WORKING PAPERS IN ECONOMICS

HIDDEN ACTION AND LEARNING-BY-DOING IN MODELS OF MONOPOLY REGULATION AND INFANT INDUSTRY PROTECTION

by

DONALD J. WRIGHT

No. 150 NOVEMBER 1990

DEPARTMENT OF ECONOMICS

The University of Sydney Australia 2006
ABSTRACT

In this paper learning-by-doing involves a relationship whereby current period marginal cost is lower the greater is cumulative output prior to the current period only if the owner/manager expends effort in the learning process. This feature is incorporated into models of monopoly regulation and infant industry protection where it is found that, even when the policy maker is unable to observe owner/manager effort, the complete information solution is still attainable. This result is achieved using a mechanism in which a lump-sum subsidy is given, in the second period of a two period model, contingent on a particular output being produced. The novel aspect of this mechanism is that in the majority of the learning-by-doing literature temporary assistance is given which is not contingent on a particular output being produced.

* Department of Economics, The University of Sydney. The author thanks John Carson and seminar participants at the University of Sydney for many helpful comments.
**CONTENTS**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2. Cost Conditions</td>
<td>3</td>
</tr>
<tr>
<td>3. A Model of Monopoly Regulation</td>
<td></td>
</tr>
<tr>
<td>3.1 Complete Information</td>
<td></td>
</tr>
<tr>
<td>3.1.1. Period Two</td>
<td>4</td>
</tr>
<tr>
<td>3.1.2. Period One</td>
<td>5</td>
</tr>
<tr>
<td>3.2 Incomplete Information</td>
<td>7</td>
</tr>
<tr>
<td>4. A Model of Infant Industry Protection</td>
<td>9</td>
</tr>
<tr>
<td>4.1 Complete Information</td>
<td></td>
</tr>
<tr>
<td>4.1.1. Period Two</td>
<td>10</td>
</tr>
<tr>
<td>4.1.2. Period One</td>
<td>12</td>
</tr>
<tr>
<td>4.2 Incomplete Information</td>
<td>14</td>
</tr>
<tr>
<td>5. Conclusion</td>
<td>16</td>
</tr>
<tr>
<td>Addendum</td>
<td></td>
</tr>
</tbody>
</table>
1. Introduction

Learning-by-doing (production costs falling with cumulative output) and its implications have been analysed in a number of recent studies. Spence (1981) demonstrated that welfare is maximized when a single firm chooses current output so that current marginal cost exceeds current price by an amount equal to the reduction in future production costs associated with learning-by-doing. Spence also found that learning-by-doing can create substantial barriers to entry and that these barriers are greatest for moderate rates of learning.

The implications of learning-by-doing were further investigated by Fudenberg and Tirole (1984) who found in a two period model that, for strategic reasons, a firm has greater incentive to produce in the first (learning) period than in the second (mature) period. This result led to a novel welfare improving policy, namely, taxing first-period output and subsidizing second-period output.

Price uncertainty was introduced by Majd and Pindyck (1989) who found that this reduced the importance of learning-by-doing as a determinant of a competitive firm's current output because learning-by-doing can be viewed as an irreversible investment, the cost of which is greater the greater is price uncertainty. Nevertheless, learning-by-doing still had some impact on current output.

Finally, Dasgupta and Stiglitz (1988) argued that in the presence of powerful learning possibilities there is a tendency for the emergence of dominant firms and, when entry costs exist, the emergence of pure monopoly. Therefore, learning-by-doing can affect market structure.

In all of these papers learning-by-doing involves a relationship whereby current marginal cost is lower the greater is cumulative output prior to the current period. This feature is incorporated in this paper but in an amended form. Specifically, learning-by-doing only occurs if the firm's owner/manager expends some effort in the learning process.\footnote{In this work it is assumed that the firm has an owner/manager so that the effects of effort on the}
is assumed that effort does not have a deterministic effect on learning but rather increases the probability that learning-by-doing will occur.

The idea that learning-by-doing is not costless and requires some managerial effort if it is to take place was suggested by Baldwin (1969, p.299). Unless an owner/manager expends effort in monitoring and analyzing the production process as well as designing mechanisms that encourage experimentation, then, although there is potential for learning-by-doing, none might ever emerge. One of the innovations in this paper is the addition of an owner/manager effort variable to the learning function. The precise form in which owner/manager effort affects the learning function is outlined in section 2, as is its stochastic element.

In section 3 this learning function is used in a two period model of monopoly regulation, where learning only occurs in the first period. It is found that, even when the effort of the owner/manager is unobservable to the regulator, the regulator is able to achieve the complete information solution. The new aspect of the mechanism which achieves this result is that a lump-sum subsidy is paid to the monopolist in the second period, contingent on a particular output being produced. In Spence (1981) and Dasgupta and Stiglitz (1988) a lump-sum subsidy is paid to the monopolist, but it is not contingent on output.

A similar result is obtained in section 4 where a model of infant industry protection is considered. The model used is based on Dasgupta and Stiglitz (1988) and involves learning-by-doing that is internal to the firm. Nevertheless, because a monopoly market structure may result, not all the social benefits of learning-by-doing are necessarily internalised by the firm. Once again it is found that, even when the effort of the owner/manager is unobservable to the policy maker, the policy maker is able to achieve the complete information solution. The mechanism that achieves this result involves a second period contingent lump-sum subsidy. This is in sharp contrast to the bulk of the literature on infant industry protection where temporary assistance is given in the first (learning) period and is not contingent on output.

