The Welfare Costs of Pricing for Innovation in Agricultural Production Technology

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Abstract

In this paper, the welfare consequences of two different methods of pricing for innovation in agricultural technology are examined One method involves the pricing of embodied technology, via a premium on the price of the new improved factor This is compared to an upfront fee which could be used to price disembodied technology, which separates payment for the innovation from factor prices This method resembles the pricing of disembodied technology which has been examined previously by Lindner (1993)

In the case of embodied technology, an innovator who has intellectual property rights on a new factor faces a downward sloping demand curve for the factor due to diminishing marginal productivity of the factor Because of this they restrict output of the new factor and this causes welfare losses. These welfare losses are different from the case of disembodied technology, where the innovator must charge an up front fee for the use of the technology In this latter case, the welfare losses occur because some potential users of the innovation are not able to afford the up front charge These welfare losses are more significant when there are large differences in demand characteristics across the users of the innovation In contrast, the welfare losses associated with embodied technology are independent of the demand distribution of potential users Further welfare losses associated with both pricing techniques are that the innovator cannot usually appropriate all the benefits from their innovation, which means that they undervalue the benefits from research Thus there is not sufficient incentive for private investment in research

The magnitude of the welfare losses caused by the pricing of embodied and disembodied technology are examined for a range of assumptions, using a simple Cobb-Douglas production model It is shown that when there are differences in the demand for innovation across farmers, embodied pricing (via a premium on the factor price) is superior to up front pricing of technology, when the innovation causes the production increases of less than 10%. However, for innovations that cause larger jumps in the production function, the disembodied pricing technique is better and this is mainly because of the large distortions created by monopoly pricing in the factor market

1. Introduction

In the past decade there has been a significant shift in emphasis towards commercialisation of rural research in Australia. For example, there has been a reduction of resources in government departments such as Departments of Agriculture, and an increase in industry funded research, with a dominant role being played by Primary Industry Research and Development Corporations (Lindner 1993). At the same time, funding corporations are insisting on legal contracts which are aimed at appropriating returns for the intellectual property generated by the research that they fund. Public organisations have also attempted to get a return on intellectual property by establishment of commercial offices for marketing their intellectual property.

This shift in emphasis towards commercialisation of applied rural research has been assisted by changes in patent laws, for example the introduction of Plant Variety Rights in 1986. Patents provide protection for intellectual property rights (IPR) which enable private researchers to appropriate a return for the knowledge they create. However, there are welfare losses associated with establishing intellectual property rights. Lindner (1993) examined the welfare consequences of applying intellectual property rights to disembodied technology. The pricing of disembodied technology resembles the price-excludable public good problem examined by Burns and Walsh (1981). Essentially, welfare losses arise because consumers are different and it is not possible to discriminate between them. Because everyone pays the same charge for a unit of knowledge, there will be some users who pay less than they are willing to pay, and others who are price excluded. As a result, the innovator under produces knowledge because he cannot appropriate all the returns for it, and under supplies any knowledge that he produces, by charging an "average" price for the knowledge. Only in the trivial case where all consumers are identical, would the innovator appropriate all the returns from the production of knowledge, and distribute it efficiently.

An interesting contrast to this type of technology is embodied technology, for example the improved genetic information that may be embodied in a new hybrid seed variety. When knowledge is embodied in a factor, the contribution made by each user will depend on the intensity of use. Larger farmers who purchase more of the factor will make a larger contribution towards the innovation, if returns for intellectual property are appropriated by charging a premium on the price of the factor. However, if the innovator has a monopoly on the factor through IPR he will restrict its output and this causes a different type of welfare loss. These welfare losses are examined in the first part of this paper.

A good example of the embodied pricing technique is the hybrid seed which cannot be replicated by a farmer, so must be purchased from the innovator. Other types of new seed varieties, which can be bulked up by the farmer, resemble more closely the disembodied pricing technique. This is because the farmer can buy a minimal amount of the seed for experimental purposes, then grow up the seed he needs on the farm. In this way, the initial payment made by a farmer may be less dependent on the eventual scale of use. In contrast, it has been suggested that an end-point collection process be used instead to collect a return for Plant Variety Rights, where farmers pay a premium per unit of output. This technique would mean that farmers did pay according to intensity of use of the seed, and therefore the pricing technique would be more like the embodied pricing technique examined in this paper. Another example of disembodied pricing is the pricing of computer software used in farm decision making.

Because both methods of pricing can be used in agriculture, it is useful to compare the welfare losses associated with each technique. In the second part of the paper, the welfare losses associated with monopoly pricing in the factor market (embodied technology) are compared to the welfare losses associated with up front pricing for technology (disembodied technology). Then a simple Cobb-Douglas production model is used to quantify these welfare effects for a range of assumptions about the production relationship and the distribution of demand for the innovation.

The focus of the analysis in this paper is on the pricing of a discrete amount of knowledge. The welfare losses associated with distribution of a particular innovation are examined. There is no attempt to look at the second dimension of the problem, which is the effect of imperfect appropriability on the amount of innovation that is produced. However, some general observations can be drawn on this point by examining the appropriability of returns for a particular innovation.

2. Welfare Analytics of Pricing for Embodied Innovation

2.1 Representing Technical Change

In the following presentation, technical change is represented as an improvement in the quality of one or several factors of production. Initially, the focus is on embodied technical change. This representation reflects many forms of innovation in agriculture, such as higher yielding varieties, fertilisers and chemicals. For the purposes of this discussion, consider the case of a new hybrid seed variety, from which the innovator can extract a return from the sale of the seed.

The innovation (embodied in the higher yielding variety) provides a technically superior factor in that higher production is achieved from a given application of seed. However, compared to the existing technology, the relationship between the new seed and other factors of production may change. For example, a new variety of seed may have a different yield response function for fertiliser application. Thus it is necessary to represent the technical change as a change in the underlying production function.

In the case of a discrete technological innovation which is embodied in a new improved factor, technical change can be represented by a new production function

Let the original technology be described by:

(1) $$y_1 = f_1(x, \mathbf{z})$$

where x is the factor in which technical change is embodied. Here x refers to the quantity of the factor used, for example tonnes of seed per hectare, and $\mathbf{z}$ is a vector of other inputs.

The new improved technology is represented by a new production function:

(2) $$y_2 = f_2(x, \mathbf{z})$$

It describes a new way of combining the same set of inputs. That is, under the new technology, we describe a different relationship between seed and other inputs in producing output. In this representation, the factor is represented in each production function in terms of the quantity applied. The technical change embodied in the improved factor (the change in quality of the factor) is represented by a shift in the production function. In this general formulation, this shift can take any form (pivotal or parallel).

2.2 The Demand for Embodied Technical Change

To demonstrate the welfare analytics of embodied technical change, consider first the simplified scenario where there is only one factor of production, and there is only one farmer in the market so that the individual factor demand curve is the market demand for the factor. In this simple case, the old technology is represented as

(3) $$y_1 = f_1(x)$$

and the new technology is represented by

(4) $$y_2 = f_2(x) \qquad \text{where } f_1(x) < f_2(x)$$

The price of output is represented as P, the price of the old factor is w_1 and the price of the new factor is w_2.

