

# **Economic Policies for Sustainable Water Use in Thailand**

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## **Abstract**

This paper has been prepared as part of the ongoing CREED project, Macro Economic Policies and the Environment in Thailand. The objective of the paper is to illustrate how the Social Accounting Matrix of Thailand may be extended to incorporate water resources and give examples of what the supply and demand functions for water would look like. The framework is based upon an integrated approach to demand and supply management of water resources and its implications for water pricing policies. The discussion concentrates on modifications and extensions of the social accounting matrix and on demand and supply equations for water that reflect the true scarcity of water for different uses and from different sources. There is an attempt, at the conceptual level, to introduce the user cost of water in the accounting matrix, thereby enabling a link between Computable General Equilibrium (CGE) models and user costs. Incorporation of the modified social accounting matrix and demand and supply equations for different water resources into the general equilibrium model would be a follow up of this exercise, to be undertaken at a later stage.

## **Resumen**

Este trabajo se ha preparado para formar parte del proyecto de CREED, la Política Macro Económica y de Medio Ambiente en Tailandia. El objetivo de este artículo es el de ilustrar cómo se podría ampliar la Matriz de Contabilidad Social de Tailandia para incorporar los recursos hídricos, y para dar ejemplos de una aproximación hacia el carácter de las funciones de demanda y oferta de agua. La estructura se basa en un enfoque integrado hacia la administración de la oferta y la demanda de los recursos hídricos y lo que esto significaría para las políticas de precios para agua. El argumento se centra en las modificaciones y extensión de la matriz de contabilidad social y sobre las ecuaciones la demanda y oferta de agua que reflejan las escasez real del agua para diferentes usos y de fuentes distintas. Se intenta de manera conceptual introducir a la matriz de contabilidad el precio del agua al usuario. De este modo se pueden establecer vínculos entre los modelos del Equilibrio General Computable (Computable General Equilibrium = CGE) y los costos al usuario. La incorporación de la matriz de contabilidad social modificada y las ecuaciones de demanda y oferta para diversos recursos hídricos al modelo de equilibrio general sería el próximo paso de este trabajo para ser realizado posteriormente.

## **Abrégé**

Ce document a été rédigé dans le cadre d'un travail en cours du CREED, traitant des rapports entre politiques macroéconomiques et environnement en Thaïlande. Ce texte veut montrer comment la matrice de la comptabilité sociale thaïlandaise pourrait être étendue afin d'incorporer les ressources hydriques et donne des exemples de ce que pourraient être des fonctions d'offre et de demande d'eau. Les hypothèses de base employées pour ce faire reposent sur une approche intégrée de la gestion de l'offre et de la demande de ressources hydriques et sur ses implications pour les politiques de fixation des prix de l'eau. La discussion se concentre sur les modifications et extensions de la matrice de la comptabilité sociale et sur les équations d'offre et de demande d'eau reflétant la rareté réelle de cet élément par rapport à différents usages et selon ses différentes sources. Au plan conceptuel, on essaie d'introduire dans la matrice comptable le coût de l'eau pour l'utilisateur, ce qui permet d'instaurer un lien entre les modèles informatisés d'équilibre général et les coûts subis par les consommateurs. L'incorporation au modèle d'équilibre général de la matrice de la comptabilité sociale et des équations d'offre et de demande d'eau établies pour différentes ressources hydriques, représenterait une suite à donner à cet exercice, ce qu'on entreprendra à un stade ultérieur.

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# Introduction

Thailand has recorded impressive growth in its GDP, averaging almost 8% per annum during 1991-1992. Industry has been the most dynamic sector with a growth rate of 9.3% in 1992, followed by the services sector (especially transportation) which grew at 7% in the same year. The environmental consequences of this rapid growth and changing economic structure are causing increasing concern, particularly the management and use of natural resources and the impacts of pollution and congestion on natural resources.

This paper presents a conceptual exercise to examine the consequences of rapid growth in Thailand on the management and use of water resources. An attempt is made to demonstrate how the water sector can be integrated into the overall macroeconomic framework with a view to devising a comprehensive water management strategy based on economic costs and principles.

Water resources in Thailand are both abundant and scarce at the same time. There is excessive rainfall and flooding in the Central and Southern regions while the Northeast suffers from drought. The demand for water, however is fairly evenly distributed and is growing substantially due to the high rate of economic growth, industrialisation and population pressure. The response to this growing demand for water has so far been to increase water storage capacity and transporting water over long distances. But this approach has limitations: the construction of new dams is costly and faces opposition from local communities; the diversions and interregional transfer of water exacerbates environmental, social and economic problems; ground water aquifers around urban areas are being exploited beyond their replenishment rate resulting in land subsidence, flooding and water salination. Since water resource systems are closely related to patterns of land use, it is essential to undertake a comprehensive analysis of water use in Thailand.

Due to the changing economic structure in favour of industry and services, increases in demand for water come from these sectors. However agriculture is still the largest user of water, accounting for 90% of annual withdrawals. In the present system, opportunities to reduce water use in the agricultural sector are minimal: since water is currently available free of charge for agricultural uses, farmers have little incentive to economise. In order to investigate ways of improving efficiency in water usage, this paper concentrates on the non-agricultural sector since not only it is the main source of increased demand for water but it also holds the key to more efficient water use throughout the economy.

Given that water usage in the industrial sector is a major focus of the paper, it is important that an analysis of water conservation and recycling of waste water be included as components of an integrated water management scheme. A recent World Bank study (1994) on pollution and congestion impacts in Thailand found that surface water pollution due to microbiological contamination, and biological oxygen demand (BOD) and toxic discharges into water by manufacturing firms and households are high priority concerns. Microbiological contamination of water is due mainly to discharges of untreated sewage by households; it is not dealt with explicitly in this paper since it is not expected to increase with economic growth. Toxic and hazardous wastes have risen in the past decades, but are generated by sectors - chemicals and basic metals - that still account for a small percentage of manufacturing value added. In the short and medium term, therefore, policy makers should concentrate on the increasing discharge of BOD into surface water. The major generators of BOD are sugar, pulp and paper, rubber and beverage industries. Other contributors include tapioca mills, slaughter houses, canned fish and crustacean industries, tanneries and the canned pineapple industry. Most of this biodegradable waste is discharged untreated as industrial effluent into the Chao Phraya and Tachin rivers. The water quality in these rivers is already

below the ambient standards set by the National Environment Board and is expected to deteriorate further if proper measures to encourage waste water treatment and reduce waste water discharge are not initiated.

