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

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

by

DONALD J. WRIGHT*

No. 150 NOVEMBER 1990

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.

National Library of Australia Card Number and ISBN 0 86758 372 X

CONTENTS

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 subsidising 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.[1] It

[1] 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 affect 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 analysing the production process as well as designing mechanisms that encourage experimentation, then, although there is potential for learning-by-doing none might eventuate. One of the innovations in this paper is the addition of an owner/manager effort variable in 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 novel 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.

learning curve are not hidden by a principal-agent relationship between shareholders and managers.

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

$$c_1 = c_0 - \theta \cdot f(q_0), \tag{2.1}$$

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

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

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 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 θ (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

$$\max_{q_1,L_1} \; \{W_1(q_1,L_1,q_0,\theta) \equiv U(q_1) - p(q_1)\cdot q_1 - (1+\gamma)\cdot L_1 + p(q_1)\cdot q_1 - (c_0 - \theta\cdot f(q_0))\cdot q_1 + L_1\} \tag{3.1}$$

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

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

so that the first line on 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 distortionary tax scheme, so that the welfare cost of one unit of revenue raised is $(1+\gamma)$);[2] the second line of the right

[2] If the weight $(1+\gamma)$ is not attached to lump–sum subsidies, then the regulator's two period problem, even in the case of incomplete information, has a trivial solution first enunciated by Loeb and Magat (1979), namely, to allow the monopolist to choose price and then subsidise the monopolist to the extent of consumer surplus at the chosen price.

hand side is monopoly profit plus any lump–sum subsidy; constraint (3.2) ensures that the monopolist makes at least zero profit, and the constaints of (3.3) ensure nonnegativity of the choice variables.

By period 1, the values of q_0 and θ 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 $L_1 = 0$.[3] Let the solution to this maximization problem be given by $\hat{q_1} = \hat{q_1}(q_0,\theta)$ and $\hat{L}_1 = \hat{L}_1(q_0,\theta)$. Denote the maximised welfare function by $\hat{W}_1 = \hat{W}_1(q_0,\theta) = \hat{W}_1\Big(\hat{q_1}(q_0,\theta), \hat{L}_1(q_0,\theta), q_0, \theta\Big)$.

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

$$\max_{q_0,a,L_0} \; \{W^E(q_0,a,L_0) \equiv U(q_0) - c_0\cdot q_0 - \gamma L_0 + \rho(a)\cdot\hat{W}_1(q_0,1) + (1-\rho(a))\cdot\hat{W}_1(q_0,0) - v(a)\} \tag{3.5}$$

subject to:

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

and

$$q_0 \geq 0, \; a \geq 0, \; L_0 \geq 0, \tag{3.7}$$

where W^E 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 exist which allows the first order conditions for the Lagrangian of this problem to be written as

$$\frac{\partial\mathcal{L}}{\partial q_0} = p(q_0) - c_0 + \rho(a)\cdot f'(q_0)\cdot\hat{q_1}(q_0,1) + \lambda\cdot(mr(q_0) - c_0) = 0, \tag{3.8}$$

[3] 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,

$$\frac{\partial \mathcal{L}}{\partial a} = \rho'(a) \cdot \left(\hat{W}_1(q_0, 1) - \hat{W}_1(q_0, 0)\right) - (1+\lambda) \cdot v'(a) = 0, \tag{3.9}$$

$$\frac{\partial \mathcal{L}}{\partial L_0} = -\gamma + \lambda = 0, \tag{3.10}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = p(q_0) \cdot q_0 - c_0 \cdot q_0 + L_0 - v(a) = 0, \tag{3.11}$$

where λ is the Lagrange multiplier attached to constraint (3.6) and the monopolist's marginal revenue is given by $mr(q_0) = \frac{dp(q_0)}{dq_0} \cdot q_0 + p(q_0)$. It is assumed that the monopolist's revenue function is strictly concave, that is $\frac{dmr(q_0)}{dq_0} < 0$.[4]

From (3.10) it is clear that $\lambda = \gamma$.[5] Making this substitution in (3.8) and (3.9) and rearranging yields

$$p(q_0) = c_0 - \rho(a) \cdot f'(q_0) \cdot \hat{q}_1(q_0, 1) + \gamma \cdot (c_0 - mr(q_0)) \tag{3.12}$$

and

$$\rho'(a) \cdot \left(\hat{W}_1(q_0, 1) - \hat{W}_1(q_0, 0)\right) = (1+\gamma) \cdot v'(a). \tag{3.13}$$

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 a 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 $v(a) > 0$, 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.[6] To simplify the analysis this paper

[4] It is also assumed that $\rho''(a)$, $f''(q_0)$, $U''(q_0)$, and the monopolist's marginal revenue function are sufficiently concave and $v''(a)$ is sufficiently convex that a unique maximum is obtained from the first order conditions of the period one problem.

