Spillover Effects of Agricultural Research : Importance for Research Policy and Incorporation in Research Evaluation Models

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1. INTRODUCTION

The importance of understanding and measuring the spillover effects of agricultural research is identified. It is suggested that understanding the spillover effects of research is important for stimulating consistent debate on research policy and also for providing systematically based information to support research decision making. It is found that there have been few detailed attempts to provide a clear model of research spillovers. The second part of the paper outlines a matrix based procedure which explicitly incorporates agricultural production environments and research spillovers into a multi-regional research evaluation model. Some of the important issues relating to research management which stem from this model are highlighted using an empirical illustration.

2. THE IMPORTANCE OF RESEARCH SPILLOVERS AND PREVIOUS ASSESSMENTS

2.1 The Importance of Research Spillovers

There are three aspects of the spillover effects of research which provide a strong basis for developing a better understanding of them. Each of these are discussed briefly below:

(i) Input into Research Policy Debate

Probably the most compelling basis for government involvement in agricultural research is the efficiency argument. This argument suggests that 'market failure' may often be a feature of research activity. The primary source of this market failure is the inability of private individuals, firms and, even perhaps, countries to appropriate a major share of the potential gains from many forms of research. Most other arguments for public intervention, although often used, rarely stand up to close scrutiny. One necessary (but not sufficient) condition for the lack of appropriability of research gains is that the technology resulting from the research be readily applicable across many geographical locations and therefore farm units. For this to be the case the research must be potentially applicable to a range of agricultural production conditions or environments. Clearly many research outputs may have these characteristics yet the benefits from undertaking the research can still be appropriated by those undertaking it. For example, patentable research output or technologies embodied in an input which can be patented.

It is becoming common to refer to the wide applicability of research as the 'spillover' impacts. Although some (especially in the private sector oriented literature) have also referred to these impacts as 'leakages'. Given the importance of the spillover effects of research across many locations and environments to the case for government involvement, it is surprising to find that relatively little attention has been given to clearly modelling and measuring these effects.

(ii) Input to Support Research Management Decision Makers

The applicability of research generated technologies depends significantly on the types of production conditions where agricultural activities take place. In planning strategies research managers are often faced with issues regarding whether research programs should focus attention on developing technologies which suit particular production conditions. Since the mandates of most research planners and managers usually transcend many different and, often, diverse production conditions or environments, trade-offs must often be made regarding which production environment to focus research attention on. The more applicable research is likely to be to all production environments the easier these types of choices will be for managers. Even if there is some applicability between production environments this is unlikely to be uniform. It is important to provide some information regarding this aspect of research. The levels of these research applicabilities or spillovers can influence many choices. The focus of research programs has been mentioned, other choices are likely to include the physical location of research infrastructure and the structure of research human capital expertise.

Within research projects decisions regarding, for example, whether to concentrate on developing technologies to maximise the production improvements for a specific production environment or maximise the applicability of a smaller productivity gain over a wider set of production environments will require assessment of the extent of spillovers and whether research effort can change these rather than work within them.

To improve the consistency of these types of decisions, over time, a systematic understanding of the research spillovers and generation of information regarding these is likely to be important.

(iii) Enhancement of Research Evaluation Methodology

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. This issue still receives significant attention, however, in many cases seems to ignore 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)).

If this disaggregation option 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 uniformly applicable to all production, 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. More detailed understanding and modelling of the spillover effects of research will, therefore, facilitate more realistic disaggregation of research evaluation analysis and also provide additional dimensions for the understanding of adoption of technologies.

In summary there are at least three important reasons which suggest that a more detailed understanding and explicit modelling of research spillovers is warranted. As is usual with any modelling exercise the details of the model will be determined by the type of information required from it to assist decision making.

2.2 A Review of Previous Assessments of Research Spillovers

Resolution of the issue of whether measures to indicate whether a technology is of the appropriable type or not is still some way off. There is a considerable body of literature which considers the issue of intellectual property rights and this has been brought to bear on agricultural research. The issue of plant variety rights is an important illustration, for recent examples, see Godden (1989) and Kennedy and Godden (1989). This work has not resulted in the development of quantitative measures which can indicate appropriability, non-appropriability or degrees of appropriability. Even measures of the extent of applicability (spillover) have not been developed as part of this debate.

For the industrial sector there have been some attempts to address the issue of spillovers from technologies. The work by Levin and Reiss (1988), Bernstein and Nadiri (1988), Levin (1988), Cockburn and Griliches (1988), Bernstein (1988) and Levin et al. (1987) indicate the trends in this area. Some attempts to measure spillovers in industrial production environments and relate these to appropriability are included in this work. Nothing, at this point, is readily adaptable to agriculture which would address the issues discussed above.

