Disaggregation rather than Mathematical Manipulation for Incorporating Research Impacts on Supply.

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1. INTRODUCTION.

Most accepted approaches for evaluating the potential impact of research on agricultural production rely on a measure of the shift in the supply due to the research as the basis for estimating the welfare gains. During the past decade or more a considerable effort has been devoted to discussing the geometrical representation of this shift. Much of this work has used a national aggregate supply for a particular commodity as the focus for the analysis.

An important contribution to this area was the set of papers by Lindner and Jarrett (1978,1980) and their interaction with, especially, Rose (1980). Despite this interchange, and the important results which stemmed from it, there has still been significant emphasis placed on further development of geometric representations to solve the identified problems.

Few papers have taken up an important point raised in the Lindner and Jarrett/Rose debate. They concluded that the best solution to most of the problems was to disaggregate the level of analysis. If this is done they suggested that the simpler linear-parallel shift model is likely to provide a good approximation of the research impact.

This paper looks more closely at this suggestion. It presents a diagrammatical assessment of the issues which highlights the points raised by the Lindner and Jarrett/Rose debate. This assessment also highlights the importance of understanding and modelling the spillover effects of research between different farm production environments.

The paper concludes with an empirical example which emphasises the importance of the points raised in the earlier debate.

2. BACKGROUND.

During the past 30 years considerable advances have been made in the development of methodology used to evaluate the welfare gains from publicly funded research. One aspect of this development has been a significant debate about how best to represent the impact of research at an aggregated (usually national) supply level. Much of this debate has focused on the mathematical representation of the aggregate commodity supply before and after the research impact. Issues such as whether the aggregate supply can be approximated by a linear function and then whether the impact of the research is best depicted as a parallel, pivotal, divergent or some combination shift in this aggregate supply have, in particular, received considerable attention.

These issues, especially the latter, still receive significant attention. Attention was first focused on this set of issues by Lindner and Jarrett (1978). There have been a steady flow of papers which have since addressed a range of associated sub-issues. Recent examples are Lynam and Jones (1985), Miller, et al (1988) and Voon and Edwards (1991). However, in many cases the subsequent studies seem to have ignored an important conclusion which stemmed from the interchange between Rose (1980), Wise and Fell (1980) and Lindner and Jarrett (1980) based on the original work by Lindner and Jarrett (1978). This conclusion suggested that "... this would involve subdividing the production area into homogeneous regions in terms of the impact of the innovation in question on yield and production costs. Within each region, a parallel shift could be presumed without risk of serious error" (Lindner and Jarrett (1980, p.844)).

It is clearly important to understand the implications of different functional forms and shifts at an aggregate level, especially since some of this work will be important in fully understanding the impact of different types of technology. However, it is also useful to consider in more detail the comments made by Lindner and Jarrett/Rose. A better understanding of their points may provide improved appreciation of the impact of technologies and if a linear, parallel shift assumption can be shown to be a reasonable approximation in many cases, then empirical applications will be simpler and therefore the risk of user error reduced.

If disaggregation is adopted the question of spillover impacts of research becomes important. In most previous studies since the aggregate, usually national, supply level has been used, the implicit assumption has been that the research is applicable to all production either uniformly or on a proportionate basis, even when there is significant diversity in production environments in that geographical region. Instead of this implicit assumption sometimes differences in applicability of technologies has been introduced using an estimate of the ceiling adoption level for that technology. A more detailed understanding and modelling of the spillover effects of research will be an important requirement of disaggregation of research evaluation analysis and will also provide an additional basis for the understanding the of adoption of technologies.

3. A DIAGRAMMATICAL ILLUSTRATION OF SUPPLY AGGREGATION AND RESEARCH EVALUATION.

3.1 Introduction.

This section considers two aspect of the supply aggregation issue. The use of a linear parallel shift as an approximation for the impact of research in a firm level supply is discussed. The potential relationship between a disaggregated analysis and some of the conventionally suggested aggregated supply shifts are investigated.

3.2 Cost Curves Aggregated to Give Supply Functions.

Standard production and price theory suggests that the individual firm supply function is found from the firms marginal and total average cost functions. Figure 1 illustrates. Individual firms will operate where the marginal cost equals the marginal revenue, in a competitive environment the market price will be the firms marginal revenue. This situation will apply as long as the firm can cover its input costs, thus in the longer term this must be the firms total costs. In figure 1 the firm will move along the marginal cost curve (MC_0) depending upon the price faced, as long as the price remains above the firms total average cost (TAC_0). Below this price, in the longer term, the firm will be better ceasing production. The firms supply function is therefore represented by the discontinuous function S_0S_0, the important feature of this supply function is the linear segment irrespective of the assumptions regarding the functional form of the cost