[5] 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 $a > 0$ and $q_0 > 0$. Given this it can be shown that $\lambda > 0$ so constraint (3.6) binds. 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 $L_0 > 0$.

[6] If $v(a) = 0$, then $p(q_0) = c_0$ regardless of the relative sizes of the second and third term. It is also the case that $c_0 \geq mr(q_0)$.

abstracts from this case by assuming that γ is sufficiently small so that at the solution to the regulators problem $p(q_0) < c_0$.

Let the solution to the regulator's two period problem be

$$(\hat{q}_0, \hat{a}, \hat{L}_0) \quad \textit{and} \quad \left(\hat{q}_1(q_0, 0), \hat{L}_1(q_0, 0)\right) \quad \textit{or} \quad \left(\hat{q}_1(q_0, 1), \hat{L}_1(q_0, 1)\right). \tag{3.14}$$

At this solution

$$\hat{L}_0 = v(\hat{a}) - \left(p(\hat{q}_0) - c_0\right) \cdot \hat{q}_0 > 0 \tag{3.15}$$

while

$$\hat{L}_1(q_0, 0) = \hat{L}_1(q_0, 1) = 0. \tag{3.16}$$

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

$$\max_a \quad \{\pi \equiv \hat{L}_0 + (p(\hat{q}_0) - c_0) \cdot \hat{q}_0 - v(a)\}. \tag{3.17}$$

The solution to this problem is for the owner/manager to set $a = 0$ and so make a profit of $v(\hat{a})$.[7] 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 θ, so there is no incentive for the owner/manager to put in costly effort and increase the probability of achieving $\theta = 1$.

[7] Setting $a = 0$ guarantees that $\theta = 0$.

However, the complete information solution is attainable if in exchange for operating at the optimal outputs $\hat{q_0}$ and $\hat{q_1}(q_0, 1)$ or $\hat{q_1}(q_0, 0)$, a lump-sum subsidy of k is made in period 1, contingent on the output of the firm being $\hat{q_1}(q_0, 1)$ in period 1, and also a noncontingent lump-sum subsidy/tax of K is made in period 1. The monopolist's problem is now

$$\max_{a} \quad \{\Pi^E \equiv K + (p(\hat{q_0}) - c_0) \cdot \hat{q_0} + \rho(a) \cdot k - v(a)\}, \tag{3.18}$$

where Π^E denotes expected profit of the monopolist net of the cost of effort. The first order condition of this problem is

$$\frac{d\Pi^E}{da} = \rho'(a) \cdot k - v'(a) = 0. \tag{3.19}$$

If

$$k = \hat{W}_1(\hat{q_0}, 1) - \hat{W}_1(\hat{q_0}, 0) - \gamma \cdot \frac{v'(\hat{a})}{\rho'(\hat{a})}, \tag{3.20}$$

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

$$\Pi^E = K + (p(\hat{q_0}) - c_0) \cdot \hat{q_0} + \rho(\hat{a}) \cdot k - v(\hat{a}) \tag{3.21}$$

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 can not observe owner/manager effort.*[9]

[8] Essentially K is chosen so that $K + \rho(\hat{a}) \cdot k = \hat{L}_0$, thus guaranteeing that welfare is the same under complete and incomplete information.

[9] Proposition 1 is an application of a well known proposition in the hidden action literature, namely, that the complete information solution is attainable in a principal-agent relationship if the agent is risk neutral [Shavell (1979)].