Section 2 presents the analytical framework for an integrated approach to demand and supply management of water resources and its implications for water pricing policies. The following sections provide the building blocks of the model. Section 3 describes how different types of water may be incorporated as distinct sectors in the Social Accounting Matrix (SAM). Section 4 discusses supply issues which will form the basis for deriving behavioural water supply functions aggregated for different water sources (raw water, ground water, pipewater ie treated surface water, recycled water). Section 5 examines with the demand for different types of water from different sectors (residential, services, industry and agriculture). As mentioned above the major focus is on deriving demand equations for different types/qualities of water.

# The Analytical Framework for Integrated Water Resources Management

The management of water resources, including issues of water pricing, have so far not been tackled in a truly market determined framework even in developed economies such as the USA, where irrigated water is still supplied at nominal rates unrelated to costs of supply. The reasons for this are that in most countries water services are publicly owned and their prices are administratively determined. As described by Szesztay (1976), three phases in water resource management can be identified: first is the water abundant phase where the main emphasis is on increasing water supply to match growing demand; in the second phase as water scarcity problems arise, there is an attempt to increase supply along with measures to increase the efficiency of water use; in the third stage, with increased pressures on water availability, marginal costs of water supply rise rapidly and more emphasis is placed on demand management through conservation, recycling and effective pricing mechanisms.

The need to increase efficiency of water use, and to conserve, recycle and price water at its true value is becoming increasingly evident in Thailand. It should, therefore, be moving towards the third phase of water resource management, if it has not already done so. There is a definite need to combine both demand and supply management in a market oriented framework of water resource management. Four major components in water resource management that need to be studied are:

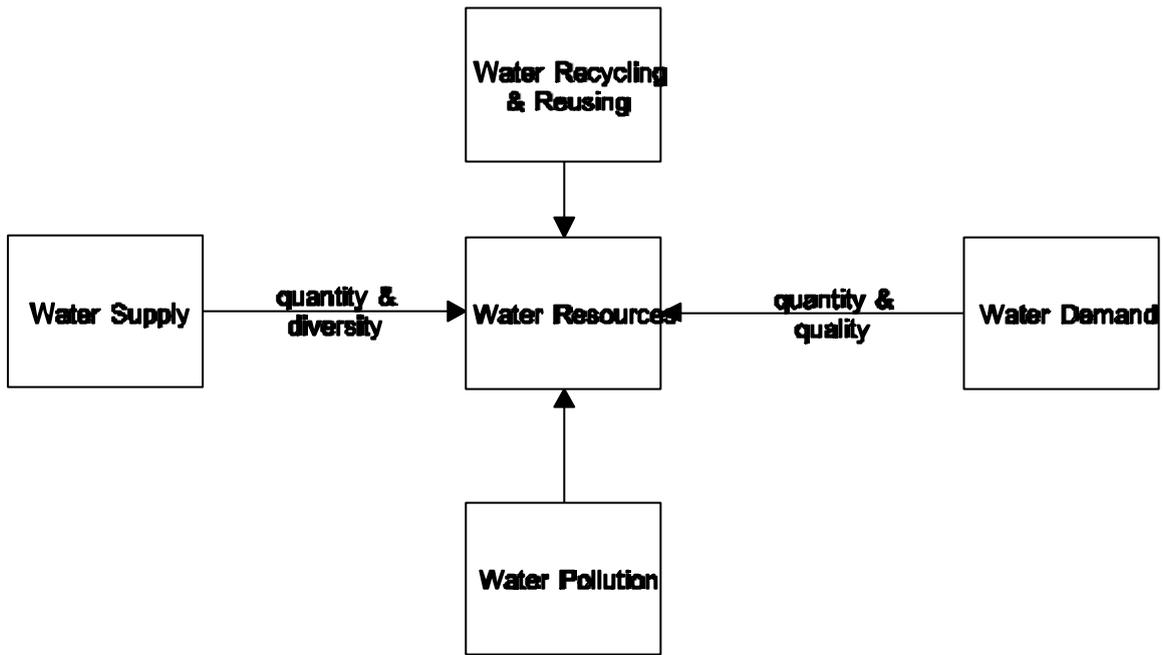
- i. quantity and type of water supply
- ii. quantity and quality of water demand
- iii. pollution
- iv. recycling and reusing

The interactions of these elements are depicted in Figure 1.

An analysis of these components will be undertaken to arrive at demand and supply equations for different sectors and qualities of water. Based on this, a management scheme with water pricing as a key element, will be developed. As is well known in economic theory, for any resource to be allocated to its highest use its price must reflect the opportunity cost. The marginal cost, equated to price, must include both recovery costs as well as the opportunity cost of inputs needed to produce a unit of water. In practice however, political and social considerations must also be included when setting water prices. The best approach, therefore, would be to bring water pricing progressively closer to market pricing without undue adverse social and political consequences.

**Figure 1**

**Components of Water Resource Management**



**Source: Spulber and Sabbaghi 1994**

# Water in the Social Accounting Matrix

Computable General Equilibrium (CGE) models are used to analyse economy wide impacts of changes in external environment and economic policies. The basic characteristics of these types of model are first, that they generate a set of prices consistent with equilibrium in an economy. These prices are based on production and consumption decisions, which in turn determine employment and incomes in various sectors of the economy. Second, the model specifies interactions and linkages between markets. Third, the CGE model is based on a specification of the economic structure which is critical for tracing the impact of an external shock or policy change.

The equations of any CGE model consist of equilibrium conditions, behavioral equations and budget constraints. The latter are best determined by constructing a schematic social accounting matrix (SAM) of the economy, which also serves as the data base of the model. This section describes how the existing SAM, constructed by Thailand Development Research Institute (TDRI) for 1990 may be modified or extended to incorporate the intersectoral flows and economic structures pertaining to water resources. The following sections will attempt to define the behavioral equations for the supply and demand for water, the equality of which will give the equilibrium conditions.

The SAM is the synthesis of two tools or methods of economic analysis: the input output table and national income accounting. This requires information on income and expenditure flows as well as socio-economic indices. Its construction therefore requires combining data from three different sources, ie national income and expenditure accounts, input output tables, and socioeconomic surveys. In the present case, for incorporation of water resources, it will be necessary to modify the input output table and to use the modified "green" national income accounts that incorporate environmental impacts of natural resource use and their opportunity costs. The National Social and Economic Development Board (NSEDB) of Thailand is currently establishing environmental accounts for land use and the forest sector. The results of this exercise can be incorporated in the SAM at a later stage.

## Existing situation

Water supply originates mainly from three sources: ground water, surface (river) water, and recycled water. The first two are the most common sources in Thailand. In the Bangkok Metropolitan Region (BMR), surface water is treated by the Metropolitan Waterworks Authority (MWA) and supplied as pipe water for domestic and commercial use. Ground water appears to be the most economical source of water for manufacturing plants in BMR. Uncontrolled pumping from deep wells in the past has resulted in serious land subsidence problems in the city particularly in the Samut Prakan area. The extent of recycled waste water used by industry or other sources is as yet uncertain. However it is included in this analysis since it can be a potentially important source of industrial water supply and will have an impact on the pricing structure for water resources.