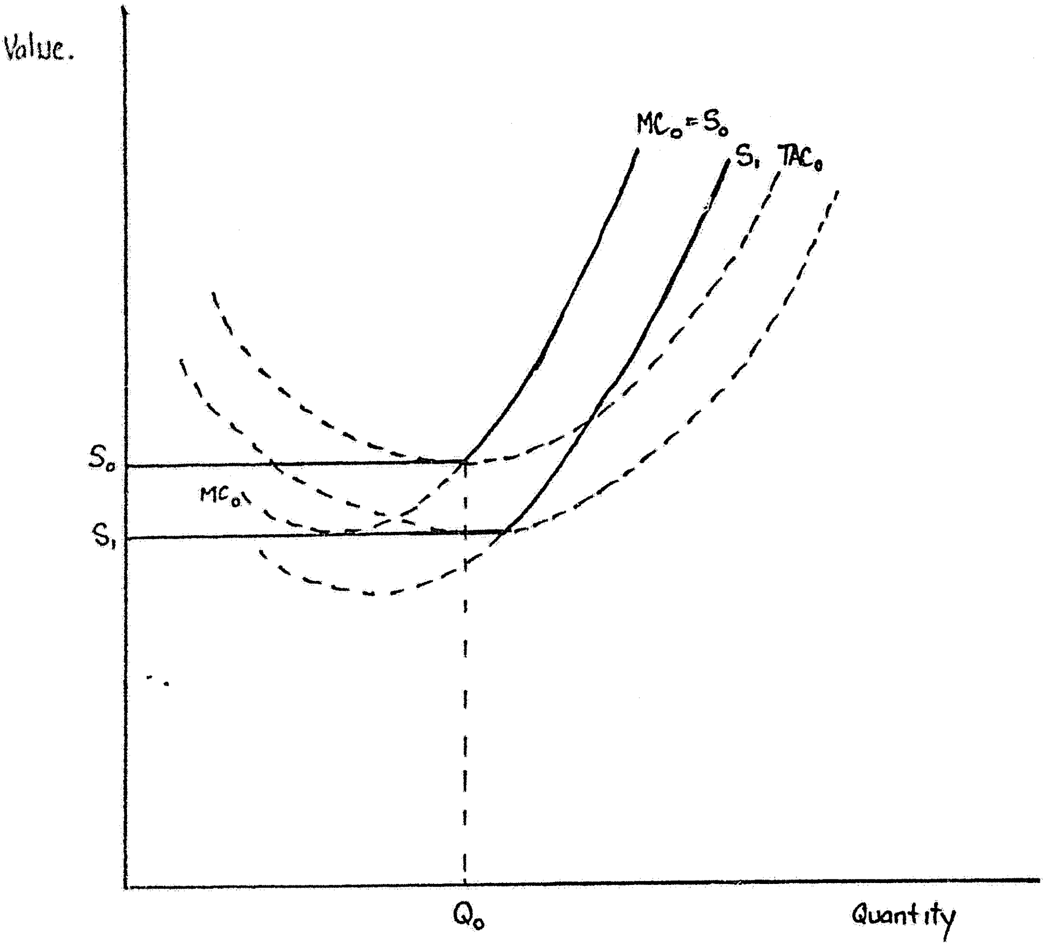


Figure 1: Firm Costs and Supply.

functions.

If research develops a new technology relevant to the firm the cost functions will be changed if the firm adopts the technology. The form of these changes will depend upon many factors. The nature of the technology will be important, for example, whether it is factor neutral or biased. Alston (1990) highlights several aspects but not specifically at a firms cost function and/or supply function level. Davis and Bantilan (1991) highlight some important cost function level points, however, do not focus on the specific issue of linear approximations at the marginal cost and, therefore, supply level. While this paper will not focus in detail on this issue, it is important to note that it is an area which does seem to require more attention than it has in the literature. These underlying considerations are important when it comes to individual research project level evaluations.

As shown in Figure 1 if the adoption of research results in a shift in the firms cost functions and therefore the supply function (to, say, S_1S_1), there are two areas which will represent the welfare gains from the research. The first is an area associated with the linear segment of the supply function. The second is an area between the marginal cost functions above the minimum total average cost with and without research. The 'before research' firm equilibrium will be at or to the right of output Q_0. It is most likely that Q_0 will be a major share of the equilibrium firm output. If so a linear approximation to the discontinuous supply function and the assumption that the supply shift is parallel may provide reasonable approximations of the research gains. This may be the so even if the linear approximation extends into the negative quadrant before intersecting the price axis. A crucial factor in this conclusion is the estimation procedure used to provide the cost impact of the research. If this cost impact estimate is close to the change in the minimum average total costs due to the research, then a good approximation of the horizontal linear component of the welfare change will be provided. Also important, however, is the fact that the use of a continuous nonlinear approximation will not necessarily provide a more accurate approximation of these gains, especially if the linear horizontal segment is the larger area. To-date studies comparing the two estimation methods have not used the actual discontinuous function as the reference.

While this issue warrants further attention it is not the primary focus of this paper. The brief discussion above does, however, suggest that the Lindner and Jarrett/Rose conclusion has some basis, at least at the homogeneous firm level.

3.3 Industry Disaggregation with a Linear Approximation of Supply.

If the firm supplies as depicted in Figure 1 are aggregated to the industry level and if all firms faced identical production and cost conditions, then the industry supply will be discontinuous and will also include a substantial linear horizontal segment. Again research which introduces a new technology will change this aggregated firm supply. If the firms operate in a homogeneous set of production conditions then there will be a parallel shift segment plus a potentially non-parallel shift segment, depending on the nature of the technology and how it influences the production process. A linear approximation at this homogeneous aggregate level may well be appropriate. This is presumably the basis for Lindner and Jarrett/Rose conclusion.

For the rest of this discussion, the linear approximation conclusion will be accepted. Therefore, for homogeneous production regions a linear supply draw from some current equilibrium situation is accepted as a reasonable approximation. If a parallel shift is also accepted then even if the elasticities used infer that the supply intersects the price axis in the negative quadrant the research gain approximation is not affected. This conclusion seems to worry many and it is a puzzle why.

Figure 2 represents a country commodity situation which is comprised of three homogeneous production environments suitable for the production of the commodity. There is sufficient variability between the production environments to result in different cost conditions. Each of the aggregated individual production environment supplies are approximated by a linear supply function. In Figure 2(a),(b) and (c) these supplies are draw to represent this situation. The national aggregated supply is draw in Figure 2(d). As is usual it has three kinks at prices sufficient to encourage some production in each region. The demand is draw only at the aggregate level, although demands may be relevant to each production environment. This is to simplify the diagrams, in the mathematical model each homogeneous region (production environment) has its own demand.

If research is undertaken on a production constraint relevant to production environment 3 (PE3) and it results in a technology which is only relevant to PE3 then, after research only the supply in PE3 will shift. If this situation is draw in Figure 2 it is seen that the aggregate national supply shifts but only over the top segment. Also notice that the vertical shift in the aggregate supply is smaller than in the underlying regional supply. This is a result of the aggregation process. At an aggregate level the approximation of the welfare change will be given as the shaded area in Figure 2(d). Notice that this area is similar to a pivotal shift representation except that the shift does not pivot from the price axis, indeed it could well pivot well away from this point. This area can be estimate several ways. One way is to estimate the area between the two supplies and the changed price line in Figure 2(c) or PE3 where the research was focused. Another is to estimate the changes in consumer and producer surplus in each of the individual regions and then add these surpluses together (some obviously being negative). Either of the two alternative approaches is likely to be simpler than estimation at the aggregate level.

Figure 3 illustrates an alternative research focus option. In this case the research focuses on PE1. The (parallel) shift in Figure 3(a) transfers through to the national aggregate supply as shown in Figure 3(d). Here as the other region supplies are aggregated with that from PE1 the shift in the aggregate supply becomes tapered. In terms of the aggregate level representations this shape would be similar to the convergent shift discussed in previous studies.

