A General Equilibrium Approach to the Efficiency of Indonesian Irrigation Development and its Impact on the Agricultural Sector

Ray Trewin
Australian National University

Yiping Huang
Australian National University

Erwidodo
Centre for Agri-Socioeconomic Research

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ABSTRACT

Indonesia has a large physical potential for further irrigation to aid rice self-sufficiency. However, the high cost of construction, due in part to delays as well as cost blowouts, and the resultant low rate of return could constrain irrigation development and hence agricultural growth. This is an example of how arrangements in one sector can impact on the performance of another. In this paper, the foundations of a model to be used to analyse such aspects are developed. A preliminary version of this model is applied to analyse the broad impacts of inefficiencies in both the construction and irrigation sectors.

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Introduction

Indonesia has invested substantially in irrigation during its development, especially on Java where the pace of development and the amount of land suitable for irrigation are greatest. Irrigation development, when properly maintained and managed, has led to higher yields and agricultural production, not only during the 'green revolution' but even back in the last century (Booth 1988). Social welfare is also affected by irrigation development. However, it is an open question as to whether irrigation development improves social welfare, the answer depending on such factors as the type of development and how benefits are shared. A similar story applies in the case of environmental impact. Some developments, such as those with a component of flood control, will benefit the environment. However, irrigation development can also damage the environment, the most obvious form of damage being the pollution of waters as they move through the irrigated lands.

Back in the last century much of the irrigation development was undertaken by individuals or communities, with little government involvement. In such circumstances the perceived private benefits would have been seen to have outweighed the associated costs. Nowadays irrigation developments are of a larger scale and governments are strongly involved in most aspects, including feasibility studies, construction and management (Booth 1988). In addition, the costs of irrigation development have risen steadily. This is no doubt because the easier irrigation developments have already been completed, but it is also reflective of a blowout in the costs of construction. Developments which on the drawing board looked viable have by the time of completion become non-viable, not because of a miscalculation of the agricultural benefits but because of delays in construction and unanticipated cost increases (World Bank 1992).

In a physical sense, Indonesia has a large potential for further irrigation developments. The constraining factor is the net social benefit of such developments given the higher costs of construction and the low rate of return. Agencies such as the World Bank are unwilling to finance these developments in view of the low rates of return. Efficiency gains in the construction of irrigation infrastructure — as a result of greater competition, say — or greater benefits flowing from investments in irrigation facilities, for instance as a result of better management or improved technology, would be necessary for further investment to take place. Otherwise, any irrigation development would have to be subsidised relative to other investments; and although this may be seen as fair compensation to the agricultural sector for inefficiencies in other sectors, it could have a detrimental effect on the wider economy.

The situation just described is a perfect example of how arrangements in one sector impact on performance in other sectors; in other words, the economy-wide implications of a sectoral policy need to be taken into account. This paper lays the foundations for an economy-wide model that can be used to analyse a range of such issues. The usefulness of the model is illustrated by some preliminary analysis of the broad impacts of addressing inefficiencies in the construction and irrigated agricultural sectors. The next section presents some background on the agricultural and irrigation sectors that is relevant to the efficiency issue. The foundations of the economy-wide model are then detailed along with some preliminary simulations to measure the impacts of the various levels and forms of inefficiencies. The conclusion suggests some policy options that may assist in overcoming inefficiencies in the irrigation sectors.

Background

Irrigation has been for many years an important aspect of Indonesian agriculture. When reliable statistics were first collected during the latter part of the last century it was evident that irrigation was well established in many regions of Java and that it was a major determinant of high yields. Around 55 per cent of all sawah in Java in

1865 was irrigated, with this percentage ranging from just over 10 per cent in some regions to nearly 90 per cent in others (Booth 1988). Java has tended to lead the development of irrigation in Indonesia because of the pace of its overall development and the suitability of much of its land.

Most irrigation development was undertaken privately up to 1870, when governments became more involved through budgetary expenditures. Irrigation development is an important public good. It has been part of an official strategy or ethical policy that has attempted to raise indigenous living standards. It also has environmental implications. For example, by taking the pressure off more intensive cropping of dry lands it has mitigated the process of soil erosion and land degradation in the uplands. However, it could be contributing to Indonesia's water pollution problems although currently there is little evidence about this.

The nature of irrigation development has also changed over time. More technical systems with permanent canals, control structures and measuring devices have evolved as government involvement has increased. However, the majority of the systems are still small 'run of the river' types, with schemes under 1,000ha making up 86 per cent of all systems and 34 per cent of the area under irrigation (Varley 1989). The structure of the irrigation sector is important, as some systems are amenable to alternative forms of management. Small systems, for example, are more amenable to decentralisation of control and greater financial responsibility.

Since independence, irrigation development has continued to grow rapidly, proportionally more so in more technical systems and off Java because of catch-up effects. During the period 1969–87, total wetland area grew at an annual rate of 1.7 per cent: 1.3 per cent on Java and 2.2 per cent off Java. The growth in new irrigation developments has been counteracted to some extent by the conversion of some irrigated land to non-agricultural uses, especially on Java and Bali. In 1985, irrigated and wetland areas accounted for about 90 per cent of total area harvested to rice (Rosegrant and Pasandaran 1990).

To illustrate the impact of irrigation development on yields and agricultural production requires the compilation of data from a number of sources. This task was undertaken by Rosegrant and Pasandaran (1990) and some of the results of their analysis are presented in Table 1. The impact of irrigation on production is reflected in the fact that irrigated areas accounted for 68 per cent of the total paddy area harvested in 1988 yet contributed 83 per cent of total paddy production. Another key feature of the table are the differences in cropping intensities between technical irrigated lands and drylands: the former can be harvested 1.81 times per annum compared to the latter's once. Similarly, the average yield of 5.15 metric tonnes per hectare, was nearly three times that of drylands at 1.80 metric tonnes per hectare.

The period of irrigation growth since 1969 contains subperiods of differing levels of growth. Irrigation investment grew rapidly during the first three five-year plans, with an annual growth rate of about 28 per cent in actual terms and 15 per cent in real terms. However, since 1984 investment expenditures have fallen by almost 16 per cent per annum in real terms.

Per unit costs and rates of return have also varied. Varley (1989) calculated a five-year moving average of budgetary realisations divided by the reported physical development completed and showed that costs per hectare in 1989 in Rupiahs per hectare steadily increased for all types of irrigation development. The World Bank (1992) reported that rates of return on recent irrigation developments were generally well below 10 per cent. Greater rates of return would be obtainable with improvements in the design and operation of irrigation schemes. Acceptable rates of return should take into account the public good aspects of irrigation development, for example its impact on risk, social welfare and the environment.

Economic cost constraints are limiting the considerable potential of irrigation development. There are still large areas of land suitable for irrigation in a physical sense. The World Bank (1992) quotes the Ministry of Public Works in estimating that about 7 million hectares of land off Java has been identified as suitable for irrigation development and that about 80 thousand hectares of land within existing systems on Java could be irrigated at minimum cost.

The observed lower rates of return on irrigation investment are not a function of lower than expected returns on the investment, but of a blowout in costs. Some of this cost blowout can be put down to the fact that the most suitable lands have already been irrigated. However, significant components of the blowout are delays and cost overruns in construction. Greater competition in this sector could lead to lower costs. As mentioned earlier, higher rates of return could also be achieved through improvements in the design and operation of irrigation schemes. Included in the design aspect is the basic nature of the irrigation system, for example the costs and benefits of installing more technical systems as opposed to the currently dominant low-catchment systems that are cheaper but more susceptible to drought.

Given the above background, what are the key issues that a computable general equilibrium (CGE) model could usefully analyse? Irrigation development has a number of objectives, including aspects of economic efficiency, social welfare and environmental benefit. The costs and benefits of various policy options in terms of meeting these objectives need to be measured and compared. A CGE model enables the full extent of costs and benefits to be analysed, and not just costs and benefits directly related to a particular irrigation development. Various options can be compared: that of allowing inefficiencies in construction to continue with no new irrigation developments to be undertaken, versus a second best compensation approach where inefficiencies continue but the acceptable rate of return is lowered, versus a first best efficient construction sector approach, for example. Another option is the incorporation of efficiency gains in the irrigation sector from better technologies and management.