With respect to *surface water* ambient standards have been set for 26 surface water pollutants, including the conventional physical and biological parameters, organic compounds, heavy metals, radioactive substances, pesticides and other toxic substances. The standards are based on a beneficial use classification (defined by physical and biological parameters) divided into five categories ranked according to their level of "purity". From monitoring data collected by the Ministry of Public Health, it appears that river water quality for Chao Phraya has been deteriorating over time, with standards for all pollutants being exceeded in the area from Bangkok to the mouth of the river. In the middle reaches, which is the drinking water supply region, none of the standards

have been violated.

Water supply in Thailand has been dependent on three sources:

(a) *raw surface water* used for irrigation purposes by agriculture is supplied at nominal rates or free of charge. The responsibility of supplying water rests with the Royal Irrigation Department of the Ministry of Agriculture and Cooperatives (MOAC).

(b) *surface pipe water* is supplied by the municipal and provincial water authorities. In the case of BMR (Bangkok, Samut Prakan, Nonthaburi), the main organisation responsible for piped water supply is the Municipal Water Works Authority (MWA). Two agencies responsible for pipe water supply outside the BMR are the Provincial Water Works Authority (PWA) and the Public Works Department (PWD). The main users of surface pipe water are the residential and service sectors. According to a recent TDRI study, industry (excluding those in the industrial estates) reported using only 4.1% of its water from MWA or PWA (Chalomwong and Sussangkarn 1994). The largest proportion is from ground water extracted by their own artisan wells.<sup>1</sup>

Surface water is procured by the MWA, PWA or PWD, and treated before being supplied in the form of pipe water.

(c) *ground water* is used mainly by industry in and around Bangkok, by digging artisan wells. TDRI has estimated that 80.3% of industrial water usage is from this source. Preference for use of ground water derives from its lower costs to industry. A consequence of this has been excessive and unregulated pumping by industry resulting in problems of land subsidence and consequent damage to houses, business losses and electricity disruptions.

*Recycled water* produced from waste water generated by industry is at present an unimportant source of water supply for industry. We will however include it in our analysis: it could be a potentially important source of relatively inexpensive water supply to industry, provided that an efficient water pricing system, reflecting the true value of water resources (incorporating opportunity costs of other forms of water production) is adopted. As such our analysis will focus on four sources and uses of water supply: raw surface water, surface pipe water, groundwater, and recycled waste water.

Following is a schematic and condensed SAM including four water sources, namely, raw water, pipe water, ground water and recycled water (see Table 1). Industry, agriculture and the services sector are at present treated as aggregate sectors. The final analysis will, of course, be based on a disaggregation of these into different sub-sectors and their respective water usage. In order to determine the latter it is necessary to postulate a relationship between production levels (in value terms) and water use. Given this relationship and information on values of sectoral and sub-sectoral outputs it would be quite straight forward to deduce the levels of water usage in the different sectors.

Payment flows in this schematic are measured at market prices as well as shadow prices where appropriate. The latter is indicated for cases where the user cost or opportunity cost of water usage is considered to be significant. The practical measurement of these costs may well pose a problem while running the model, however, it is important at this stage to give an indication of where such costs will arise and suggest possible ways of incorporating them.

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<sup>1</sup> It should be noted however that the reported figure is an underestimate because a number of industries are using MWA supplies for industrial purposes, even though this is officially reported as domestic or residential use.

It should be noted that even though recycling of waste water is at present negligible, some data, albeit limited, on cost estimates for recycling waste water is available for Thailand and other countries with similar industrial cost structures. This can be used as a basis for estimating the extent and feasibility of recycling waste water for industrial uses.

**Table 1 - Expanded SAM**

|     | AGR | IND | SER | NWA | MWA   | GWA | RWA | DD | HHD | GOV | INV | X-M | FDD | TOT   |
|-----|-----|-----|-----|-----|-------|-----|-----|----|-----|-----|-----|-----|-----|-------|
| AGR |     |     |     |     |       |     |     |    |     |     |     |     |     |       |
| IND |     |     |     | E   | J     | O   | W   |    |     |     |     |     |     |       |
| SER |     |     |     |     |       |     |     |    |     |     |     |     |     |       |
| NWA | A   |     |     |     | K     |     |     |    |     |     |     |     |     | A+K   |
| MWA |     | B   | D   |     |       |     |     |    | T1  | T2  |     |     |     | B+D+T |
| GWA |     | C   |     |     |       |     |     |    |     |     |     |     |     | C     |
| RWA |     | Y   |     |     |       |     |     |    |     |     |     |     |     | Y     |
| INP |     |     |     |     |       |     |     |    |     |     |     |     |     |       |
| LAN |     |     |     | F   | L     | P   |     |    |     |     |     |     |     |       |
| LAB |     |     |     | H   | N     | R   | Z   |    |     |     |     |     |     |       |
| TAX | -A  | -B  |     | -U1 | -K-U2 | -U3 |     |    |     |     |     |     |     |       |
| CAP |     |     |     | G   | M     | Q   | X   |    |     |     |     |     |     |       |
| WAT |     |     |     | U1  | U2    | U3  |     |    |     |     |     |     |     |       |
| INC |     |     |     |     |       |     |     |    |     |     |     |     |     |       |
| TOT |     |     |     | A+K | B+D+T | C   | Y   |    |     |     |     |     |     |       |

### Raw surface water

Irrigation water for agricultural purposes comes primarily from raw surface water, stored either in reservoirs or dams. Rain water is stored in reservoirs and fed to the farms by canals. Dams on major rivers are another source of irrigation water for farmers. The Royal Department of Irrigation is responsible for supplying water to the fields, as well as for constructing and maintaining the canals.

No fee is charged for irrigated water. The costs associated with producing irrigated water are, however, positive and borne by the government. As such the government, through the MOAC, is subsidising farmers for the use of water.

Production of irrigation water includes:

*Fixed costs* associated with the construction of reservoirs and dams for storing rain water and river water (as the case may be) which include:

- the cost of land on which the reservoir or dam is built<sup>2</sup>
- construction cost

The above costs are incurred by the MOAC, the funds for which are provided by the government in the national budget.

<sup>2</sup> The costs should be calculated at current prices as well as at prices corresponding to the year of purchase of land by the government.

*Opportunity costs* of building the reservoir or dam, including:

- costs associated with deforestation and clearing of land in order to build the reservoir. This would also include loss of earnings from forest activities for the local population.
- opportunity costs of alternative water usage. (If we assume that farmers use a fixed quantity of water and that lesser usage would result in productivity losses, then the quantity of water would not be a decision variable for the farm unit).