We derive a demand curve for the factor, based on these production and cost relationships. The actual amount of the factor used by a farmer, if they do decide to adopt the new technology, is determined by the farmer's marginal willingness to pay for the factor. However, the decision to switch to the new technology will only be made if there is to be a gain in profits, so the demand for the factor is affected by the average as well as the marginal value of the factor. This is demonstrated below.

The marginal value of the new factor is given by:

(5) $$w_2 = P.\frac{\partial f_2}{\partial x}$$

If we define the inverse of the factor demand equation,

(6) $$x_2^* = g_2(w_2)$$

We can define the maximum profit function for the new technology

(7) $$\pi_2 = P.f_2(x_2^*) - w_2.x_2^*$$

However, there is an opportunity cost associated with adopting the new technology. This is the profit that could be earned if fixed factors were allocated to producing output under the old technology. If we define maximum attainable profit under the old technology as π_1^* then the net gain from adopting the new technology is

(8) $$\pi_2 - \pi_1^* = P.f_2(x_2^*) - w_2.x_2^* - \pi_1^*$$

The firm will choose to adopt the new technology, provided this gain is positive. Rearranging Equation 9, we can see that adoption will proceed where

(9) $$P.f_2(x_2^*) - \pi_1^* \geq w_2.x_2^*$$

Dividing this relationship by x_2^*, we obtain

(10) $$\frac{P.f_2(x_2^*) - \pi_1^*}{x_2^*} > w_2$$

The left hand side of this equation is the gross average benefit from technology adoption, denoted by $AV(x_2)$ in the following discussion. It is like the value of average product, only the value is expressed net of the opportunity cost of the fixed factors used in production, which could have been employed in combination with the old factor to earn π_1^*. Clearly, the farmer will only adopt the new technology if this average surplus is less than the price of the new factor.

The average surplus curve can be drawn as a function of x_2^* and compared with the value of marginal product curve. This is shown in Figure 1. The VMP curve shows the optimal level of factor use that would be associated with each factor price. The average value curve shows the average gain from adopting the new technology, at each level of factor

use. It is the average producer surplus (expressed per unit of factor use) from switching to the new technology. Also drawn on Figure 1 is the Value of Average Product curve. The difference between the VAP curve and the average surplus curve is that the average surplus curve subtracts the opportunity cost of the fixed factors. When this opportunity cost is relatively large (there are competitive alternatives to the new technology), then the difference between average surplus curve and the VAP will be greater, and the average surplus curve will cross the VMP curve further to the right (at a lower factor price and higher level of input use).
It can be seen that the new technology will only be adopted if the average gain is at least as high as the marginal value, so the factor demand curve is defined as the section of the marginal value of product curve that lies below the average surplus curve. This means that the monopolist faces discontinuous demand curve and the maximum price they can charge is w^{max}. The point where the average surplus crosses the VMP curve, and the size of w^{max}, depends on the "significance" of the innovation. When an innovation only represents a small improvement in technology, so the profits under the alternatively technology are relatively large, then the maximum price that the innovator can charge will also be limited. This is demonstrated further below.

2.3 Output of the Factor

The production of the new factor involves a sunk cost (the research cost) plus a marginal cost of production (for example, seed propagation). The socially optimal level of output of the factor (which embodies the discrete technological improvement) is the point where the marginal cost of factor production is equal to its marginal value. This is shown in Figure 2.

An innovator who has monopoly rights to the new technology which is embodied in the new factor, is faced with a downward sloping demand curve, and consequently has a marginal revenue curve which lies below this curve. As a result, output will be restricted, compared to the socially optimal case. There are two possibilities, however, depending on whether or not the innovation is significant enough to place the monopolist on the continuous section of the marginal revenue curve.

The first case, of an unconstrained monopoly, is demonstrated in Figure 2. Welfare loss caused by this output restriction in the factor market is given by the shaded triangle. This welfare loss is unavoidable if the innovator acts as a monopoly. The distribution of benefits are demonstrated in Figure 3. The social value of the innovation is the rectangular region under the average value curve. The amount going to the monopolist is the rectangular region under the demand curve. It can be seen that the monopolist cannot appropriate all the returns from the innovation. At the profit maximising level of factor output, the average value exceeds the marginal value of the factor. This inability to appropriate all the returns from the innovation will causes further losses in the long term, because it will discourage investment in the search for innovation.