A range of combinations of these shifts and there aggregation can be represented. If the research focused on conditions in PE1 was also partially applicable to PE2, that is, the research has spillover effects, a large range of aggregate representations are possible. All of these, recall, are still based on the underlying assumption that the homogeneous level supply shift can be approximated by a linear parallel shift.

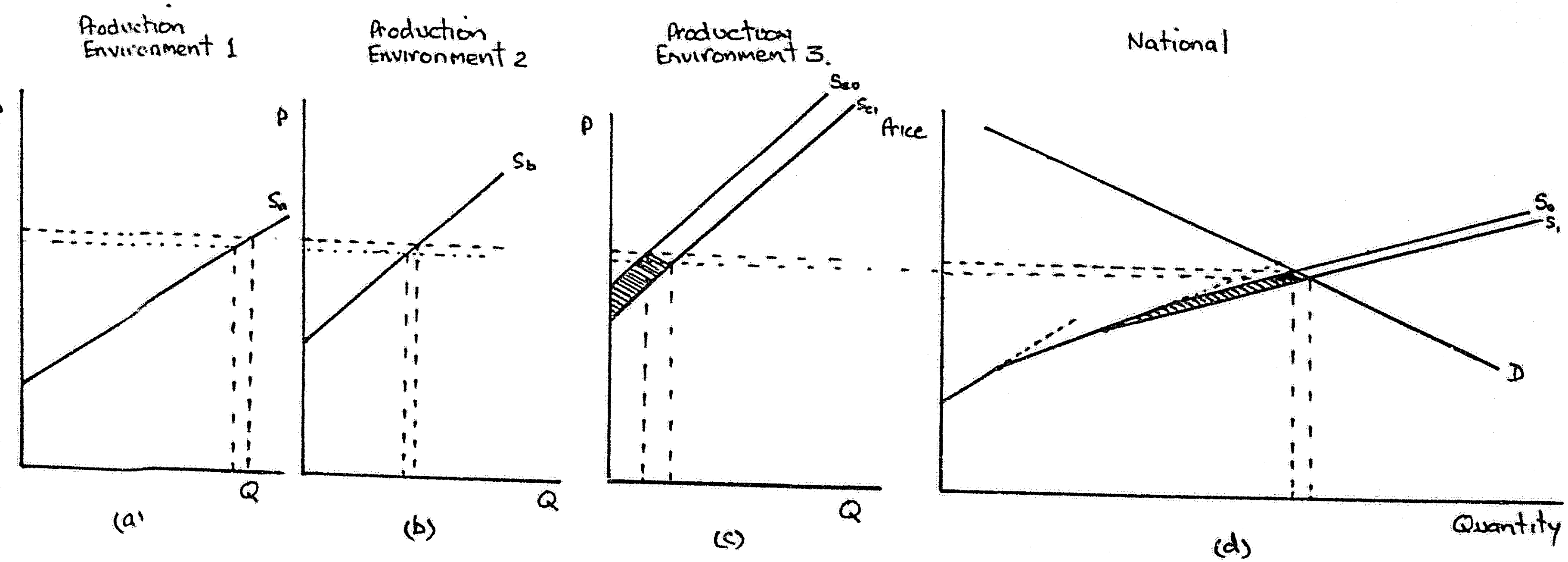


Figure 2: Supply Disaggregation to Three Homogeneous Production Environments.

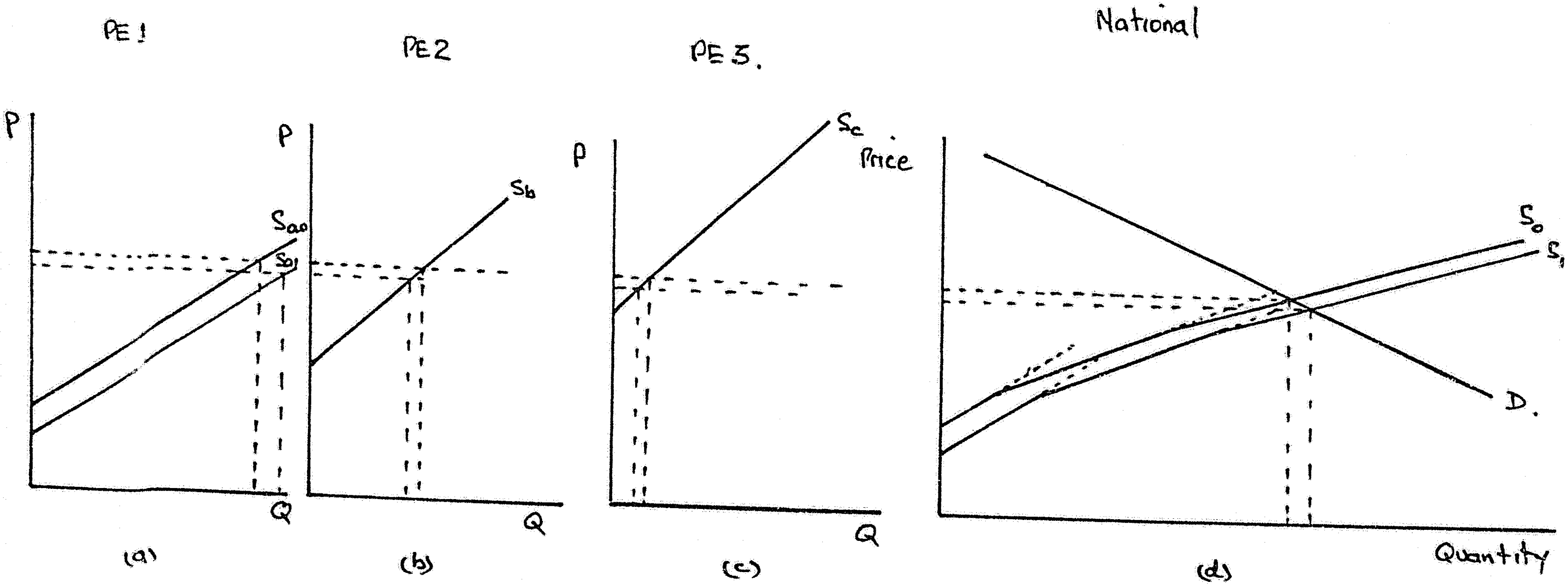


Figure 3: Three Production Environment Supply Disaggregation Model.