An economy-wide model for agricultural policy analysis

Indonesian agricultural policies, such as rice self-sufficiency and fertiliser subsidies, have undergone much economic analysis (see, for example, Booth 1988, Fane 1991, Parton et al. 1990, Rosegrant et al 1987, Tabor 1992, Timmer 1986 and 1991, and Tomich 1992). Most studies use a partial equilibrium framework to analyse agricultural policies and their changes. While partial equilibrium analysis can reveal important direct effects of agricultural policies, it fails to capture feedback or second-round effects. A fertiliser subsidy, for example, may directly affect the level of demand for fertilisers by farmers and, thus, agricultural outputs. However, such a subsidy would also have impacts on the other parts of the economy, at least the fertiliser sector, and these would affect further the performance of agriculture. The importance of these second-round impacts depends on the significance of adjustment behaviour to a change in the fertiliser subsidy. A partial equilibrium framework is obviously unable to capture all these effects, and CGE models are the most suitable vehicle for examining such issues. The spirit of CGE modelling originated in the debate over the feasibility of the centralised calculation of a Pareto optimal allocation of resources within an entire market economy through input–output analysis. The basic structure of this type of model can be broken down into two main blocks: the accounting identities (for example, SAM) that are so important to input–output analysis; and behavioural equations.

An Indonesian CGE model — general characteristics and potential uses

Broadly speaking, the model developed in this study will build on the Dee model (Dee 1991) and may be classified as an economy-wide, comparative-static, computable general equilibrium model of the Johansen type. The key features of this type of model will be discussed in turn.

Economic models come in many shapes and sizes, with the type of model to be constructed depending entirely on the tasks envisaged for the model. Economic models are abstractions from reality, designed to provide a simplification of some parts of a highly complex economic system. The appropriateness of a specific economic model for policy analysis depends largely on the specifications chosen and assumptions made. CGE models are no exception. In developing the Indonesian CGE model, the set of crucial assumptions usually made in CGE modelling are retained. These assumptions will be set out below.

The Indonesian CGE model will address three levels of economic policy problems, with particular emphasis on the agricultural sector. First, it will be applied to examine the effects of policies and changes at the sectoral level (industry or commodity). Of interest are changes to taxes and subsidies on industry production (for example, irrigation), export and import charges, and sector-specific technical change at the farm level. Second, the model will be used to explore the consequences of changes occurring at the macroeconomic level, in the aggregate level of government spending (for example, irrigation budget) or in the exchange rate, for instance. Finally, the model can be used to explore the impacts of external shocks, such as changes in world markets that are relevant to Indonesia (for example rice prices).

Economy-wide and multisectoral modelling

The policy analysis objectives determine that the model must be capable of representing the intersectoral features of the Indonesian economy. As already stated, the art of model-building is to incorporate sufficient detail to capture the essence of the problem under study while excluding those aspects likely to be of lesser importance. Although a large part of the economy is substantially simplified in the specification, the model is comprehensive in that all sectors of economic activity are included. Projections from the model add up in the sense that outcomes for each sector appropriately weighted are equivalent to outcomes for the relevant macroeconomic variables. Hence, following an adjustment of incentives to the agricultural sector, the sum of changes in outputs for each sector equals the change in the economy's aggregate output.

The economy-wide aspect of CGE modelling concerns the inclusion of all sectors at an appropriate level of aggregation for the issues under analysis, with all important interindustry linkages explicitly represented. By describing the operation of a market economy through specifying in considerable detail the structure of production, consumption, government revenue and expenditure, as well as foreign trade, etc. CGE models emphasise the interdependence of the decisions taken by all economic agents. Whenever the government intervenes in agriculture, or an exogenous shock occurs, resources are re-allocated across all markets of the economy, with efficiency and distributional consequences. The CGE model describes where the resources come from, what implications the policy has for the rest of the economy and to what extent feedbacks from other sectors will impact on agriculture. Interindustry linkages are captured by considering an industry's purchase of other industries' outputs, competition for available resources and constraints such as the balance of trade.

General equilibrium/neoclassical economic theory

In its treatment of production and demand, the Indonesian CGE model incorporates the conventional features of neoclassical microeconomics. It assumes optimising behaviour on the part of producers (profit maximisation and/or cost minimisation) and of users (cost minimisation and/or utility maximisation) subject to various constraints in the economy such as the supply of factors (labour, capital and land), balance of payments, technology, etc. The resultant equations emphasise the responsiveness of economic agents to changes in relative prices, with the degree of responsiveness dependent on the value assigned to substitution elasticities.

All markets are assumed to be competitive, and thus no activity earns pure profits. This aspect requires the further assumption of constant return to scale in production activities. Market clearing with the simultaneous determination of prices is assumed in all commodity and factor markets.

The general equilibrium aspect is more concerned with providing a solution to the model system than supply equalling demand in each market; for example wages can be treated as endogenous and unemployment can exist in such markets. CGE models contrast with partial equilibrium models in terms of their size, especially in the number of endogenous variables.

Johansen-type models

To date CGE models fall into two groups classified according to the way in which they are solved: in the levels of the variables, or in logarithmic differentials or percentage changes. The first type is used widely by the World Bank (Dervis, de Melo and Robinson 1982) and a number of other North American centres. Indonesian models built by Gelb (1985a, 1985b) and by Lewis (1991) fall into this category. The second type, pioneered by Johansen (1960), is used extensively by Australian modellers (see Dixon et al. 1982) and several centres in Europe and North America. In this branch of CGE modelling, percentage changes in equilibrium values of economic variables are solved using linear algebra. Following the tradition of the ORANI model of the Australian economy, Dee (1991) developed a multisectoral equilibrium model of Indonesia of this type for use in analysing forestry issues.

Johansen-type CGE models involve first totally differentiating all equations of the model to achieve a system linear in percentage changes of variables. Simple manipulation methods are then used to generate solutions. The general equilibrium conditions can be written as:

$$F(X) = 0 \qquad (1)$$

where X is the vector of variables of the model while $F(.)$ is the set of excess demand and unit profit functions of the model. X may be partitioned into a vector of endogenous variables (Y) and a vector of exogenous variables (Z) through what is known as an appropriate closure. This partitioning enables a solution and reflects the circumstances of the application, for example whether aggregate consumption or the balance of trade are considered fixed. Totally differentiating equation (1) with respect to X, an expression

$$A\,y + B\,z = 0 \quad (2)$$

is obtained where lower case represents percentage changes. This expression can be solved for y as follows:

$$y = -A^{-1} B\,z$$

Compared with the type of model that is solved at levels, the Johansen type has one distinct disadvantage, namely that results are only linear approximations of the non-linear system and hence strictly are valid only for small changes. Johansen types, however, possess a number of balancing advantages. The solution algorithm is separate from the specific model form (for example, the closure) and therefore easier to implement; the mechanisms underlying the results are easier to understand and explain to policy-makers; and when there are several policy changes under study the separate effects of each can be decomposed additively (NCDS 1990). Recent developments with the GEMPACK software enable linearisation errors to be minimised, bringing the percentage change and level model specifications closer together. These aspects and the argument that linearisation errors are unlikely to be a problem (Dixon et al. 1982) are reasons for developing the Dee–Johansen-type model.

A model specified as linear in percentage change can normally determine only relative prices. However, setting a variable such as the nominal exchange rate, the CPI or a wages index as exogenous enables it to act as a numeraire and determine absolute price levels. Alternatively, monetary sector can be incorporated and the quantity theory of money could provide an explanation of price levels (Martin 1991).

Comparative static/dynamic models

The model provides projections at only one point of time, the solution year. This solution contains no information about the time path of each economic variable as provided by many dynamic models. Johansen-type models give 'gap' measures of the effects of external shocks alone after *t* years. That is, the gap shows how much Indonesia's economic activity levels would increase (decrease) as a result of a shock, such as a reduction in incentives to agriculture, compared with the levels they would have reached had the shock not taken place.

Comparative-static models are also not specific about timing. A model is referred to as a long-run model if it is assumed in the simulations that the capital stock is not held to be fixed or exogenous, and short-run otherwise. The time frame is reflected in the elasticity response estimates incorporated in the model and the extent of resource adjustments envisaged in the way the model is closed.

Dynamics have been incorporated into this type of model including the Dee model (Dee 1991). In the Dee model dynamics are included in the treatment of physical capital accumulation along the lines of Wilcoxen (1989).

Previous CGE models of Indonesia

As mentioned above, there exist several Indonesian CGE models built for different policy analysis purposes. Gelb (1985a, 1985b) set up an Indonesia-like model to simulate the impacts of a set of oil shocks and policy changes on the Indonesian economy. In the first exercise, Gelb (1985a) examined the impact of: alternative uses of additional oil income revenues (public investment, private consumption, subsidies, etc.); removal of domestic petroleum prices subsidies; and policies aimed at neutralising the undesired side-effects of oil booms. Later, Gelb (1985b) also conducted a simulation of absorption policies of a representative oil exportor when there are oil windfalls. Agriculture was not a major component of the model.

Behrman, Lewis and Lofti (1989) analysed the impact of commodity price instability on Indonesia using a CGE model. However, this work was based on a 1980 Social Accounting Matrix, parameter estimates did not make use of available time series of data and the model did not fully represent the costs of commodity price instability (for example, adjustment costs and stabilising through stocks were ignored). Devarajan and Lewis (1991) also used a CGE model of Indonesia to examine a set of trade policies. The type of CGE model used in these studies is well documented in Lewis (1991). Three out of the 13 sectors in the model relate to agriculture (food agriculture, traded agriculture and food industries).

