A Model for Evaluation of Waste Reducing Postharvest Research.

Jeff Davis.

Australian Centre for International Agricultural Research
Canberra.

Contributed Paper for the 37 th Annual Conference of the Australian Agricultural Economics Society, Sydney University, February 9-11, 1993.

1. Introduction.

Evaluation of the impact and potential impact of agricultural (and other sector) research has been the focus of a significant amount of research during the past 25 to 30 years. The methodology which has resulted from the research has now reached the stage where it covers a range of types of research which might take place at various stages in the production, processing, distribution and marketing of agricultural products. Despite these significant developments it is only recently that some research institutions are starting to incorporate information generated from applications of this methodology as an integral part of their research decision-making systems. Examples of these activities are given in Davis and Ryan (1993), Scobie et al (1991), GRDC (1992) and Johnston et al (1992). At this stage though there is still considerable variability in the level of integration and institutionalisation of this information.

Even with some of the recent developments it is common to find that when quantitative research evaluation assessments are undertaken for use within research institutions there is still a tendency not to make use of the detailed body of literature. Indeed a major share of the literature, especially in professional journals, has been developed independently of applications specifically focused at supporting day-to-day decision-making by research managers and decision-makers.

There is still an essential need to make further progress in refining and developing various theoretical aspects of research evaluation methodology. However, there appears to be an important need to bridge the gap between the theory and empirical applications specifically focused at supporting day-to-day research project development and research policy decision-making.

This paper attempts to focus some attention on this issue. It begins by summarising a few points regarding the importance of interfacing theoretical developments with decision-making requirements. This is followed by the development of a simple model of wastage reduction research which is used to illustrate the type of gap-bridging effort which might be required to ensure that more complex research evaluation models are eventually adopted by research institutions as part of their general support for decision-making.

2. Importance of Interfacing Research Evaluation Methodology with Decision-Making Requirements.

The Australian Centre for International Agricultural Research (ACIAR) has for the past seven to eight years been developing a detailed Information System specifically to support day-to-day research resource allocation decision-making at both an individual project and an aggregate level. (Davis and Ryan (1993) provide a detailed description of the historical development of this effort and Davis and Fearn (1992) provide a brief description of its current status). This effort was commenced specifically recognising that few research institutions, at that time, were making use of the extensive research evaluation literature to support their day-to-day operation. During the development period of this Information System, interaction and collaboration with many other research institutions has been crucial, it has been surprising to find that in many instances even when institutions have decided to attempt to quantify the impact of their research efforts, that they have often made very limited use of the range of methodology available in the literature.

On reflection there are perhaps some important constraints on research institutions which could well have contributed to this situation. It is possible that the failure of the methodology development to take these constraints into account has also contributed. These constraints are:

(i) Assessments are usually required relatively quickly. In most research institutions where research evaluation assessments, especially at a project level, are used to support decision-making there is rarely time for a 6 to 12 month research effort. This is often the time required to develop an empirical application of some of the complex methodology. As these assessments become accepted as an important part of the decision-making information system, large numbers of assessments are required. In these situations there is rarely time to undertake detailed econometric on other programming model analyses to provide estimates of some of the complex model parameters. This is not to say that in the longer term these complex models will not be important just that in the early stages of an information system development it can be very important to have simpler models which can be applied quickly. The crucial factor is to ensure that there is a clear link between the simple and complex models so that simple adaptation can occur as the information system matures. A sometimes observed trend to develop simple methods which are not related to the more theoretically acceptable models is a concern and should be discouraged.

(ii) During the development of information systems within research institutions the effective interaction between economists and the technical scientists undertaking the research is crucial. Without this the level of acceptance is likely to be low and the chance of institutionalisation small. In addition experience, especially at ACIAR, has shown that one of the most important benefits of these economic evaluation assessments flows from the interaction between both groups and the subsequent impact on research project formulation. The flow of benefits is in both directions. The economists also develop a better understanding of the technical details and can, therefore, develop assessment models which more realistically represent the impact of the specific types of research. To achieve this effective interaction it is very important to have models which can be explained quickly and in terms which are easier to understand. This requires the adoption of relatively simple models, at least in the early stages. Once the confidence of the scientists has been established the more complex forms of the models can be introduced. Indeed experience suggests that this is a crucial part of the evolution of the information system, since these models facilitate inclusion of more realistic aspects of the impact of the research. If these are not eventually incorporated it has been found that the scientists often start to question the scientific basis of the evaluations.

(iii) There must be a clear link between the parameter(s) used to represent the impact of research in the theoretical model and the manner in which the results of research projects can be interpreted as impacting on the production, processing or consumption of the product. This is probably the major weakness in the current set of literature and has received the least attention. For example, there has been considerable debate regarding the geometric form of the shift in the product supply due to research, but very little discussion about how the shift is measured and how these measures might differ depending on the type of research undertaken.