This mechanism has intuitive appeal as the regulator wants there to be some positive probability that the firm produces $\hat{q_1}(q_0, 1)$ in period 1 (as long as $\hat{a} > 0$), and it achieves this by making the payment k contingent on $\hat{q_1}(q_0, 1)$ 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 (1986) 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 sudsidy 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 Dasgupta 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

[10] If learning-by-doing is internal to the firm then the firm obtains the benefits of any learning and so does not need protection.

price equals the domestic price which in turn allows domestic consumption to be obtained from

$$p^w(q+q^*) \equiv p^d(q^c), \tag{4.1}$$

where $p^d(q^c)$ 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 frim 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 maximize expected welfare. In the second period, given q_0, a, and θ (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

$$\begin{aligned} \max_{q_1, L_1} \ \{W_1(q_1, L_1, q_0, \theta) \equiv U^d\Big(q_1^c\big(p_1^w(q_1+q_1^*)\big)\Big) \\ - p_1^w(q_1+q_1^*)\cdot q_1^c\big(p_1^w(q_1+q_1^*)\big) - (1+\gamma)\cdot L_1 \\ + p_1^w(q_1+q_1^*)\cdot q_1 - (c_0 - \theta\cdot f(q_0))\cdot q_1 + L_1\} \end{aligned} \tag{4.2}$$

subject to:

$$p_1^w(q_1+q_1^*)\cdot q_1 - (c_0 - \theta\cdot f(q_0))\cdot q_1 + L_1 \geq 0, \tag{4.3}$$

$$c^* - p_1^w(q_1+q_1^*) \geq 0, \tag{4.4}$$

and

$$q_1 \geq 0, \ L_1 \geq 0 \tag{4.5}$$

where

$$U^d(q_1^c) = \int_0^{q_1^c} p^d(x)dx; \tag{4.6}$$

domestic consumption is given by q_1^c;[11] 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^*;[12] and the constraints of (4.5) ensure nonnegativity of the choice variables.

The solution to this problem depends on q_0. Let $\bar{q}_0$ be given by $c_0 - \theta\cdot f(\bar{q}_0) = c^*$. If $q_0 \leq \bar{q}_0$, then $c_0 - \theta\cdot f(q_0) \geq c^*$ and $q_1 = 0$. 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 $q_1 = 0$, then $L_1 = 0$.

[11] q_1^c is a function of world price, p_1^w, which in turn is a function of the sum of domestic and foreign output $(q_1 + q_1^*)$.

[12] c^* is the world price without domestic production.

If $q_0 > \tilde{q}_0$, then $c_0 - \theta \cdot f(q_0) < c^*$, $p_1^w(q_1) \leq c^*$, $q_1 > 0$, and $q_1^* = 0$. For there to be an argument for infant industry protection, it must be the case that $p_1^w(q_1) < c^*$, otherwise social and private benefits coincide. Therefore, this paper is concerned with the case where constraint (4.4) does not bind. If constaint (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

$$p_1^w(q_1) + \frac{\partial p_1^w(q_1)}{\partial q_1} \cdot (q_1 - q_1^c) = (c_0 - \theta \cdot f(q_0)). \tag{4.7}$$

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.[13] From (4.7) it is clear that $p_1^w(q_1) > (c_0 - \theta \cdot f(q_0))$ and that $L_1 = 0$.

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

4.1.2. Period One

In period one $c_0 > c^*$ and perfect competition in the foreign country ensures that $p_0^w = c^*$. The policy maker'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 is

$$\begin{aligned} \max_{q_0, a, L_0} \quad \{W^E(q_0, a, L_1) \equiv {} & U^d(q_0^c(c^*)) - c^* \cdot q_0^c(c^*) - (1+\gamma)L_0 \\ & + c^* \cdot q_0 - c_0 \cdot q_0 + L_0 \\ & + \rho(a) \cdot \bar{W}_1(q_0, 1) + (1 - \rho(a)) \cdot \bar{W}_1(q_0, 0) - v(a)\} \end{aligned} \tag{4.8}$$

subject to:

$$c^* \cdot q_0 - c_0 \cdot q_0 - v(a) + \rho(a) \cdot \bar{\Pi}_1(q_0, 1) + L_0 \geq 0, \tag{4.9}$$

13 It is assumed that the revenue function is concave so the second order conditions for a unique maximum are satisfied.

and

$$q_0 \geq 0, \; a \geq 0, \; L_0 \geq 0 \tag{4.10}$$

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 nonnegativity 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 $q_0 > \tilde{q}_0$, q_0 being such that the solution to the period two problem involves $p_1^w(q_1) < c^*$, and $L_0 > 0$. If $q_0 \leq \tilde{q}_0$, 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 $q_0 > \tilde{q}_0$ and the solution to the period two problem involves $p_1^w(q_1) = c^*$, 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 $q_0 > \tilde{q}_0$, the solution to the period two problem involving $p_1^w(q_1) < c^*$, and $L_0 > 0$.