Figure 4 combines the aggregated supply from Figures 2 with the conventional diagram from other aggregated studies. The previous conclusion that an aggregate parallel shift gives about double the pivotal estimate can be seen, that is the area 'abgf' compared with 'abh'. A comparison of the disaggregated shift with the pivotal shift highlights some important points.

Clearly the way the level of the supply shift is estimated becomes crucial. Since many studies use a pivotal shift because it is felt to better represent the differences in adoption, the tendency would be to use the original research impact, that is, 'be' which is, in this case, the full shift in the PE3 supply. As can be seen depending upon the underlying research impact, this (implicit) assumption could result in considerable over estimation of the research gains, that is, the area 'abh' compared with 'dbc'. Even if an accurate estimate of the adjusted supply shift was available (which would require detailed information at the disaggregated level) over or under estimation could still result.

In some circumstances a divergent or even convergent shift could give a reasonable approximation. However, this would require a detailed knowledge of the disaggregated interactions, for example, spillovers, production shares, etc. If this data is available more detailed information would be provided by using it in a disaggregated approach with a parallel linear shift approximation.

4. AN ILLUSTRATIVE EXAMPLE OF RESEARCH IMPACT ASSESSMENTS WITH DISAGGREGATED SUPPLY.

4.1 Model for Supply Disaggregation.

The majority of research evaluation studies have used the aggregate national level as the basis for analysis. In many of these studies a closed economy assumption has also been invoked. Edwards and Freebairn (1981, 1982) were one of the early authors to disaggregate their analysis to the regional level within a country and also include the possibility of trade between countries. The emphasis in, especially, the second study was to highlight the within country regional distribution of research benefits when the research was not universally applicable across the whole country. Since the focus of the study was the regional distributive effects they did not place much emphasis on the empirical aspects of modelling the spillover or applicability effects of the research between regions.

They later expanded this work to highlight the importance of accounting for between country trade in a research evaluation analysis. (See Edwards and Freebairn (1984)). Again though little attention was given to how the spillover effects of research could be quantified.

Davis, Oram and Ryan (1987) used this basic open economy model to develop information to support decision-making at an international research organisation level. The nature of the decision-making environment they were faced with required that many countries be included in the analytical model. This in turn focused attention on the need to estimate the potential country to country spillover effects from research undertaken in a particular country. Previous studies had usually treated these as an aggregate spillover to

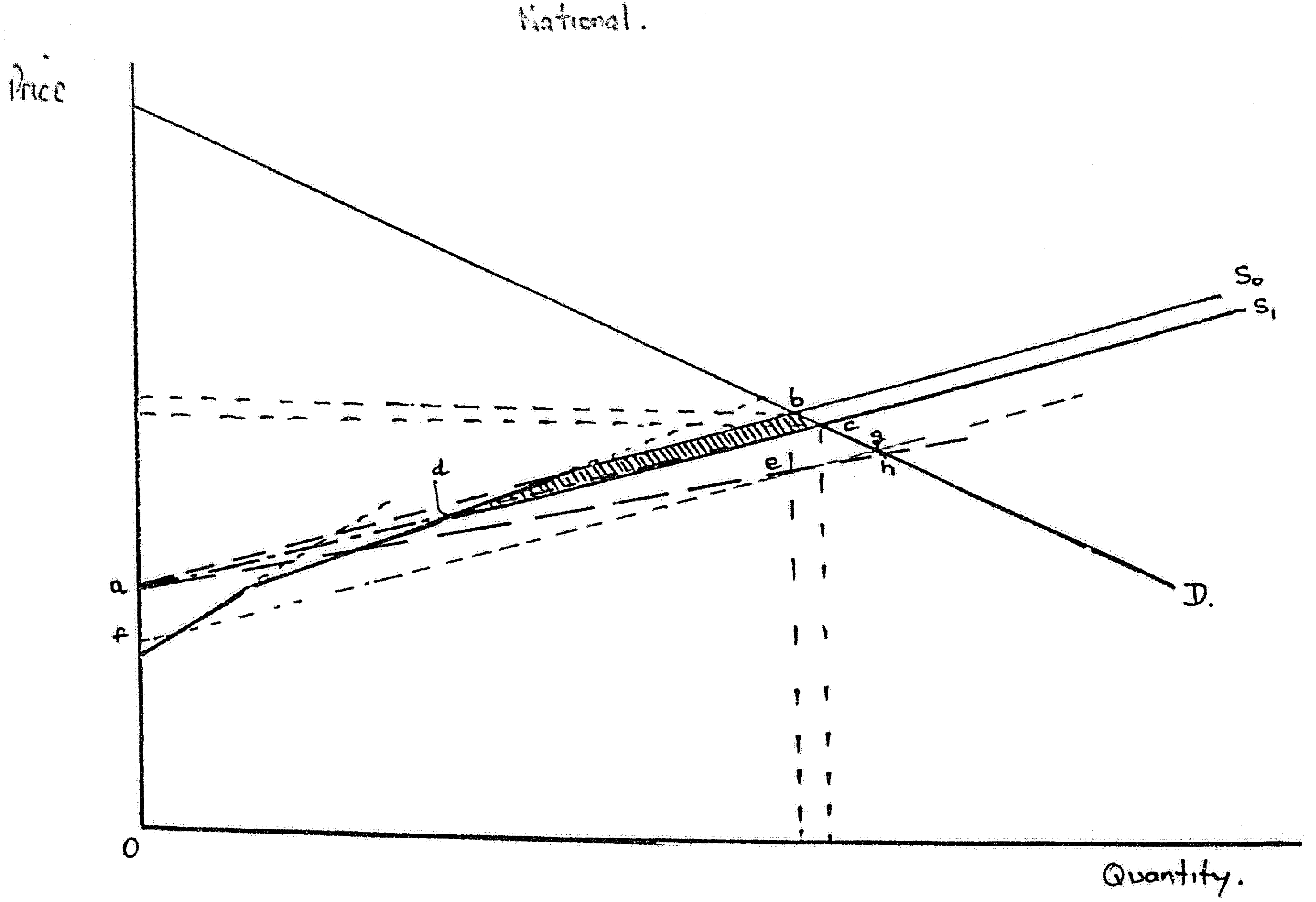


Figure 4: Comparison of Disaggregated and Aggregated Estimation.

the 'rest of the world'. This requirement to disaggregate to many countries also highlighted several points, these included:

(i) The importance of considering spillovers from two different perspectives. For research decision-makers spillovers between geographic/political defined regions are usually of most interest. However, since most of these regions incorporate several, if not many, environmental conditions the applicability of research over wide areas is likely to be influenced by differences in physical and socioeconomic production environments.