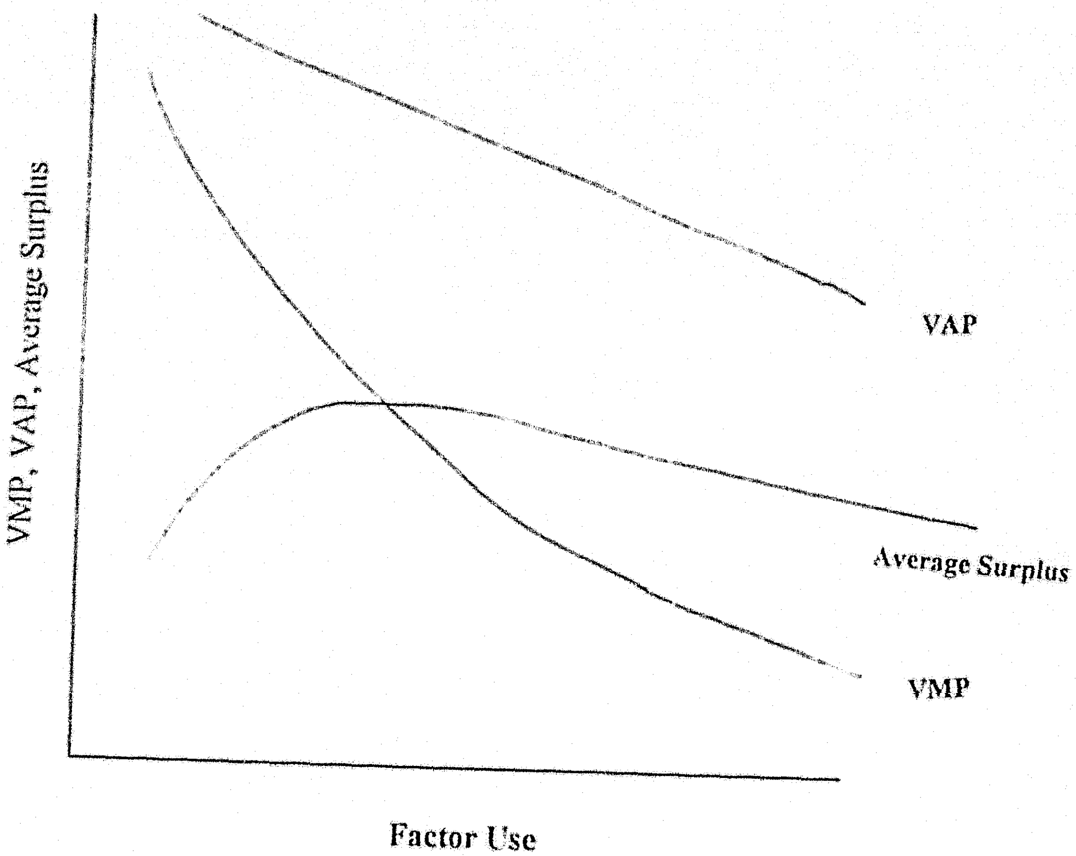

Figure 1: Demand for New Factor

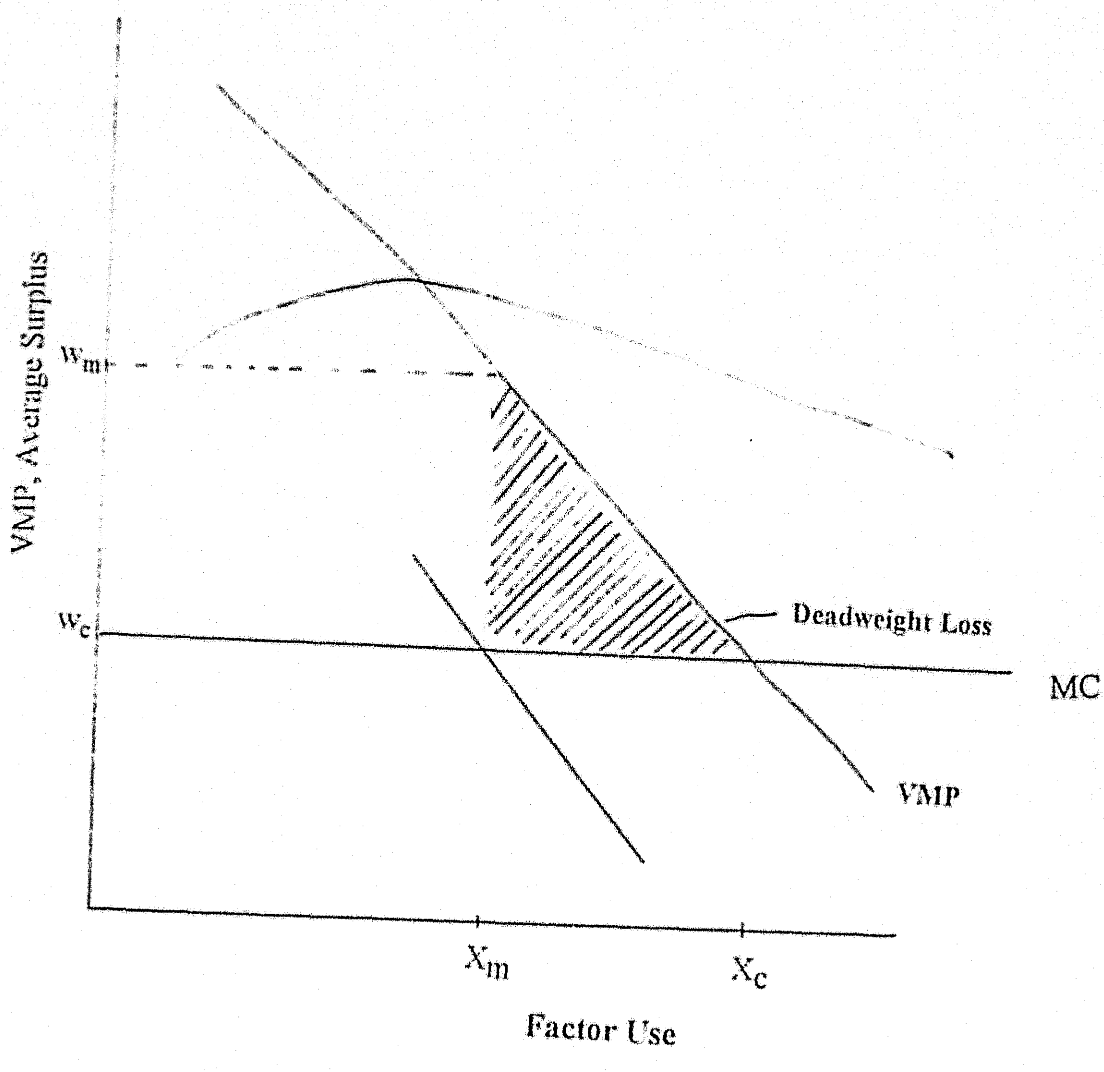

Figure 2: Welfare Effects of Unconstrained Monopoly

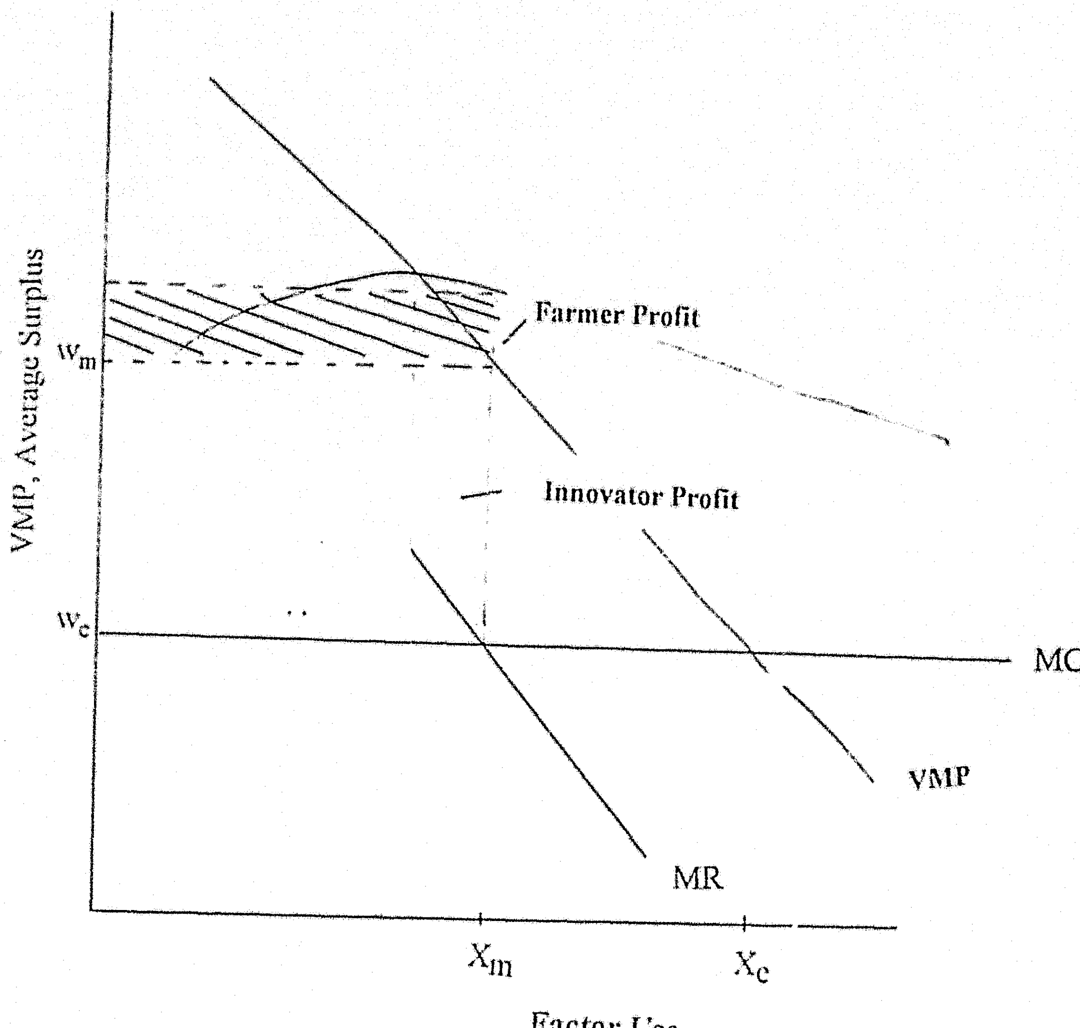

Figure 3: Distributional Effects of Unconstrained Monopoly

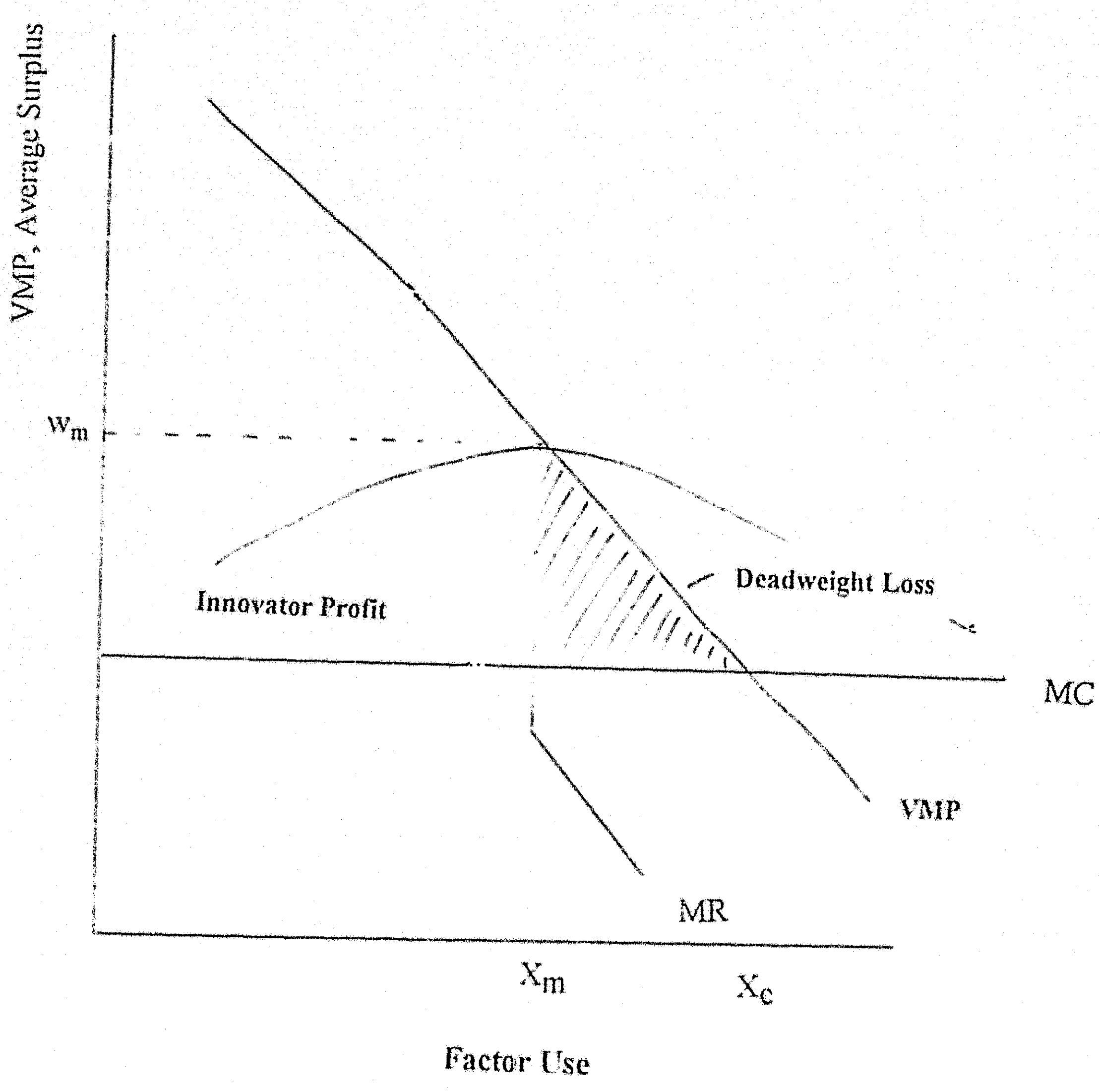

Figure 4: Welfare Effects of Monopolist Constrained by Competition

(Innovation gives small increase in production)

The second case arises when the innovation is not very large, so that the marginal cost of factor production crosses the discontinuous point of the marginal revenue curve. This is shown in Figure 4. In this situation, the monopolist charges w^{max}, and profits are lower than they would be without the price ceiling imposed by the competitive alternative technology, and factor output is higher (they are constrained from raising price and contracting output). There is still some restriction in output, which means that welfare losses arise. However, the monopolist manages to appropriate all the benefit from the technology.

In either situation, the monopolist contracts output below the socially optimal level, and this causes welfare losses. Because of this welfare loss, the monopolist can never appropriate the full benefits of an innovation. Even though they appropriate 100% of the realised benefits when they are operating in the discontinuous section of the marginal revenue curve, profits are larger when they are unconstrained and can contract output according to profit maximising conditions.

One way of overcoming this welfare loss, that arises because the innovator faces a downward sloping demand curve for the factor, would be to price separately for the innovation. That is, to keep factor markets competitive and charge an upfront fee for the use of the new factor. In this simple example, the welfare losses from under production of the factor would be avoided. Furthermore, the amount that the innovator could charge as an upfront fee would be determined by the area between the average and marginal benefit curves, at the point of socially optimal output (see Figure 3). They could therefore extract the entire benefits from the innovation, and this would remove the investment disincentive demonstrated previously. In the simple example examined here, a pricing mechanism for innovation that is separated from the pricing of the factor (resembling disembodied technology) is superior on welfare grounds.