*Operating or variable costs* including maintenance costs, labour costs etc.

Transmission of irrigation water includes:

*Fixed costs* associated with the construction of canals for transporting irrigation water;

These costs are also borne by the MOAC and funds provided by the regular budget.

*Opportunity costs* of building canals;

*Operating or variable costs* including maintenance costs, labour costs etc.

### Intersectoral linkages in the SAM framework

The intersectoral flows that reflect the process by which irrigation water is produced and transmitted to farmers are explained below. Each of these flows appears as a cell entry in the condensed SAM in Table 1.

1. For the sake of clarity we assume that there is a Natural (raw) Water Management Authority (NWA)<sup>3</sup> which provides irrigation water to farmers. Agriculture, treated here as an aggregate (detailed breakdown will be presented later), uses irrigation water (at zero price) supplied by the NWA as an input in its production process. There is then in principle a flow from agriculture to NWA represented by the amount "A". This amount would be measured at market prices and corresponds to the actual costs of production and transmission of water to the farmers. Opportunity costs are not included at this stage and will be accounted for in item 4. Note that at present this is equal to zero since water is free for the farmers.
2. Since the NWA bears positive costs from supplying irrigation water to farmers free of charge, the agriculture sector is in effect receiving a subsidy or transfer payment from the government. This appears as entry "-A" in Table 1.
3. Irrigation water is produced by the NWA from natural or raw water. In order to produce this irrigation water, it purchases intermediate products from industry (construction equipment, building materials etc. for construction of reservoirs and canals). There is thus a flow from the NWA to industry denoted here by entry "E" in Table 1. This is measured at market prices and excludes opportunity costs.

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<sup>3</sup> Currently the closest approximation to these functions is provided by the Irrigation Department.

4. If natural surface water is a scarce resource, its depletion should be associated with the sacrifice imposed on future production, ie the user cost. Whenever water production by the NWA is higher than the natural replenishment rate, there is a disinvestment of the natural asset stock. Thus, the "true" (social) value of NWA's operating surplus should be net of the user cost caused by water depletion. This is denoted by "U<sub>1</sub>" in Table 1.<sup>4</sup>
5. In order to incorporate opportunity costs of alternate land use, eg, costs associated with deforestation and clearing of land in order to build the reservoirs and dams, it would be necessary to undertake some kind of valuation of the lost benefits due to deforestation and incorporate these in the national income accounting.

As far as modifications to the SAM are concerned, an additional input, namely land area, would need to be added in the Input-Output table.

### **Surface pipe water**

Surface pipe water is supplied by the MWA, the PWA or the PWD as the case may be. It is most commonly used for residential and commercial purposes. Industry uses only a small percentage of piped water, drawing the majority of water intake from ground water sources. In the existing SAM only the MWA is included as the Water Works and Supply Authority. Data for the other agencies (PWA and PWD) are not available in the same detail, and their contribution to total water supply is significantly smaller. Therefore, only the MWA is considered in Table 1.

The source of water supply for the MWA is the Chao Phrya river, ie water "produced" by the NWA. Currently there is no charge for withdrawing water from the river although there is a quota or limit to the extent of withdrawals depending on seasonal fluctuations and flow of water in the river. This is equivalent to a subsidy to the MWA (entry K), in the same way that agriculture benefits from free provision of irrigation water by NWA. If the opportunity cost of withdrawing water from the river was significant this would be a positive entry valued at its shadow price.

Raw water is treated by the MWA at an average cost of 5.5 baht per cubic meter, and supplied to consumers according to a progressive tariff structure. The average price is around 7.1 baht per cubic meter.

Production of surface pipe water includes:

*Fixed costs* associated with the production of pipe water including:

- the cost of building the treatment plant: construction costs, machinery and equipment
- cost of chemicals etc. (eg chlorine) required per unit of water treated

*Opportunity costs* of producing pipe water (if significant)

*Operational or variable costs* including maintenance and labour costs etc.

Transmission of surface pipe water include

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<sup>4</sup> In practice, difficulties will be encountered in estimating user costs and therefore in arriving at U<sub>1</sub> (which is by definition measured at shadow prices). In this case the SAM may be built on actual flows only, while allowing for the possibility of incremental increases in water charges and its impact on water depletion.

*Fixed costs* which would include costs associated with the construction of pipe lines, ie pumps, ferrous metals etc.

*Opportunity costs* (if significant)

*Operating or variable costs* including maintenance, labour etc.

#### Intersectoral linkages in the SAM framework

Based on the above production and cost structure, the following intersectoral flows are envisaged:

1. We assume for the sake of analysis that the MWA procures natural water from the NWA in order to produce pipe water. Assuming that water is procured at a positive price (note however that currently this price is zero), there is, in principal, a flow from the MWA to the NWA. This appears as a cell entry "K" in Table 1.
2. In order to produce pipe water from natural or raw water, the MWA purchases inputs from various industrial sub-sectors such as cement and construction companies, machinery and equipment, chemicals, pumping equipment, pipelines for transmission etc. For the moment we consider all of these as one aggregate under the industrial sector. This implies that there is a flow, in monetary terms, from the MWA to industry and appears as entry "J" in the table.
3. Pipe water is used mainly by the residential and services sector and to a limited extent by industry. The row entries corresponding to MWA consist of "T<sub>1</sub>" (final demand: household consumption), "T<sub>2</sub>" (final demand: government), "D" (intermediate consumption: industry) and "B" (intermediate consumption: services) in Table 1.

## Ground water

The ground water system in Thailand is recharged by rainfall and seepage from rivers. In the BMR area it is estimated that only 5 to 6 % of the rainfall reaches the aquifers and these recharges are regarded as the "safe yield"<sup>5</sup> of the aquifers. The actual extraction in the area far exceeds the safe yield, resulting in land subsidence of about 10-14 cm/yr in the eastern and southern suburban areas of Bangkok (United Nations, 1991a).

Water pumped directly from the ground is an important source of supply for industrial uses. As mentioned earlier, industry has found it less costly to pump ground water than to buy pipe water from the MWA/PWA. Much of this pumping is illegal and regulation and enforcement to limit direct withdrawal is weak. As mentioned above, this has contributed to considerable land subsidence, especially in and around the BMR, as well as to salt water encroachment. Over-exploitation of aquifers eventually leads to declines in water levels, increasing costs of pumping and declining water quality as the salt content rises.

The Ground Water Act of Thailand was passed in 1977 to control drilling of ground water and its use as well as disposal of waste water into aquifers through wells. Under the Act a permit is required for ground water utilisation in specific areas. Despite this act, there has been considerable unreported ground water pumping in the BMR.