(ii) Whether research results are used in other regions or countries will often depend on whether some additional adaptive research is undertaken in that region. If adaptive research capacity in the relevant area is not available the potential research spillovers may not be realised.

(iii) There are likely to be differences in the time lags associated with the incidence of the research spillovers. These are likely to be different for different countries.

While the original analysis by Davis, Oram and Ryan (1987) considered some of these issues direct estimates of the geographic/political spillovers were used to generate estimates of the potential impact of research.

Davis, McKenney and Turnbull (1989) and Davis (1991) suggested a matrix based approach to facilitate the separation of spillover estimation into the underlying technically based production environment to production environment spillovers, which are then combined with production environment research foci and production share information to give the geographic/political spillovers. This model was initially applied to agriculture and forestry commodities and then fisheries (see Fearn and Davis (1991)) at an international level. It has also been adapted to suit the provision of information to support decision-making at a national level in the Philippines, Thailand and Indonesia. (Papers documenting these applications were presented at a Workshop in May 1991 and will appear in various chapters of Davis and Ryan (eds) (forthcoming)).

The important features of this spillover estimation approach are discussed in Davis (1991) and include:

(i) Choose an Appropriate Production Environment Classification System

(ii) Estimate the Production Environment to Production Environment Spillovers

(iii) Estimate the Region to Region Spillovers. This requires estimation of the following:

    (a) The production environment production shares.

    (b) The production environment focus of the research.

In this paper the multi-regional traded good model as originally suggested by Edwards and Freebairn (1984) will be combined with the spillover estimation model discussed above to investigate the disaggregation option suggested by Lindner and Jarrett (1980) and Rose (1980).

4.2 Form of Disaggregated Model and Basic Data.

An hypothetical set of data has been constructed to illustrate the potential implications of supply disaggregation. Although hypothetical the commodity has some resemblance to wheat. Some aspects of the data set resemble Australia, however, not very well. For example, to simplify the implication a closed national aggregate economy is assumed. Thus although there is considerable trade between regions within the country all of the production is assumed to be consumed within the twenty regions used.

Table 1 includes the first set of information required to estimate research benefits and their distribution using the multi-regional model as discussed in Davis et al (1987). A standard set of information is used for the direct and adaptive research strength relativities and the ceiling level of adoption. These are all set at a value of 1. This is, first, because most aggregate level assessments make these assumptions and, second, it will therefore avoid confusing differences due to just the disaggregation and those due to the further refinements this disaggregation facilitates.

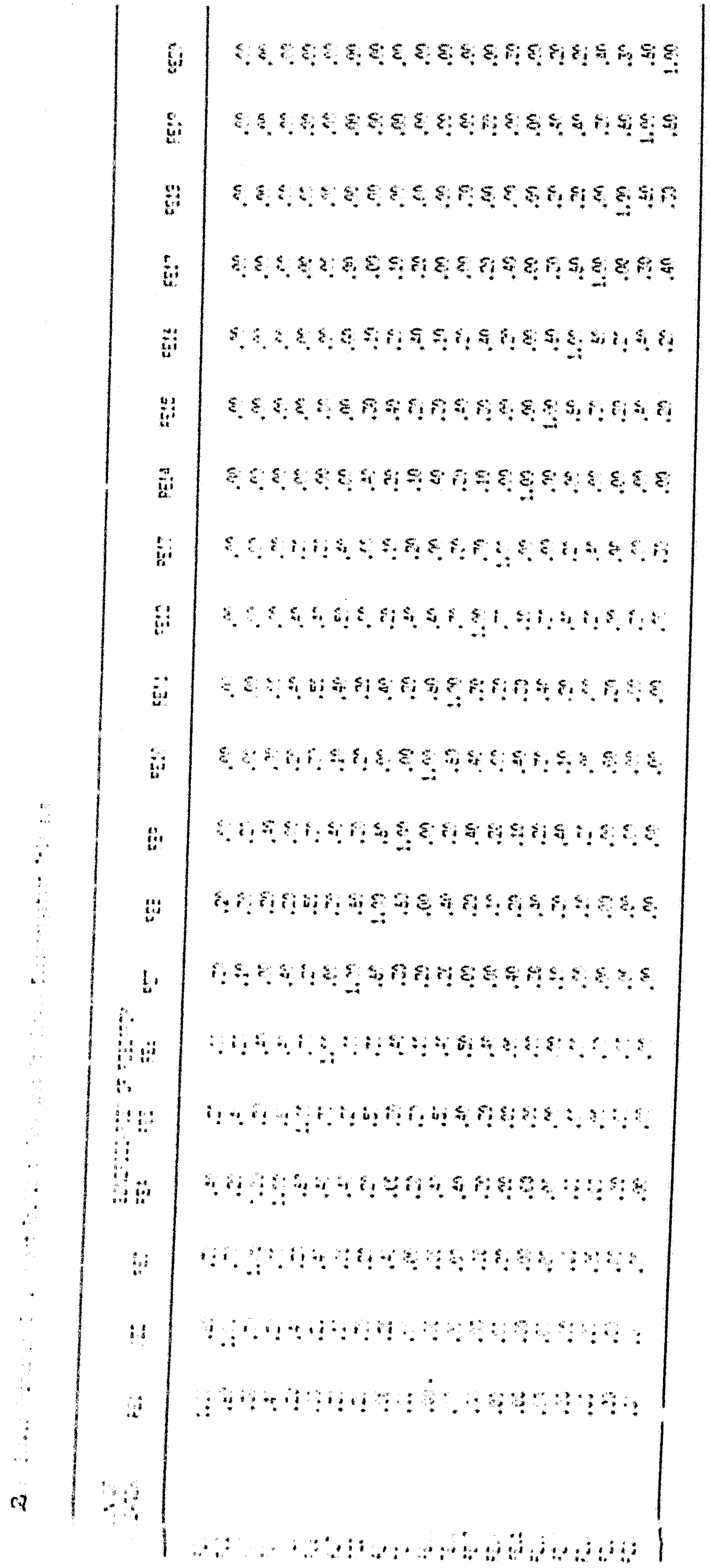
The country is assumed to be separated into 20 homogeneous production environments and each of these is regarded as a production region. To standardise the analysis further, research focused on each region is assumed to result in the same production cost reduction, in this case $6.50 per tonne. The final row in Table 1 is the equivalent information for a national aggregate level focus. Notice that the aggregate production and consumption are the sum of the regional estimates. The supply and demand elasticities for the national level are the weighted sum of the individual regional estimates.