However, when a more realistic situation is considered, where there are many individuals demanding the factor and the innovation, and these individuals differ in their willingness to pay for the innovation, disembodied pricing mechanisms create two types of welfare losses, which were outlined in the introduction. Welfare losses arise because an average charge for the technology results in some customers being excluded from the market, and in others paying less than their willingness to pay for the innovation. This second problem means that innovators are unable to fully appropriate the returns from the innovation, which could discourage the search for innovation.

3. A Comparison of Embodied and Disembodied Pricing

In the following analysis, the welfare effects of pricing of embodied technology are quantified for a range of assumptions and compared with an upfront fee for innovation which might be associated with disembodied technology. To do this, we need to look at a market demand curve that is made up of many individuals who have different demand characteristics, as this affects the welfare loss in the case of an upfront fee.

It was necessary to impose functional form to the production relationship, in order to quantify these effects. A Cobb Douglas production function was assumed. The model has two variable factors of production, to illustrate the effect of price distortions (caused by monopoly pricing of embodied technology) on other factor markets. Demand for each individual depends on a fixed factor which represents farm characteristics (for example it could represent farm size). It is assumed that there is a continuous distribution describing the farm characteristic (F) for the ith farm. The n farms are ordered in terms of the size of their F value, with i=1 describing the farm with the largest value of F. This representation allows the summation over the n farms to be represented as an integral.

(11) $F_i = F_0 - e.i$

For the original technology (denoted by subscript 1), the output for the ith farm is:

(12) $y_{1i} = A_1.x^{\alpha}.z^{\beta}.F_i^{\gamma}$

Output from the ith farm is a function of input of the embodied factor x, another variable input z, and a fixed factor F_i which is specific to each farm. Constant returns to scale are assumed, so that $\alpha + \beta + \gamma = 1$.