Two other CGE models of Indonesia are described in Thorbecke (1992). One of the models, by Keyzer, van Veen and Tims, builds on work begun at the Centre for World Food Studies in 1988. This model is highly disaggregated, particularly in agriculture where 27 different sectors are identified. However, no financial sector is specified in the model. The other model is a more recent development by Thorbecke and al[illegible] much more aggregated incorporates a financial as well as a real sector. The two models were used jointly to analyse adjustment issues.

The final model discussed here is the one used as a basis for the model to be developed in this study. Dee (1991) developed a modelling framework for Indonesia to evaluate the economic consequences of various forestry policies. A rich treatment of the forestry sector was incorporated into a standard multisectoral, general equilibrium model along the lines of the ORANI model mentioned earlier. Two innovations were introduced: the steady state treatment of forestry, and the intertemporal treatment of capital accumulation.

The Dee model contains eight industries: agriculture; mining; forestry; mineral processing; agricultural processing; logging processing; other manufacture; and services.

The agricultural sector in the model is highly aggregated. Some agriculture-related features, are however, worthy of notice. First, the model distinguishes agriculture, minerals (mainly oil) and forestry from other sectors, since they are all land using, and classifies labour into four occupations: agricultural workers, production workers, administrators and professionals. Second, real wages for agricultural and production workers are exogenous and their employment levels endogenous, while employment levels for skilled administrative and professional staff are exogenous and their real wages endogenous. The underlying assumption is that Indonesia is treated as a surplus labour economy for unskilled but not for skilled occupations. Third, land is mobile between agriculture and forestry, and moves toward the use in which discounted returns to land are greater. Returns to land therefore adjust until their discounted value is equalised between the two industries. Land use in the minerals sector is held to be exogenously fixed.

Compared to other CGE models, the striking feature of this model is that investment demand and capital creation inputs are modelled in greater detail, reflecting the purpose of modelling.

An Indonesian CGE model for agricultural policy analysis

This study builds on the Dee model, incorporating more detail on the agricultural sector while simplifying aspects of investment and capital creation. This section introduces the development of a model for analysing agricultural policies in Indonesia. Particular attention has been placed on modelling the disaggregated agricultural structure.

Sector detail

One important step in CGE modelling is to decide on the degree to which production should be disaggregated, as this is a crucial determinant of the model's potential usefulness in policy analysis. Disaggregation and a detailed sector structure are a feature of CGE models, particularly compared with macroeconomic models. The Indonesian model described in this paper has a detailed structure for the agricultural sector since the primary purpose of the model lies in the impacts of agricultural and general policies on the sector as a whole as well as on individual farm commodities like rice. However, disaggregation does not come without a cost. A detailed model structure may provide insights into structural change but demands a higher quality of inputs as well. CGE models are built on parameters and coefficients characterising the behaviour of economic agents. The availability of data (both input–output parameters and behavioural elasticities), therefore, is an important determinant of model structure. The non-agricultural sectors are relatively aggregated. In adding up individual industrial sectors, attention was given to distinguishing export-oriented and import-competing industries, following the APEX model (Clarete and Warr 1992), and to separate activities that use different production techniques (input combinations), following the Papua New Guinea model (NCDS 1990).

The initial version of the Indonesian model contains 16 sectors, of which one-half is agricultural and the other half (including agricultural irrigation) is non-agricultural (Table 2).

Agriculture

Agriculture is the industry of particular interest to this study. For the purposes of policy analysis, particular sectors are separated out. These include rice production (both on Java and off Java) and key inputs such as the fertiliser and agricultural irrigation sectors. This treatment allows detailed examination of the impacts of any policy changes or shocks to rice, fertiliser and irrigation services. Agriculture consists of irrigated rice, other irrigated food crops, estate and other crops, livestock, rainfed crops, smallholder production, forestry and fisheries. Rainfed crops and smallholder production are multiproduct sectors while the other sectors each produce only a single product.

One important characteristic of the model is that regional factors are incorporated into the modelling structure for agriculture. Java and off Java are two distinct regions in terms of their agricultural infrastructures, and in particular their irrigation system, and productivities. The technologies used in these two regions could be different. The agricultural sectors of irrigated rice, other irrigated food crops, estate and other crops and livestock are therefore broken down into two regional subsectors (on Java and off Java).

In the production process, each agricultural sector uses two categories of production inputs — intermediate inputs and primary factors — to produce either a single output (for a single product industry) or a composite output (for a multiproduct industry) (Figure 1). Intermediate input is distinguished as being eitherdomestically produced or imported, while primary factors include labour, capital and land. Composite output is then split into individual commodities through a specified transformation mechanism.

Mining

Indonesia has a relatively small mining sector when compared to resource-rich countries like Australia and the Middle East. Mining industry, however, distinguishes itself from other sectors in that it is both resource and capital intensive (compared to some other industrial sectors) and its output is relatively stable (compared to agriculture). In addition, given the size of the Indonesian economy, the performance of its mining sector, and especially the crude oil sector, is critical to the overall growth of the economy.

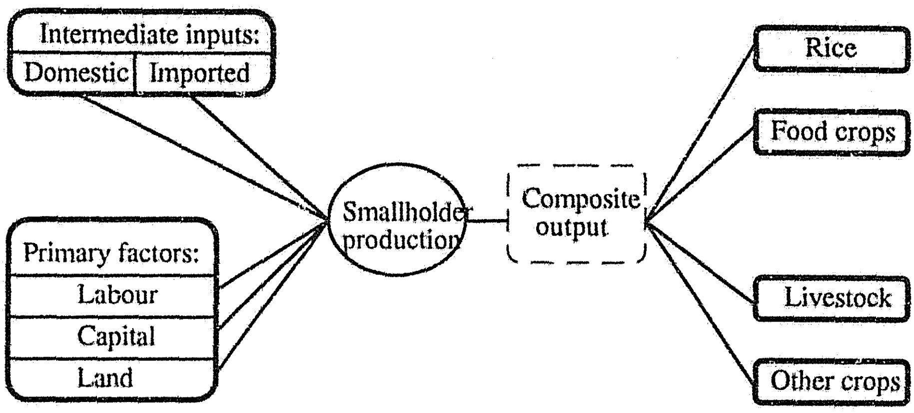
However, the mining sector as reflected in the model is rather aggregated. The minerals sector contains coal, crude oil, iron ore, tin ore, nickel ore, bauxite ore, copper ore, gold and silver ore and crude salt.

Manufacturing

Manufacturing is also highly aggregated in the model, reflecting the focus of the study. Extensions or disaggregation of this industry can easily be carried out if more information is required or if a different issue is to be addressed.

A relatively detailed structure was specified for those manufacturing industries heavily dependent on such agricultural outputs as raw materials. The interactions between agriculture and these manufacturing industries are expected to be significant. The upstream or downstream effects of any exogenous changes or feedbacks are of particular interest in this study. Agricultural processing and fertiliser production are of fundamental interest. Other manufacturing industries in the model are separated according to distinct characteristics of their production process. These include minerals processing, forestry processing and other manufacturing industries.

Figure 1 Agricultural production



Services

Service industries are currently small in the Indonesian economy. Two service sectors are included in the model, namely agricultural irrigation and other. This treatment enables examination of the impact of a change in the irrigation system on agricultural production and rice self-sufficiency in Indonesia.

Input–output information

Links between different parts of the Indonesian economy, and between the domestic and external economies, are captured by an input–output database. The database used in constructing the model is the 1985 Indonesian Input–Output Table with 171 sectors. Appendix 1 discusses the methods applied in constructing a 36 sector input–output table based on the above more disaggregated table.

Production activities

Since producers are assumed to be price takers in both output and input markets, they choose input levels that minimise production costs subject to production technologies. The technology of current production is illustrated in Figure 2. Producers choose their input mixes to minimise their costs subject to the production function described in levels 2 and 3. Following ORANI, at the third level, effective inputs of each of g (=30) produced inputs are defined as CES[1] combinations of domestic supplies and imports of the particular commodity classification. That is, demand for intermediate input i (i=30) of source s (s=1, domestically produced, s=2, imported) by industry j (j=25), $x^{(1)}_{(is)j}$, can be expressed as:

$$x^{(1)}_{(is)j} = z_j - \sigma^{(1)}_{ij} [p_{(is)j} - \sum_s S^{(1)}_{(is)j} p_{(is)j}] \tag{3}$$

ignoring the technological factors $\sigma^{(1)}_{ij}$, the elasticity of substitution between two sources of intermediate inputs. The effective units of primary factors are defined as CRESH[2] combinations of fixed capital, labour and agricultural land. The demand for primary factor v by industry j, $x^{(1)}_{vj}$, in its simplest form, is:

$$x^{(1)}_{vj} = z_j - \sigma^{(1)}_{vj} [p^{(1)}_{vj} - \sum_v S^{*(1)}_{vj} p^{(1)}_{vj}] \tag{4}$$

where $\sigma^{(1)}_{vj}$ is the CRESH parameter reflecting the degree of substitutibility between primary factor v and other primary factors in the production process. Capital and agricultural land are treated as though they cannot be shifted between industries (fixed in the modelling). In effect, it is assumed that there is a rental market for the capital and agricultural land of each industry and that each producer in industry j treats the rental prices of capital and agricultural land of type j as given. The rental rates adjust so that for each j, the sum of the demands from all producers in industry j equals the available supplies of capital and agricultural land of type j.