It is assumed that an interior solution exist to the period one problem, in which case rearranging the first order conditions of the Lagrangian yields[14]

$$(1+\gamma) \cdot (c_0 - c^*) = \rho(a) \cdot f'(q_0) \cdot \bar{q}_1(q_0, 1) + \rho(a) \cdot \gamma \cdot \frac{d\bar{\Pi}_1(q_0, 1)}{dq_0} \tag{4.11}$$

and

$$\rho'(a) \cdot (\bar{W}_1(q_0, 1) - \bar{W}_1(q_0, 0) + \gamma \cdot \bar{\Pi}_1(q_0, 1)) = (1+\gamma) \cdot v'(a). \tag{4.12}$$

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

14 It is assumed that $\rho''(a)$ and $f''(q_0)$ are sufficiently concave and $v''(a)$ is sufficiently convex that a unique maximum is obtained from the first order conditions of the period one problem.

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

$$(\bar{q}_0, \bar{a}, \bar{L}_0) \quad \textit{and} \quad \Big(\bar{q}_1(q_0,0), \bar{L}_1(q_0,0)\Big) \quad \textit{or} \quad \Big(\bar{q}_1(q_0,1), \bar{L}_1(q_0,1)\Big). \tag{4.13}$$

At this solution

$$\bar{L}_0 = v(\bar{a}) - (c^* - c_0)\cdot\bar{q}_0 - \rho(\bar{a})\cdot\bar{\Pi}_1(1,\bar{q}_0) > 0 \tag{4.14}$$

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 $\bar{L}_0$ in exchange for operating at $\bar{q}_0$, the problem the owner/manager faces is

$$\max_a \quad \{\pi \equiv \bar{L}_0 + (c^* - c_0)\cdot\bar{q}_0 - v(a)\}. \tag{4.16}$$

The solution to this problem is for the owner/manager to set $a = 0$ and so make a profit of $v(\bar{a}) - \rho(\bar{a})\cdot\bar{\Pi}_1(\bar{q}_0,1)$. It therefore 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 $\bar{L}_0$ is made regardless of the value of θ, 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

$$\max_a \quad \{\Pi^E \equiv K + (c^* - c_0)\cdot\bar{q}_0 + \rho(a)\cdot k - v(a)\}, \tag{4.17}$$

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

$$\frac{d\Pi^E}{da} = \rho'(a)\cdot k - v'(a) = 0. \tag{4.18}$$

If

$$k = \bar{W}_1(\bar{q}_0,1) - \bar{W}_1(\bar{q}_0,0) + \gamma\cdot\bar{\Pi}_1(\bar{q}_0,1) - \gamma\cdot\frac{v'(\bar{a})}{\rho'(\bar{a})}, \tag{4.19}$$

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) summarises 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 sudsidy. 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 $(c^* - c_0) \cdot \bar{q}_0 + \rho(\bar{a}) \cdot k - v(\bar{a})$) is coupled with a period 1, output contingent, lump-sum subsidy is able to achieve the complete information solution even though the policy maker can not 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 $\bar{q}_1(q_0, 1)$ in period 1 (as long as $\bar{a} > 0$), and it achieves this by making the payment k contingent on $\bar{q}_1(q_0, 1)$ 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 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 posssible the effects of unobservable owner/manager effort in models where learning-by-doing plays an important role.

REFERENCES

Baldwin, R.E., "The Case Against Infant Industry Tariff Protection," *Journal of Political Economy*, **77**, June 1969, 295–305.

Baron, D.P., and R.B. Myerson, "Regulating a Monopolist with Unknown Costs," *Econometrica*, **50**, July 1982, 911–930.

Clemhout, S., and H.Y. Wan, "Learning-by-Doing and Infant Industry Protection," *Review of Economic Studies*, **37**, January 1970, 33–56.

Dasgupta, P., and J. Stiglitz, "Learning-by-Doing, Market Structure and Industrial and Trade Policies," *Oxford Economic Papers*, **40**, June 1988, 246–268.

Fudenberg, D., and J. Tirole, "Learning-by-Doing and Market Performance," *Bell Journal of Economics*, **14**, Autumn 1983, 522–530.

Kemp, M.C., "The Mill–Bastable Infant-Industry Dogma," *Journal of Political Economy*, **68**, February 1960, 65–67.