Technical change is represented by a change in the efficiency parameter, A. Thus the original technology is described by A_1, and the new technology is described by A_2 Where $A_1 < A_2$

In the case of embodied technology it is assumed that the innovation is tied to the use of factor x, and the innovator has a monopoly on production of the factor which embodies the technology. It is assumed that the other factor, z, is competitively priced. The welfare effects are compared to a case where there is an identical shift in the production function (ΔA), but where both factors are competitively priced and the innovators extracts a return by means of an upfront fee (resembling a disembodied pricing technique).

The cost of producing the factors x and z are denoted by c_x, c_z, and are assumed to be the same under both technologies. The prices of factors x and z are denoted by w and v

3.1 Embodied Technology

Consider first the case of an innovation which is embodied in the factor x. Profit under the new technology is described by:

(13) $$\pi_{2i} = P.A_2.x^{\alpha}.z^{\beta}.F_i^{\gamma} - w.x - v.z$$

The derivation of factor output and social benefits under competitive and monopolistic factor markets is shown in the appendix.

The socially optimal level of the factor (which embodies a discrete technology) is found by equating factor demand with marginal factor production cost. Hence:

(14) $$w_c = c_x$$

The monopolist contracts output and charges a higher price. The extent of the pricing raising behaviour depends on whether the monopolist is operating in the continuous part of the marginal revenue curve. An unconstrained monopolist will charge

(15) $$w^m = \frac{(1-\beta)}{\alpha} c_x$$

The constrained monopolist will charge w^{max}, as defined in the appendix. Thus monopoly factor price is:

(16) $$\text{Min}\left(\frac{(1-\beta)}{\alpha} c_x, w^{max}\right)$$

and since $w_m > c_x$, output of the factor is restricted.

Social benefits are the sum of innovator and farmer profits. These are shown in the appendix. The social deadweight losses are given by

(17) $$\frac{SV^c - SV^m}{SV^c} = \frac{(1-\beta)(c - w_m)X^m + (1-\beta-\alpha)c(X^c - X^m)}{(1-\beta-\alpha).c.X^c}$$

These losses are independent of the demand distribution. This is because each farmer determines how much of the factor to use by equating his marginal evaluation of the factor with the factor price. Thus while factor use is dependent on the farm characteristic, the premium for innovation, paid per unit of factor, is independent of the farm specific characteristic. This is a realistic representation for innovations such as higher yielding varieties where each farmer's valuation per unit of seed will depend on the anticipated yield increase, and be independent of farm characteristics such as farm size.

3.2 Disembodied Pricing

Consider a situation where there was an identical shift in the production function, determined by a change in A in the Cobb-Douglas, but where this technical change was in the form of disembodied technology. The innovator could charge an upfront fee for the use of this technology. An upper limit on this fee would be the gain in profits associated with adopting the new technology.[1]

A farmer will adopt the innovation provided the fee is not greater than the expected gain in profits. The problem faced by the innovator in setting the fee is that farmers willingness to pay will vary, and by raising the fee, the innovator may reduce the size of the market. The problem for the innovator is to choose the optimal number of clients.

While average surplus (average change in profit) is independent of F (the farm specific factor), as shown in the appendix, factor use and consequently total surplus is directly related to F. Since F is a declining function of the number of clients (equation 11), the innovator can only attract more clients by lowering their charge. Revenue earned by the innovator depends on the number of clients (called k) and the charge, which is determined by the gain in profits (ie. total surplus) for the marginal user k.

(18) $\text{Revenue}R = D_k.k$, where $D_k = \pi_{2k} - \pi_{1k}$

This problem is solved using numerical techniques due to tractability problems. The revenue function is dependent on the distribution of demand, and when demanders are very similar, it is a monotonically increasing function of the number of users, with revenue being maximised by supplying the entire market. However, when the demand distribution is more disperse, there is a point where lowering the charge to gain more customers results in declining revenue. Figure 5 shows innovator revenue as a function of number of clients, for similar and disperse distributions on F. Parameters used in deriving these demand distributions are described in Table 1.

As the factor markets in the disembodied case are undistorted, the value of the factors, for those users who end up being in the market are equal to the social value. The welfare losses arise only when $k < n$. Deadweight losses can be described by

(19) Social Loss (disembodied)= $SV^c.\frac{h-r}{h}$

[1]Since technology adoption requires learning and search costs, and is subject to risk, some premium on the maximum possible charge is likely. However, this is considered negligible for both the embodied and disembodied cases in this paper.

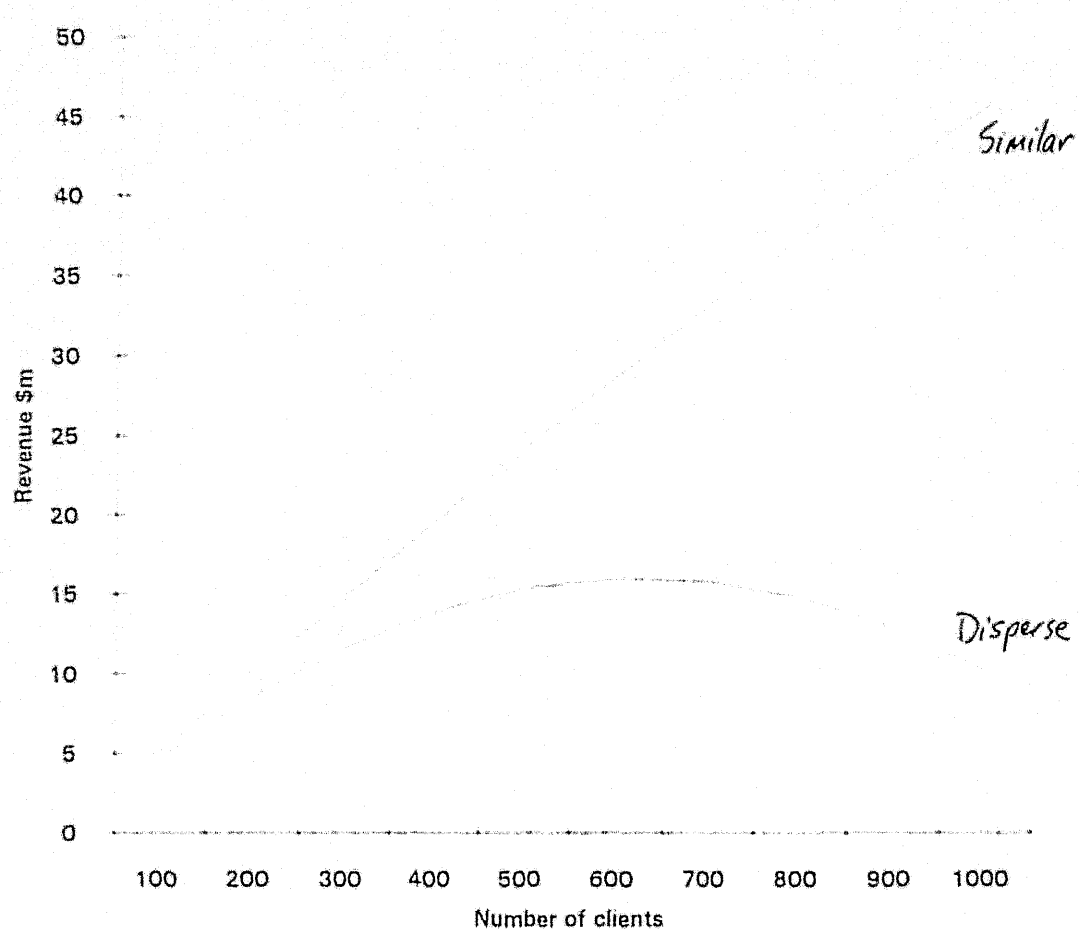

Figure 5: Revenue Function for Two Demand Distributions

where r and h are aggregation constants $r = \frac{1}{2e}(F_1^2 - F_k^2); h = \frac{1}{2e}(F_1^2 - F_n^2)$ as derived in the appendix