2. Cost Conditions

The firm can produce output in two periods. Period 0 is the learning phase and it is assumed that learning can only occur in this period. Period 1 is the mature phase where learning has ceased. In period 0 marginal cost is constant and given by $c_0$. In period 1 marginal cost is also constant and given by

$$c_1 = c_0 - \theta \cdot f(q_0),$$

where $q_0$ is period 0 output, $f(q_0)$ encapsulates the traditional formulation of the learning curve with $f'(q_0) > 0$ and $f''(q_0) < 0$, and

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

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 more effort that is expended by the owner/manager to obtain learning, the higher is the probability that learning will occur.

3. A Model of Monopoly Regulation

Given the monopolist's inverse demand curve, $p(q)$, and costs in each period, the regulator acts to maximize welfare, always ensuring that at the regulated solution the monopolist is achieving at least zero profit. If necessary, the latter is achieved via payment of a lump-sum subsidy.

3.1. Complete Information

In this section, it is assumed that the regulator can observe the monopolist's output and costs as well as the amount of effort expended by the owner/manager to obtain learning. It
is also assumed that both the regulator and the monopolist are risk neutral and that there is no discounting.

The regulator's faces a two period problem. In the first period the regulator chooses \( q_0 \), \( a \), and a lump-sum subsidy to maximize expected welfare. In the second period, given \( q_0 \) and \( a \) and \( \theta \) (the uncertainty having been resolved), the regulator chooses \( q_1 \) and a lump-sum subsidy to maximize welfare. To guarantee optimal decisions are made at the end of each period, this problem is solved backwards.

### 3.1.1. Period Two

Welfare is assumed to be the sum of net consumer surplus (net of any lump-sum subsidy paid to the firm) and firm profits and it is maximized by choice of output and a lump-sum subsidy. The regulator's problem is

\[
\max_{q_1, L_1} \left\{ W_1(q_1, L_1, q_0, \theta) \right\} = U(q_1) - p(q_1) \cdot q_1 - (1 + \gamma) \cdot L_1 + p(q_1) \cdot q_1 - (c_0 - \theta \cdot f(q_0)) \cdot q_1 + L_1 \right\} \tag{3.1}
\]

subject to:

\[
p(q_1) \cdot q_1 - (c_0 - \theta \cdot f(q_0)) \cdot q_1 + L_1 \geq 0, \tag{3.2}
\]

and

\[
q_1 \geq 0, \quad L_1 \geq 0, \tag{3.3}
\]

where

\[
U(q_1) = \int_0^q p(x)dx, \tag{3.4}
\]

so that the first line of the right-hand side of (3.1) is consumer surplus minus any lump-sum subsidy paid to the monopolist weighted by \((1 + \gamma)\) (it is assumed that the regulator can obtain revenue to pay a lump-sum subsidy only through a distoritionary tax scheme, so that the welfare cost of one unit of revenue raised is \((1 + \gamma)\)); the second line of the right-hand side is monopoly profit plus any lump-sum subsidy; constraint (3.2) ensures that the monopolist makes at least zero profit, and the constraints of (3.3) ensure nonnegativity of the choice variables.

By period 1, the values of \( q_0 \) and \( \theta \) have been determined. Assuming an interior solution for \( q_1 \), the solution to this problem is the familiar condition that price is set equal to marginal cost, \( p(q_1) = c_0 - \theta \cdot f(q_0) \), and \( L_1 = 0 \). Let the solution to this maximization problem be given by \( q_1 = q_1(q_0, \theta) \) and \( L_1 = L_1(q_0, \theta) \). Denote the maximised welfare function by \( W_1 = W_1(q_0, \theta) = W_1(q_1(q_0, \theta), L_1(q_0, \theta), q_0, \theta) \).

### 3.1.2. Period One

The regulator's problem is to maximize expected welfare by choosing \( q_0, a \), and \( L_0 \), looking forward to the affect these choices have in period two. This problem after some cancellation is

\[
\max_{q_0, a, L_0} \left\{ W_0(q_0, a, L_0) = U(q_0) - c_0 - q_0 + a - (1 - \rho(a)) \cdot W_1(q_0, 1) + (1 - \rho(a)) \cdot v(a) - (a) \right\} \tag{3.5}
\]

subject to:

\[
p(q_0) \cdot q_0 - (c_0 - v(a)) + L_0 \geq 0, \tag{3.6}
\]

and

\[
q_0 \geq 0, \quad a \geq 0, \quad L_0 \geq 0, \tag{3.7}
\]

where \( W_0 \) is expected welfare and \( v(a) \) is the cost to the owner/manager of effort with \( v'(a) > 0 \) and \( v''(a) > 0 \). It is assumed that an interior solution exists which allows the first order conditions for the Lagrangian of this problem to be written as

\[
\frac{\partial E}{\partial q_0} = p(q_0) - c_0 + \rho(a) \cdot f'(q_0) \cdot q_1(q_0, 1) + \lambda \cdot (\text{mrt}(q_0) - c_0) = 0, \tag{3.8}
\]

\[
\frac{\partial E}{\partial q_0} = p(q_0) - c_0 + \rho(a) \cdot f'(q_0) \cdot q_1(q_0, 1) + \lambda \cdot (\text{mrt}(q_0) - c_0) = 0, \tag{3.9}
\]