Table 2 presents the production environment to production environment research spillovers adopted. This is, in fact, a subset of the larger matrix for wheat as included in the ACIAR Information System discussed in Davis and Ryan (forthcoming, Ch 10). This matrix was estimated using a subjective elicitation process from technical research experts. Each production environment refers to a set of agroecological conditions as used in the FAO classification system (see for example, FAO (1978)). Only a subset of production environments in the subtropics to temperate groupings are used. Notice with Table 2 the matrix is block diagonal in nature which is a feature of these matrices. This structure results largely from the way in which the production environments are ordered. That is, similar production environments are, as far as possible, grouped together with the least similar further apart. If this ordering is adopted then the north east and south west corners of the matrix will usually contain zeros. That is, the potential for spillovers from the earlier ordered production environments to the later ones is small, since the environmental diversity is greatest between these groups.

Since each production environment group is assumed to be homogeneous and a geographical region, this example includes some special case properties, compared with the general model discussed by Davis (1991). With a homogeneous production

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Production [illegible]	Consumption [illegible]	Price	Elasticity Supply	Elasticity Demand
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	6.50	[illegible]	[illegible]	[illegible]	[illegible]	1.50
[illegible]	[illegible]	[illegible]	[illegible]	6.50	511.00	440.00	120.00	1.00	1.20
[illegible]	[illegible]	1.00	[illegible]	6.50	[illegible]	[illegible]	[illegible]	0.70	[illegible]
[illegible]	[illegible]	1.00	1.00	6.50	[illegible]	[illegible]	[illegible]	0.90	1.10
[illegible]	[illegible]	[illegible]	1.00	6.50	[illegible]	654.00	[illegible]	0.70	1.20
[illegible]	1.00	[illegible]	1.00	6.50	1421.00	157.00	120.00	1.00	1.50
[illegible]	[illegible]	[illegible]	[illegible]	6.50	713.00	[illegible]	[illegible]	0.80	1.10
[illegible]	[illegible]	[illegible]	[illegible]	6.50	454.00	787.00	[illegible]	1.00	1.20
[illegible]	[illegible]	[illegible]	[illegible]	6.50	775.00	563.00	120.00	[illegible]	1.10
[illegible]	[illegible]	1.00	[illegible]	6.50	1524.00	555.00	120.00	0.9	1.20
[illegible]	1.00	1.00	[illegible]	6.50	451.00	761.00	120.00	0.8	1.50
[illegible]	[illegible]	1.00	1.00	6.50	454.00	1151.00	120.00	1.50	1.20
[illegible]	[illegible]	1.00	1.00	6.50	775.00	151.00	120.00	[illegible]	1.30
[illegible]	[illegible]	1.00	[illegible]	6.50	1125.00	2045.00	120.00	0.70	1.10
[illegible]	[illegible]	1.00	[illegible]	6.50	554.00	501.00	120.00	1.30	1.20
[illegible]	1.00	1.00	1.00	6.50	1557.00	55.00	120.00	1.20	1.60
[illegible]	[illegible]	[illegible]	[illegible]	6.50	261.00	51.00	120.00	0.80	1.10
[illegible]	[illegible]	[illegible]	[illegible]	6.50	1555.00	104.00	120.00	0.90	1.20
[illegible]	[illegible]	1.00	1.00	6.50	451.00	173.00	120.00	0.95	1.10
[illegible]	[illegible]	1.00	1.00	6.50	14947.00	14947.00	120.00	1.04	1.20



environment the regional matrix of production shares will contain 1's on the diagonal and zeros elsewhere. Similarly, the research focus matrix will also be a matrix of the same type. The result is, obviously, a region to region matrix the same as the production environment spillover matrix.

4.3 Results of Analysis.

The data outlined above was used to calculated the regional benefits to research and the distribution of these benefits between consumers and producers in each region (in this case production environment). Two cases were estimated. A linear parallel shift model at both the individual region and national aggregate level and a linear pivotal shift at the aggregate national level. The pivotal model was chosen for comparison since, of the alternatives usually considered, this model generally gives the smaller benefits estimates. As was discussed earlier most pivotal shift models have been used at an aggregate level, one of the primary arguments for adopting these models being that they better approximate the impact of a technology at this aggregate level. A linear model was chosen for the pivotal case for simplicity. In addition, based on the results in Voon and Edwards (1991), with the parameters included in the data set, used the results for a linear model will be about the same as for a nonlinear model.

The parallel shift estimates were found using the Research Evaluation (RE4) software developed at ACIAR. The pivotal shift estimates were found using the formulae given in Voon and Edwards (1991).

Table 3 presents a sample of the detailed results which were generated in the analysis. Annual research gains (losses) for nine of the individual homogeneous production environments are reported along with the parallel and pivotal aggregate level estimates. As would be expected the disaggregated regional results contain considerably more information than the aggregated results. Inspection of Table 3 reveals the type of research benefit pattern which would be expected given the production environment spillovers in Table 2. Those regions with closely related production environments receive cost reductions and producer gains from the research if it is focused on developing technologies relevant to these environments. Different production environments find that the technologies are not applicable and, therefore, they will not replace the currently available best technologies for the environment. The producers surplus in these regions will fall due to the price effects of the research applicable in other regions. Notice that even though the research has been assumed to focus on developing a technology relevant to a specific production environment, the spillover gains still represent a major share of the national gains.