If the appropriability issue is ignored there have, however, been several studies which have addressed the spillover issue and have been specifically focused on agriculture. The review by Norton and Davis (1980) revealed only one set of previous studies which considered spillover effects. These centred around the work by Evenson (1978) which used aggregate productivity or production function specifications with public research expenditure levels to estimate, in an aggregate sense, the relationship between expenditure on research at one location on the output in others. Evenson (1989) reported a further refinement to this work. The appropriate level of aggregation of any analysis clearly depends on the type of decision making the information generated is to support. Aggregated studies such as these usually provide useful information to assist general research policy discussions. If many 'what if' type issues are relevant and raised, the aggregative nature of these models and usually very limited sources of accurate disaggregated data on which model estimation is based, restrict their usefulness.

Several case study type analyses have been undertaken which have identified spillover benefits from research. For example, Brennan (1986) estimated significant economic gains to Australia from CIMMYT wheat research. These studies, however, have taken specific technologies and developed analyses specific to the particular situation. The models used do not give any direct consideration to a generalised spillover impact.

In terms of the generally accepted economic surplus type research evaluation models, Edwards and Freebairn (1981, 1982, 1984) developed a two region trade model which included an allowance for spillovers between the two regions. These regions are usually geographically/politically defined, in their case one country and the rest of the world. Mullen, Alston and Wohlgenant (1989) used a similar two region spillover model to look at processing sector research. In both cases hypothetical guesses of a zero to one spillover index were used to weight the unit cost reduction estimates.

Davis, Oram and Ryan (1987) extended the Edwards and Freebairn model to include many regions and used agroclimatic zonation work to identify agricultural production environments. Similarities in these environments were used to subjectively assess spillover effects (again as a zero to one index) for different commodities. Here too, however, the spillover estimates were derived for geographical/political regions - in most cases countries.

In all of the previous studies implicit assumptions regarding the production environment focus of the research are made and assumed fixed. If changes in the focus of the research occur, re-assessment of geographical spillovers will usually be required.

3. A MODEL FOR ESTIMATING REGION TO REGION RESEARCH SPILLOVERS

3.1 Model Requirements

As with any early model development an important requirement is to keep the model as simple as possible. The discussion in the previous section suggests three minimum requirements for any extension to existing research spillover estimation models. These include:

(i) The model should be compatible with existing methodology used in research evaluation studies. Given recent trends in this area this means ensuring the model can readily interface with the existing economic surplus type research evaluation methodology. As a recent paper by Alston (1990) highlights, a relatively extensive set of multi market models are readily available. Future developments should be made in a manner which facilitates, where possible, interface with these.

(ii) The model should use as its basic reference point a suitably defined set of relatively homogeneous production environments. These are unlikely to be the same as most geographical/political regions. Since much of the economic data required is available on a geographical/political region basis and also research decision making is often organised this way it is important to include a method for transformation between these two in the estimation process.

(iii) The model should be able to readily facilitate the consideration of research strategies which focus on developing technologies for different production environments. It should be able to assess the potential consequences of changing this focus.

3.2 Outline of the Proposed Model

3.2.1 Interface with Existing Methodology

Figure 1 summarises the basic multi-regional traded good developed by Edwards and Freebairn (1984) and extended by Davis, Oram and Ryan (1987). As indicated by Rose (1980) and Lindner and Jarrett (1980) with suitable disaggregation this type of model will provide as good, if not better, approximations of research benefits than the mathematical manipulations to aggregate supply functions sometimes proposed.

The main omission from this model is the vertical market separation and more complex farm level input disaggregation summarised by Alston (1990). The decision to incorporate these extra complexities will depend on the decision making situation information is being generated for. In this discussion and development the farm level orientation is maintained.

The research benefit estimation formulae developed in Davis, Oram and Ryan (1987) incorporate the estimate of the final monetary value of the spillover unit cost reduction. In Edwards and Freebairn (1984) and the empirical application in Davis, Oram and Ryan (1987) a spillover index vector or matrix is used. If the analysis covers many regions this approach reduces the data changing task if different cost reduction analyses are required. Notationally this extra component can be represented as:

$$K = K^{*}S \qquad \ldots\ldots \qquad (1)$$

where

K is a matrix of monetary direct and spillover unit cost reductions. K is an n x n matrix where n is the number of geographical regions in the analysis. k_{ij} is then the unit cost reduction in region j resulting from research undertaken in region i.

K^{*} is diagonal matrix of base rate cost reductions for each region. k^{*}_{ii} is the expected cost reduction in region 'i' where the research is undertaken. $k^{*}_{ij} = 0$.

S is a matrix of research spillover indexes or weights. In most cases it is expected that $0 < s_{ij} < 1$. Although this is not a necessary condition.