At level 2, effective inputs of each of g produced commodities and effective primary factor inputs are required for the production process in the fixed proportion:

$$z_j = \min \{ \frac{X^{(1)}_{1j}}{A^{(1)}_{1j}}, \frac{X^{(1)}_{2j}}{A^{(1)}_{2j}}, \ldots, \frac{X^{(1)}_{gj}}{A^{(1)}_{gj}}, \frac{X^{(1)}_{vj}}{A^{(1)}_{vj}} \} \tag{5}$$

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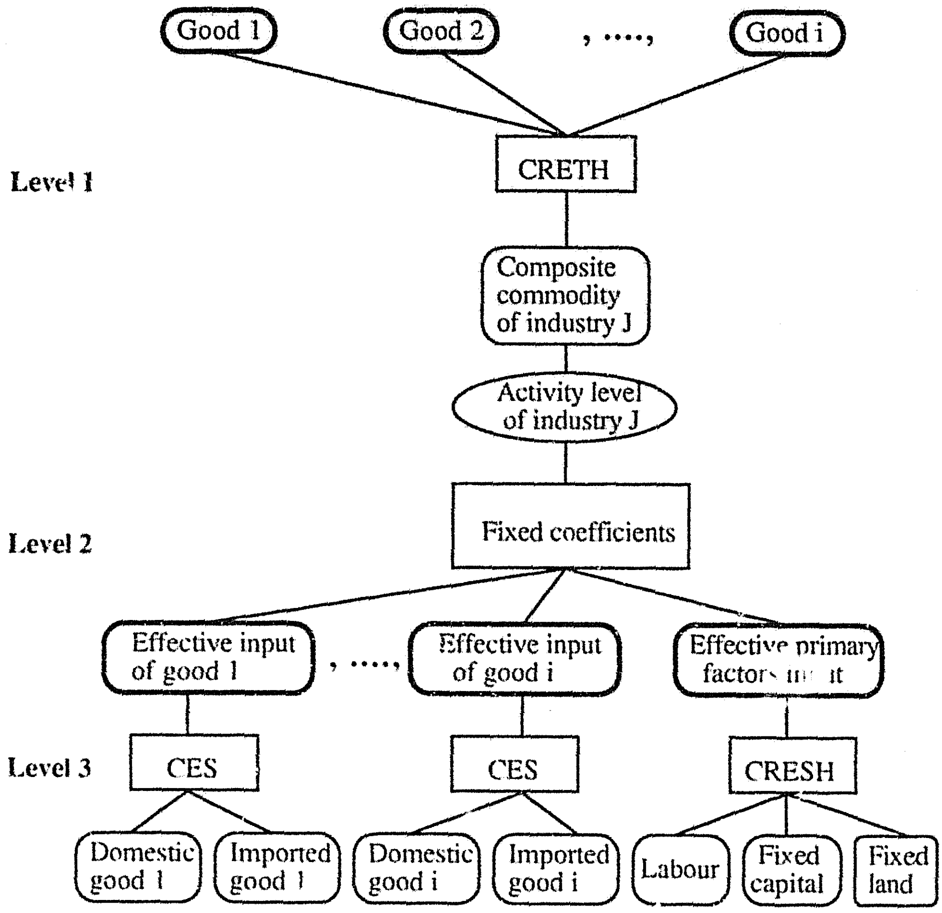
[1] CES (Constant Elasticity of Substitution) was developed by Arrow, Chenery, Minhas and Solow (1961).

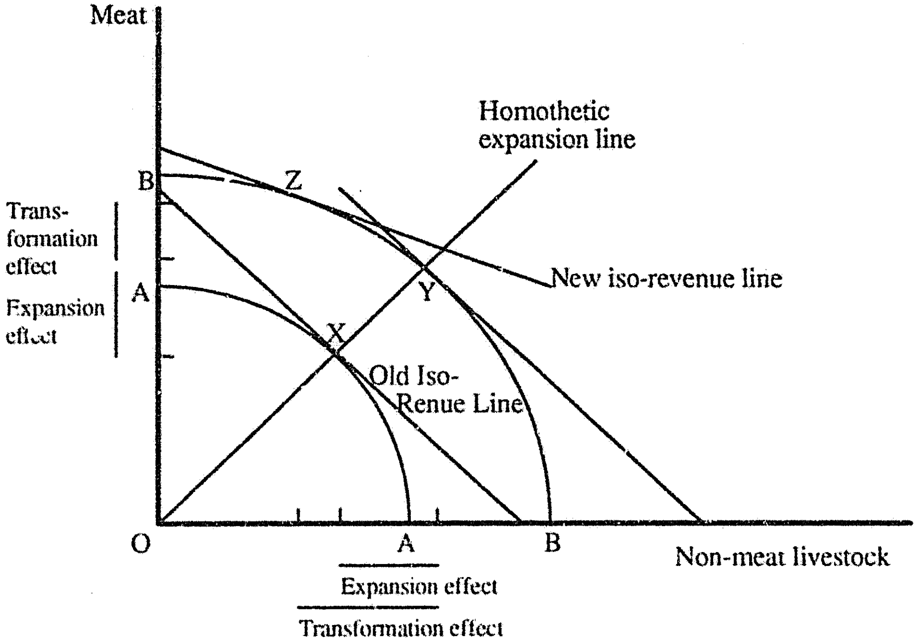
[2] CRESH (Constant Ratios of Elasticities of Substitution, Homothetic) a generalisation of CES, defines the ratio of the elasticity between inputs h and j to the elasticity between h and k as having to be equal to the ratio of the elasticities between i and j, and i and k.

Figure 2. Technology of current production



The industry is viewed as buying an activity level or general production capacity (z_j). The supply decision — which bundle of commodities to produce — is based on producers' behaviour to maximise total revenue subject to purchased activity level and given technology. Take as an example the livestock industry in the Indonesian model producing two products: meat and non-meat livestock products (Figure 3). The livestock industry purchases the activity level on the production frontier *AA* in the figure. Area *OAA* represents the feasible production combinations of meat and non-meat products. It is not difficult to determine the output levels for two products (at point *X*), given the price levels (p_m and p_n).

Figure 3. Industry output decision: the case of the livestock industry



Now assuming that the price of meat increases from p_m to p'_m, the producer will make two adjustments. First, a higher activity level of the industry, $\dot{z}_j$, will result from the higher composite price of the industry. The production frontier shifts outward to BB, which is a product-neutral (homothetic) expansion of the old transformation frontier. This is the expansion effect (from point X to Y). Second, the product mix will change in favour of meat. Since the relative price of meat to non-meat has increased, the product mix will move along the new transformation frontier to Z. This is referred to as the transformation effect.

In the model, the supply behaviour is specified as a CRETH[3] relation between products:

$$x_{ij}^{(0)} = z_j + \sigma_{ij}^{(0)*}[p_i^{(0)} - \sum_i S_{ij}^{(0)*} p_i^{(0)}] \qquad (6)$$

where $x_{ij}^{(0)}$ is the supply of commodity i by industry j, $p_i^{(0)}$ is the producer price of good i. $\sigma_{ij}^{(0)*}$ is the CRETH parameter reflecting the ease of transformability between commodity i and other commodities in the output bundle of industry j, and $S_{ij}^{(0)*}$ plays the role of weights and sums to one.

[3] CRETH represents a transformation process with Homothetic and Constant Ratios of Elasticities of Transformation.

