial s_2}}{\frac{\partial\bar{q}_1}{\partial s_1}}\right)=s_2\cdot\Big(\rho'(\bar{a})\cdot\big(\bar{q}_2(1)-\bar{q}_2(0)\big)\Big). \quad (4.1)$$

From the comparative static results

$$\left(\frac{\partial\bar{a}}{\partial s_2}-\frac{\frac{\partial\bar{a}}{\partial s_1}\cdot\frac{\partial\bar{q}_1}{\partial s_2}}{\frac{\partial\bar{q}_1}{\partial s_1}}\right)=0, \quad (4.2)$$

so $\bar{s}_2 = 0$.

Given $\bar{s}_2 = 0$, the first order condition associated with s_1 becomes

$$\big(\rho(\bar{a})\cdot B(\cdot)\cdot f'(\cdot)-s_1\big)\cdot\frac{\partial\bar{q}_1}{\partial s_1}+\rho'(\bar{a})\cdot B(\cdot)\cdot\frac{\partial\bar{a}}{\partial s_1}=0. \quad (4.3)$$

Now $\frac{\partial\bar{q}_1}{\partial s_1}>0$ and $\rho'(\bar{a})\cdot B(\cdot)\cdot\frac{\partial\bar{a}}{\partial s_1}>0$, so $\big(\rho(\bar{a})\cdot B(\cdot)\cdot f'(\cdot)-s_1\big)<0$. This implies that

$$\bar{s}_1>\rho(\bar{a})\cdot B'(\cdot)\cdot f'(\cdot). \quad (4.4)$$

(Q.E.D.)

As a result, $\bar{s}_1$ is set greater than the size of the externality associated with q_1 in order to get a closer to its desired level.

It may seem surprising that one of the choice variables available to the policy maker is set equal to zero when only two choice variables are available. However, the intuition for $\bar{s}_2 = 0$ comes from there being a first order benefit, but only a second order cost from decreasing s_2, where $s_2 > 0$. A decrease in s_2 decreases $q_2(1)$, $q_2(0)$, q_1, and a which results in a first order benefit of

$$s_1\cdot\frac{\partial\bar{q}_1}{\partial s_2}+s_2\cdot\left(\rho(\bar{a})\cdot\frac{\partial\bar{q}_2(1)}{\partial s_2}+\big(1-\rho(\bar{a})\big)\cdot\frac{\partial\bar{a}}{\partial s_2}\right), \quad (4.5)$$

and a second order net cost of

$$\left(\rho(\bar{a})\cdot B(\cdot)\cdot f'(\cdot)-s_2\cdot\frac{\partial\bar{q}_2(1)}{\partial q_1}\right)\cdot\frac{\partial\bar{q}_1}{\partial s_2}+\Big(\rho'(\bar{a})\cdot\Big(B(\cdot)-s_2\cdot\big(\bar{q}_2(1)-\bar{q}_2(0)\big)\Big)\Big)\cdot\frac{\partial\bar{a}}{\partial s_2}. \quad (4.6)$$

As $\bar{s}_2 = 0$, there is no need to consider the case where the policy maker can not commit to a Period 2 per unit output subsidy.

4.2. The Policy Maker's Period One Problem With Contingent Lump-Sum Subsidies

In this section, it is assumed that the policy maker can commit in Period 1 to a Period 2 lump-sum subsidy which is contingent on Period 2 output of $\hat{q}_2(1)$. This is a variation on a mechanism first suggested by Loeb and Magat (1979) and essentially involves changing the domestic firm's objective function so that it coincides with that of the policy maker.[8]

Proposition 3: *In the presence of asymmetric information, if a Period 2 lump-sum subsidy equal to* $B\Big(f(\hat{q}_1(\hat{s}_1, \hat{w}_1))\Big)$ *is paid to the firm contingent on Period 2 output being* $\hat{q}_2(1)$ *and an output subsidy of* $\hat{s}_1$ *is paid in Period 1, then the symmetric information solution is attainable.*