As indicated earlier Edwards and Freebairn (1984) used values for s_{ij} that were arbitrarily chosen. Davis, Oram and Ryan (1987) used subjectively determined values for s_{ij}, although these were based on detailed information regarding the production environments and their distribution for each commodity. Given the large number of regions (countries) involved and diversity of production environments within some of these, the subjective weighting process involved often taxing mental gymnastics. A need for a less subjective weighting process became apparent as the application of the analysis progressed.

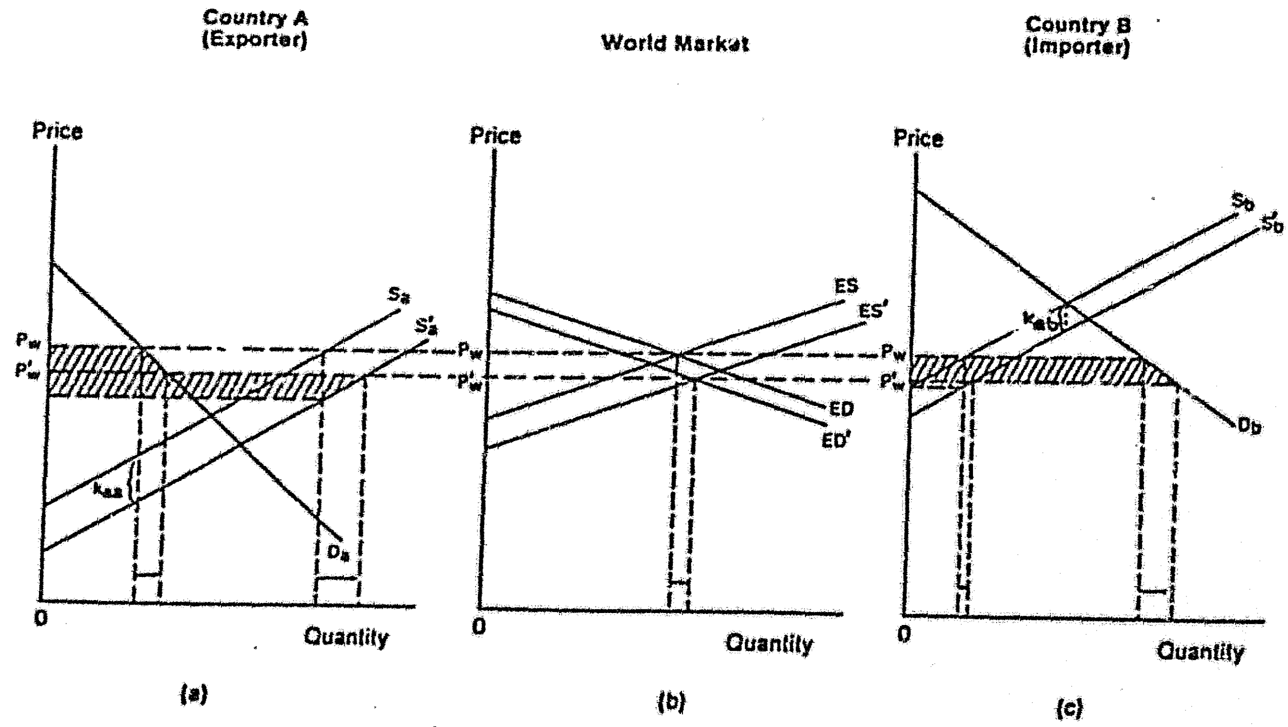


Figure 1 : Two Region Research Evaluation Model with Spillovers.

3.2.2 Revised Procedure for Estimating Regional Spillovers

The need to separate assessments of the impact of technologies from arbitrary geographical/political boundaries became apparent. Depending on a host of environmental, factor endowment and other technical variables, plants and animals perform in different ways. Technologies are invariably developed to suit some locations and may not suit others. All or many of these may exist within the same geographical/political boundary. The need to relate spillover modelling to these production environment factors was recognised by Davis, Oram and Ryan (1987). Expansion of the subjective estimation procedure requires the following

(i) Choose an Appropriate Production Environment Classification System

There are a large number of studies which have developed agroclimatic classification systems for the world. For most plant based commodities the problem is usually too many to choose from. With some commodity groups and especially fisheries the options are more limited. The important considerations in choosing the classification system are:

(a) It must be applicable to possible technologies. Too much detail is likely to be redundant, too little likely to result in aggregation errors.

(b) It must match and suit the preferences of the decision makers likely to use the information. If they currently related and decide on the basis of a simple system, then use of a complex extensive system may provide information in the wrong form.

(c) Information and computational requirements may limit the level of disaggregation.