Ground water management is a complex task with multidimensional requirements, institutional organisation, policy reforms and comprehensive planning. The emphasis must shift from pure supply management to demand management. For this an attempt to conserve water use and encourage recycling through water pricing, waste water reuse and land use planning is essential. However, owing to the uncertainties of predicting future needs, plans should be flexible and adaptable to unforeseen circumstances. Decisions regarding ground water are generally not reversible as they are with surface water.

In our analysis we postulate a separate Groundwater Management Authority (GWA) that would be entrusted with the task of managing withdrawals and charging industry for the use of ground water. Thus, GWA appears as a separate sector in the SAM. (In practice, of course this task can also be performed by a department within the existing institutional framework. Currently the Department of Mineral Resources is in charge of ground water supplies).

Production of ground water includes

*Fixed costs* of ground water pumping including:

- cost of construction of wells
- boring and pumping equipment

*Opportunity costs* associated with ground water pumping including:

- costs of land subsidence: these can be approximated by an assessment of damage to houses, flood damages, costs of flood protection, structural damages approximated by business losses, power disruptions etc.

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<sup>5</sup> Safe yield is defined as the average amount being recharged. In general this is considered to be a sustained yield with the advantage that pumping costs will not increase over time, surface subsidence and salt water intrusion is avoided. However in some cases it may not be a socially desirable policy, especially when the benefits of water use and discount rates affect the optimum use over time.

- social costs due to depletion of partially renewable aquifers
- costs and benefits of using an alternative quality/type of water e.g pipe water supplied by the MWA.
- costs of alternative input (substitutes for water) use.

*Operating or variable costs* including maintenance of wells, equipment and labour costs.

#### Transmission costs of ground water

Negligible

#### Intersectoral linkages in the SAM framework

1. We assume that the (hypothetical) GWA is in charge of ground water management and collects a fee from industry for drilling wells and pumping water. The costs for ground water pumping, currently subsumed in industry costs, will then be reflected in these payments. In order to pump ground water, the GWA should then be purchasing equipment from industry to dig and operate the artisan wells. This is denoted by the entry "O" in Table 1.

The industry does not pay the scarcity cost of ground water use. This corresponds to a situation where the operating surplus is overvalued due to non payment of user costs. Hence, a social valuation should subtract the user cost associated with water depletion from the operating surplus of the GWA, and consider that it is, in fact, receiving a subsidy "U<sub>3</sub>".

2. The costs of land subsidence can be incorporated by assigning a value to damage caused to houses, flood damages and flood protection costs and business losses due to disruptions in power supply.
3. Since industry is the main user of ground water the row entry of industry expenditure on ground water is given by "C".

#### **Recycled waste water**

In Thailand industrial waste water is mainly discharged into surface water (rivers and canals) with practically no discharge into ground water. Although most industries treat waste water before discharge (UN ESCAP estimates an efficiency of 80-90% of treatment plants), they do not give much attention to water reuse. In most factories cooling water and condensed steam are not reused for boiler feeding or new steam production, and process waste water is seldom reused (United Nations, 1991a).

Surface water pollution is mainly due to organic and chemical wastes, heavy metals and oil and grease. As noted in World Bank (1994), the "main issue with regard to organic wastes is its impact on downstream productivity of fisheries, for instance, and not its health impacts. For heavy metals discharges into water, health impacts are an important concern."

Food processing, especially the sugar industry, beverages, textiles and pulp and paper accounted for the largest share of BOD discharge in 1991.

#### Production of recycled water include

*Fixed and Variable costs* associated with the production of recycled water including costs of waste water treatment and costs of recycling and reuse.

In trying to estimate the costs of waste water treatment, treatment plants will be classified into the following types (Dharmappa 1992): activated sludge, aerated lagoon, oxidation ditch, chemical treatment. Cost functions associated with these treatment processes have been estimated by Dharmappa (1992) and can be used as proxies for this analysis.

In general treatment costs will vary according to the degree of treatment that is specified by existing standards for effluent discharge, across industrial sub-sectors, by the age of capital equipment, and depending on whether treatment is source specific or centrally undertaken. A recent study by the World Bank (1994) has found that the incremental costs/kg of BOD (corresponding to 95% treatment efficiency for BOD) varied by a factor of four on average across manufacturing sub-sectors. Moreover, the variation in unit costs was nine fold within the chemicals and textiles industry, and almost 60 times in the food processing sector.

The *opportunity costs* of using recycled water are negligible.

#### Transmission of recycled water

Assuming that factories will recycle water for own use (especially in the BMR as opposed to industrial estates) the costs of transmission are minimal and can be treated as part of the production costs.

#### Intersectoral linkages in the SAM framework

In order to study the intersectoral flows, we assume, for each industrial sub-sector, a recycling unit or authority that is responsible for treating and recycling waste water. Treated waste water, according to specifications is then supplied to industrial units for reuse.

1. The recycling authority (RA) purchases inputs from various industrial sub-sectors (construction equipment, chemicals, machinery etc.) to set up waste water treatment and recycling plants. This flow of money from the RA to industry is represented by entry "W" in the condensed SAM.
2. Industry in turn purchases the recycled water as an input in its production process, represented by entry "Y".

#### **The Social Accounting Matrix: an illustration**

As mentioned above, the SAM is the synthesis of input output tables and national income accounting. In this section an attempt is made to combine these two building blocks and present a SAM structure that incorporates water both as an item of intermediate consumption and as a natural resource or primary factor of production. The former characteristic of water implies that it appears in the input output table with fixed input output coefficients in the same way as other intermediary inputs. The use of water as a natural asset is depicted in parts of Table 2 where different types of water resources appear as primary factors, along with land, labour, and capital. Substitutability between primary factors of production is allowed for by modelling production functions as CES functions.

Water can be used as an input for economic activities, production or consumption. Therefore it can be treated as an intermediate input or a final consumption good. However water is not usually "produced" as other ordinary goods.<sup>6</sup> Like other natural resources, water belongs to the asset

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<sup>6</sup> With the exception of recycled water which is produced from waste water. It is important to highlight that

frontier because it can be used as input in the production flow. It does not however belong to the production frontier since it is not the output of a previous production process.

In other words, water used in the economic system is not derived from human production but from the depletion of a previously existing stock. This stock has a natural replenishment rate, and the difference between the consumption and replenishment can be thought of as depletion.

In the tradition of the new UN System of Economic and Environmental Accounts (Bartelmus *et al.* 1993), Table 2 incorporates these special features. Water appears in the conventional input output analysis as an intermediate input (area IDD) or final consumption good (area FDD). Hence the conventional (Leontieff) hypothesis of fixed coefficients can be applied to model the use of water as an intermediary input.