The general conclusion which flows from these points is that there is an important need to develop theoretically sound methodology for evaluating the impact of research. However, in doing this it is important to develop a range of models which cover all aspect of specific research project outputs. It is also important to have a range of complexity within these models to accommodate the constraints on their use within different research institutions and also to ensure their longer term consistency with the methodological peer reviewed literature.

The objective of the rest of this paper is to take one area where it is felt that there is a gap between the relatively simple model and the more complex model developed in the literature. This is in the area of postharvest or market service and processing sector research. The next section briefly reviews this area and relates it to the current research program in a research institution. The last section develops an intermediate model which it is felt helps fill the gap between the current simple and complex models.

3. An Overview of Models for Estimating the Welfare Effects of Postharvest Research and Classification of ACIAR's Postharvest Research Program.

Many early attempts to evaluate the welfare impacts of postharvest research adopted a simple value of output model. The model used in these attempts relies on estimates of the expected change in output after the research impact and found the gains as this output change valued at the consumer commodity price. It can be readily shown that this model is a special case and implicitly makes assumptions which are, in most cases, not realistic. More importantly estimates found using this model are likely to over-estimate the research gains. Some evaluation studies still seem to adopt this simple model.

During the last 15 years there has been a growing body of literature which has focused more closely on the issue of measuring the welfare impacts of research focused on the postharvest section of the agricultural sector. This work is an extension of the relatively extensive farm level research evaluation methodology. (See for example, Norton and Davis (1981) for an early review of this farm level work). Some examples of the range of work in the postharvest area is reported in, for example, Davis (1976), Freebairn, Davis and Edwards (1982, 1983), Alston and Scobie (1983), Mullen, Alston and Wohlgenant (1989), Mullen, Wohlgenant and Farris (1988), and Unnevehr (1986). Alston (1990) has recently reviewed some of these methods and applications. In many cases the complexities of the potential interactions which can occur at the postharvest level can require quite complex estimation methodologies. So far, however, there have not been many attempts to adapt the methods developed in these research efforts to provide relatively simple procedures for quick and easy application at a project evaluation level. This requires some classification of the types of postharvest research into groups based on the whether simplifying assumptions can be adopted without a large risk of error when estimating potential research impacts.

Aston (1990) classified models based on the assumptions regarding the economic structure of the model. These classifications are very important because they enable different models to be categorised in terms of an ideal general equilibrium framework and provide a perspective of theoretically how each model relates to this ideal. However, this classification does not focus specifically on the types of research efforts which are undertaken and how the impact of these are measure empirically. The following is a preliminary list of some alternative possible categories and a brief discussion of each.

(i) Simple Cost Change Model - no (minimal) processing of the commodity.

The first variation from the simplistic value of the change in output estimation model was one which assumed the commodity effected by the research did not change its form during the postharvest process. Such commodities would only be graded on the farm and then involve postharvest activities such as transport and storage. Usually it is assumed that there is no wastage during the postharvest stage or at least that this wastage rate is fixed and not influenced by the research activity. In this case postharvest research results in a reduction in the costs of the postharvest activity, for example, transport and/or storage. Models of this type have been discussed by, for example, Freebairn, Davis and Edwards (1982), the important assumption is that the primary farm product is used in fixed proportions with the postharvest inputs and the commodity does not change form in this process, examples might be many fruits, vegetables and possibly eggs. While, relatively, simple this model can provide a reasonable approximation in some cases.

(ii) Complex Processing Model

Clearly the majority of agricultural (and forestry and fisheries) commodities involve some postharvest processing, many require complex processing before they are in the form consumers desire. When complex processing takes place scope emerges for substitution possibilities between the farm level primary commodity and other inputs used in the processing activity. In these situations the model for evaluating the welfare impacts of postharvest research can also become more complex. A large share of the recent literature on postharvest research evaluation has focused on this area, for example, see Alston (1990) for a review. A crucial implication which has come from this work has been the care which is required with postharvest research if the distribution of the research gains between different groups in the production chain is important. It has been shown that depending on the nature of the processing sector and where the research is focused it is possible that the primary producers, that is farmers, could stand to receive only a small share of the research gains and even under some conditions be worse off, after the research results are adopted by the processing sector.

Application of this type of model has the significant drawback that it requires detailed information on some of the more difficult to measure substitution and product transformation parameters. In addition the concepts associated with these parameters are some of the more difficult economic principles to grasp and often are associated with counter-intuitive implications.