Given that the demand curve is downward sloping, the second order condition for a maximum is satisfied.
where use has been made of the envelope theorem,
\[
\frac{\partial L}{\partial \alpha} = p'(\alpha) \cdot (\bar{W}_1(q_0, 1) - \bar{W}_1(q_0, 0)) - (1 + \lambda) \cdot v'(\alpha) = 0, \quad (3.9)
\]
\[
\frac{\partial L}{\partial T_0} = -\gamma + \lambda = 0, \quad (3.10)
\]
\[
\frac{\partial L}{\partial \lambda} = p(q_0) - q_0 - c_0 \cdot q_0 + L_0 - v(\alpha) = 0, \quad (3.11)
\]
where \(\lambda\) is the Lagrange multiplier attached to constraint (3.6) and the monopolist's marginal revenue is given by \(m(r(q_0)) = \frac{\partial p(q_0)}{\partial q_0} \cdot q_0 + p(q_0)\). It is assumed that the monopolist's revenue function is strictly concave, that is \(\frac{\partial^2 m(r(q_0))}{\partial q_0^2} < 0\).

From (3.10) it is clear that \(\lambda = \gamma\).\footnote{For the solution to the period one problem to be of interest it must be the case that the solution of the period one problem involves \(\alpha > 0\) and \(q_0 > 0\). Given this it can be shown that \(\lambda > 0\) so constraint (3.4) holds. Nothing in the problem guarantees that \(L_0 > 0\) so it is possible for \(\gamma > \lambda\). However, for the purposes of this paper it is assumed that \(L_0 > 0\).} Making this substitution in (3.8) and (3.9) and rearranging yields
\[
p(q_0) = c_0 - p(\alpha) \cdot f'(q_0) \cdot \bar{q}_1(q_0, 1) + \gamma \cdot (c_0 - m(r(q_0))) \quad (3.12)
\]
and
\[
p'(\alpha) \cdot (\bar{W}_1(q_0, 1) - \bar{W}_1(q_0, 0)) = (1 + \gamma) \cdot v'(\alpha). \quad (3.13)
\]
The interpretation of condition (3.12) is that \(q_0\) is chosen so that price equals marginal production cost less the expected marginal cost saving in period 1 from learning-by-doing plus the cost of marginal lump-sum subsidies which are required for the monopolist to produce positive output. The interpretation of condition (3.13) is that \(\alpha\) is chosen so that marginal expected welfare in period 1 equals the marginal cost of effort to the owner/manager weighted by \((1 + \gamma)\).

Given \(v'(\alpha) > 0\), at the solution to (3.12) and (3.13) it is possible for \(p(q_0) > c_0\) if the third term in (3.12) is greater than the second term.\footnote{It is also assumed that \(v''(\alpha), f''(q_0), U''(q_0)\), and the monopolist's marginal revenue function are sufficiently concave and \(v''(\alpha)\) is sufficiently convex so that a unique maximum is obtained from the first order conditions of the period one problem.\} To simplify the analysis this paper abstracts from this case by assuming that \(\gamma\) is sufficiently small so that at the solution to the regulator's problem \(p(q_0) < c_0\).

Let the solution to the regulator's two period problem be
\[
(\hat{q}_1, \hat{\alpha}, \hat{L}_0) \quad \text{and} \quad \left(\hat{q}_1(q_0, 0), \hat{L}_1(q_0, 0)\right) \quad \text{or} \quad \left(\hat{q}_1(q_0, 1), \hat{L}_1(q_0, 1)\right). \quad (3.14)
\]
At this solution
\[
\hat{L}_0 = v'(\hat{\alpha}) - (p(\hat{q}_0) - c_0) \cdot \hat{q}_0 > 0 \quad (3.15)
\]
while
\[
\hat{L}_1(q_0, 0) = \hat{L}_1(q_0, 1) = 0. \quad (3.16)
\]

3.2. Incomplete Information

In this section, it is assumed that the regulator can continue to observe the monopolist's output and costs, but can no longer observe the amount of effort expended by the owner/manager to obtain learning because this is private information. Therefore, the regulator can force the monopolist to produce the optimal levels of output, but it can not force the monopolist's owner/manager to expend the optimal amount of effort.

If in period 0 the monopolist is given a lump-sum payment of \(\hat{L}_0\) in exchange for operating at \(\hat{q}_0\), the problem the owner/manager faces is
\[
\max_{\alpha} \left\{ e \equiv \hat{L}_0 + (p(\hat{q}_0) - c_0) \cdot \hat{q}_0 - v'(\hat{\alpha}) \right\}. \quad (3.17)
\]
The solution to this problem is for the owner/manager to set \(\alpha = 0\) and so make a profit of \(v'(\hat{\alpha})\).\footnote{Setting \(\alpha = 0\) guarantees that \(\theta = 0\).} Therefore, it appears that the complete information solution is not attainable when a lump-sum subsidy is paid in period 0. The problem is that the payment \(\hat{L}_0\) is made regardless of the value of \(\theta\), so there is no incentive for the owner/manager to put in costly effort and increase the probability of achieving \(\theta = 1\).
However, the complete information solution is attainable if in exchange for operating at the optimal outputs \( \hat{q}_0 \) and \( \hat{q}_1(\hat{q}_0, 1) \) or \( \hat{q}_1(\hat{q}_0, 0) \), a lump-sum subsidy of \( k \) is made in period 1, contingent on the output of the firm being \( \hat{q}_1(\hat{q}_0, 1) \) in period 1, and also a noncontingent lump-sum subsidy/tax of \( K \) is made in period 1. The monopolist’s problem now is

$$
\max_a \left( \Pi^K = K + \left( p(\hat{q}_0) - c_0 \right) \cdot \hat{q}_0 + \rho(a) \cdot k - v(a) \right),
$$