An important aspect of supply disaggregation is highlighted in these results. If research is focused on different production environments, then large variations in the level of national research gains can result. In Table 3 the range, depending on the production environment research focus, is from $11m to $26m per year once the research has had it expected full impact. Notice that the disaggregated results are considerably smaller than the aggregate level results. For the parallel shift this is $99m while for the pivotal shift $50m is the estimate of the research gains. The difference between the parallel and pivotal estimates is that shown in many previous studies. Usually it has been suggested that the pivotal

Table 3 [illegible]

	Region where Research is Undertaken									Aggregate	
	RE1	RE2	RE3	RE4	RE5	RE6	RE7	RE8	RE9	Parallel	Pivotal
National Benefits	[illegible]	11.1	11	18.3	24.2	22.3	19.9	27.6	24.7	93.6	50.1
Spillover Benefit	[illegible]	6.7	7.7	17.2	19.4	15.9	11.2	24.6	20.1	ne	ne
Breakdown of Regional Benefits											
RE1 - Consumers	0.7	1	1.1	1.7	2.2	2.1	1.9	2.6	2.4	ne	ne
- Producers	1	[illegible]	0.2	0.3	0.1	-0.1	0.2	0.1	-0.1	ne	ne
RE2 - Consumers	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	ne	ne
- Producers	1.4	2.1	1.6	0.3	0.7	0.2	0	0.4	0.2	ne	ne
RE3 - Consumers	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.3	ne	ne
- Producers	[illegible]	[illegible]	[illegible]	-0.2	0.3	1	-0.3	0.2	0.9	ne	ne
RE4 - Consumers	[illegible]	[illegible]	[illegible]	0.4	0.5	0.5	0.4	0.6	0.5	ne	ne
- Producers	0.5	0.2	-0.1	[illegible]	1.7	0.4	0.4	0.1	-0.2	ne	ne
RE5 - Consumers	[illegible]	0.4	0.4	[illegible]	0.8	0.9	[illegible]	1	1	ne	ne
- Producers	0.7	1.5	[illegible]	2.2	3.9	2.6	0.5	1.6	0.8	ne	ne
RE6 - Consumers	0.2	0.2	0.2	0.4	0.5	0.5	0.4	0.6	0.5	ne	ne
- Producers	[illegible]	1	[illegible]	1	3.8	7.9	-0.6	1.1	1.6	ne	ne
RE7 - Consumers	[illegible]	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	ne	ne
- Producers	2.8	[illegible]	[illegible]	[illegible]	[illegible]	-1	5.6	4.4	1.7	ne	ne
RE8 - Consumers	[illegible]	[illegible]	0.5	0.3	1	1	0.9	1.2	1.1	ne	ne
- Producers	[illegible]	0.9	[illegible]	[illegible]	0.8	0.4	1	1.7	[illegible]	ne	ne
RE9 - Consumers	[illegible]	[illegible]	[illegible]	[illegible]	0.6	0.5	0.5	0.7	[illegible]	ne	ne
- Producers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.3	0.9	2.1	4	ne	ne
RE10 - Consumers	[illegible]	[illegible]	[illegible]	[illegible]	0.4	0.4	0.3	0.5	0.4	ne	ne
- Producers	[illegible]	[illegible]	[illegible]	[illegible]	0.2	0	0.2	-0.2	-0.2	ne	ne
RE11 - Consumers	[illegible]	[illegible]	[illegible]	[illegible]	0.4	0.4	0.4	0.5	0.5	ne	ne
- Producers	[illegible]	[illegible]	[illegible]	3.1	3.9	2.9	1.1	2.7	0.9	ne	ne
RE12 - Consumers	[illegible]	[illegible]	[illegible]	[illegible]	0.6	0.5	0.5	0.6	0.6	ne	ne
- Producers	[illegible]	[illegible]	[illegible]	1.3	1.2	1.7	-0.4	0.3	1.2	ne	ne
RE13 - Consumers	[illegible]	0.4	0.4	0.7	0.9	0.8	0.7	1	0.9	ne	ne
- Producers	[illegible]	[illegible]	-0.2	[illegible]	1.8	1.3	-0.4	-0.1	0.2	ne	ne
RE14 - Consumers	[illegible]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	ne	ne
- Producers	[illegible]	-0.1	-0.1	-0.2	-0.2	-0.2	0.7	0.2	0	ne	ne
RE15 - Consumers	[illegible]	0.7	0.7	1.2	1.5	1.4	1.3	1.7	1.6	ne	ne
- Producers	[illegible]	-0.4	-0.4	-0.6	-0.6	-0.9	1.5	2	0.6	ne	ne
RE16 - Consumers	[illegible]	0.2	0.2	0.3	0.4	0.3	0.3	0.4	0.4	ne	ne
- Producers	[illegible]	[illegible]	-0.3	-0.5	-0.6	-0.6	0	1	[illegible]	ne	ne
RE17 - Consumers	[illegible]	0	0	0	0	0	0	0	0	ne	ne
- Producers	[illegible]	-0.8	[illegible]	-0.9	-1.1	-1.1	-1	-0.3	[illegible]	ne	ne
RE18 - Consumers	0	0	0	0	0	0	0	0	0	ne	ne
- Producers	[illegible]	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	ne	ne
RE19 - Consumers	[illegible]	0	0	0.1	0.1	0.1	0.1	0.1	[illegible]	ne	ne
- Producers	[illegible]	-0.7	-0.7	-1.1	-1.4	-1.4	-1.2	-1.7	-1.6	ne	ne
RE20 - Consumers		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	ne	ne
- Producers	[illegible]	[illegible]	[illegible]	-0.3	-0.3	-0.3	-0.3	-0.4	-0.4	ne	ne
[illegible]											
- Consumers	[illegible]	ne	ne	ne	ne	ne	ne	ne	ne	[illegible]	[illegible]
- Producers	[illegible]	ne	ne	ne	ne	ne	ne	ne	ne	[illegible]	2.9

[illegible]

approximation is a conservative estimate of the gains, which at an aggregate level it normally is.

Clearly the results shown here are dependent on the assumption that production of the crop is spread over a range of diverse production environments and that the spillover between these environments are dispersed. In some small countries this diversity will be smaller than used here. However, in such cases what would be being observed would be a homogeneous production environment for the whole country. In such cases it is less clear that a pivotal supply shift is the best approximation. (See the discussion in section 3). Sometimes studies use adoption estimates to adjust these estimated benefits. Without understanding the interactions, such as, the applicability via production environment spillovers and the importance of the focus of the research effort, estimating this adoption level will not be straight forward. The results in Table 3 highlight this point, adoption (or rather the preferred applicability) will vary considerably depending upon the original focus of the research effort and, therefore, the technology developed. What the spillover model used here highlights is the importance of separating the applicability of research from actual use of the technology. Many discussions of research adoption inevitably integrate these notions. Whether farmers use an applicable technology depends on a different set of factors than those which influence whether it is applicable in the first place. As noted earlier in this analysis it has been assumed that all farmers use the new technology, if it is indeed applicable. There are a number of important issues which require consideration as a consequence of these points but will not be taken up here.