Laffont, J.-J., and J. Tirole, "Using Cost Observation to Regulate Firms," *Journal of Political Economy*, **94**, June 1986, 614–641.

Loeb,M., and W.A. Magat, "A Decentralized Method for Utility Regulation," *Journal of Law and Economics*, **22**, October 1979, 399–404.

Majd, S., and R.S. Pindyck, "The Learning Curve and Optimal Production Under Uncertainty," *Rand Journal of Economics*, **20**, Autumn 1989, 331–343.

Matsuyama, K., "Perfect Equilibria in a Trade Liberalization Game," *American Economic Review*, **80**, June 1990, 480–492.

Shavell, S., "Risk Sharing and Incentives in the Principal and Agent Relationship," *Bell Journal of Economics*, **10**, Spring 1979, 55–73.

Spence, A.M., "The Learning Curve and Competition," *Bell Journal of Economics*, **12**, Spring 1981, 49–70.

Succar, P., "The Need for Industrial Policy in LDC'S – A Restatement of the Infant Industry Argument," *International Economic Review*, **28**, June 1987, 521–534.

W o r k i n g   P a p e r s

in Economics

104	P. Groenewegen	Taxation and Decentralisation: A Reconsideration of the Costs and Benefits of a Decentralised Tax System; March 1988
105	L. Ermini	Some New Evidence on the Timing of Consumption Decisions and on Their Generating Process; March 1988
106	G.Mills	Satially-Differentiated Trucking Markets: Equilibria under Price Regulation without Entry Restrictions; April 1988
107	B.W.Ross	Strategic Commitment, Unknowledge and the Nature of Entreprenuerial Activity; April 1988
108	S.S.Joson	Offsets and Development of Defence Support Industries in Small Economies; April 1988
109	B.W.Ross	The Conglomerate and the Focussed Agglomerate: Modern Forms of the Leader-Commanded Firm; July 1988
110	L Ermini	Inertial Behavior on Schedule and Hierarchical Decomposition; July 1988
111	L.Ermini	The Limits of Systems Control Theory in Economic Policy-Making; July-October 1988
112	P.Groenewegen	Neo-Classical Value and Distribution Theory: The English Speaking Pioneers;September 1988
113	V.B.Hall, T.P.Truong & V.A.Nguyen	An Australian Fuel Substitution Tax Model: ORANI-LFT; October 1988
114	V.B.Hall, T.P.Truong & V.A.Nyuyen	Responses to World Oil and Coal Shocks, in an Australian Short-Run Fuel Substitution Tax Model; October 1988
115	F.Gill	Social Justice and the Low-Paid Worker; October 1988
116	G.Kingston	Theoretical Foundations of Constant-Proportion Portfolio Insurance; October 1988
117	V.B.Hall & D.R.Mills	Is Medium Temperature Solar Thermal Process Steam Viable for Australia? Some Preliminary Results; November 1988
118	W.P.Hogan	Insider Information and Market Adjustment: November 1988
119	L.Ermini	Reinterpreting a Recent Temporally Aggregated Consumption-Cap Model; December 1988
120	P.Groenewegen	Progressive Personal Income Tax - A Historical Perspective; December 1988
121	M.C.Blad & N.Oulton	Rubinstein's Solution of the Bargaining Problem: Some Generalisations and Extensions; December 1988
122	W.P.Hogan & I.G.Sharpe	Prudential Regulation of Bank Ownership and Control; January 1989
123	G.Mills	The Reform of Australian Aviation; June 1989
124	L.Ermini	Transitory Consumption and Measurement Errors in the Permanent Income Hypothesis; June 1989
125	E.Kiernan	Is Austerity Necessary?; July 1989
126	F.Gill	Labour Market Flexibility - To What End?; August 1989