Household and other final demands

There is only one household in the current Indonesian CGE model, which means that all the households in the Indonesian economy are assumed to be homogenous and their behaviour characterised by a single representative. This could be considered a strong assumption as distinctions can easily be made between rural and urban households, and between high- and low-income households. However, seeing as the interest of this initial analysis centres on incentive distortions and their impacts on agricultural performance, this is an acceptable simplification.[4]

The household in the model derives its income from returns to the factors of capital, labour and land. It is assumed that the household, as a price-taker in the market, maximises a single utility function subject to an aggregate expenditure constraint. Substitutions are allowed between goods (by applying the linear expenditure system) and between sources of one good, domestically produced or imported (through a CES mechanism). The specification of household consumption is depicted in Figure 4. The effects of changes in household preferences can be simulated via quantity-augmenting variables, $a_i^{(3)}$, with the demand specification:

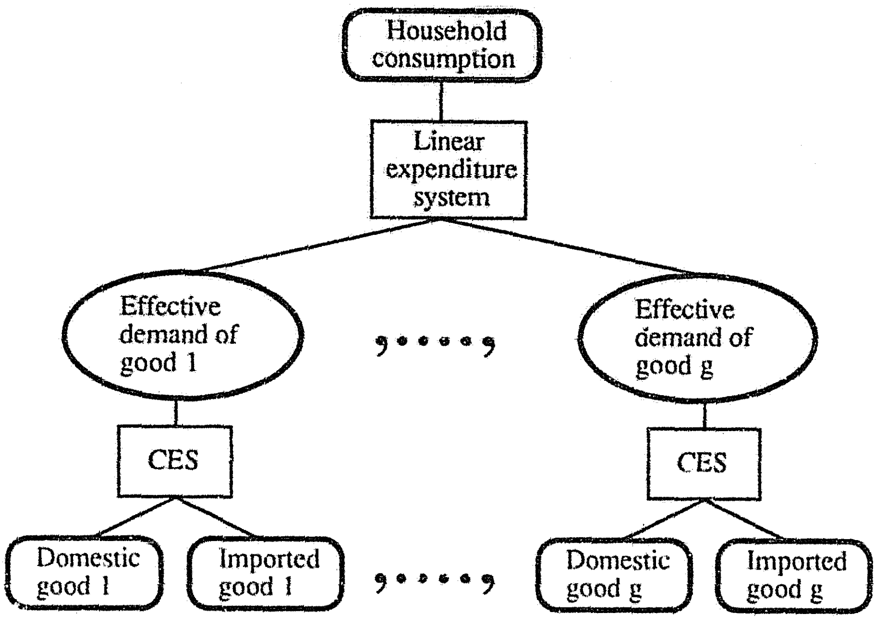
$$x_i^{(3)} = \varepsilon_i * c + \sum_l \eta_{(il)} p_l^{(3)} + a_i^{(3)} + \sum_l \eta_{(il)} [a_l^{(3)} + \sum_s S_{(ls)}^{(3)} a_{(ls)}^{(3)}] \tag{9}$$

in which a positive value of the quantity-augmenting variable indicates a change in preference in favour of good i.

The other final demands include capital investment, stock and government consumption demands. (Export demand is not discussed here.) As a short-run model, these demands are assumed, for simplicity, to change proportionally according to changes in absorption.

[4] Dixon et al argue that '*while the inclusion of different types of consumers would be an obvious improvement to the model, the pay-off in terms of more accurate simulation of aggregate consumer behaviour might be quite small. Only in very long-run simulations, allowing large demographic changes, or in simulations which introduce major changes in income distribution, is the single-consumer assumption likely to be inadequate*' (Dixon et al. 1982:97–98). If research interest extends to distributional effects and disaggregated consumption and income structure in the future, this single household can be disaggregated into household groups, such as those in Clarete and Warr (1992).

Figure 4 Household consumption



External sector

The small economy assumption is maintained for the Indonesian economy in this model. This is a debatable assumption in the case of Indonesia, particularly with respect to some products such as rice.

The external sector is mainly involved in two activities: exporting, and importing. Import supply of each good to Indonesia by the world economy is specified as a function of the importing price with an elasticity that is empirically set.

The export market is separated into two parts, namely exports by Indonesia and exports by the rest of the world. Total world demand for exported goods from these two regions are responsive to changes in composite exporting prices. Demand is substitutable between alternative sources and the substitution is modelled by a CES mechanism.

Equations of the model

Table 3 presents the equations, variables and parameters of the Indonesian model. All the variables that appear in the model are in percentage change form unless otherwise indicated. The equations of the model can be classified into ten groups which will be discussed briefly in turn.

The first group of equations defines the input demands, both intermediate inputs and primary factors, of non-agricultural industry production (equations in group I). Equation 1.1 specifies industry demands for intermediate inputs of commodities in the production process. This is derived from the producers' cost minimisation problem with possible technical changes incorporated (Dixon et al. 1982). To interpret this, first suppose that there is no change in relative prices, so a change in z_j will lead to a proportional change in demand for each intermediate input by sector *j*. This reflects the assumption of constant returns to scale. If there are changes in the relative prices (if the relative price of intermediate input *m* to *n* increases) then demand for *m* would increase less rapidly than z_j. Substitution will occur between the demands for *m* and *n*. The strength of this substitution will depend on the value of *S1ISJ(i,s,j)*.

Equation 1.2 defines the demands for the primary factors of labour, capital and land by each industry as a function of the output level in the industry and relative prices of each of the primary factor inputs.[5] An assumption is made that the factors can be aggregated into a composite primary factor bundle using a CES function. This form of demand equation is obtained by imposing the first-order conditions for cost-minimisation and linearising this in percentage changes. Similarly, substitutions between primary factors are assumed and the strength of the substitution depends on the value of $\sigma_{vj}^{(1)}$. A substitution in demand for different types of labour in production is also possible (equation 1.3). Equation 1.4 gives a price index and equation 1.5 considers some other possible costs for production.

Equation 1.6 deals with commodity supply by non-agricultural sectors of the economy. Supply of commodities is modelled at two levels: first the total amount of the commodity to be produced, and then a transformation between domestic and exporting destinations. The specification for non-agricultural sectors follows the usual ORANI format. The amount produced depends on the activity level, technical factors and output prices. It is assumed that only a commodity's own price and the general price of the group it comes from affect the supply level of a particular commodity. Equation 1.7 specifies the imperfect transformation between domestically produced goods supplied to domestic and export markets. This equation is a linearisation in percentage changes of the constant elasticity of transformation (CET) function (Robinson 1988). The interpretation of this equation is similar to previous ones. When there are no relative price changes between domestic and exported goods, the amounts supplied to both destinations will change proportionally to that of the total output of the product. Whenever the price for one destination increases relatively, the amount supplied to this destination will rise more rapidly.

Equation group II deals with agricultural production. Again, equation 2.1 is demand for intermediate inputs while equation 2.1 is demand for primary factors. Fertiliser is treated as another important input to agricultural production, substitutable with other primary factors (equations 2.2 and 2.3). Equation 2.4 specifies the supply relation of the agricultural sector.

Household income and consumption is characterised in equation group III. The functional forms for consumption demand, equations 3.1 and 3.2, contain two levels. Total demand for one commodity is dependent on income and prices (represented by relevant elasticities). The distribution between domestic and imported sources of the commodity is determined by the price difference and substitution elasticity ($\sigma_i^{(3)}$ for commodity *i*). Equations 3.3–3.5 calculate several important indices for consumers. Equations 3.6–3.8 give household income from labour, capital (dividends) and land. Equation 3.9 specifies total real disposable factor income of the household,

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[5] Labour is assumed to be perfectly mobile within agriculture or non-agriculture.

and equation 3.10 total real disposable income. Equation 3.11 is the aggregate consumption function.

Other final demands possess a rather simple specification in the model (equation groups IV and V). Equation 4.1 deals with export demand, 5.1 government consumption and 5.2 with investment in stock. Differentiated by sources of commodities, both government consumption and investment keep step with the growth rate of real absorption.

Equation group VI is a set of zero profit conditions. Equation 6.1 states that total revenue from production is equal to intermediate inputs plus returns to primary factors. This condition implicitly involves two assumptions: that of constant returns to scale of the technology; and that of sufficient competition to drive the pure profit at the margin to zero. The zero profit in equations 6.3 and 6.5 for importing and exporting are easy to understand and interpret.

The equation group of market clearing conditions contains six equations. Equation 7.2 says that the domestic demand for good *i* from a domestic source must be equal to domestic production for the home market, while equation 7.1 specifies the domestic output level. Similarly, in equation 7.3, the import of good *i* to Indonesia must be equal to total demands for imports by different parts of the economy. Equation 7.4 implies that the demands for labour by all industries are equated to the total supply of labour, differentiated by occupations. Equations 7.5, 7.6 and 7.7 specify the equilibrium condition for capital and land.

Equation group VIII gives a very detailed description of the government budget, particularly its revenue and expenditure. The equations in group IX are mostly identities or indices.