(3.18)

where \( \Pi^K \) denotes expected profit of the monopolist net of the cost of effort. The first order condition of this problem is

$$
\frac{d\Pi^K}{da} = \rho'(a) \cdot k - v'(a) = 0.
$$

(3.19)

If

$$
\begin{align*}
\hat{W}_1(\hat{q}_0, 1) - \hat{W}_1(\hat{q}_0, 0) - \gamma \frac{v'(\hat{a})}{\rho'(\hat{a})},
\end{align*}
$$

(3.20)

then first order condition (3.19) is identical to first order condition (3.13) at \( \hat{a} \) and the monopolist’s owner/manager chooses the optimal amount of effort \( \hat{a} \).

The expected profit of the monopolist net of the cost of effort is

$$
\Pi^K = K + \left( p(\hat{q}_0) - c_0 \right) \cdot \hat{q}_0 + \rho(\hat{a}) \cdot k - v(\hat{a})
$$

(3.21)

which can be made at least zero by choice of \( K \). This guarantees the participation of the monopolist in the optimal solution.\(^8\)

Proposition 1: A regulatory mechanism in which a period 1, noncontingent, lump-sum subsidy or tax (depending on the size of \( \rho(\hat{a}) \cdot k + (p(\hat{q}_0) - c_0) \cdot \hat{q}_0 - v(\hat{a}) \)) is coupled with a period 1, output contingent, lump-sum subsidy is able to achieve the complete information solution, even though the regulator cannot observe owner/manager effort.\(^9\)

---

This mechanism has intuitive appeal as the regulator wants there to be some positive probability that the firm produces \( \hat{q}_1(\hat{q}_0, 1) \) in period 1 (as long as \( \hat{a} > 0 \)), and it achieves this by making the payment \( k \) contingent on \( \hat{q}_1(\hat{q}_0, 1) \) being produced in period 1.

To implement the complete information solution requires a contingent lump-sum subsidy to be paid in period 1 when learning has ceased. This result runs counter to most of the literature regarding learning-by-doing in which a lump-sum subsidy is paid which is not contingent on a particular output being produced. This highlights the importance of specifying carefully the information available to the regulator, as very different policies are optimal depending on whether owner/manager effort is observable or not.

The above model could be extended by allowing \( c_0 \) and \( f(q_0) \) to be private information. In this case, the models of Baron and Myerson (1982) and Laffont and Tirole (1985) would be relevant. However, this extension is not carried out in this paper as it would tend to cloud the importance of the contingent lump-sum subsidy in period 1 in obtaining optimal effort from the firm’s owner/manager.

4. A Model of Infant Industry Protection

The traditional argument for infant industry protection in the presence of learning-by-doing assumes that any learning is external to the firm [Kemp 1960, Clemhout and Wan 1970, and Succar 1987].\(^{10}\) However, in this section, a model of infant industry protection is developed which is based on Dagsvort and Stiglitz (1988) and in which learning-by-doing is internal to the firm, the domestic market structure is monopoly, and the foreign market, where learning has ceased, is perfectly competitive. In this framework there might be a role for policy intervention because the domestic monopolist may not internalise all the social benefits of learning-by-doing.

The world inverse demand curve in each period is given by \( p^w(q + q^*) \), where \( q \) is domestic output and \( q^* \) is foreign output. Zero transportation costs ensure that the world...
price equals the domestic price which in turn allows domestic consumption to be obtained from

\[ p^*(q + q^*) = p^d(q^d), \]  

(4.1)

where \( p^d(q^d) \) is the domestic inverse demand curve. It is assumed that \( c_0 > c^* \) and that \( c_1 = (c_0 - f(q_0)) < c^* \) for some \( q_0 \), where \( c^* \) is foreign marginal cost in each period.

Given this data, the policy maker acts to maximise domestic welfare, always ensuring that at the solution the domestic firm is achieving at least zero profit. The set up of the infant industry model is very similar to that of the preceding monopoly regulation model.

4.1. Complete Information

In this section, it is assumed that the policy maker can observe the domestic firm’s output and costs as well as the amount of effort expended by the owner/manager to obtain learning. It is also assumed that the policy maker and the domestic firm are risk neutral and that there is no discounting.

The policy maker’s faces a two period problem. In the first period the policy maker chooses \( q_0, a, \) and a lump-sum subsidy to maximise expected welfare. In the second period, given \( q_0, a, \) and \( \theta \) (the uncertainty having been resolved), the policy maker chooses \( q_1 \) and a lump-sum subsidy to maximize welfare. To guarantee optimal decisions are made at the end of each period, this problem is solved backwards.