127	E.Kiernan	Financial Reform: A Perspective; September 1989
128	S.Lahiri & J.Sheen	On Optimal Dumping; September 1989
129	S.Hargreaves-Heap & Y.Varoufakis	Multiple Reputations in Finitely Repeated Games; October 1989
130	J.Sheen	International Monetary and Fiscal Policy Cooperation in the Presence of Wage Inflexibilities; October 1989
131	E.Jones	Was the Post-War Boom Keynesian?; October 1989
132	S.Lahiri & J.Sheen	A Risk Averse Price-Setting Monopolist in a Model of International Trade; October 1989
133	F.Gill	A Target-Wage Dilemma: Some Consequences of Incomplete Information; December 1989
134	W.P. Hogan	New Banks in Australia; December, 1989
135	Y. Varoufakis	Modelling Rational Conflict: The Limits of Game Theory; February 1990
136	L. Ermini	Shock Persistence in Australian Output and Consumption; March 1990
137	S. Ziss	Strategic Investment, Competition and the Independence Result; March 1990
138	D.J. Wright	International Technology Transfer with an Information Asymmetry and Endogenous Research and Development; April 1990
139	D.J. Wright	International Technology Transfer and Per Unit Royalties; April 1990
140	P. Ganguli & S. Nath	Optimal Mix of Urban Public Services: The Case of Three Indian Cities; May 1990
141	P.D. Groenewegen	Alfred Marshall's Principles of Economics: A Centenary Perspective from the Antipodes; June 1990
142	J. Sheen	Real Wages and the Business Cycle in Australia; June 1990
143	C.J. Karfakis	A Model of Exchange Rate Policy: Evidence for the US Dollar-Greek Drachma Rate 1975-1987; August 1990
144	C.J. Karfakis & D.M. Moschos	Interest Rate Linkages within the European Monetary System: A Time Series Analysis; August 1990
145	C.J. Karfakis & D.M. Moschos	Asymmetries in the European Monetary System: Evidence from Interest Rates; September 1990
146	W.P. Hogan	International Capital Adequacy Standards; October 1990
147	J. Yates	Shared Ownership: The Socialisation or Privatisation of Housing?; October 1990
148	G. Butler	Contracts in the Political Economy of a Nation; November 1990
149	B. Rao	Some Further Evidence on the Policy Ineffectiveness Proposition; November 1990
150	D.J. Wright	Hidden Action and Learning-By-Doing in Models of Monopoly Regulation and Infant Industry Protection; November 1990

Copies are available upon request from:

Department of Economics,
The University of Sydney,
N.S.W. 2006, Australia.

Working Papers in Economics Published Elsewhere

2	I.G.Sharpe & R.G.Walker	Journal of Accounting Research, *13*(2), Autumn 1975
3	N.V.Lam	Journal of the Developing Economies, *17*(1), March 1979
4	V.B.Hall & M.L.King	New Zealand Economic Papers, *10*, 1976
5	A.J.Phipps	Economic Record, *53*(143), September 1977
6	N.V.Lam	Journal of Development Studies, *14*(1), October 1977
7	I.G.Sharpe	Australian Journal of Management, April 1976
9	W.P.Hogan	Economic Papers, 55, The Economic Society of Australia and New Zealand, October 1977
12	I.G.Sharpe & P.A.Volker	Economic Letters, 2, 1979
13	I.G.Sharpe & P.A.Volker	Kredit and Kapital, *12*(1), 1979
14	W.P.Hogan	Some Calculations in Stability and Inflation, A.R.Bergstrom et.al.(eds.),J.Wiley & Sons,1978
15	F.Gill	Australian Economic Papers, *19*(35),December 1980
18	I.G.Sharpe	Journal of Banking and Finance, *3*(1),April 1978
21	R.L Brown	Australian Journal of Management, *3*(1),April 1978
23	I.G.Sharpe & P.A.Volker	The Australian Monetary System in the 1970s, M.Porter(ed.),Supplement to Economic Board 1978
24	V.B.Hall	Economic Record, *56*(152), March 1980
25	I.G.Sharpe & P.A.Volker	Australian Journal of Management, October 1979
27	W.P.Hogan	Malayan Economic Review, *24*(1), April 1979
28	P.Saunders	Australian Economic Papers, *19*(34),June 1980
29	W.P.Hogan, I.G.Sharpe & P.A.Volker	Economic Letters, 6 (1980), 7 (1981)
30	W.P.Hogan	Australian Economic Papers, *18*(33),December 1979
32	R.W.Bailey, V.B.Hall & P.C.B.Phillips	Keynesian Theory, Planning Models, and Quantitative Economics, G. Gandolfo and F. Marzano (eds.), *2*, 703-767, 1987
38	U.R.Kohli	Australian Economic Papers, *21*(39),December 1982
39	G.Mills	Journal of the Operational Research Society, (33), 1982
41	U.R.Kohli	Canadian Journal of Economics, *15*(2),May 1982
42	W.J.Merrilees	Applied Economics, 15, February 1983
43	P.Saunders	Australian Economic Papers, *20*(37),December 1981
45	W.J.Merrilees	Canadian Journal of Economics, *15*(3),August 1982
46	W.J.Merrilees	Journal of Industrial Economics, *31*,March 1983
49	U.R.Kohli	Review of Economic Studies, *50*(160),January 1983
50	P.Saunders	Economic Record, *57*(159), December 1981
53	J.Yates	AFSI, Commissioned Studies and Selected Papers, AGPS, IV 1982
54	J.Yates	Economic Record, *58*(161), June 1982
55	G.Mills	Seventh Australian Transport Research Forum-Papers, Hobart, 1982
56	V.B.Hall & P.Saunders	Economic Record, *60*(168), March 1984
57	P.Saunders	Economic Record, *59*(166), September 1983
58	F.Gill	Economie Appliquee, *37*(3-4), 1984