(ii) Estimation of Production Environment to Production Environment Spillovers

Notationally this matrix has been termed the 'C' matrix (this is an m x m matrix where m is the number of production environments). It is a matrix of the spillover indexes briefly outlined above. In interpreting the c_{tw} elements of this matrix it is important to refer to figure 1. Instead of viewing each supply/demand diagram as a country it should be viewed as a homogeneous production environment. The c_{tw} values are found by using the ratios of the k_{ij}'s. For example, for the production environment where the technology was developed for, say a,

$$c_{aa} = \frac{k_{aa}}{k_{aa}} = 1 \qquad \ldots\ldots \qquad (2)$$

On the other hand, in production environment b, for research undertaken in a,

$$c_{ab} = \frac{k_{ab}}{k_{aa}} \qquad \ldots\ldots \qquad (3)$$

The interpretation of k_{ab} is important. It is the unit cost reduction in production environment 'b' if the technology developed specifically for 'a' is used in 'b'. For k_{ab} to be positive the technology must be superior to the best already available technology for production environment 'b'. Note this could be a different technology than the pre-research technology in 'a'. In most cases it is expected that $c_{ab} < 1$, that is, the cost reduction is less in a production environment that the technology was not specifically designed for. However, this is not a restriction of the model.

This notion of a production environment to production environment spillover introduces many dimensions which can be discussed and may need resolution. Below lists a few and does not attempt to discuss them in detail:

(a) The C matrix is unlikely to be unique. For example, the elements might change depending on the type of research, say, plant breeding versus plant protection or soils. Depending on the decision making environment the analysis is being used to support individual estimates may be required or a weighted average.

(b) Research may be undertaken with the view of maximising the cost reduction for a specific production environment or perhaps be interpreted as aiming to increase the size of the C matrix elements. The latter could be viewed as reducing the production environment sensitivity of a crop.

(c) Estimation of these parameters could be through elicitation from technical experts or procedures developed to make use of research trial results.

(iii) Estimate the Region to Region Spillovers

Aggregation of the 'C' matrix to give the 'S' matrix or region to region spillovers requires two additional sets of information. These include:

(a) The production environment production shares for each commodity. This is given the notation of an 'F' matrix which is an m x n matrix (where m is the number of production environments and n the number of regions). For each region this is the proportion of production in each production environment.

(b) The production environment focus of the research. The notation for this information is an 'R' matrix which is n x m. It specifies the share of research focused on each production environment in a region. If a region (country) has production in eight production environments, research decision makers will need to determine whether research will focus on all production environments or a sub-set. If so will each be given equal attention or will 70 percent of the effort be focused on one production environment. For assisting aggregate level decision making applications, so far, have assumed research effort is focused in proportion to the production in each production environment. In matrix notation this is the same as assuming $R = F'$. Clearly, a range of alternatives are possible and the model can generate a rich set of information regarding possible decisions and their subsequent potential impact on research applicability (spillovers).

With the above sets of information the aggregated region to region spillovers can be found using:

$$S = R\ C\ F \qquad \ldots\ldots \qquad (4)$$

This set of information can then be used in the multi-regional research evaluation model to estimate possible research benefits associated with the different options.

The next section highlights several aspects of the model with an illustrative application.

4. AN ILLUSTRATIVE APPLICATION TO ESTIMATE FORESTRY RESEARCH SPILLOVERS

4.1 Introduction

An empirical application of any model is usually the best way to highlight the important features. The type of spillover estimation procedure outlined in section 3 is in the process of being applied as part of information systems to assist research decision making in several institutions. It is an integral component of the information system used to assist decision making in ACIAR. In this application analysis has been completed or is nearing completion for 24 agricultural, 8 forestry and 11 fisheries commodities. Together this coverage includes around 95 percent of ACIAR's research expenditure. Davis and Ryan (1988), Davis, McKenney and Turnbull (1989) and Fearn and Davis (1991) summarise progress with this application. Related collaborative studies, jointly funded by ACIAR and national research institutions, are nearing completion in the Philippines and Thailand. Both of these have adapted the basic spillover estimation procedure described above to suit the particular decision making environment. A similar effort is underway in Indonesia via collaboration with ISNAR.

Since the spillover estimation component is only one part of the information system being developed, current documentation has not provided details of just the spillover estimation. This section provides a brief discussion using the forestry commodity saw and veneer logs (non-coniferous).

4.2 Country-to-Country Spillover Estimates for a Forest Product

Davis, McKenney and Turnbull (1989) provide a description of the application of an economic surplus model application to measuring the potential gains from forestry research. They also describe how this information is adjusted and presented to support research decision making in ACIAR. They only present a brief description of the spillover estimation procedure used. Here a more detailed description is developed.