There are four sectors responsible for the supply of water: NWA, MWA, GWA and RWA, but only the latter actually "produces" water. All the others extract water from natural sources. A social account should account for the losses caused by excessive (unsustainable) water consumption represented by the value of water depletion (difference between consumption and replenishment). This value should be deducted from the gross operating surplus as a user cost (area UNa), in the same way as depreciation of man made capital is deducted (area UPA). The final result will give an environmentally adjusted net value added (EVA).

On the horizontal axis, the environmentally adjusted net value added should be identical to the value of final demand (FDD) minus the consumption of produced assets (DPA) and non-produced assets (DNA).

It is worth noting that this structure of the SAM corresponds with the UN framework of natural resource accounting currently being developed by the NSEDB. It is envisaged that the NSEDB will provide necessary data to complete the study.

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"production" in this paper denotes an economic activity which transforms inputs to generate a new output (in the sense of having a new use). It should not be confused with the idea of creating physically new material or energy.

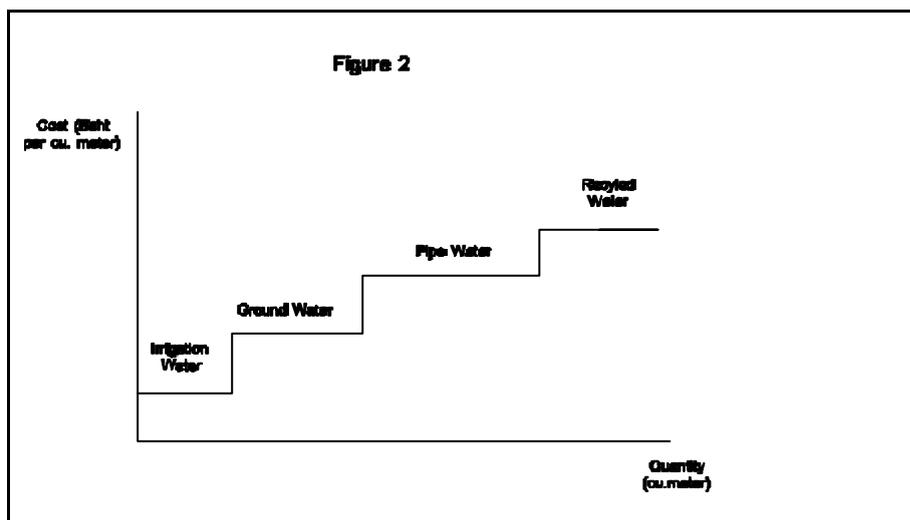
# The Supply Function

In the present analysis water supply originates from four different sources: natural or raw water, groundwater, pipe water and recycled water. The aggregate supply function for water will be a sum of these four sources.

The determinants of water supply include the fixed and variable costs of producing water. Fixed costs consist of i) capital costs of increasing water supply, eg new wells, pumps, major pipe lines, and ii) costs of extending the water distribution and sewage networks. Variable costs include i) operating and maintenance costs, ii) repair costs for water supply, transmission, and distribution, and iii) costs for wastewater collection, treatment and disposal. (Spulber and Sabbaghi, 1994). These cost components have been discussed above and can be used to estimate the short run and long run costs of producing different types of water<sup>7</sup>.

The supply function for each type of water can be derived from the total cost function. Since the long run marginal cost function better represents the social costs of producing water (eg user costs attributable to scarcity of nonrenewable resources and externalities from water pollution), the ideal situation would be to consider the long run marginal cost as the supply function for water. In practice however there can be limitations in calculating marginal costs for water. One important drawback is the problem of identifying marginal costs when a large proportion of costs are common. For example, the cost of one reservoir may be shared by water supply systems, flood control projects or recreational facilities. It may therefore be easier to use average cost pricing to derive the supply function.

The aggregate water supply function, based either on marginal or average costs, will be a horizontal summation of the four supply functions. It would in all probability be a step function as depicted in Figure 2.



<sup>7</sup> In practice there may be some difficulty in separating fixed costs from variable costs. The longer the time period, the more previously fixed costs become variable costs. For a water facility however there is no guide to how short run costs should be i.e. should they include constructing new plants or expansions to new areas, should they include costs of shut downs etc.

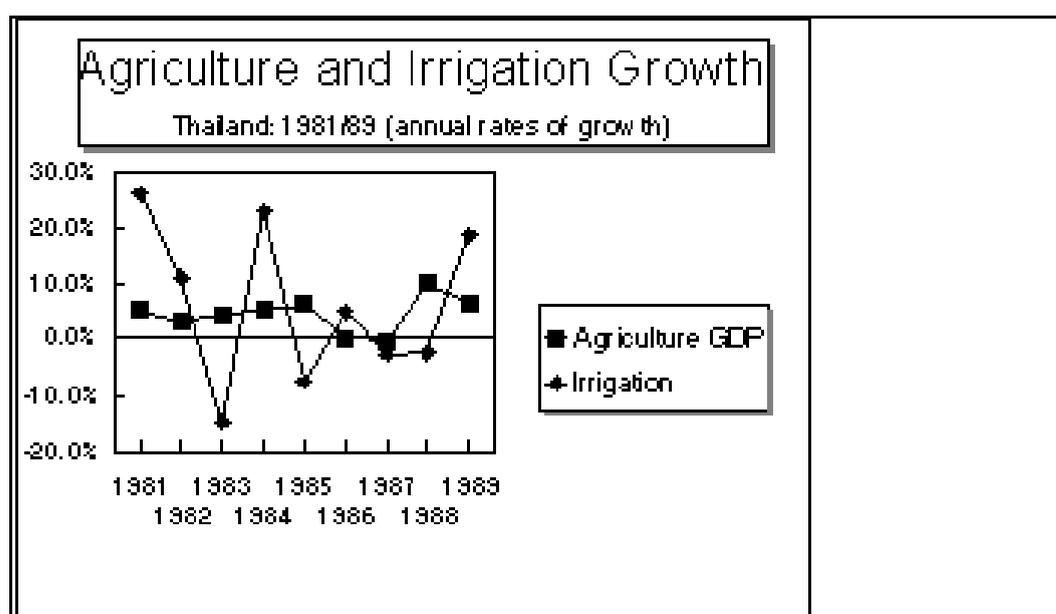
# Modelling Water Demand

An attempt was made by TDRI to estimate the demand for water by industry, residential and service sectors. For various reasons (see Annex 1), these estimates were found inadequate for present purposes. An alternative framework that may be used for modelling water demand is presented below for the industrial and agricultural sectors. Note that figures presented below are used only for illustrative purposes and do not correspond to actual data that will be used in the model.

## Agricultural water demand

Agriculture has the largest market share of water amongst its users. Irrigation water is provided free of charge despite the considerable costs involved. The consequence of this free-pricing policy has been that between 1980 and 1989 water supplied for irrigation has increased at an annual rate of 4.9% (to meet the demand for water at zero price) whereas agricultural GDP has grown 4.1% (see Figure 3).