59	G.Mills & W.Coleman	Journal of Transport Economics and Policy, *16*(3), September 1982
60	J.Yates	Economic Papers, Special Edition, April 1983
61	S.S.Joson	Australian Economic Papers, *24*(44),June 1985
62	R.T.Ross	Australian Quarterly, *56*(3), Spring 1984
63	W.J.Merrilees	Economic Record, *59*(166), September 1983
65	A.J.Phipps	Australian Economic Papers,*22*(41),December 1983
67	V.B.Hall	Economics Letters, 12, 1983
69	V.B.Hall	Energy Economics, *8*(2), April 1986
70	F.Gill	Australian Quarterly, *59*(2), Winter 1987
71	W.J.Merrilees	Australian Economic Papers,*23*(43),December 1984
74	J.Yates	Australian Quarterly, *56*(2), Winter 1984
77	V.B.Hall	Economics Letters, 20, 1986
78	S.S.Joson	Journal of Policy Modeling, *8*(2), Summer 1986
79	R.T.Ross	Economic Record, *62*(178), September 1986
81	R.T.Ross	Australian Bulletin of Labour, *11*(4), Sept.1985
82	P.D.Groenewegen	History of Political Economy, *20*(4),Winter 1988 Scottish Journal of Political Economy,*37*(1)1990
84	E.M.A.Gross, W.P.Hogan & I.G.Sharpe	Australian Economic Papers, *27*(50), June 1988
94	W.P.Hogan	Company and Securities Law Journal, *6*(1), February 1988
95	J.Yates	Urban Studies, *26*, 419-433, 1989
96	B.W.Ross	The Economic and Social Review, *20*(3),April 1989
97	F.Gill	Australia's Greatest Asset: Human Resources in the Nineteenth and Twentieth Centuries, D.Pope(ed.), Federation Press, 1988
99	R.T.Ross	Australian Bulletin of Labour, *15*(1), December 1988
100	L.Haddad	Hetsa Bulletin, (11), Winter 1989
101	J.Piggott	Public Sector Economics - A Reader, P.Hare(ed.), Basil Blackwell, 1988
104	P.D.Groenewegen	Decentralization, Local Government and Markets: Towards a Post-Welfare Agenda, R.J. Bennet (ed.) Oxford University Press, *6*, 87-115, 1990
107	B.W.Ross	Prometheus, *6*(2), December 1988
108	S.S.Joson	Rivista Di Diritto Valutario e Di Economia Internazionale, *35*(2), June 1988
112	P.Groenewegen	NeoClassical Economic Theory 1870 to 1930 K.Hennings & W.Samuels (eds.), 13-51, 1990
113	V.B.Hall, T.P.Truong & V.A.Nguyen	Energy Economics, *12*(4) October 1990
114	V.B.Hall, T.P.Truong & V.A.Nguyen	Australian Economic Review, (87) 3'89
115	F.Gill	Australian Journal of Social Issues, *25*(2), May 1990
116	G.Kingston	Economics Letters, 15 (1989)
117	V.B.Hall & D.R.Mills	Pacific and Asian Journal of Energy, *2*(2), December 1988
118	W.P.Hogan	Abacus, *25*(2), September 1989.
122	W.P.Hogan & I.G. Sharpe	Economic Analysis and Policy, *19*(1), March 1989
123	G.Mills	Journal of Transport Economics and Policy, *23*, May 1989
126	F.Gill	The Australian Quarterly, *61*(4), 1989
128	S.Lahiri & J.Sheen	The Economic Journal, *100*(400), 1990
144	C.J.Karfakis	Journal of Money, Credit, and Banking, *22*,(3),1990