(iii) Minimal Processing with Product Wastage Model

Some commodities require postharvest processing which involves more than just transport and storage but this processing does not necessarily have complex substitution relationships. In such cases the quantity of the commodity leaving the farm will often change by the time it reaches consumers. This change is usually in the form of processing shrinkage or wastage. For example, with fruit and vegetables there are often significant differences between the quantity leaving farms and that eventually used by consumers, even though the physical form of the commodity has not necessarily changed very much. For this group of commodities the more complex substitution relationships can be assumed to be relatively simple without much risk of error. Research in this area of postharvest activity often focuses on factors which result in a reduction in the postharvest "wastage". In most cases this new technology has increased costs associated with it which need to be off-set against the wastage reduction gains. This type of research might be regarded as developing a new technology which in fact changes the fixed proportions relationship between the processing inputs and farm product, however, once the new technology is adopted a new fixed proportions relationship exists. The cited literature has not given direct attention to this group of commodities and type of research outcome. They can be accommodated by using special case values of the substitution parameters in the complex processing model, however, closer consideration of the measurement of the technical change parameters is required.

(iv) Health impacts of Research Model.

In several areas of the agricultural sector there is increasing awareness of the potential health impacts of production, processing and distribution activity. At the farm level one obvious example is the impact of pesticides. At the postharvest level several examples are available, such as the aflatoxin problem in stored grains. There has been a substantial set of analyses which have looked at the issue of estimating the welfare effects of public health. Only a small subset of this has focused on assessments of the gains from health related research. There is a need to adapt this to suit possible areas of on-farm and postharvest agricultural research. None of the current set of research evaluation models specifically address this area and it does not seem possible to provide a simple adaptation of the complex models.

(v) New Product Development Model.

Although probably not as common as some often suggested, some research does result in the development of a commodity or product from a commodity which has not been available before. The latter is more relevant for postharvest research. Some are inclined to value the gains from this research as the value of the new product. This is certain to overestimate the gains. Account needs to be taken of the alternative uses of the resources which are likely to be diverted into the production of the new product. Use of the difference between the new and old product price to value the gains also needs to be treated with caution. The complex processing research evaluation model needs to be adapted to estimate these types of gains. The "multiple products related in both production and consumption" model briefly discussed by Alston(1990) is the direction for progress. A simple version is required to provide guidance for quick applications.

(vi) Change in Quality Model.

Some research can result in a change in the quality of the commodity or product. Several past studies have tended to estimate the gains from this type of research using the difference in the price between the low and high quality product. While this may be an appropriate method is some cases, these are likely to be special cases. In general a model which incorporates complex demand and even production substitution possibilities will be required. Some progress has been made in this area, however, a straightforward, easily applied model is not yet readily available. The most common simple model used is to assume the research shifts the demand of the commodity. As pointed out by Aston (1990, p33) this type of model needs to be applied with considerable caution.

Any research project may well have several impacts on the postharvest process. For example, it may reduce the cost of transport and storage and have an impact on public health. In such cases to fully measure the gains (or losses) from a research effort more than one of the welfare measurement models may need to be employed.

To this stage there have not been many attempts to determine which types of research are most common in the research programs of research institutions. Table 1 summarises the results of this exercise for ACIAR's postharvest research program.

Table 1: Categorisation of Most of ACIAR's Past and Current Postharvest Research Program Projects.

Project Description	Project Number	Cost Change Model	Complex Processing	Wastage Reduction	Health Effects	New Product	Quality Change
Long-Term Storage of Grain Under Plastic	8307/8845			X			
Drying of High Moisture Grain in Humid Tropical Climates	8508			X			X
Integrated Pesticides in Grain Storage in Humid Tropics	8609			X			
Fungi and Mycotoxins in Asian Food and Feed Stuffs	8806			X	X		
Development of Postharvest Handling Technologies for Fruit	8844			X			
Improved Processing Systems for Dried Fish	8304/8313 /8846			X			
Increasing Efficacy of Pest Control and Pesticide Residues	9009	X			X		
Integrating Grain Protectants into Storage Pest Management	9035			X	X		X
Development of Heat Systems for Disinfectation in Tropical Fruit	9051			X			X
Factors Affecting Aflatoxin Formation in Asian Peanuts	9104			X	X		
Development of Simple Edible Coatings for Fruit and Vegetables	9105			X			
Multipurpose Instore Grain Dryers	9008	X		X			X
Novel Tuna Products	9124					X	
The Impact of Phosphine Exposure on the Quality of Stored Grains	na						X
TOTAL		2	0	11	4	1	5

Fourteen research areas/projects are included. It is seen that by far the most common area of research impact is wastage reduction, with 11 of the 14 focusing on this issue. Next most common is product quality with five projects focusing on this issue. Health impacts are also important with four projects emphasising this area. There have been no projects which have focused on research related to products which involve complex processing . This is probably primarily due to the nature of ACIAR's mandate for research which focuses on collaborative research with developing country partners. However, it could also be due to the fact that much of the research in this area fits more appropriately into the private good category. If this is the case it will (hopefully) be unusual to find public sector research institutions funding this type of research.

This simple categorisation seems to suggest that there may be a gap in the simpler methods available to evaluate wastage reducing types of research. It may be important to develop a simplified version of the complex processing model to support project level evaluations of this type. In addition models which consider the health and quality changing impacts of research also seem to require closer attention. The first area is the focus of the rest of this paper.