Following the discussion in section 3 the following choices and information are required:

(i) Choice of Appropriate Production Environment Classification System

After discussions with forestry research experts it was decided that, for the purposes of information generated, an agroclimatic classification system was sufficient. The Papadakis (1975) system was chosen after reviewing a range of possibilities. For the agricultural application the FAO (1978a,b, 1980a,b) agroecological zone system was used. For fisheries, see Fearn and Davis (1991), a species based production environment system was adopted. There are no clear guidelines for making this choice. The approach adopted in applications so far has been to rely on the advice of the research experts, especially those involved in the decision making process that the information is being developed to support.

Figure 2 illustrates this classification system for Australia and New Zealand. The system is available for all countries of the world. For forestry a total of 72 production environments were included. The C matrix developed was therefore 72 x 72. Figure 2 indicates that Australia agroclimatically is quite diverse. It is interesting to note that the initial choice of this production environment was made before exposing the final information to the decision making process. Subsequently it has been found that the information system has much more flexibility and can provide a more detailed set of information to support decision making if, where possible, a standardised classification system is adopted for all commodities. As a result the forestry data base is being revised to use the FAO classification.

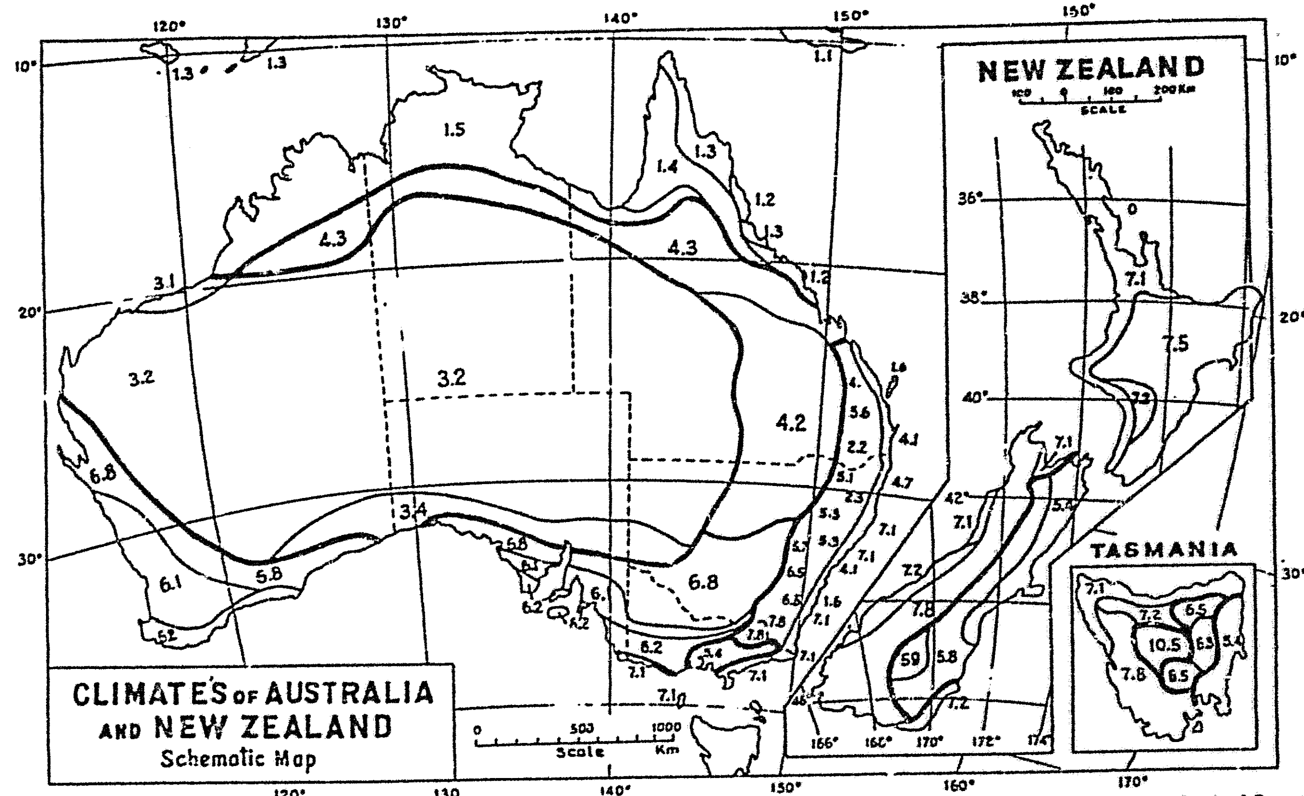
(ii) Estimate the Production Environment Spillovers

In the ACIAR work where a world wide analysis is required, logistically it has been necessary to rely on technical research experts' judgements to provide the elements of the 'C' matrix. Nationally focused studies, such as those in Thailand and the Philippines, are investigating empirical procedures for estimating these parameters from research trial information. This is a critical area which requires further investigation and refinement.