4.1.1. Period Two

Welfare is assumed to be the sum of net domestic consumer surplus (net of any lump-sum subsidy paid to the firm) and firm profit and it is maximized by choice of output and a lump-sum subsidy. The policy maker’s problem is

\[
\max_{a, t} \left\{ W_t(q_t, L_t, q_0, \theta) = U^d\left(q_t^d(q_t + q^d)\right) \right. \\
- p^d_t(q_t + q^d) \cdot q_t - (c_0 - \theta \cdot f(q_0)) \cdot q_t + L_t \\
+ \left. p^d_t(q_t + q^d) \cdot q_t - (c_0 - \theta \cdot f(q_0)) \cdot q_t + L_t \right\} 
\]

(4.2)

subject to:

\[
p^d_t(q_t + q^d) \cdot q_t - (c_0 - \theta \cdot f(q_0)) \cdot q_t + L_t \geq 0, \quad (4.3)
\]

\[
c^* - p^d_t(q_t + q^d) \geq 0, \quad (4.4)
\]

and

\[
q_t \geq 0, \quad L_t \geq 0 \quad (4.5)
\]

where

\[
U^d(q^d) = \int_{q^d}^{q^*} p^d(q) dq; \quad (4.6)
\]

domestic consumption is given by \( q^*_t \). The first and second lines of the right hand side of (4.2) represent domestic consumer surplus minus any lump-sum subsidy paid to the domestic firm weighted by \( (1 + \gamma) \); the third line is the domestic firm’s profit in the domestic and foreign markets plus any lump-sum subsidy; constraint (4.3) ensures that the monopolist makes at least zero profit; constraint (4.4) ensures that the world price with domestic production is less than or equal to \( c^* \); and the constraints of (4.5) ensure nonnegativity of the choice variables.

The solution to this problem depends on \( q_0 \). Let \( q^*_0 \) be given by \( c_0 - \theta \cdot f(q_0) = c^* \). If

\[
q_0 \leq q^*_0, \text{ then } c_0 - \theta \cdot f(q_0) \geq c^* \text{ and } q_1 = 0. \quad \text{That is, it is not optimal to produce in period 1 because the product can be imported at lower cost than produced domestically. Clearly if } q_1 = 0, \text{ then } L_1 = 0.
\]

\[ q^*_0 \] is a function of world price, \( p^d_t \), which in turn is a function of the sum of domestic and foreign output \( (q_t + q^d) \). The world price without domestic production.
If $q_0 > q_0^*$, then $c^* - q_0 \cdot f(q_0) < c^*$, $p_0^*(q_1) \leq c^*$, $q_1 > 0$, and $q_1^* = 0$. For there to be an argument for infant industry protection, it must be the case that $p_0^*(q_1) < c^*$, otherwise social and private benefits coincide. Therefore, this paper is concerned with the case where constraint (4.4) does not bind. If constraint (4.4) does not bind then neither does constraint (4.3), and the first order condition of the Lagrangian to the period two problem can be written as

$$p_0^*(q_1) + \frac{\partial p_0^*(q_1)}{\partial q_1} \cdot (q_1 - q_1^*) = (c^* - q_0 \cdot f(q_0)).$$

(4.7)

The interpretation of this condition is that $q_1$ is chosen so that the consumers' marginal evaluation of $q_1$, plus the loss in revenue from existing foreign sales equals marginal production costs.\footnote{It is assumed that the revenue function is concave so the second order conditions for a unique maximum are satisfied.} From (4.7) it is clear that $p_0^*(q_1) > c^* - q_0 \cdot f(q_0)$ and that $L_1 = 0$.

Let the solution to this maximization problem be given by $\delta_1 = \delta_1(q_0, \theta)$ and $L_1 = \bar{L}_1(q_0, \theta)$. Let the maximized welfare function be $\bar{W}_1 = \bar{W}_1(q_0, \theta)$ and the domestic firm's profit at this solution be given by $\bar{F}_1(q_0, \theta)$.

### 4.1.2. Period One

In period one $c^* > c^*$ and perfect competition in the foreign country ensures that $p_0^* = c^*$. The policy maker's problem is to maximize expected welfare by choosing $q_0$, $\alpha$, and $L_0$, looking forward to the affect these choices have in period two. This problem is

$$\max_{q_0,\alpha, L_0} \{ W_0^E(q_0, \alpha, L_0) = U^d(q_0(c^*)) - c^* \cdot q_0 - (1 + \gamma) L_0 \}
+ c^* \cdot q_0 - c_0 \cdot q_0 + L_0
+ \rho(\alpha) \cdot \bar{W}_1(q_0, 1) \}
$$

subject to:

$$\begin{align*}
&c^* \cdot q_0 - c_0 \cdot q_0 - v(\alpha) + \rho(\alpha) \cdot \bar{F}_1(q_0, 1) + L_0 \geq 0,
\end{align*}$$

(4.9)

and

$$q_0 \geq 0, \quad \alpha \geq 0, \quad L_0 \geq 0$$

(4.10)

where $W^E$ is expected welfare; the first line of the right hand side represents domestic consumer surplus minus any lump-sum subsidy paid to the domestic firm weighted by $(1 + \gamma)$; the second line of the right hand side represents the domestic firm's loss in the domestic and foreign markets plus any lump-sum subsidy; the third line of the right hand side represents expected welfare in period 1 net of the cost of owner/manager effort; constraint (4.9) ensures that the monopolist makes at least zero expected profit, and constraints (4.10) ensure non-negativity of the choice variables.

As this paper is concerned with infant industry protection, the only solution to the period one problem that is of interest involves $q_0 > q_0^*$, $q_0$ being such that the solution to the period two problem involves $p_0^*(q_1) < c^*$, and $L_0 > 0$. If $q_0 \leq q_0^*$, then $q_1 = 0$ and there is no role for infant industry protection as it is optimal to produce no output in period 1. If $q_0 > q_0^*$ and the solution to the period two problem involves $p_0^*(q_1) = c^*$, then as argued above, the social benefits of learning—by-doing are all captured by the domestic firm and there is no role for infant industry protection. Therefore, this paper is only concerned with solutions to the period one problem that involve $q_0 > q_0^*$, the solution to the period two problem involving $p_0^*(q_1) < c^*$, and $L_0 > 0$.