4. An Alternative Model for Postharvest Waste Reduction Research Evaluation

In line with the views expressed earlier in this paper it is important to have as a longer term aim the introduction of research evaluation models which are consistent with the best available theoretical models. As was emphasised it is often important to have available simpler models which can be used reliably during the development phase of introducing information systems to support decision-making in research institutions. The currently available complex processing sector models often do not satisfy the constraints discussed in section 2. They are not very easy to explain to non-economists; the parameter requirements are demanding and at this stage there is not a readily available set of these parameters which have been assembled, the benefit estimation requirements are still demanding which are not simply incorporated in spreadsheets; and the procedures for estimating the impact parameter are not well developed. (Although with respect to the last point studies, such as, Lemieux and Wohlgenant (1989) have made some progress).

In this section a model is outlined which attempts to fill the gap between the complex processing model and the simple no-processing model from previous studies. This model is called a waste reducing postharvest research model.

Figure 1 illustrates the simple cost change model used in, for example, Freebairn et al (1982) and reviewed in Alston (1990). Figure 1(a) is the conventional supply/demand model without any postharvest sector costs. The farm level supply is give as S_f and the retail demand by D_r. Figure 1(b) illustrates a possible postharvest service sector supply situation. The supply of postharvest services, before research, is given as S_m. The demand for postharvest services, D_m, is a derived demand and is given by the vertical distance between the retail demand and farm level supply, therefore, this demand intersects the quantity axis in Figure 1(b) at the quantity where the retail demand and farm supply intersect. The intersection of the postharvest supply and derived demand determines the equilibrium, determining; the retail price P_r, the farm level price P_f the postharvest of marketing margin P_m and the equilibrium quantity, Q_0. An important feature of this model is the assumption of fixed proportions, thus the postharvest services are used in the same proportion as the farm product for all prices and quantities. This enables the postharvest services to be measured in terms of farm level output equivalents. In addition the model assumes that the retail quantities are in the same units as the farm quantities. Alston (1990) uses a similar diagrammatic representation but separates the farm and retail levels which allows for different price units at the retail level and the ability to measure each quantity axis in different units. If this is done, however, the equilibrium interconnections in Figure 1 are lost and equilibrium changes have to be deduced from a mathematical model and inferred onto the figure.

If postharvest research reduces postharvest costs, this can be represented in Figure 1(b) as a shift from S_m to S'_m. The farm and retail levels remain unchanged. The "after research" equilibrium is given by the intersection of the derived demand and the new postharvest supply. This gives the following: an increase in the quantity produced and consumed; a fall in the retail level price; an increase in the price to producers; and a reduction in the postharvest service price. The benefits from the research can be measured in two ways. The total welfare gains are the area between the two postharvest service supplies and under the derived demand in Figure 1(b). Alternatively it is the sum of the changes in surpluses of each of the three groups. This is the sum of the shaded areas in Figure 1.