The results illustrated in Table 3 can be summarised as for example in Table 4. All 20 regions (production environments) are included with the two aggregate results. The national benefits plus own regional and a subset of regional spillover gains are presented. The range of national benefits for different research foci are seen to be $8m to $33m with the average (weighted by regional production levels) being $24m. Again these compare with the aggregate estimates of $99m for the parallel shift and $50m for the pivotal shift. The disaggregated analysis gives considerably lower estimates of research gains than the aggregate analysis. It should also be recalled that potential for difference in the likelihood of successful adaptive research, which is nearly always required, and the possibility of addition lags before adaptive research is completed, are not included in these estimates. The disaggregated model used here incorporates these aspects if estimates of these parameters are available. Consideration of these aspects will result in even larger differences between the two estimation approaches.

Table 5 highlights another important set of information which emerges from the disaggregated analysis. The distribution of research gains between producers and consumers is often an important issue. Table 5 illustrates some important distributive consequences which the aggregate level assessments do not include. The aggregate parallel shift analysis shows the usual result of consumer and producer shares directly related to the supply and demand elasticities. This direct relationship is not necessarily maintained with the shift to a disaggregated analysis. Two important points emerge. First, the separation of producer surplus changes into gainers and losers is possible and reveals some potentially important information. Depending on the production environment focus of the research, considerable variation in the share of producer surplus losses can occur. The range in this example is from 11 to 36 percent of the net national welfare gains. It is

[illegible]	[illegible]	[illegible]	RE1	RE2	RE3	RE4	RE5	RE6	RE7
[illegible]	[illegible]	[illegible]	1.7	1.1	1	0.7	1	-0.1	2.5
[illegible]	11.5	[illegible]	1.6	[illegible]	2.3	0.4	1.9	1.2	0.5
[illegible]	[illegible]	[illegible]	1.3	1.7	3.4	[illegible]	1.1	[illegible]	-1.1
[illegible]	[illegible]	[illegible]	2.1	0.4	0	1.6	[illegible]	2.1	
[illegible]	[illegible]	1.2	2.3	0.3	1.6	1.2	4.3	4.4	1
[illegible]	[illegible]	[illegible]	2	0.1	1.3	[illegible]	3.4	5.4	-0.9
[illegible]	[illegible]	[illegible]	2.1	-0.2	[illegible]	[illegible]	1.2	-0.2	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	1.6	0.6	0.7	[illegible]	[illegible]	4.6
[illegible]	[illegible]	1.6	2.3	0.4	1.3	3.4	1.7	2.1	1.5
[illegible]	[illegible]	[illegible]	1.4	-0.1	0	0.5	1.6	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-0.1	0	0.3	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-0.1	-0.1	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	2	-0.1	0	0.7	1.7	2.1	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0.2	0.2	-0.1	[illegible]
[illegible]	[illegible]	[illegible]	2.7	-0.1	-0.1	0.4	0.5	-0.2	1.6
[illegible]	[illegible]	[illegible]	2.9	-0.1	-0.1	0.5	0.6	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	2.4	-0.1	0	0.4	0.5	[illegible]	-1
[illegible]	[illegible]	[illegible]	[illegible]	-0.1	0	0.2	[illegible]	-0.1	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-0.1	0	0.1	0.5	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	1.2	-0.1	0	0.3	0.4	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	2.2	0.2	0.3	0.6	1.5	1.4	1
[illegible]	[illegible]	[illegible]	ns	ns	ns	ns	ns	ns	ns
[illegible]	[illegible]	[illegible]	ns	ns	ns	ns	ns	ns	ns

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	Distributive Effects (% of Total Benefits)			
				Consumers	Producers		
					Gainers	Losers	Total
[illegible]	[illegible]	[illegible]	[illegible]	47	[illegible]	-44	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	47	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	46	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	45	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	46	[illegible]	[illegible]	54
[illegible]	[illegible]	[illegible]	[illegible]	46	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	46	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	47	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	42	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	43	71	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	47	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	43	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	43	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	45	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	43	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	43	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	45	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	47	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	46	74	[illegible]	54
[illegible]	[illegible]	[illegible]	[illegible]	45	na	na	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	44	na	na	[illegible]

important to note that in some regions those producers who gain receive almost the equivalent of the net national welfare gains. This should not be a surprise since farmers are unlikely to adopt technologies which do not make them better off, also the price effect cannot be larger than the largest cost reduction impact of the research. Often interpretations place on aggregate, especially, pivotal shift research evaluation results do not seem to appreciate this implication. Notice also that these shares are now not directly related to the regional (or national) elasticities, rather they depend on an interaction between elasticities, production shares and the spillover effects.

The second important point is the substantial difference in the producer versus consumer shares between the disaggregated parallel and aggregated pivotal analyses. For the set of elasticities used in this analysis the aggregated pivotal shift indicates that nearly all of the national welfare change due to the research is obtained by consumers. The disaggregated analysis suggests a very different situation. While significant numbers of producers have producer surplus losses as a result of the research, those for whom the research is applicable are still likely to gain. Importantly, as a group producers do not lose. The shares are in fact close to the aggregate parallel shift result. Note though that the absolute level of benefits are considerably smaller than in both the aggregate analyses. Also note that this result is obtained when the disaggregated model is not depicted as a parallel shift if aggregated to the national level. The shape of the implied surplus area at the national level is also likely to be a more unusual shape than that assumed with a smooth pivotal shift.

5. CONCLUSIONS.

This paper has investigated an important point raised by Lindner and Jarrett/Rose in the discussion of alternative mathematical representations of the impact of research on supply functions. They suggested that if the research evaluation analysis was disaggregated to relatively homogeneous production situations, then an linear parallel supply shift would, in most cases, provide a good approximation of the research gains. Despite this comment few have considered this point, rather most research on this issue has still focused on developing alternative mathematical representations and discussed the implications of these.

This paper illustrated diagrammatically what the implications of the earlier conclusion might be. It then uses an empirical example to highlight the potential implications of this approach.

The results suggest that more attention should be given to the suggestion that disaggregation be considered. This will most likely lead to a clearer understanding of the nature of the impact of research and, therefore, technical change on the production of agricultural commodities. In addition it has been shown here that this approach could lead to more caution in interpreting the distributive implication of the impact of research. This seems to be especially the case with a pivotal supply shift. A clearer understanding of the wider applicability or spillover effect of research is important.

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