If elicitation of spillover estimates from one production environment to another is used it has been found to be very important to ensure the technical expert has a clear perspective of the concept as summarised in section 3. Especially important is to keep in mind the notion of a cost reduction relative to the best currently available technology.

Table 1 presents the estimates for saw and veneer logs (non-coniferous). Only 21 of the 72 production environments are used for illustration. Throughout this section only a small subset of each set of information are given because of the logistics of table presentation. Any calculated results are, however, based on the full set of data.

It is noticed that the diagonal elements c_{ii} are all one. Using the definition of c_{ii} from section 3 this is expected. If, however, the production environments are aggregated and not 'sufficiently' homogeneous this may not always be the case. Also notice that the matrix is symetric, this is based on the judgement of the researchers, however, is not a requirement of the model. Finally notice that the matrix is block diagonal. This is expected as the production environments are listed in order of those most likely to be similar.



1., TROPICAL: 1.2, humid tropical; 1.3, marine savanna; 1.4, continental savanna; 1.5, semiarid tropical; 1.6, cool tropical; 1.9, cool-winter tropical.– 2., TIERRA FRIA: 2.1, semi-tropical tierra fria; 2.2, low tierra fria; 2.3, medium tierra fria.– 3., DESERT: 3.1, hot tropical desert; 3.2, hot subtropical desert; 3.4, marine subtropical desert.– 4., SUBTROPICAL: 4.1, humid subtropical; 4.2, continental subtropical; 4.3, continental semi-tropical; 4.6, semi-steppic semi-tropical; 4.7, marine subtropical.– 5., PAMPEAN: 5.1, typical pampean; 5.3, subtropical pampean; 5.4, marine pampean; 5.6, monsoon pampean; 5.7, semiarid pampean; 5.8, patagonian grassland; 5.9, semiarid patagonian.– 6., MEDITERRANEAN: 6.1, subtropical mediterranean; 6.2, marine mediterranean; 6.3, cool-marine mediterranean; 6.4, tropical mediterranean; 6.5, temperate mediterranean; 6.6, cold mediterranean; 6.8, subtropical semiarid mediterranean.– 7., MARINE: 7.1, warm marine; 7.2, cool marine; 7.5, temperate mediterranean; 7.6, cool temperate; 7.8, humid patagonian; 10.5, alpine. In the Great Dividing Range climates are so mixed, that it is impossible to map them at so small scale.

Source : Papadakis (1975,p.187).

Figure 2 : Agroclimatic Classification System Used For Forestry.

Table 1 : Production Environment Spillover Estimates ('C' Matrix) -
Saw and Veneer Logs (Non Coniferous).

Production Environment Where Research Is Focused	Production Environment Where Research Has Impact.																			
	1.3	1.4	1.5	2.2	3.2	3.7	4.2	4.3	4.7	5.4	6.2	6.5	6.8	7.1	7.3	9.3	9.5	9.7	9.8	10.1
1.3	1.0	0.5	0.5	0.3			0.3	0.3	0.3											
1.4	0.5	1.0	0.5	0.3			0.3	0.3	0.3											
1.5	0.5	0.5	1.0	0.3			0.3	0.3	0.3											
2.2	0.3	0.3	0.3	1.0	0.3	0.3	0.3	0.3	0.3	0.3										
3.2				0.3	1.0	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3							
3.7				0.3	0.5	1.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3							
4.2	0.3	0.3	0.3	0.3	0.3	0.3	1.0	0.5	0.5	0.3										
4.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	1.0	0.5	0.3										
4.7	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	1.0	0.3										
5.3				0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.3	0.3	0.3	0.3	0.3					
5.4				0.3	0.3	0.3	0.3	0.3	0.3	1.0	0.3	0.3	0.3	0.3	0.3					
6.2					0.3	0.3				0.3	1.0	0.5	0.5	0.3	0.3					
6.5					0.3	0.3				0.3	0.5	1.0	0.5	0.3	0.3					
6.8					0.3	0.3				0.3	0.5	0.5	1.0	0.3	0.3					
7.1										0.3	0.3	0.3	0.3	1.0	0.5					
7.3										0.3	0.3	0.3	0.3	0.5	1.0					
9.3																1.0	0.5	0.5	0.5	
9.5																0.5	1.0	0.5	0.5	
9.7																0.5	0.5	1.0	0.5	
9.8																0.5	0.5	0.5	1.0	
10.1																				1.0

Source : Estimated by Dr John Turnbull, ACIAR Forestry Program Co Ordinator in Consultation with Others.

(iii) Determine the Production Shares by Production Environment

The share or proportion of production in each production environment for each country is required. Ideally this is the share expected to exist when the results are available as a technology. In most cases estimates have been based on existing production levels. For the forestry application these estimates were subjectively determined by forestry experts familiar with forestry production in each country. The agricultural estimates were based on detailed estimates made by FAO. For fisheries the species production data tapes produced by FAO were used to calculate this information.