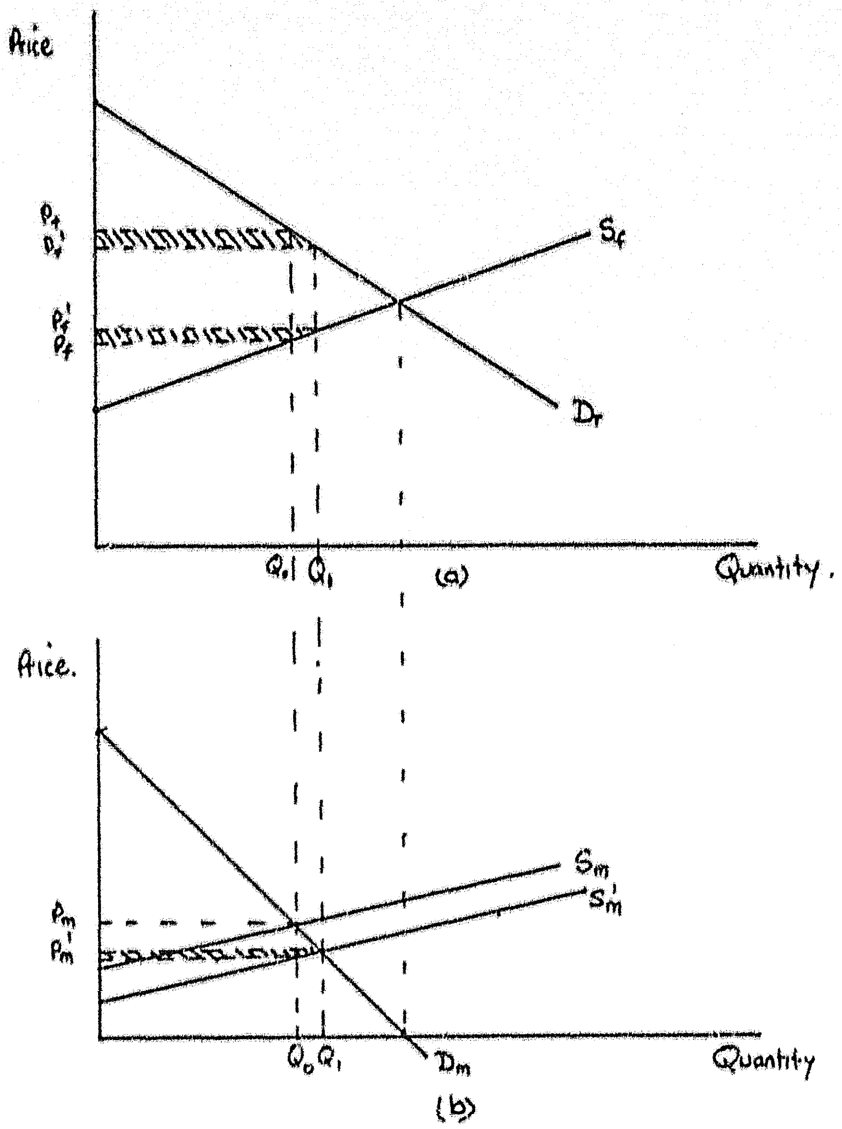

FIGURE 1: Simple Cost Reduction Model - No Processing

Figure 2 illustrates the same situation in a single diagram. In this case the postharvest service supply (costs) are added to the farm level supply to give the retail level supply, S_r. The same results are illustrated, although it is a little more difficult to demonstrat. un impact of the research. As has been shown in other papers if the postharvest service supply is perfecti, *'.astic, then all of the research gains will be distributed between the producers and consumers. In many situations when the agricultural commodity activity uses only a small share of these types of inputs this might be a realistic representation.

This model clearly does not allow for many aspects of postharvest agricultural activity. As was discussed in the pervious section it does not account for the case where there are losses of the product between the farmgate and the retail outlet. Many commodities are characterised by this even if the product is not processed to any degree. Figure 3 illustrates a four quadrant diagrammatic model which can accommodate this feature and retain the feature of internal determination of the market equilibrium. In this illustration, for simplicity, the postharvest service costs are assumed to be zero.

Figure 3(a) is the retail sector of the market for the commodity. Figure 3(b) is the farm level supply sector and is a mirror image of the usual supply diagram. In this case the two quantity axes are measure in units of the product, processing which substantially changes the form is assumed not to take place. This might, therefore, represent many fresh fruit and vegetables and even many cereal crops such as rice , pulses, etc. In these crops it is common for the transport and storage activities to result in a reasonable share of the crop which leaves the farmgate not reaching the consumers. This can be due to pest and disease attack, shrinkage, early ripening, handling damage, etc. In Figure 3 two cases are illustrated. First the situation when no wastage occurs This is represented by drawing a 45 degree line in sections (b) and (d) of Figure 3. By using this wastage transformation line the farm level supply S_f can be transformed into a retail level supply S_{r0}. In this "no-waste" example the retail supply is identical to the farm level supply.

If the product is transported, stored and handled using existing technologies and 40 percent losses are expected then a wastage transformation line with a slope of 0.6 to the farm product and retail price axes (a line of about 31 degrees) can be used to generate the retail level supply, now S_{r1} With the retail demand as it has been drawn the equilibrium "with wastage" gives a higher price (by 40%) at the retail level and no change in price and quantity at the farm level This is only a coincidence with this particular specification of the demand

Figure 4 adds the postharvest service costs to Figure 3 In this illustration these service cost are assumed to have a perfectly elastic supply. Therefore the "with postharvest services" farm sector level supply S_m is drawn parallel to the farm level supply, S_f With technology which gives fixed proportions postharvest losses of 40% the retail supply S_r is appropriate. If postharvest research is undertaken with develops a new technology which reduces wastage to 35% then the wastage transformation line is shifted by the research. In most cases, however, the adoption of these types of technologies requires the use of some additional resources and therefore associated costs. If this is the case the supply including postharvest costs will also shift to S'_m The combined effect of both changes is a shift in the retail level supply to S'_r. In equilibrium the following changes are occur: the retail price falls; the quantity consumed increases; farm production falls because of the slight fall in the farm level price; and the cost of postharvest services increases.

The welfare gains from the research are given in net terms as the area "*wxyz*" which is the sum of the shaded areas in Figure 4 (a) and (c). Notice that for the conditions depicted consumers gain by the shaded area in figure 4(a) while farmers loss by the shaded area in Figure 4(c). Because of the perfectly elastic supply of postharvest services assumption there are no surpluses and therefore surplus changes at this level.

There are many variations of this model which can be developed and discussed. The following are a few point which are important:

(i) Estimation of the impacts of this type of technology is relatively straight forward. The wastage reduction change and the change in associated postharvest service costs are the two important sets of information. From experience at ACIAR this type of information is relatively easy to obtain and technical scientists can relate to this relatively easily.