**Figure 3**



The costs of supplying water are not small. A 1987 estimate, using the average cost of irrigation (0.46 baht/cum), shows that the annual irrigation costs carried out by the Royal Irrigation Department (RID) were approximately 4.5% of the total agricultural GDP during the 1980s, representing a considerable subsidy to agricultural production (see Table 3).

It can be estimated that the expansion in water supply will result in a total cost increase of 28% for the period 1990/2000 (see Table 4). This is a conservative figure because the costs were calculated on the basis of average costs of 1987. Data for 1988 and 1989 show increasing average costs for irrigation which implies an even higher burden for the RID budget.

**Table 3 - Irrigation and agriculture GDP 1980 - 89**

| Year | Agricultural GDP<br>(Billion Baht) | Water Use in Irrigation<br>(Billion cu.m/yr) |       | Irrigation Cost<br>(Million Baht) | Cost/GDP |
|------|------------------------------------|--|-------|-----------------------------------|----------|
|      |                                    | Total  | RID   |                                   |          |
| 1980 | 162                                | 18.80  | 14.46 | 6,639                             | 4.1%     |
| 1981 | 170                                | 23.70  | 18.23 | 8,369                             | 4.9%     |
| 1982 | 176                                | 26.30  | 20.23 | 9,287                             | 5.3%     |
| 1983 | 183                                | 22.40  | 17.23 | 7,910                             | 4.3%     |
| 1984 | 194                                | 27.60  | 21.23 | 9,746                             | 5.0%     |
| 1985 | 205                                | 25.50  | 19.62 | 9,005                             | 4.4%     |
| 1986 | 206                                | 26.80  | 20.62 | 9,464                             | 4.6%     |
| 1987 | 206                                | 26.00  | 20.00 | 9,181                             | 4.5%     |
| 1988 | 227                                | 25.40  | 19.54 | 8,969                             | 4.0%     |
| 1989 | 242                                | 30.20  | 23.23 | 10,664                            | 4.4%     |

Source: UN ESCAP, Assessment of Water Resources and Water Demand by User Sectors in Thailand (1991).

**Table 4 - Forecast irrigation costs 1990 - 2000**

| Year | Water Use in Irrigation<br>(Billion cu.m/yr) |       | Irrigation Cost<br>(Million Baht) |
|------|--|-------|-----------------------------------|
|      | Total  | RID   |                                   |
| 1990 | 30.05  | 23.12 | 1,061                             |
| 1991 | 30.89  | 23.76 | 1,091                             |
| 1992 | 31.74  | 24.42 | 1,121                             |
| 1993 | 32.58  | 25.06 | 1,150                             |
| 1994 | 33.42  | 25.71 | 1,180                             |
| 1995 | 34.26  | 26.35 | 1,210                             |
| 1996 | 35.10  | 27.00 | 1,239                             |
| 1997 | 35.95  | 27.65 | 1,269                             |
| 1998 | 36.79  | 28.30 | 1,299                             |
| 1999 | 37.63  | 28.95 | 1,329                             |
| 2000 | 38.48  | 29.60 | 1,359                             |

Source: UN ESCAP, Assessment of Water Resources and Water Demand by User Sectors in Thailand (1991).

The introduction of a pricing system for irrigation may represent an improvement in the efficiency of water use and relief in the RID budget, as well as a reduction in environmental pressures. A simple model can illustrate how water pricing would affect the demand for water. The potential economy wide impacts of such a policy could subsequently be traced through by integrating it into a CGE model.

Agricultural production is related to the availability of water, labour, capital and land. For a simplified illustration, a CES production function is assumed where each of these factors are substitutes<sup>8</sup>.

Install Equation Editor and double-click here to view equation. **1**

For each level of output the farmer intends to minimize the total cost, given by

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where  $Q$  is the agriculture output,  $\tilde{\alpha}$  is the substitution parameter, the inputs are water ( $W$ ), labour ( $L$ ), capital ( $K$ ) and land ( $N$ ), and  $p_i$  represents the price of input  $i$ . The first order conditions may be written as:

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where  $\tilde{\lambda}$  is the Lagrangian.

The solution of the set of equations above provides the sectoral demand for each production factor:

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<sup>8</sup> The actual application and CGE model would in all probability use a nested CES function where there is one elasticity between labour and capital, another between land and water, and a third between aggregates of these two pairs.

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9

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10

where  $\hat{\sigma}$  represents the elasticity of substitution ( $\hat{\sigma} = 1/(1+\tilde{\alpha})$ ).

This model shows that the demand for water for agricultural use is a function of water price ( $p_H$ ) and total agricultural output ( $Q$ ). As expected, the introduction of water price for irrigation will reduce the demand for water<sup>9</sup>.

### **Industrial Water Demand**

The firms' demand for water as an intermediate good will depend on quality and the cost of water. In addition to this firms may have access to multiple water sources: municipal pipe water, own recycled water, recycled water of other firms, groundwater, direct withdrawal from lakes and streams. In the present case pipe water, ground water and recycled water are included in the analysis since these are the main sources of water supply for industry in Thailand. Recycled water is included because of its benefits to the firm in the form of reduced costs on account of lower water charges or improved quality.

The methodological approach to derive industrial demand for water is based on that used by Bhatia et al (1992), Kneese and Bigler (1968), and Russell and Vaughan (1976). The firm is considered to be a cost minimising firm with a given production function.

Again, a simple model can be used to illustrate the importance of pricing policies for efficient water use. The decision problem for the firm is presented for the single firm in a competitive market, as follows. The firm is assumed to have a production function.

The above function can be modelled as a CES production function to allow for substitutability between different types of water usage and between different factors of production.

where:  $X$  = output

$L$  = labour used in production

$K$  = capital used in production

$Z$  = materials used in production

$E$  = effluents released outside the plant (quality of water)

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<sup>9</sup> Note that a nested CES production function may give better results since it allows for one elasticity between labour and capital, another between land and water, and a third between the aggregates of these two pairs.

$W_g$  = groundwater used and contaminated in the process  
 $W_r$  = waste water treated and recycled  
 $W_p$  = pipe water supplied by the MWA  
 $p$  = price  
 $p_z$  = price of materials used in production  
 $p_e$  = price of effluent  
 $p_{wg}$  = price of groundwater  
 $p_{wr}$  = price of recycled water  
 $p_{wp}$  = price of pipe water  
 $w$  = wage rate  
 $r$  = interest rate

For each level of output the firm then minimises its costs  $C$  given by

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**12**

subject to the production function specified in (11).