Table 2 presents example information on production share information for nine of the total number of countries used in the analysis. All countries of the world are included, however, some are aggregated to reduce the data table size. As a rule all countries in ACIAR's mandate are kept as separate countries, as are other large countries. The rest are suitably aggregated. The final set is 75 countries or regions.

Table 2 highlights the world pattern for this production share information. Some countries, such as Australia, India and China have diverse distributions of production environments, which often include the production of similar products. On the other hand other countries only have limited production environment diversity. By definition the sum of these shares should be 1.

(iv) Specification of Research Focus

Information regarding the expected research focus strategies of each country is not available. In the standard analysis an assumption similar to congruence is made. That is, it is assumed that a commodity research effort within a country or region is focused according to the importance of the production environment for that commodity. For the aggregate level of decision making, currently of importance at ACIAR, this assumption has been acceptable. For other decision making environments alternative assumption may be more appropriate. The ability of the estimation procedure to accommodate alternative strategies and assess their impact on regional spillovers and their potential benefits is one of its attractive features.

For the illustration used here the 'R' matrix is therefore assumed to be the transpose of the production share matrix, F.

The information included in tables 1 and 2 can be used to calculate the aggregated region-to-region spillover estimates. These are presented in table 3 for the nine countries used in this illustration. Many points regarding these can be discussed. The following are only a few to illustrate.

(a) There is considerable diversity in the direct effect estimates, that is, s_{ii}. The countries with production spread over a diverse range of production environments obviously have lower direct research effects. Inspection of tables 1 and 2 reveal this relationship. Australia, for example, has production in environments where there are, for most applied research, unlikely to be any spillover effects. Thus technologies developed for one

Table 2 : Production Environment Production Shares ('P' Matrix) -
Saw and Veneer Logs (Non Coniferous).

Production Environment Code	PRODUCTION SHARES P(i)a								
	AUSTRALIA	INDIA	PHILIPPINES	THAILAND	CHINA	KENYA	EGYPT	BRAZIL	CANADA
1.1		0.025	0.300	0.200				0.300	
1.2					0.025				
1.3		0.025	0.050			0.100		0.050	
1.4	0.050	0.200	0.050	0.800				0.300	
1.5	0.100	0.150				0.150		0.050	
1.7								0.100	
1.9		0.150						0.050	
2.1					0.275				
2.2								0.050	
3.1						0.450			
3.2	0.200						0.700		
3.7					0.050				
4.2	0.100	0.200							
4.3	0.100	0.250							
4.7								0.100	
5.3	0.100								
5.4	0.050								
6.2	0.050								
6.5	0.050								
6.8	0.100						0.300		
7.1	0.100								
7.5									0.075
7.9									0.075
8.1					0.200				
8.2					0.050				
9.3									0.250
9.5									0.100
9.7									0.050
9.8					0.300				
10.1									0.200

Table 3 : Region - to - Region Spillover Estimates ('S' Matrix) - Saw and Veneer Logs (Non Coniferous).

Country Undertaking The Research	COUNTRY WHERE RESEARCH HAS IMPACT								
	AUSTRALIA	INDIA	PHILIPPINES	THAILAND	CHINA	KENYA	EGYPT	BRAZIL	CANADA
AUSTRALIA	0.284	0.227	0.136	0.155	0.099	0.201	0.341	0.160	0.023
INDIA	0.222	0.495	0.427	0.493	0.139	0.299	0.095	0.444	
PHILIPPINES	0.136	0.427	0.908	0.610	0.125	0.278		0.614	
THAILAND	0.155	0.493	0.610	0.840	0.125	0.275		0.620	
CHINA	0.099	0.139	0.125	0.125	0.510	0.131	0.101	0.131	0.143
KENYA	0.201	0.299	0.278	0.275	0.131	0.415	0.198	0.285	
EGYPT	0.341	0.095			0.101	0.198	0.706	0.032	0.014
BRAZIL	0.160	0.444	0.614	0.620	0.131	0.285	0.032	0.552	
CANADA	0.023				0.143		0.014		0.297

production environment are not likely to be used by producers in another.

(b) The spillover effects to other countries are variable. In some cases these can be larger than the direct effect in the country doing the original research. At first glance this often puzzles an observer. However, it becomes clear if tables 1 and 2 are inspected. For example, in the case of Egypt most of its production is in production environment 3.2, hot subtropical desert. While a relatively small share of Australian production is in this production environment it is still important. Since there are only small spillovers to some other production areas and none to others, any research will have limited applicability to total Australian production. On the other hand this research will potentially apply to a large share of Egypt's production.