3.3 Quantification of Welfare Losses

In the following, the welfare losses for embodied and disembodied technology are compared for a range of assumptions about demand distribution and the productivity of the variable factors

Two scenarios for demand distribution is represented, a "similar" and "disperse" scenario. The parameters for F are shown in Table 1. The value of γ is assumed to be relatively large, to reflect the importance of farm specific fixed factors (notably farm size). Moreover, the low value parameters on the variable factors is consistent with findings on crop yield responses to variable factors (for example, Just and Pope (1979) estimated a coefficient of .3 for yield response to fertiliser). The value of α is varied for a range of assumptions about the value of γ. These assumptions are also presented in Table 1.

Table 1. Assumptions used in analysis

	Base Case	Case 2	Case 3	Case 4	Case 5
α	.1	.05	.15	.1	.1
γ	.7	.7	.7	.8	.6
Other Assumptions					
F_1=5000	F_n=4500 (similar)	F_n=1000 (disperse)			n=1000
A_1=2	ΔA=2.5% to 20%		P=100	C_x=100	C_z=200

Table 2: Realised Aggregate Factor Output as a % of Optimal, and % Deadweight Loss, for Base Case

	Embodied Pricing Both Demand Distributions				Disembodied Similar	Disperse
ΔA	2.5%	5%	10%	20%	All Shifts	
X	75	57	34	12	100	72
Z	96	93	87	77	100	72
Deadweight Loss	13	23	40	60	0	28

Results from the base case are shown in Table 2. The first thing that can be noted from the table is that the distortions created by embodied pricing are independent of the demand distribution. This is because the price paid per unit of the factor (hence the per unit premium for the innovation) is independent of the farm specific characteristic. Each farmer's total contribution to the innovation depends on farm size however, as each farmer's purchase of the factor will vary.

The degree of the distortion made by embodied pricing technology depends on the degree of shift in the production function. This is because it is the "significance" of the innovation that affects whether or not innovators can gain a full monopoly situation in the factor market. The constrained monopoly prices are shown in Table 3. Over modest shifts in the production function, for the assumptions examined here, the monopoly never gets to exploit full monopoly power (is operating on the discontinuous part of the factor demand curve). Generally, innovations in agriculture would be expected to be of this magnitude. Thus, the monopolist is constrained from raising price and contracting output by the presence of competitive alternatives (the old technology). Obviously the degree of monopoly power increases as the innovation becomes more significant. As a result, the distortion in the factor markets gradually get worse as the assumed shift in the production function gets larger. Distortions occur in both factor markets, although the effect in the other input market is reduced because of substitution towards the other input as the factor price ratio becomes distorted.

Table 3: Monopoly Price for Embodied Factor (Base Case)

Competitive Factor Price	100
Monopolist's Factor Price	
ΔA=2.5%	126
ΔA=5%	163
ΔA=10%	259
ΔA=20%	618
Unconstrained Monopoly Price	800

The distortions created by the disembodied pricing technique depend on the demand distribution. This is because with disperse demand the innovator must make a trade off between the price charged and the number of clients. Not all of the potential market can afford to pay the upfront fee which enables access to the technology. In the case of the disperse demand distribution, those clients which gain access to the technology realise the full social value of the innovation because factor markets are competitively priced. However, there is a reduction in aggregate output and associated deadweight losses because of the exclusion of some clients. The reduction in output in both input markets are the same because factor price ratios are not distorted, so those clients that are satisfied adopt the socially optimal input mix. Distortions are independent of the size of the shift in the production function, in the case of disembodied pricing, because the number of clients depends on the demand distribution and is independent of the size of the shift in the production function.

It can be seen that the disembodied pricing technique is less distortionary when the innovator faces very similar demand distributions. However, when demand is disperse the embodied pricing technique is superior on welfare grounds because deadweight losses are less. It can also be noted that for the small demand shift, the distortion in factor output is almost the same for both pricing techniques (75,72%), however the size of deadweight losses is very different, being much smaller for the embodied pricing technique. This is because the factor is distributed efficiently at the margin. In the disembodied case, those farmers who are restricted access to the technology have a much higher marginal evaluation than those who do have access to the technology (and adopt up to the point where marginal willingness to pay is equal to factor cost). In the embodied case, the factor is rationed efficiently, which each user equating marginal willingness to pay with the (distorted) factor price.

The appropriability of the realised social benefit of the innovation are illustrated for the base case in Figures 6 and 7, for the range of demand shifts. Figure 6 shows the similar demand case. It can be seen that the disembodied pricing scenario is better from the innovators point of view, when demands are similar. However, for small demand shifts, there is little difference between the embodied and disembodied cases. In the case of the embodied pricing technique the innovator gets all the realised social benefit from the invention (because they are constrained by competition so marginal value equals average value). With the disembodied technique the innovator loses some returns to the farmer (because some farmers have a gain in profits that is larger than the upfront fee). For the similar demand distribution this effect is small however. The desirability of disembodied pricing from the innovators (and society's) point of view increases as the size of the demand shift gets larger. This is because of the deadweight losses caused by the embodied pricing technique get large.

In the case of the disperse demand distribution in Figure 7, the embodied pricing technique is superior from the innovators point of view for demand shifts up to 10%. This result is due to the fact that deadweight losses are now significant, for the case of disembodied pricing, and also because the innovators share of the realised social benefit is lower under disembodied pricing when demand is disperse. Only for very large shifts (20%) is the disembodied technique better from the innovators point of view when demand is disperse. This is because of the significance of deadweight losses in the case of embodied technology, reducing the size of the realised social surplus.

The appropriability of returns also has long term implications, because the innovator's incentive to invest in research is affected by the appropriability of returns from intellectual property. In the case where demand characteristics differ across farms, then returns will be higher and more research effort will arise if innovators use embodied pricing techniques, *if*