Proof: In Period 2, the probability of output being $\hat{q}_2(1)$ is $\rho(a)$. Therefore, in Period 1, the domestic firm receives $B\Big(f(\hat{q}_1(\hat{s}_1, \hat{w}_1))\Big)$ with probability $\rho(a)$. The firm's Period 1 problem becomes

$$\max_{a, q_1}\{\Pi^E(a, q_1, p^w, s_1, s_2, w_1) = p^w \cdot q_1 - c_1(q_1) + s_1 \cdot q_1 + \rho(a) \cdot \hat{\Pi}_2(1) + (1 - \rho(a)) \cdot \hat{\Pi}_2(0) - v(a) + \rho(a) \cdot B\Big(f(\hat{q}_1(\hat{s}_1, \hat{w}_1))\Big). \tag{4.7}$$

Assuming an interior solution, the first order conditions for a maximum are

$$\frac{\partial \Pi^E(\cdot)}{\partial a} = \rho'(a) \cdot (\hat{\Pi}_2(1) - \hat{\Pi}_2(0)) - v'(a) + \rho'(a) \cdot B\Big(f(\hat{q}_1(\hat{s}_1, \hat{w}_1))\Big) = 0 \tag{4.8}$$

and

$$\frac{\partial \Pi^E(\cdot)}{\partial q_1} = p^w - c_1'(q_1) + s_1 + \rho(a) \cdot f'(q_1) \cdot \hat{q}_2(1) = 0. \tag{4.9}$$

If $\hat{w}_1$ and $\hat{s}_1$ are substituted into first order conditions (3.6) and (3.7), then conditions (4.8) and (4.9) are identical to (3.6) and (3.7) at $\hat{a}(\hat{s}_1, \hat{w}_1)$ and $\hat{q}_1(\hat{s}_1, \hat{w}_1)$. (Q.E.D.)

[8] Loeb and Magat examine a decentalised method for utility regulation in the presence of asymmetric information which consists of the monopolist choosing price and the regulator then paying the monopolist a lump sum equal to consumer surplus at this price. That is, the lump-sum subsidy is contingent on the price (and so output) of the monopolist.

The implication of Proposition 3 is that a form of permanent assistance (subsidies being given in both the learning and mature periods) is able to achieve the symmetric information solution even where the policy maker can not observe the effort of the owner/manager. However, this permanent assistance is of a very special type in that it involves a Period 2 lump-sum subsidy which is contingent on Period 2 output. This is consistent with the hidden action (moral hazard) literature where payments are based on observable variables [Laffont and Tirole (1986)]. In the context of this paper, the observable variable is Period 2 output.[9]

5. Conclusion

This paper has explicitly considered the incentive effects of permanent compared to temporary infant industry assistance. To do this a two period model was developed in which a dynamic external economy, in the form of learning-by doing spillovers, provided the rationale for assistance. The incentive effects of this assistance were examined by introducing owner/manager effort into the learning process.

It was shown that under conditions of symmetric information, where the policy maker could observe owner/manager effort, that temporary assistance, in the form of first period per unit output and effort subsidies, was optimal.

Under conditions of asymmetric information, where the policy maker could not observe owner/manager effort and was restricted to per unit output subsidies, it was shown that temporary assistance, in the form of a first period per unit output subsidy, was optimal. Where the policy maker could commit to a Period 2 lump-sum subsidy contingent on Period 2 output as well as a Period 1 per unit output subsidy, it was shown that this form of permanent assistance was optimal. In fact, this form of assistance can duplicate the symmetric information solution. This last result suggests more care is needed in designing

[9] If the second period cost function was observable, then the lump-sum subsidy could be made contingent on the cost fantion being $c_2(q_2) = c_1(q_2) - f\big(\hat{q}_1(\hat{s}_1, \hat{w}_1)\big) \cdot q_2$.

infant industry assistance, in the presence of asymmetric information, because, to the authors knowledge, no infant industry assistance package contains contingent lump-sum subsidies.

More research needs to be done in this area and some natural extensions to this paper include examing the effect of risk aversion as well as the effect of separation of ownership and control.

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