Preliminary simulations of the impact of irrigation development on the agricultural sector and on the economy in general

One of the appeals of CGE models is the flexibility they provide in the actual model specification or economic environment through closure or the choice of exogenous variables. However, such choices should be judiciously made as the model results are often more sensitive to closure than to the choice of parameters. Some of the closures of the model have already been mentioned but will be listed here to emphasise their importance to the results obtained. Key closure choices were:

- real wages for unskilled workers were exogenous and employment levels endogenous with the reverse being true for skilled workers;
- industry rates of return on capital were held to be fixed, with capital stocks being allowed to adjust through investment and interindustry capital flows (thus the results should be interpreted as being long run);
- land is mobile between agriculture and forestry, and fixed for mining;
- exports of raw logs and unprocessed agricultural products are held to be fixed;
- the nominal exchange rate is held to be fixed; and
- real interest rates are he' l to be fixed.

As a means of illustrating the usefulness of the model to the type of irrigation issues discussed earlier, the results of a 1 per cent improvement in the efficiency of the irrigation sector are presented. This shock was introduced into the model via the output neutral technical shifter for the irrigation sector. The results are for a disaggregated version of the model in which the irrigation sector has been separated from the services sector, fertiliser from minerals processing, and rice, etc. from the agricultural sector. However, regional disaggregation and other refinements requiring more detailed parameter estimates have not been introduced. The results are reported for two main type of variables, namely macroeconomic and output supply variables. The changes in the endogenous variables can be thought of as elasticities with respect to a change in irrigation efficiency and are presented in Table 4.

The key result in the macroeconomic variables is the 0.36 per cent growth in GDP. The reciprocal of this estimate compares favourably with an elasticity estimate of irrigation investment with respect to GNP per capita of between 2.00–2.61 per cent (Rosegrant and Pasandaran 1993). The GDP result reflects the strong linkages between the irrigation sector and other large sectors such as rice production which draw on the pool of unskilled workers and, under the assumptions of the model, receive a large stimulus from such efficiency gains. The result also reflects the impact of the shock on factor inputs, and hence activity levels in different industries; this and the impact of the shock on domestic commodity supply are discussed next. The GDP increase represents greater activity levels resulting in an increase in government revenue and expenditure and in imports of investment goods. The increase in the cost of factor inputs leads to an increase in general costs as reflected by the CPI and GDP deflator.

Looking at the domestic commodity supply, as might be expected the irrigation sector, and agricultural sectors that are highly dependent on irrigation, such as rice and other food commodities, increase in supply. However, some commodities competing with these for land, such as forestry and estate commodities, decrease in supply, as do commodities such as manufactured goods that compete with agriculture for resources such as unskilled labour. Fertiliser production falls. However, domestic supply of fertiliser increases because of a relatively larger fall in exports of fertiliser. The large increase in mining activity reflects mining's high capital intensity. The irrigation sector has a higher cost share of capital than labour. An efficiency improvement in the irrigation sector leads to a release of a greater value of capital than labour and hence a greater relative increase in labour than capital costs. Capital intensive activities such as mining are therefore favoured as a result of the shock. More is produced from the fixed stock of mining land and so the price of mining land falls. Demand in mining industry export markets is highly responsive to price changes and hence to changes in domestic costs. Processed products follow a similar pattern to raw commodities, with agricultural and processed mineral products increasing in supply and processed forest products decreasing in supply.

There are a number of qualifications that apply to these results. For example, Java/off Java are aggregated even though these regions differ widely with regard to irrigation and its effects. In addition, aggregate parameter estimates from the Dee model have been applied to disaggregated equations in the model so that the relationship of mining to irrigation in the disaggregated model is the same as that of mining to aggregated services in the Dee model. In general, the linkages between mining and irrigation are unlikely to be as broad as those between mining and services.

The current simulation shows the economy-wide impacts of an improvement in the efficiency of the agricultural irrigation sector. GDP is estimated to increase by 0.36 per cent or around 300 billion Rp (approximately $US 150 million). In a partial equilibrium approach the measured benefits of such efficiency gains would be limited to the increase in rice production (see Varley 1989). From the model the increase in rice production is estimated to be 0.26 per cent which is valued at around 20 b Rp (approximately $US 10 million). It should be borne in mind that other activities would have similar multiplier effects throughout the broader economy and that the model can be used to analyse these as well as the efficiency gains in irrigation.

4. Conclusion

The purpose of the paper was to develop the foundations of an economy-wide model that could be used to analyse a range of agricultural issues that impact on the broader economy and general issues that have agricultural implications. The usefulness of such a model is illustrated through initial analysis of the impact of efficiency gains in the irrigation sector on the production of agricultural commodities and on key macroeconomic indicators such as GDP.

Irrigation makes a major contribution to the Indonesian economy. Rice, which dominates agricultural production and consumption, is mainly produced on irrigated lands. Irrigation also plays a fundamental role in regional development and could have important implications for the environment. Indonesia has a large physical potential for further irrigation development, but higher costs of construction have resulted in low rates of return on new irrigation developments. These low rates of return measure only the direct benefits of irrigation development, such as increases in rice production. These direct benefits like many activities will, however, have multiplier effects throughout the economy and will free up resources that could be used productively elsewhere in the Indonesian economy. Thus to obtain a true picture of the benefits of efficiency gains in a sectoral activity, an economy-wide model that captures key intersectoral linkages in the economy is required.

The model described in this paper builds on a previously developed CGE model of the Indonesian economy used to evaluate the economic implications of a variety of forestry policies (Dee 1991). The Dee model follows the specification of the ORANI model, incorporating two innovations aimed at handling forestry issues, namely a steady state treatment of forestry and an intertemporal treatment of capital accumulation. (These were removed from the model developed in this paper.) In the model, labour is classified into four occupations: agricultural and production workers, administrators and professionals. Eight industries are defined in the model, and this is the area on which initial further development of the Dee model will concentrate. In the initial version of the model developed here, 8 agricultural sectors are specified out of 16 overall. Disaggregation captures both commodity and regional aspects with some agricultural commodities representing multiproduct sectors (for example, rainfed crops and smallholder production). The key non-agricultural disaggregations were fertiliser from the minerals processing sector and irrigation from the services sector.

To illustrate the usefulness of such models some preliminary simulations of the impact of irrigation development on the agricultural sector and the broader economy were undertaken. The version of the model used did not incorporate regional disaggregation and other refinements that require more detailed parameter estimates. The main aspects of the economic environment reflected in the closure of the model were that real wages of unskilled workers were exogenous and employment levels endogenous, industry rates of return on capital were fixed and capital stocks allowed to adjust through investment and interindustry capital flows, and land was mobile between agriculture and forestry. The shock was a 1 per cent improvement in the efficiency of the irrigation sector, introduced via the output neutral technical shifter for the sector. The key result was a 0.36 per cent growth in GDP, reflecting the strong linkages between irrigation, rice production and economic activity as well as the impact of the shock on factor inputs and hence on industries such as mining that are highly sensitive to changes in these inputs. A partial equilibrium framework, so often used in the assessment of rates of return from irrigation developments, would have suggested a much smaller economic benefit from efficiency gains in irrigation, namely those associated with increases in rice production. This analysis is preliminary and would need to be repeated when the model is fully developed with regional and other disaggregations incorporated and associated parameter estimates calculated.

What are the policy implications of the analysis? At a minimum, the analysis suggests that an economy-wide perspective needs to be taken in assessing what may be considered sectoral policies. In terms of policy changes, the model may be able to assess the relative appeal of broad approaches, efficiency gains versus a compensation approach for instance, but will generally say little about specific approaches such as realising potential efficiency gains through competition or user-pays policies. But too much should not be expected of such models. Their purpose is to support policy analysis through quantitative measures of orders of magnitudes of the impact of policy changes. Specific policy prescriptions would have to undergo broader analysis of aspects such as insututional arrangements before well-founded specific policy advice could be proffered.

Appendix: Deriving the 20 sector input–output table for Indonesia

No.	*Industry description*	*Codes in 169 sector I/O table*
1	Irrigated rice, Java	derived from 1
2	Irrigated rice, off Java	derived from 1
3	Other irrigated food crops, Java	derived from 2–12
4	Other irrigated food crops, off Java	derived from 2–12
5	Estate and other crops, Java	derived from 13–27
6	Estate and other crops, off Java	derived from 13–27
7	Livestock, Java	derived from 28–32, 35
8	Livestock, off Java	derived from 28–32, 35
9	Rainfed crops	derived from 1–
10	Smallholder production	derived from 28–
11	Forestry	33–34
12	Fisheries	36–38
13	Minerals	39–51
14	Agricultural processing	52–74
15	Minerals processing	93, 95–97, 101–103
16	Fertiliser	94
17	Forestry processing	84–88, 90–92
18	Other manufacturing	75–83, 89, 100, 104–112, 113–114, 115–138
19	Services	139, 141, 143–169
20	Irrigation	140, 142

Table 1 Irrigation service area, cropping intensity, area harvested, yield and production in Indonesia by types of land, 1988

Type of Land	Potential service area (,000 ha)	Actual service area (,000 ha)	Area harvested (,000 ha)	Cropping Intensity (,000 ha)	Yield (MT/ha)	Production (,000 MT)
Irrigated	5,449	3,935	6,704	1.70	4.84	32,462
Technical	2,237	1,650	2,988	1.81	5.15	15,388
Semitechnical	1,202	850	1,434	1.69	4.87	6,984
Simple	974	584	929	1.59	4.50	4,182
Village	1,036	851	1,353	1.59	4.37	5,913
Swamp/Valley	1,167	1,167	1,217	1.04	1.75	2,130
Rainfed	673	673	748	1.11	3.11	2,330
Dryland	1,163	1,163	1,163	1.00	1.80	2,098
Total	8,452	6,938	9,832	1.42	3.97	39,025

a Area harvested divided by actual service area.