It is assumed that an interior solution exist to the period one problem, in which case rearraanging the first order conditions of the Lagrangian yields\footnote{It is assumed that $p_0^*(\alpha)$ and $f^*(q_0)$ are sufficiently concave and $\psi^*(\alpha)$ is sufficiently convex so a unique maximum is obtained from the first order conditions of the period one problem.}

$$
(1 + \gamma) \cdot (c_0 - c^*) = \rho(\alpha) \cdot f_1^*(q_0) \cdot \delta_1(q_0, 1) + \rho(\alpha) \cdot \gamma \cdot \frac{d\bar{F}_1(q_0, 1)}{dq_0}
$$

(4.11)

and

$$\rho(\alpha) \cdot (\bar{W}_1(q_0, 1) - \bar{W}_1(q_0, 0) + \gamma \cdot \bar{F}_1(q_0, 1)) = (1 + \gamma) \cdot \psi^*(\alpha).
$$

(4.12)

The interpretation of condition (4.11) is that $q_0$ is chosen so that the weighted marginal loss on period 0 output equals the expected marginal benefit of cost savings in period 1 from...
learning-by-doing plus the expected marginal benefit of period 1 profits in period 0. The interpretation of condition (4.12) is that \( a \) is chosen so that marginal expected welfare in period 1 plus the marginal expected benefit of period 1 profits equals the marginal cost of effort to the owner/manager weighted by \((1 + \gamma)\).

Let the interior solution to the policy maker’s two period problem, given \( q_0 > \bar{q}_0 \), be

\[
\left( \bar{q}_0, \bar{a}, \bar{L}_0 \right) \quad \text{and} \quad \left( \bar{q}_1(q_0, 0), \bar{L}_1(q_0, 0) \right) \quad \text{or} \quad \left( \bar{q}_1(q_0, 1), \bar{L}_1(q_0, 1) \right) \tag{4.13}
\]

At this solution

\[
\bar{L}_0 = v(\bar{a}) - (c^* - c_0) \cdot \bar{q}_0 - \rho(\bar{a}) \cdot \bar{II}(1, \bar{q}_0) > 0 \tag{4.14}
\]

while

\[
\bar{L}_1(q_0, 0) = \bar{L}_1(q_0, 1) = 0. \tag{4.15}
\]

4.2. Incomplete Information

In this section, it is assumed that the policy maker can continue to observe the domestic firm’s output and costs, but can no longer observe the amount of effort expended by the owner/manager to obtain learning because this is private information. Therefore, the policy can force the domestic firm to produce the optimal levels of output, but it can not force the firm’s owner/manager to expend the optimal amount of effort.

If in period 0 the domestic firm is given a lump-sum payment of \( L_0 \) in exchange for operating at \( \bar{q}_0 \), the problem the owner/manager faces is

\[
\max_a \left\{ v(\bar{a}) - (c^* - c_0) \cdot \bar{q}_0 - \rho(\bar{a}) \cdot \bar{II}(1, \bar{q}_0) \right\}. \tag{4.16}
\]

The solution to this problem is for the owner/manager to set \( a = 0 \) and so make a profit of \( v(\bar{a}) - \rho(\bar{a}) \cdot \bar{II}(1, \bar{q}_0) \). It therefore appears that the complete information solution is not attainable when a lump-sum subsidy is paid in period 0. The problem in that the payment \( L_0 \) is made regardless of the value of \( \theta \), so there is no incentive for the owner/manager to put in costly effort and increase the probability of achieving \( \theta = 1 \). This result is identical to that obtained in the monopoly regulation model. It should also be noted that this result provides some theoretical support for the argument that if an infant industry is given temporary first period assistance, then it never grows up, that is, its marginal cost remains above that of foreign firms.\(^{15}\)

However, as in the monopoly regulation model, the complete information solution is attainable if in exchange for operating at the optimal outputs \( \bar{q}_0 \) and \( \bar{q}_1(q_0, 1) \) or \( \bar{q}_1(q_0, 0) \), a lump-sum subsidy of \( k \) is made in period 1, contingent on the output of the firm being \( \bar{q}_1(q_0, 1) \) in period 1, and also a noncontingent lump-sum subsidy/tax of \( K \) is made in period 1. The domestic firm’s problem is now

\[
\max_a \left\{ \Pi^E \equiv K + (c^* - c_0) \cdot \bar{q}_0 + \rho(\bar{a}) \cdot k - v(\bar{a}) \right\}. \tag{4.17}
\]

where \( \Pi^E \) denotes expected profit of the firm net of the cost of effort. The first order condition of this problem is

\[
\frac{d\Pi^E}{da} = -\rho'(\bar{a}) \cdot k - \psi'(\bar{a}) = 0. \tag{4.18}
\]

If

\[
k = \bar{W}_1(\bar{q}_0, 0) - \bar{W}_1(q_0, 0) + \gamma \cdot \bar{II}(\bar{q}_0, 1) - \frac{\psi'(\bar{a})}{\rho'(\bar{a})}, \tag{4.19}
\]

then first order condition (4.18) is identical to first order condition (4.12) at \( \bar{a} \) and the domestic firm’s owner/manager chooses the optimal amount of effort \( \bar{a} \).