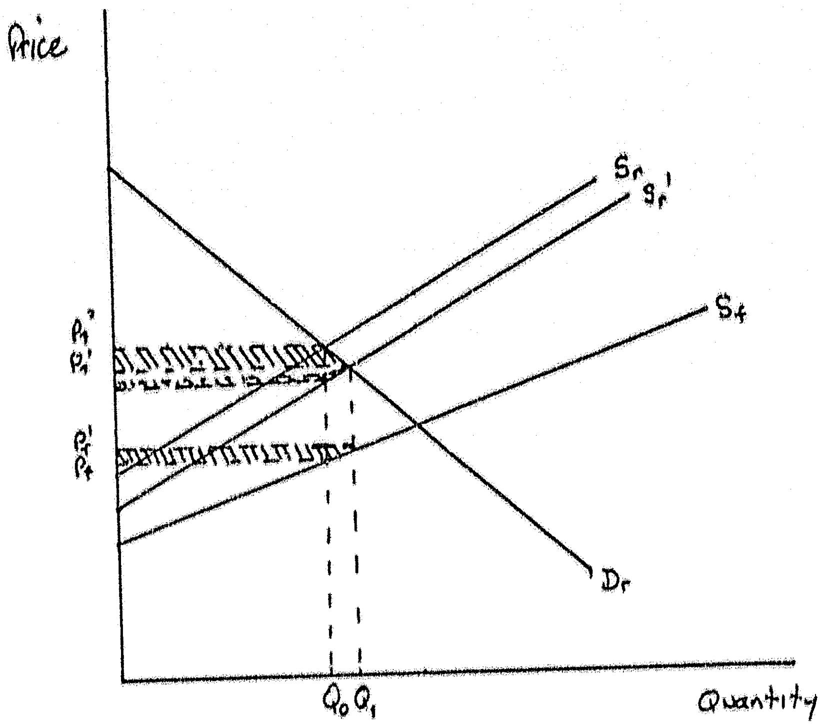

FIGURE 2: Single Diagram Model of Simple Cost Change

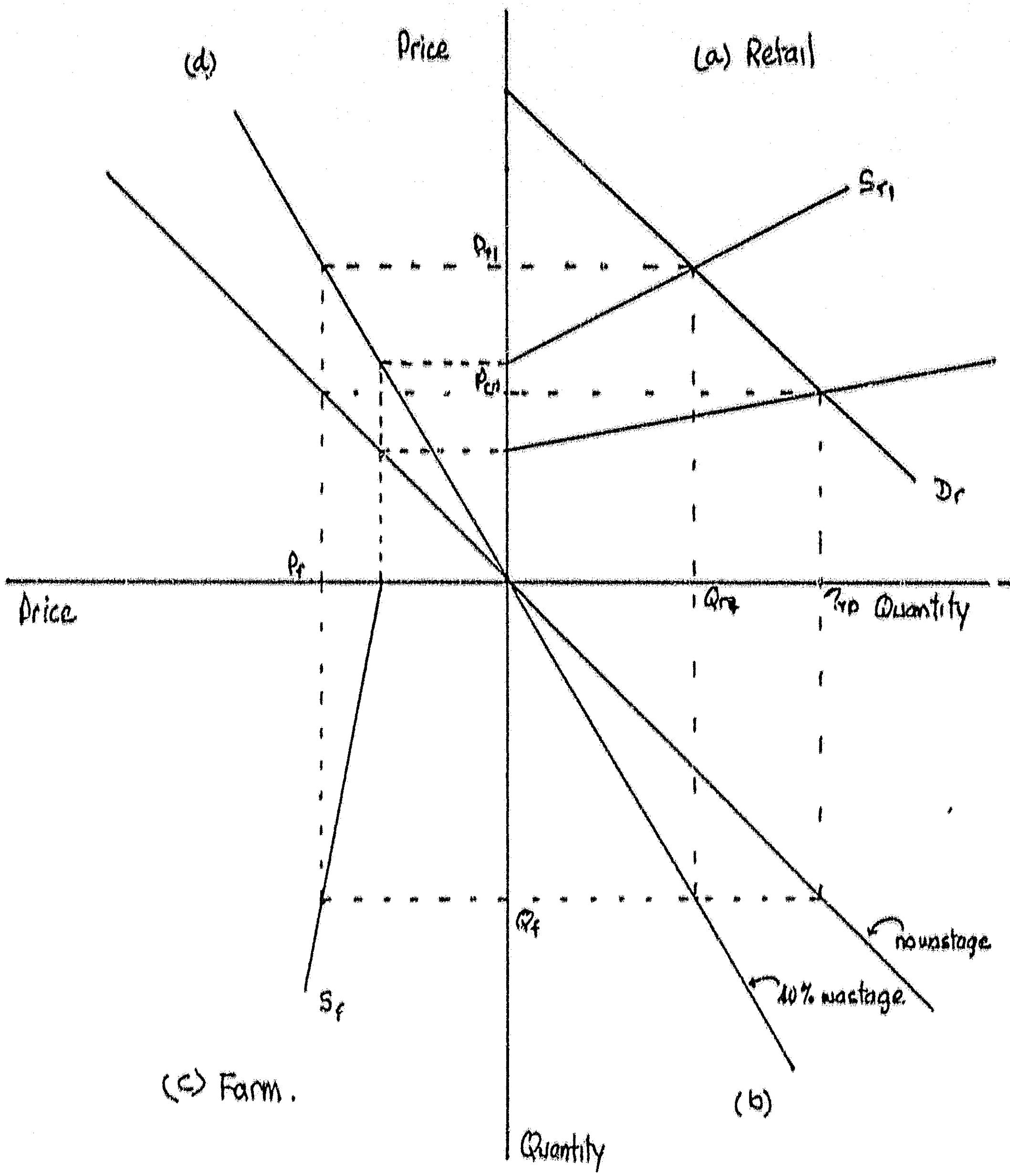

FIGURE 3 : Illustration