Source: Rosegrant and Pasandaran (1990).

Table 2 Industries in the agricultural model of the Indonesian economy

No.	Industry description	No.	Product description
1	Irrigated rice, Java	1	Rice
2	Irrigated rice, off-Java	1	Rice
3	Other irrigated food crops, Java	2	Other irrigated food crops
4	Other irrigated food crops, off-Java	2	Other irrigated food crops
5	Estate and other crops, Java	3	Estate and other crops
6	Estate and other crops, off-Java	3	Estate and other crops
7	Livestock, Java	4	Livestock
8	Livestock, off-Java	4	Livestock
9	Rainfed crops		
10	Smallholder production		
11	Forestry	5	Forestry
12	Fisheries	6	Fisheries
13	Minerals	7	Minerals
14	Agricultural processing	8	Agricultural processing
15	Minerals processing	9	Minerals processing
16	Fertiliser	10	Fertiliser
17	Forestry processing	11	Forestry processing
18	Other manufacturing	12	Other manufacturing
19	Services	13	Services
20	Irrigation	14	Irrigation

Table 3: Equations of the Indonesian model

I. Non-agricultural industry

1.1 Industry demands for intermediate input by source

$$x1is(i,s,j) = z(j) - \sigma_1(i,j)*[p1is(i,s,j) - \sum_s S1ISJ(i,s,j)*p1is(i,s,j)] + a1j(j) + a1ij(i,j) \quad \text{2gh}$$

1.2. Factor demands

$$xv(v,j) = z(j) + \sum_v \beta_{vj} * w(v,j) - a1j(j) - a1vj(v,j) - \sum_v \beta_{vj}(v,j)a1vj \quad \text{3(h-a)}$$

1.3 Industry demand for labour by occupation

$$x1q(q,j) = xv(\text{"labour"},j) - \sigma_q(q,j)*[pq(q,j) - \sum_q S1Q(q,j)*pq(q,j)] \quad \text{mh}$$

1.4 Price to each industry of labour in general

$$pv(\text{"labour"},j) = \sum_q S1Q(q,j)*pq(q,j) \quad \text{h}$$

1.5 Industry demand for other costs

$$xoth(j) = z(j) + a1j(j) \quad \text{h}$$

1.6 Non-agricultural supply of commodities, undifferentiated by destinations

$$\begin{aligned} x0ij(i,j) = z(j) + \sigma_{ij}^{(0)}[p0i(i) - \sum_k S0IJ(k,j)*p0i(k)] \\ + a_j^{(0)} + a_{ij}^{(0)} + \sigma_{ij}^{(0)}[a_{ij}^{(0)} - \sum_k S0IJ(k,j)*a_{kj}^{(0)}] \end{aligned} \quad \text{g}$$

1.7. Transformation between domestic and exporting destinations

$$x0idj(i,d,j) = x0ij(i,j) - \sigma_{(id)ij}^{(0)*}[p0id(i,d) - \sum_d S0ID(i,d)*p0id(i,d)] \quad \text{2g}$$

II Agricultural sectors

2.1 Intermediate input demands, domestic and imported (by industry and region)

$$\begin{aligned} x1isr(i,s,j,r) = z(j,r) - \sigma_{isr}[p1is(i,s,j,r) - \sum_s S1ISJR(i,s,j,r)*p1is(i,s,j)] \\ - a1jr(j,r) - a1ijr(i,s,j,r) \end{aligned}$$

2.2 Factor demands, including composite fertiliser

$$xvr(v,j,r) = z(j,r) - \sum_v \beta_{vjr} w(v,j,r) - a1jr(j,r) - a1vjr(v,j,r) - \sum_v \beta_{vjr} a1vjr \quad \text{4a}$$

2.3 Fertiliser demand as a factor input by source

$$xv("fert",s,j,r) = xv("fert",j,r) - \sigma_1("fert",j,r) * [p1is("fert",s,j) - \sum_s S1ISJR("fert",s,j,r) * p1is("fert",s,j)] \qquad 2a$$

2.4 Supply of agricultural commodities

$$x1ir(i,j,r) = z(j,r) + \sum_k \beta_{kr} p0(i) + a_{ir} + \sum_k \beta_{kr} a_{ir} \qquad a$$

2.5 Total supply of agricultural products (by two regions)

$$x1i(i,"agri") = \sum_r S1IR(i,r) * x1ir(i,j,r) \qquad a$$

2.6 Transformation between domestic and exporting destinations

$$x1id(i,d,"agri") = x1i(i,"agri") + \sigma_{id}^{(1)}[p1id(i,d) - \sum_d S1ID(i,d) * p1id(i,d)] \qquad 2a$$

III Household consumption

3.1 Household demands for commodities by source

$$x3is(i,s) = x3i(i) - \sigma_3(i)[p3is(i,s) - \sum_s S3IS(i,s) * p3is(i,s)] \qquad 2g$$

3.2 Household demand for commodities undifferentiated by source

$$x3i(i) - pop = \varepsilon(i)[c - pop] + \sum_k \eta(i,k) * p3i(k) \qquad g$$

3.3 Prices of commodities to households

$$p3i(i) = \sum_s S3IS(i,s) * p3is(i,s) \qquad g$$

3.4 Aggregate real household consumption

$$cR = c - pu \qquad 1$$

3.5 Consumer price index

$$pu = \sum_i \sum_s W3IS(i,s) * p3is(i,s) \qquad 1$$

IV Other final demands

4.1 Export demand

$$pe(i) = [1/\sigma_a(i)] * x4i(i) + f4i(i) \qquad g$$

4.2 Government demand for current consumption

$$x5is(i,s) = h5is(i,s) * cR + f5is(i,s) \qquad 2g$$

4.3 Demand for changes in stocks

$$x6is(i,s) = h6is(i,s) * cR + f6is(i,s) \qquad 2g$$

V Zero pure profits

5.1 Zero pure profits in industry

$$\sum_i CJOINT(i,j)*p0(i,\text{"domestic"}) = \sum_i\sum_s H1ISJ(i,s,j)*p1is(i,s,j) + \sum_v HIV(v,j) + HO(j) + a(j) \qquad \text{h}$$

5.2 Technical change in production

$$a(j) = a0j(j) + a1j(j) + \sum_i\sum_s H1IS(i,s)*a1ij(i,j) + \sum_v H1V(v,j)*avj(v,j) \qquad \text{h}$$

5.3 Zero profits in importing

$$p0(i,\text{"import"}) = pm(i) + tarstar(i) + phi \qquad \text{g}$$

5.4 Relationship between tariff rate and power of the tariff

$$tarstar(i) = STTAR(i)*tar(i) \qquad \text{g}$$

5.5 Zero pure profits in exporting

$$p0(i,\text{"domestic"}) + vstar(i) = pe(i) + phi \qquad \text{g}$$

5.6 Relationship between export tax rate and power of the export tax

$$vstar(i) = STEXP(i)*v\exp(i) \qquad \text{g}$$

5.7 Taxes on intermediate inputs

$$p1is(i,s,j) = p0(i,s) + tstar*1is(i,s,j) \qquad \text{2gh}$$

5.8 Relationship between the rate and the power of taxes on intermediates

$$tstar1is(i,s,j) = ST1ISJ(i,s,j)*t1is(i,s,j) \qquad \text{2gh}$$

5.9 Taxes on investment goods

$$p2is(i,s,j) = p0(i,s) + tstar2is(i,s,j) \qquad \text{2g}$$

5.10. Relationship between rate and power of taxes on investment goods

$$tstar3is(i,s) = ST3IS(i,s)*[t3is(i,s) + fvat] \qquad \text{2g}$$

5.11 Taxes on government consumption

$$p5is(i,s) = p0(i,s) + tstar5is(i,s) \qquad \text{2g}$$

VI Market clearing conditions

6.1 Domestic commodity output levels

$$x1(i) = \sum_j CJOINT(i,j)*[z(j) - a0j(j)] \qquad \text{g}$$

6.2. Market clearing for domestically produced goods

$$x1(i) = \sum_j B1I1j(i,j)*x1is(i,\text{"domestic"},j) + \sum_j B2I1J(i,j)*x2is(i,\text{"domestic"},j) + B3I1(i)*x3is(i,\text{"domestic"}) + B4I1(i)*x4i(i) + B5I1(i)*x5is(i,\text{"domestic"}) + B6I1(i)*x6is(i,\text{"domestic"}) \qquad \text{g}$$