The expected profit of the domestic firm net of the cost of effort is

\[
\Pi^E = K + (c^* - c_0) \cdot \bar{q}_0 + \rho(\bar{a}) \cdot k - v(\bar{a}) \tag{4.20}
\]

\(^{15}\) Matsuyama (1990) summarizes the argument that infant industries never grow up if given temporary assistance. An important difference between the argument in this paper and the traditional argument about incentives in infant industry protection is that in this paper a lump-sum subsidy is used rather than a per-unit subsidy. One should note however that the policy examined in this paper is optimal whereas a per-unit subsidy is not.
which can be made at least zero by choice of \( K \). This guarantees the participation of the domestic firm in the optimal solution.

**Proposition 2**: A mechanism in which a period 1, noncontingent, lump-sum subsidy or tax (depending on the size of \((c^* - c_0) \cdot \bar{g}_0 + p(\bar{a}) \cdot k - v(\bar{a})\)) is coupled with a period 1, output contingent, lump-sum subsidy is able to achieve the complete information solution even though the policy maker cannot observe owner/manager effort.

This mechanism has the same intuitive appeal as the monopoly regulatory mechanism in that the policy maker wants there to be some positive probability that the firm produces \( \bar{q}_1(\theta_0, 1) \) in period 1 (as long as \( \bar{a} > 0 \)), and it achieves this by making the payment \( k \) contingent on \( \bar{q}_1(\theta_0, 1) \) being produced in period 1.

To implement the complete information solution requires a contingent lump-sum subsidy to be paid in period 1 when learning has ceased. This result runs counter to most of the literature regarding infant industry protection and learning-by-doing in which a temporary protection is given in period 0, when learning occurs, and is removed, when learning has ceased. Once again this highlights the importance of specifying carefully the information available to the policy maker as very different policies are optimal depending on whether owner/manager effort is observable or not.

5. **Conclusion**

This paper introduced owner/manager effort into the literature on learning-by-doing. This was done by assuming that current period marginal cost is lower the greater is cumulative output prior to the current period only if the owner/manager expends some effort in the learning process.

A cost function which incorporated this feature was then imbedded in two period models of monopoly regulation and infant industry protection. The major result was that, in both models, although owner/manager effort was not observable by the policy maker, the complete information solution was attainable. This was achieved via a mechanism in which a lump-sum subsidy was paid in the second period (i.e. after learning had ceased) contingent on a certain output being produced in that period. As the majority of the literature on learning-by-doing has the policy maker giving temporary assistance which is not contingent on a particular output being produced, this paper highlights the need to be careful when specifying the information available to policy makers because quite different policies may be optimal under different information assumptions.

An obvious extension to this paper is the introduction of incomplete information on the part of the policy maker about the firm's costs. However, this paper has not incorporated this feature in an attempt to bring into as sharp relief as possible the effects of unobservable owner/manager effort in models where learning-by-doing plays an important role.
REFERENCES


104 P. Groenevagen
105 L. Ermini
106 G. Mills
107 B.W. Ross
108 S.S. Joson
109 B.W. Ross
110 L. Ermini
111 L. Ermini
112 P. Groenevagen
113 V.B. Hall, T.P. Truong, & V.A. Nguyen
114 V.B. Hall, T.P. Truong, & V.A. Nguyen
115 F. Gill
116 C. Kingston
117 V.B. Hall & D.R. Mills
118 M.P. Hogan
119 L. Ermini
120 P. Groenevagen
121 M.C. Black & N. Dallan
122 W.P. Hogan & J.O. Sharpe
123 G. Mills
124 L. Ermini
125 E. Kiernan
126 F. Gill

Working Papers
in Economics

Taxation and Decentralisation: A Reconsideration of the Costs and Benefits of a Decentralised Tax System; March 1988
Some New Evidence on the Timing of Consumption Decisions and on Their Generating Process; March 1988
Socially-Differentiated Trucking Markets: Equilibria under Price Regulation without Entry Restrictions; April 1988
Strategic Commitment, Uncertainty, and the Nature of Entrepreneurial Activity; April 1988
Offsets and Development of Defence Support Industries in Small Economies; April 1988
The Conglomerate and the Focused Agglomeration: Modern Forms of the Leader-Commanded Firm; July 1988
Inertial Behavior on Schedule and Hierarchical Decomposition; July 1988
The Limits of Systems Control Theory in Economic Policy-Making; July-October 1988
Neo-Classical Value and Distribution Theory: The English Speaking Pioneers; September 1988
An Australian Fuel Substitution Tax Model: ORAM-LIFT; October 1988
Responses to World Oil and Coal Shocks, in an Australian Short-Run Fuel Substitution Tax Model; October 1988
Social Justice and the Low-Paid Worker; October 1988
Theoretical Foundations of Constant-Proportion Portfolio Insurance; October 1988
Is Medium Temperature Solar Thermal Process Steam Viable for Australia? Some Preliminary Results; November 1988
Insider Information and Market Adjustment: November 1988
Reinterpreting a Recent Temporarily Aggregated Consumption-Cap Model; December 1988
Progressive Personal Income Tax - A Historical Perspective; December 1988
Rubinstein's Solution of the Bargaining Problem; Some Generalisations and Extensions; December 1988
Prudential Regulation of Bank Ownership and Control; January 1989
The Reform of Australian Aviation: June 1989
Transitory Consumption and Measurement Errors in the Permanent Income Hypothesis; June 1989
Is Austerity Necessary?; July 1989
Labour Market Flexibility - To What End?; August 1989
Working Papers in Economics Published Elsewhere