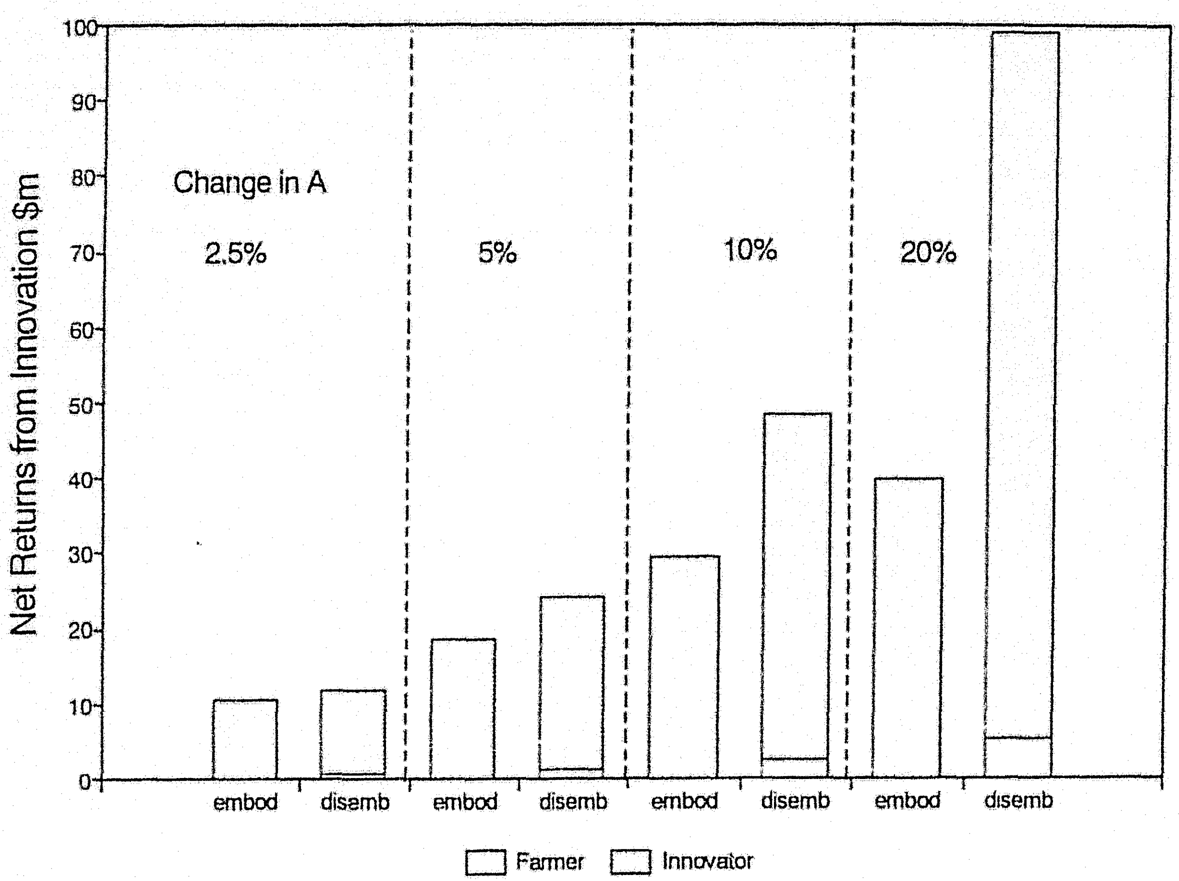

Figure 6: Distribution of Returns for Similar Demand (ΔA=2.5%)

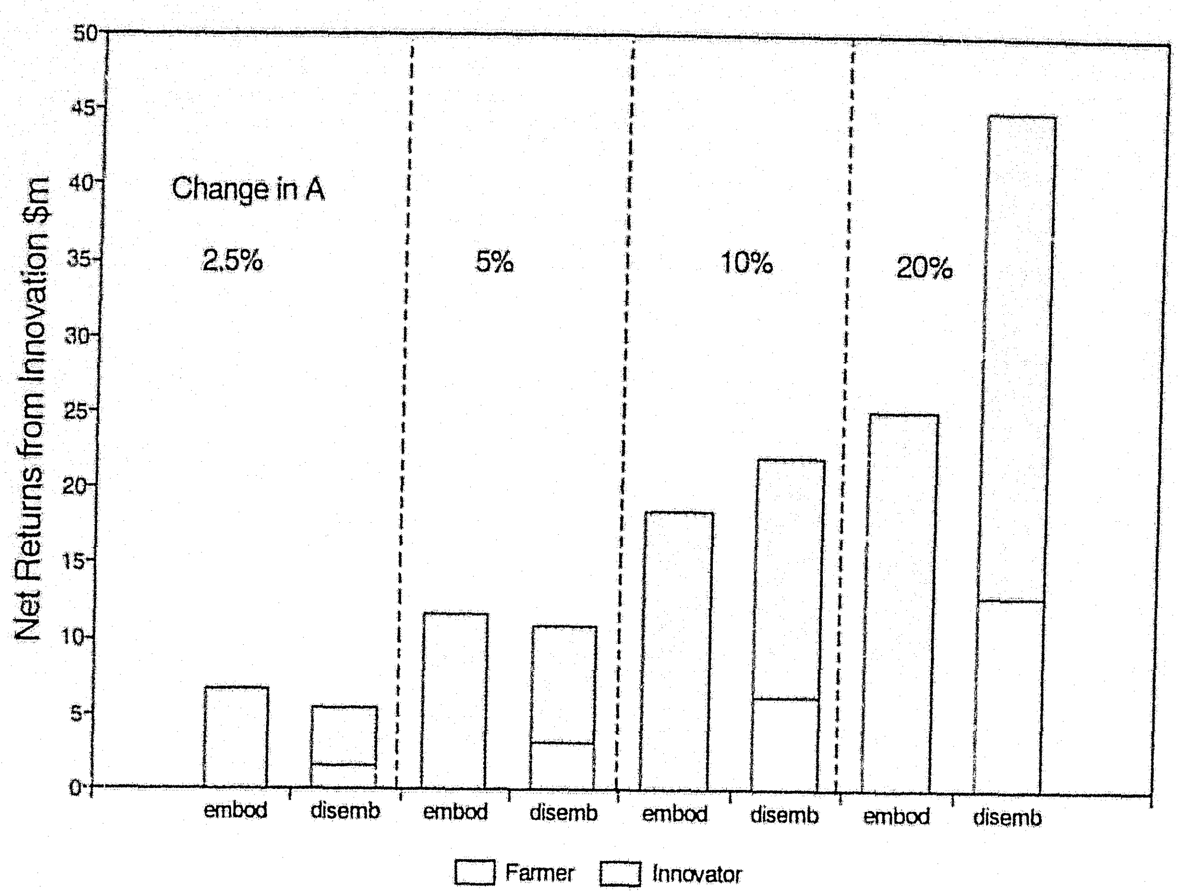

Figure 7: Distribution of Returns for Disperse Demand (ΔA=2.5%)

each innovation only causes a small shift in the production function, and there are a number of potential innovators.

3.4 Sensitivity Analysis

Table 4: Realised Aggregate Factor Output as a % of Optimal, and % Deadweight Loss, for Range of Assumptions When demand shift is 2.5%

	Embodied Pricing					Disembodied	
α	.1	.05	.15	.1	.1	All cases	
γ	.7	.7	.7	.8	.6		
X	75	59	82	76	75	100	72
Z	97	97	97	97	96	100	72
Deadweight Loss	13	22	9	13	13	0	28

Table 4 shows the effect of changing assumptions about α and γ, when the size of the production shift is small. It can be seen that as α declines (Factor demand becomes steeper) there is greater distortion associated with embodied pricing, in terms of reduction in factor output and deadweight losses. The results are unresponsive to changes in γ and β if α remains the same.

4. Conclusion

The welfare effects of pricing for embodied technology were shown using a general representation of production. It was shown that innovators will restrict output of the factor because they face a downward sloping demand curve. This general result arises because of diminishing marginal productivity of the factor. However, monopolists are constrained from exploiting full monopoly power by the presence of alternative technologies. When an innovation only produces a small shift in the production function, (as is likely for something likely a new seed variety) the degree of distortion arising from monopoly pricing in the factor market is dampened. In this case, the innovator charges all farmers their average surplus for the factor, and manages to appropriate all the returns from the technology. However, their restriction of factor output causes deadweight losses.