(c) It is important to remember that this information is an index. The potential welfare gains from these spillovers are scaled by several other factors in the research evaluation framework. These eventual monetary gains are not presented here but are discussed in Davis, McKenney and Turnbull (1989). (Note that numbers may not match exactly since those included here have incorporated some refinements to the original data and format of analysis.)

(d) The results have interesting implications in terms of the notion of technology adoption. It is possible to regard the elements of the direct effect as containing some of the dimensions of what is often folded into the term adoption. In Australia we would expect to find a relatively low average adoption of any forestry technology, in terms of total production. From table 3, in fact, about 28 percent is the likely average. For the rest of production the 'average' technology will not provide sufficient improvement of the existing set to warrant adoption. Sometimes analysts are inclined to attribute these low figures to other adoption factors, for example, lack of extension etc.

(e) If countries are disaggregated into sub-regions similar regional spillovers can be calculated between states or smaller geographical/political areas. Similar pattern to that in table 3 can be found, although the diversity is sometimes not as large. It is possible to show, however, that this disaggregation is a more productive approach to the issue of the type of supply shift, as opposed to using mathematical manipulations of the aggregate supply function. It can be shown that it is possible that pivotal divergent with non-linear supply shifts at the aggregate level can give higher estimates than parallel linear shifts applied at the disaggregated level. This confirms the suggestions of Lindner and Jarrett (1980) and Rose (1980). Davis (forthcoming) uses this spillover modelling and disaggregation to illustrate this point.

4.3 Spillover Estimates with Alternative Production Environment Research Foci

A range of alternative research strategies can be investigated with this simple spillover estimation model. One is illustrated here.

In table 3 spillover estimates were based on the so called 'congruence' assumption. That is, research was focused on production environments according to existing production in each environment. The impact of alternative research strategies can be investigated. Table 4 illustrates a range of possibilities for Australia and saw and veneer log (non-coniferous) research.

The first row in table 4 repeats the Australian row from table 3. The other seven rows assume that all research effort is focused on only one production environment. The resultant technology will only directly influence production in this environment. Spillovers still occur as indicated by table 1. The diversity of Australian production conditions produces some significant variations in spillover estimates, indicating important sensitivity to the choice of research strategy. Again a range of points can be discussed. For example,

(a) The congruent strategy does not always product the highest direct effect. Although by definition it will be near to this.

(b) Some significant changes can occur in the spillovers to other countries' regions from changes in these strategies. Sometimes significant increases in spillovers to other countries can result from small changes in direct effects.

(c) The distribution of research gains within a region/country can change significantly due to different strategies. These impacts can only be extracted by disaggregation from a national to intra-national level.

(d) Again it is important to remember that these spillovers are indices and differences can be adjusted when spillover research benefits are calculated.

(e) An important issue which needs to be interfaced with this information is the unit cost reduction that is likely to be achievable in each production environment. This is a so called research production function type issue. If this information can be estimated it can be incorporated in a research benefit assessment with the spillover indices.

While not a primary concern of the initial information system developed to assist decision making at ACIAR, information on changes in these research strategies and options are proving to be useful additional complements to the basic information developed. For a related discussion see Ryan and Davis (1990).

5. CONCLUSIONS

This paper began by identifying several reasons why more detailed modelling of research spillovers appears warranted. These included the possibility of being able to provide more detailed information to assist research policy debate, research program planning and satisfy a gap in the existing research evaluation methodology.

Table 4 : Research Spillover Estimates for Alternative Australian Production Environment Research Foci - Saw and Veneer Logs (Non Coniferous).

Production Environment Focus of Research	SPILLOVER RESEARCH FOR								
	AUSTRALIA	INDIA	PHILIPPINES	THAILAND	CHINA	KENYA	EGYPT	BRAZIL	CANADA
Focus Congruent	0.284	0.222	0.136	0.155	0.039	0.201	0.341	0.160	0.023
Focus on 7.1	0.205						0.090		0.075
Focus on 6.3	0.260				0.015	0.135	0.360		0.045
Focus on 1.5	0.185	0.485	0.500	0.500	0.125	0.350		0.495	
Focus on 3.2	0.365	0.135			0.130	0.225	0.790	0.045	
Focus on 4.2	0.300	0.490	0.300	0.300	0.155	0.300	0.210	0.320	
Focus on 5.3	0.335	0.135			0.128	0.135	0.390	0.045	0.045
Focus on 9.6					0.225				0.265

A simple linear model was developed in this paper which is suggested as a further step in this area. The model highlights the need to:

(i) Separate the notion of research spillovers to relate to technical production environments. These can then be aggregated to geographical/political regions to suit the level of tolerable aggregation error.

(ii) Address clear attention to the issue of research strategies, especially regarding the types of production environments research is expected to focus on.

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