of Postharvest Wastage Model - No Research and no Postharvest Costs.

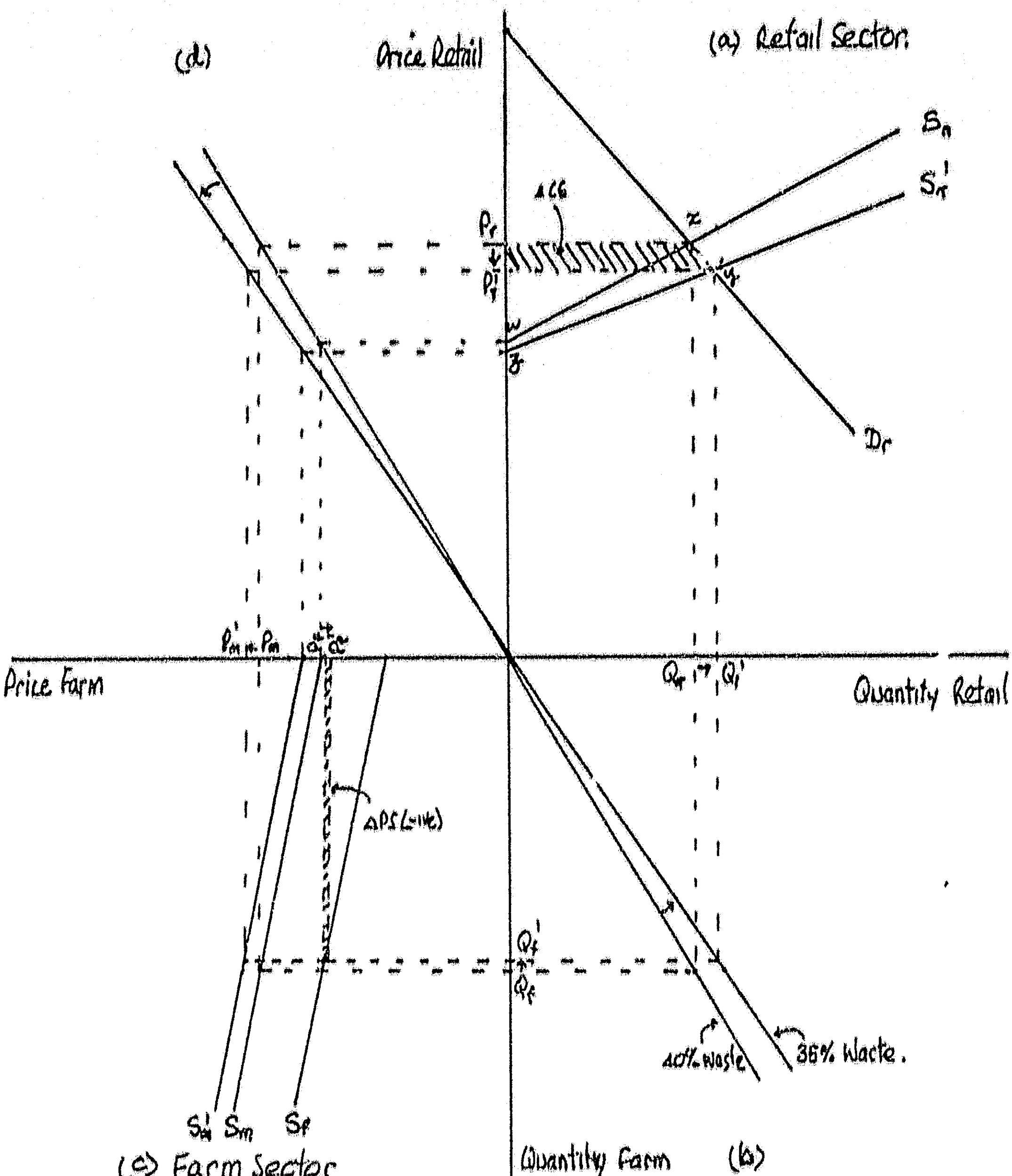

FIGURE 4: Postharvest Wastage Model With Research.