6.3 Market clearing for imports

$$x2(i)=\sum_{j}B1I2j(i,j)*x1is(i,"import",j)+\sum_{j}B2I2J(i,j)*x2is(i,"import",j)$$
$$+B3I2(i)*x3i(i,"import")+B5I2(i)x5is(i,"import")+B6I2(i)*x6is(i,"import") \tag{g}$$

6.4 Labour employment of each occupation

$$lq(q)=\sum_{j}BIQJ(q,j)*x1q(q,j)+\sum_{j}B2Q(q,j)*x2q(q,j) \tag{m}$$

6.5 Capital stock in each industry

$$cap(j)=xv("capital",j) \tag{h}$$

6.6 Aggregate capital stock

$$k0=\sum_{j}BK(j)*cap(j) \tag{1}$$

6.7 Aggregate land

$$n=\sum_{j}BN(j)*xv("land",j) \tag{1}$$

VII Government budget

7.1 Nominal revenue from taxes on intermediates

$$r1c=\sum_{i}\sum_{s}\sum_{j}SR1(i,s,j)*[p0(i,s)+x1is(i,s,j)+t1is(i,s,j)] \tag{1}$$

7.2 Nominal revenue from taxes on investment goods

$$r2c=\sum_{i}\sum_{s}\sum_{j}SR2(i,s,j)*[p0(i,s)+x2is(i,s,j)+t2is(i,s,j)] \tag{1}$$

7.3 Nominal revenue from taxes on consumption goods

$$r3c=\sum_{i}\sum_{s}SR3(i,s,j)*[p0(i,s)+x3is(i,s,j)+t3is(i,s,j)+fvat] \tag{1}$$

7.4 Nominal revenue from taxes on exports

$$r4c=\sum SR4(i)*[p0(i,"domestic")+x4is(i)+v\exp(i)] \tag{1}$$

7.5 Nominal revenue from taxes on government consumption

$$r5c=\sum_{i}\sum_{s}SR5(i,s,j)*[p0(i,s)+x5is(i,s,j)+t5is(i,s,j)+fvat] \tag{1}$$

7.6 Nominal tariff revenue

$$r0c=\sum_{i}SR0(i)*[pm(i)+phi+x2(i)+tar(i)] \tag{1}$$

7.7 Total nominal commodity tax revenue

$$rc=SC1*r1c+SC2*r2c+SC3*r3c+SC4*r4c+SC5*r5c+SC0*r0c \tag{1}$$

7.8 Nominal revenue from taxes on production

$$100*delprod=\sum_{j}SPROD(j)*[x0th(j)+poth(j)] \tag{1}$$

7.9 Nominal revenue from taxes on use of labour in production

$$rusel1 = \sum_q \sum_j SUL1Q(q,j)*[rusel(q,j) + pg(q,j) + x1q(q,j)] \qquad 1$$

7.10 Tax rates on use of labour

$$pq(q,j) = pg(q,j) + STUL(q,j)*tusel(q,j) \qquad mh$$

7.11. Nominal revenue from taxes on use of capital

$$rusek = \sum_j SUK(j)*[tusek(j) + rho(j) + xv(\text{"capital"}, j) \qquad 1$$

7.12 Nominal revenue from taxes on production and use of factors

$$ruse = SUPROD*delprod + SUL1*rusel1 + SUK*rusek \qquad 1$$

7.13 Nominal revenue from taxes on income from land

$$rdirn = \sum_j SDNJ(j)*[tdirn(j) + pv(\text{"land"}, j) + xv(\text{"land"}, j)] \qquad 1$$

7.14 Nominal revenue from direct taxes

$$rdir = SDL*rdirl + SDK*rdirk + SDN*rdirn \qquad 1$$

7.15 Domestic other government revenue

$$rodom = gdp + pigdp + frd \qquad 1$$

7.16 Foreign other government revenue

$$rofor = pigdp + frfor \qquad 1$$

7.17 Total nominal government revenue

$$rev = SERV1*rc + SERV2*ruse + SERV3*rdir + SERV4*rodom + SERV5*rofor \qquad mh$$

7.18 Schedule of direct tax rates on labour income

$$tdirl(q,j) = floi(q,j) + flo(q) + fl + fy \qquad 1$$

7.19 Tax rate on income from land

$$tdirn(j) = fni(j) + fn + fy \qquad h$$

7.20 Nominal government consumption expenditure

$$gc = \sum_i \sum_s S5IS(i,s)*[x5is(i,s) + p0(i,s)] \qquad 1$$

7.21 Nominal expenditure on investment subsidy

$$gisub = \sum_j SISUB(j)*[invj(j) + tisub(j)] \qquad 1$$

7.22 Domestic other government expenditure

$$godom = gdp + pigdp + fgdom \qquad 1$$

7.23 Foreign other government expenditure

$$gofor = pigdp + fgfor \qquad 1$$

7.24 Total nominal government expenditure

$$\exp = SEXP1*gc + SEXP2*gi + SEXP3*gisub + SEXP4*godom + SEXP5*gofor \qquad 1$$

7.25 Real public sector borrowing requirement

$$100*delgbr = GR*[rev - pigdp] - GE - pigdp] \qquad 1$$

VIII Household income

8.1 Real disposable labour income from production

$$rydl1(q,j) = pg(q,j) + x1q(q,j) - STDL1(q,j) - pic$$ mh

8.2 Real disposable income from dividends

$$rydk(j) = grossdiv(j) - STDK * tdirk(j) - pic$$

8.3 Real disposable income from land

$$rydn(j) = pv("land",j) + xv("land",j) - STDN * tdirn(j) - pic$$ h

8.4 Total real disposable factor income

$$rydfact = \sum_q \sum_j SYD1(q,j) * rydl1(q,j) + \sum_j SYD2 * rydk(j) + \sum_j SYD3 * rydn(j)$$ 1

8.5 Total real disposable income

$$ryd = SINC1 * rydfact + SINC2 * [godom - pic] + SINC3 * [rodom - pic]$$ 1

8.6 Aggregate consumption function

$$cR = ryd + fr$$ 1

IX Miscellaneous

9.1 Aggregate imports in domestic currency

$$m = \sum_i MI2(i) * [pm(i) + x2(i) + phi]$$ 1

9.2 Aggregate exports in domestic currency

$$e = \sum_i EI1(i) * [pe(i) + x4i(i) + phi]$$ 1

9.3 Balance of trade

$$100 * delb = TOTE * e - TOTM * m$$ 1

9.4 Export price index

$$pie = phi + \sum_i EI1(i) * pe(i)$$ 1

9.5 Import price index

$$pim = phi + \sum_i MI2(i) * pm(i)$$ 1

9.6 Government consumption price index

$$pig = \sum_i \sum_s S5IS(i,s) * p5is(i,s)$$ 1

9.7 Aggregate change in stock

$$stk = \sum_i \sum_s S6IS(i,s) * x6is(i,s)$$ 1

9.8 Price index for stock changes

$$pistk = \sum_i \sum_s S6IS(i,s) * p0(i,s)$$ 1

9.9 GDP deflator

$$pigdp = SC * pic + SI * piinv + SG * pig + SK * pistk + SE * pie + SM * pim$$ 1

9.10 Real GDP

$$gdp = SC*cR + SI*[invcost - piinv]SG*[gc - pig] + SK*delstk + SE*[e - pie] - SM*[m - pim] \qquad 1$$

9.11 Wage setting

$$pg(q,j) = h1q(q)*pic + foi(q,j) + f1 \qquad \text{mh}$$

9.12 Price of other costs

$$poth(j) = hoth(j)*picc + foth(j) \qquad \text{h}$$

X Monetary sector

10.1 Equilibrium in the money market

$$M^s = \varepsilon_y^m * gdp + \varepsilon_p^m * pigdp + \varepsilon_r^m * r \qquad 1$$

Table 4. Elasticities of economic variables with respect to a change in efficiency of the irrigation sector

	Elasticities
Macroeconomic variables	
GDP	0.36
GDP deflator	0.12
Consumer price index	0.19
Aggregate imports	0.22
Aggregate exports	0.47
Export price	-0.39
Total nominal government revenue	1.05
Total nominal government expenditure	0.24
Domestic commodity supply	
Rice	0.26
Other food	0.30
Estate	-1.41
Livestock	0.25
Forestry	-0.29
Fishing	0.19
Mining	2.60
Agricultural processing	0.26
Mineral processing	0.64
Fertiliser	-0.15
Forestry processing	-0.65
Manufactured goods	-0.30
Services	0.06
Irrigation	1.09

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