4. V.J. Hall & M.L. King, *Economic Record*, 53(163), September 1977
16. Economic Record, 56(152), March 1980
17. Australian Journal of Management, 10, October 1979
19. Australian Economic Papers, 19(34), June 1980
21. Australian Economic Papers, 18(33), December 1979
23. Australian Economic Papers, 21(39), December 1982
31. Economic Record, 57(159), December 1981
32. APSF, Commissioned Studies and Selected Papers, AOPS, IV 1982
33. Economic Record, 59(161), June 1982
34. Seventh Australian Transport Research Forum-Papers, Hobart, 1982
35. Economic Record, 60(168), March 1984
36. Economic Record, 59(166), September 1983
37. Economic Appliances, 37(3-4), 1984

Copies are available upon request from:

Department of Economics,
The University of Sydney,
N.S.W. 2006, Australia.
<table>
<thead>
<tr>
<th>No.</th>
<th>Author(s)</th>
<th>Title and Journal or Book Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>61</td>
<td>A. G. Forgan</td>
<td>Australian Economic Papers, 12(41), June 1985</td>
</tr>
<tr>
<td>62</td>
<td>R. T. Ross</td>
<td>Australian Quarterly, 56(3), Spring 1984</td>
</tr>
<tr>
<td>63</td>
<td>W. J. Merrilees</td>
<td>Economic Record, 59(166), September 1983</td>
</tr>
<tr>
<td>64</td>
<td>A. J. Phipps</td>
<td>Australian Economic Papers, 22(41), December 1983</td>
</tr>
<tr>
<td>65</td>
<td>V. B. Hall</td>
<td>Economics Letters, 12, 1983</td>
</tr>
<tr>
<td>66</td>
<td>V. B. Hall</td>
<td>Energy Economics, 8(2), April 1986</td>
</tr>
<tr>
<td>67</td>
<td>P. Gill</td>
<td>Australian Quarterly, 59(2), Winter 1987</td>
</tr>
<tr>
<td>68</td>
<td>W. J. Merrilees</td>
<td>Australian Economic Papers, 23(43), December 1984</td>
</tr>
<tr>
<td>69</td>
<td>J. Yates</td>
<td>Australian Quarterly, 56(2), Winter 1984</td>
</tr>
<tr>
<td>70</td>
<td>V. B. Hall</td>
<td>Economics Letters, 20, 1986</td>
</tr>
<tr>
<td>71</td>
<td>S. E. Joson</td>
<td>Journal of Policy Modeling, 8(2), Summer 1986</td>
</tr>
<tr>
<td>72</td>
<td>R. T. Ross</td>
<td>Economic Record, 62(178), September 1986</td>
</tr>
<tr>
<td>75</td>
<td>E. A. Gross</td>
<td>Scottish Journal of Political Economy, 37(11), 1990</td>
</tr>
<tr>
<td>76</td>
<td>W. P. Hogan &amp; I. G. Sharpe</td>
<td>Journal of Economic Policy, 27(50), June 1988</td>
</tr>
<tr>
<td>77</td>
<td>W. P. Hogan</td>
<td>Company and Securities Law Journal, 6(1), February 1988</td>
</tr>
<tr>
<td>78</td>
<td>J. Yates</td>
<td>Urban Studies, 25, 419-433, 1989</td>
</tr>
<tr>
<td>79</td>
<td>B. W. Ross</td>
<td>The Economic and Social Review, 20(3), April 1989</td>
</tr>
<tr>
<td>81</td>
<td>R. T. Ross</td>
<td>Australian Bulletin of Labour, 21(1), December 1988</td>
</tr>
<tr>
<td>83</td>
<td>J. Pigott</td>
<td>Public Sector Economics, 3, 13-51, 1990</td>
</tr>
<tr>
<td>85</td>
<td>B. W. Ross</td>
<td>Prometheus, 6(2), December 1988</td>
</tr>
<tr>
<td>86</td>
<td>S. S. Joson</td>
<td>Rivista Di Diritto Volontario e Di Economia Internazionale, 35(2), June 1988</td>
</tr>
<tr>
<td>88</td>
<td>V. B. Hall</td>
<td>Energy Economics, 12(4), October 1989</td>
</tr>
<tr>
<td>89</td>
<td>V. B. Hall</td>
<td>Australian Economic Review, 37, 1985</td>
</tr>
<tr>
<td>91</td>
<td>G. Kingston</td>
<td>Economics Letters, 15, 1989</td>
</tr>
<tr>
<td>93</td>
<td>V. P. Singh</td>
<td>Abacus, 25(2), September 1989</td>
</tr>
<tr>
<td>94</td>
<td>W. P. Hogan</td>
<td>Economic Analysis and Policy, 29(1), March 1989</td>
</tr>
<tr>
<td>96</td>
<td>F. Gill</td>
<td>The Australian Quarterly, 62(4), 1989</td>
</tr>
<tr>
<td>97</td>
<td>S. Lahiri &amp; J. Sheen</td>
<td>The Economic Journal, 109(400), 1990</td>
</tr>
<tr>
<td>98</td>
<td>C. J. Kartakie</td>
<td>Journal of Economic Literature, 39(3), 1990</td>
</tr>
</tbody>
</table>