(ii) Farmers may gain or loss from this type of research depending on the combination of parameters in the model. The level of cost change relative to the wastage reduction is important. However, as would be expected the demand elasticity is critical. If the crop is exported in a small country model then farmers will gain.

(iii) It is possible to relax the perfectly elastic postharvest service input supply. This results in a farm level supply (Figure 4(c)) similar to that shown in Figure 2. Under these conditions the postharvest sector can gain from the research.

(iv) It is possible to draw a version of the model which separates the changes at the retail level into those associated with the wastage reduction and those with the cost changes. This representation can be useful for understanding and illustrating the impacts of this type of research.

(v) It is possible to hav' .ю fter research" retail supply intersect the "before research" retail supply. This depends upo' ' ativity changes between the cost changes and the wastage changes.

(vi) It is possible to d. .w the postharvest sector in terms of the retail sector rather than the as shown at the farm sector level. This can be included by adding the postharvest service costs to the transformation line in Figure 4(d).

(vii) A mathematical version of this model can be developed which is similar to the previous non-displacement models.

5. Conclusions.

This paper has discussed the issue of interfacing the considerable research evaluation literature which has developed during the past few decade with the requirements of decision-makers in research institutions. It has concluded that further theoretical developments in this area are important to ensure the continued improvement in the quality of assessments using these techniques. However, there appears to be a gap between many applications and the theoretical models. To ensure that this gap does not widen it is argued that som intermediate models need to be developed which maintain the link to the complex models but which are not quite as demanding of information. These, however, need to be closely related to specific type of research areas and limited to application in these areas. The paper illustrates this point by describing a specialised model for evaluating research which results in postharvest waste reductions.

REFERENCES.

Alston J.M., (1990), "Research Benefits in a Multimarket Setting", ACIAR/ISNAR Project Paper No 18, Indonesian Country Study, July.

Alston J.M. and G.M. Scobie, (1983), "Distribution of Research Gains in Multistage Production Systems: Comment", American Journal of Agricultural Economics, Vol 65, No 4, pp. 353-6.

Davis, J.S., (1976), " The Establishment of a Basis for the Determination of Priority Areas for Egg Marketing Research", Report Prepared for the Poultry Research Advisory Committee, Marketing Sub-Committee, June.

Davis, J. and Fearn, M. (1992), "Information to Support Resource Allocation for Fisheries Research: Aggregate Priorities and Project Level Assessments", Paper presented at the ACIAR Fisheries Program Project Leaders Meeting, Bribie Island, Australia, 3-5 June, 1992.

Davis J.S. and J.G. Ryan, (1993), 'Designing Information Systems to Support Priority Assessments in Agricultural Research : Concepts and Practices for International and National Institutions', ACIAR Monograph No 26.

Freebairn J.W., J.S. Davis and G.W. Edwards (1982), "Distribution of Research Gains in Multistage Production Systems", American Journal of Agricultural Economics, Vol 64, No 1, pp. 41-9.

Freebairn J.W., J.S. Davis and G.W. Edwards, (1983), "Distribution of Research Gains in Multistage Production Systems: Reply", American Journal of Agricultural Economics, Vol 65, No 4, pp. 357-9.

GRDC (1992) " Gains form Research" Grains Research and Development Corporation, Occasional Paper Series, Volume 1 Overview, Canberra.

Johnston B., T Healy, J. I'ons and M. McGregor, (1992), "Rural Research - The Pay-off", Occasional Paper No 7, CSIRO, Canberra.

Lemieux C.M. and M.K. Wohlgenant, (1989), "*Ex Ante* Evaluation of the Economic Impact of Agricultural Biotechnology: The Case of Porcine Somatotropin", American Journal of Agricultural Economics, Vol 71, No 4, November, pp. 903-14.

Mullen J.D., M.K. Wohlgenant and D.E. Farris (1988), "Input Substitution and the Distribution of Surplus Gains from Beef Processing Costs", American Journal of Agricultural Economics, Vol 70, No 3, pp. 245-54.

Mullen J.D., J.M. Alston and M.K. Wohlgenant (1989), "The Impact of Farm and Processing Research on the Australian Wool Industry", Australian Journal of Agricultural Economics, Vol 33 No 1, pp.32-47.

Scobie G.M., V Jacobsen and M Falconer, (1991), "Investing in R&D: How Much and In What?", Paper Presented to the New Zealand Association of Economists Annual Conference, Christchurch, August.

Unnevehr L.J., (1986), "Consumer Demand for Rice Grain Quality and the Returns to for Quality Improvement in South East Asia", American Journal of Agricultural Economics, Vol 68, No 4, pp. 634-41.