In the case of disembodied pricing techniques, the degree of distortion depends on the demand distribution of farmers. If farmers' demand for the innovation is sufficiently similar, then the innovator will not be faced with the problem of trading off the size of the upfront fee with the number of clients. In this case there is no price exclusion and the socially optimal level of factor use is achieved. However, when demand characteristics are disperse, then there are deadweight losses associated with disembodied pricing techniques, because of exclusion of some potential clients. In addition, the innovator cannot appropriate all of the realised social benefit.

The deadwieght losses caused by monopoly pricing in the factor market are dependent on the size of the shift in the production function. For small innovations, causing a less than 10% shift in the production function, this deadwieght loss is small, so embodied pricing is superior to disembodied pricing if demand characteristics are disperse across farmers.

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Appendix

Embodied Technology

The profit function defined in Equation 13 is:

$$\pi_{2i} = P.A_2.x^{\alpha}.z^{\beta}.F_i^{\gamma} - w_2.x - v_2.z$$

The associated factor demand equations are:

$$w_{2i} = \alpha.P.A_2.x^{\alpha-1}.z^{\beta}.F_i^{\gamma}$$

$$v_{2i} = \beta.P.A_2.x^{\alpha}.z^{\beta-1}.F_i^{\gamma}$$

Solving these two equations for z, we have:

$$z = \frac{w_{2i}\beta}{v_{2i}\alpha}x$$

Substituting, the production relationship can be expressed solely in terms of factor x.

$$\pi_{2i} = P.A_2.w_2^{\beta}.d.x^{\alpha+\beta}F_i^{\gamma} - w_2(1+\frac{\beta}{\alpha})x$$

Where d is $(\frac{\beta}{v_{2i}\alpha})^{\beta}$

And the demand for factor x by the ith farmer is

$$w_{2i} = [\alpha.P.A_2.d.F_i^{\gamma}.x^{\alpha+\beta-1}]^{\frac{1}{1-\beta}}$$

The inverse demand function for the ith farmer is:

$$x_i = (\frac{\alpha.P.A_2.d.F_i^{\gamma}}{w_2^{1-\beta}})^{\frac{1}{1-\alpha-\beta}} \qquad \text{if } AV_i \geq w_2$$

$$x_i = 0 \qquad \text{if } AV_i < w_2$$

The average value for the ith farmer is:

$$AV_{2i} = P.A_2.w_2^{\beta}.d.x_{2i}^{\alpha+\beta-1}F_i^{\gamma} - w_2(\frac{\beta}{\alpha}) - \frac{P.A_1.w_1^{\beta}.d.x_1^{\alpha+\beta}F_i^{\gamma}}{x_2} - w_1(1+\frac{\beta}{\alpha})\frac{x_{1i}}{x_{2i}}$$

Substituting for x_{2i}, x_{1i}

$$AV_{2i} = w_2(\frac{1-\beta}{\alpha}) - w_1(\frac{1-\beta}{\alpha} - 1)(\frac{A_1.w_2^{1-\beta}}{A_2.w_1^{1-\beta}})^{\frac{1}{1-\alpha-\beta}}$$

Which is independent of F, so $AV_i = AV_j$ for all $i \neq j$. This makes the aggregation simple, because the initial discontinuous point on the factor demand curve occurs at the same factor price for all farmers.

The maximum price a monopolist can charge is the solution to the following equation:

w^{max} satisfies $\quad w_2 = w_2(\frac{1-\beta}{\alpha}) - c(\frac{1-\beta}{\alpha} - 1)(\frac{A_1.w_2^{1-\beta}}{A_2.c^{1-\beta}})^{\frac{1}{1-\alpha-\beta}}$

Aggregate Demand

The aggregate demand function is:

$$\sum_n x_i \equiv \int^n x_i \partial i \qquad \text{where } w^{max} \geq w_2$$

$$\sum x_i = X = h.(\frac{\alpha.P.A_2.d.}{w_2^{1-\beta}})^{\frac{1}{1-\alpha-\beta}}$$

where $h = \int (F_0 - e.i)^{\frac{\gamma}{1-\alpha-\beta}} \partial i = \frac{1}{2e}(F_1^2 - F_n^2)$

and the inverse market demand function is:

$$w_2 = [(\alpha.P.A_2.d)(h/X)^{1-\alpha-\beta}]^{\frac{1}{1-\beta}}$$

Competitive and Monopolistic Output

The social optimal level of production of the factor (which embodies a discrete amount of technology) is found by equating factor demand with marginal factor production cost.

$w_{2c} = c_x$

Competitive output of factor X, is:

$$X^c = h.\left(\frac{\alpha.P.A_2.d}{c_x^{\alpha+\gamma}}\right)^{\frac{1}{\gamma}}$$

If operating in the continuous section of the demand curve, the monopolist's revenue curve is:

$$TR = w.X^m$$

$$TR = [(\alpha.P.A_2.d)]^{\frac{1}{1-\beta}} h^{\frac{1-\alpha-\beta}{1-\beta}} X^{\frac{\alpha}{1-\beta}}$$

Hence

$$MR = \frac{\alpha}{1-\beta}(\alpha.P.A_2.d)^{\frac{1}{1-\beta}}.h^{\frac{1-\alpha-\beta}{1-\beta}}.X^{\frac{\alpha+\beta-1}{1-\beta}}$$

so $w^m = \frac{(1-\beta)}{\alpha}c_x$

However, if the monopolist is constrained to be in the discontinuous part of the marginal revenue curve, price is limited to w^{max}

Thus monopoly price is:

$$w^m = \min(w^{max}, \frac{1-\beta}{\alpha}c_x)$$

Monopoly output is given by:

$X^m = h.\left(\frac{\alpha.P.A_2.d}{w_m^{\alpha+\gamma}}\right)^{\frac{1}{\gamma}}$, and since $w_m > c_x$, $X^m < X^c$

Benefits of Innovation

Farmer profit from the new innovation is:

$$\pi_{2i} = P.A_2.d.w^{\beta}F_i^{\gamma}x^{\alpha+\beta} - w_2(1+\frac{\beta}{\alpha})x$$

Substituting for x, and summing over F, we have

$$\sum \pi_{2i} = (P.A_2.d.)^{\frac{1}{\gamma}}(\frac{1}{w})^{\frac{\alpha}{\gamma}}h(\alpha)^{\frac{\alpha+\beta}{\gamma}} - w_2(1+\frac{\beta}{\alpha})X$$

Hence aggregate profit is $\pi_2 = (\frac{\gamma}{\alpha})w_2.X$

The social value of the innovation is equal to the sum of farmer and innovator profits. For the socially optimal situation, this is

$$SV^c = (\frac{1-\alpha-\beta}{\alpha})c_x.X^c$$

For the monopoly situation it is:

$$SV^m = (\frac{(1-\beta)w_m - \alpha.c_x}{\alpha})X^m$$

The social deadweight losses are therefore

$$\frac{SV^c - SV^m}{SV^c} = \frac{(1-\beta)(c-w_m)X^m + (1-\beta-\alpha)c(X^c - X^m)}{(1-\beta-\alpha).c.X^c}$$

which is independent of the demand distribution