The first order conditions will give the derived demands for ground water, recycled water and pipe water as functions of the output level, input prices, water charges and water quality (assuming that recycled water is of a higher quality than ground water or pipe water for industrial use). The following model is based on a paper by Bhatia, Rogers et al, Water Conservation and Pollution Control in Indian Industries: How to use Water Tariffs, Pollution Charges and Fiscal Incentives.

First order conditions may be written as:

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**13**

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Solving equations (13) to (19) gives demand equations for  $L$ ,  $K$ ,  $Z$ ,  $E$ ,  $W_g$ ,  $W_p$  and  $W_r$ . Since we are mainly interested in water demand functions, the following three are presented below:

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Given that the demand for water is relatively unresponsive to  $w$ ,  $r$ , and  $p_e$ , we get the following demand equations for ground water, recycled water and pipe water:

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These functions define the quantities of water inputs that minimise the firms production costs, for any given set of input prices, water qualities, and output level. It demonstrates that water demand is a function of price of water as well price of the effluent and therefore the concentration of wastes emitted.

The price of ground water would reflect the externality costs associated with land subsidence, flooding, water salinity etc. due to excessive pumping of ground water.

The individual demand curves for firms can then be aggregated over all firms to arrive at industry demand for groundwater, pipe water and recycled water.

The above theoretical demonstration can be validated by empirical estimates of elasticities of demand.

The role of pricing policies can be demonstrated by assuming a CES production function<sup>10</sup>:

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**26**

The firm will minimise its costs, as given in equation (12) subject to the above production function. The set of first order conditions can then be solved to arrive at demand equations for different types of water. A horizontal summation of these will give the total demand for water by industry.

The first order conditions will result in a set of sectoral demand equations for each type of water:

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**28**

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**29**

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**30**

As expected, the price of each type of water is inversely related to its demand. As in section 5.1, the incorporation of this set of equations in a CGE model will facilitate the estimation of economy wide and sectoral impacts of water pricing reforms.

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<sup>10</sup> Here too, as in the case of the agricultural demand function, it would be better to use a nested CES function for the actual exercise.

## Conclusion

This paper presents a detailed account of how the social accounting matrix can be modified to take account of different types of water, incorporating changes in intersectoral flows that this entails. Examples of behavioural equations for the demand and supply of different water sources are also postulated. Methodological modifications along these lines (with more sophisticated functional forms) can be incorporated into a general equilibrium model to ascertain the impacts of changes in water pricing policies on different sectors of the economy, in particular on land use, deforestation, agricultural productivity and industrial output. In addition to its purely methodological aspect, the paper has also highlighted the seriousness of over exploitation of aquifers, land subsidence, and wasteful utilisation of water resources by agriculture and industry.

It is hoped that the results of this exercise will be used to modify the existing general equilibrium model for Thailand<sup>11</sup> that can then be used to estimate and analyse the impacts of water pricing reforms on water use and on other sectors of the economy.

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<sup>11</sup> The Thailand Development Research Institute has developed a Computable General Equilibrium model which will be used for analysing the economy wide consequences of water pricing reforms.

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## Annex 1: An Analysis of TDRI Estimates for Water Demand

This section analyses the TDRI estimates for water demand in Thailand for the residential, service and industry sectors (Sethaputra et al. 1990). Some methodological issues and the comparability of results are briefly discussed, and the section concludes with a summary of problems identified.

### Residential and Service Sector Demand in BMR and Pattaya

#### a. Bangkok Metropolitan Region

Water demand equations in the BMR were modelled as translog functions. Separate equations were estimated for the residential and service sectors. In both cases demand is supposed to be a function of water price, income and the number of users. However, these variables are presented in distinct functional forms.

Residential water demand in BMR is given by:<sup>12</sup>

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where  $Q_R$  is the residential sector demand for water (million cubic metres)  
 $P_R$  is the real minimum price charged for residential use (baht per cu. m per month)-- is this the same as the "effective price"?  
 $I$  is the income per capita ('000 baht)  
 $U_R$  is the number of residential users ('000)

The respective elasticities are:

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To obtain elasticity values, the mean of the logarithm of observed values (averaged over 14 years) for each variable (eg,  $\Sigma (\ln I)/n$ ) was applied to the above relations. The results are:

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<sup>12</sup> The equation was printed with two mistakes: the term  $(\ln P)(\ln P)$  should be replaced by  $(\ln P)(\ln I)$ , and the correspondent coefficient is 0.69 rather than 0.68.

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The equation for service sector demand appears to have a number of typing errors. Using values from appendix 3 it seems that the correct equation should be:

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where  $Q_S$  is the service sector demand for water  
 $P_S$  is the real minimum price charged for service use  
 $O$  is the total output of the service sector  
 $U_S$  is the number of service users

The elasticities can be obtained through:

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Values for elasticities were obtained by applying the mean of the logarithm of observed values. The results are:

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According to this specification, the service sector demand for water is inelastic with respect to the number of users.<sup>13</sup> One possible explanation for this could be the use of total output of the service sector (rather than output/number of establishments) as an exogenous variable.

The report concludes that the higher values for the elasticities in the service sector mean that water demand is more flexible than in the residential sector. In particular, the higher price elasticity of demand indicates that the service sector is slightly more responsive to pricing policies than the residential sector.

The estimated coefficients were used to simulate the effects of increases in water prices on demand.

Results show that an increase of 45% in water prices (from 6.2 to 9.0 baht/cu.m) reduced residential sector demand reduced by 13% ( $E_{p,p} = -0.28 \cdot 0.45 = 0.126$ ) and service sector demand by 14% ( $E_{p,p} = -0.31 \cdot 0.45 = 0.140$ ). Revenues from water sales would increase by 27% in the residential sector and 25% in the service sector: in both cases, the rise in prices more than compensate the decrease in demand.

### Water demand in Pattaya

The procedures to estimate water demand in Pattaya were different. Residential and service demand were not treated separately. The water demand equation was assumed to be a simple (non-logarithm) linear function of real minimum water price ( $P_P$ ), number of tourists ( $T$ ) and available hotel rooms ( $R$ ). The two last terms are proxies for demand generated by tourism, the major economic activity in Pattaya. No explanation is given for differences in functional forms between Pattaya and BMR.

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The price elasticity of demand was estimated by applying the average values for the real minimum price ( $P_P$ ) and water produced ( $Q_P$ ). The value obtained was -0.41 ( $-0.76 \times 3.16 \div 5.81$ ), considerably higher than that for BMR. The report concludes that consumers are more price-responsive in Pattaya. However, one can argue that the use of different functional forms may affect the comparability of results in BMR and Pattaya.

Pattaya has a problem of water shortage, specially in the dry season. It was assumed that a reduction of 18% in water consumption (2.9 million cu.m) would restore the imbalance between supply and demand. A simulation was carried out in order to estimate the price change necessary to achieve this reduction in consumption.

Assuming the price elasticity of demand equal to -0.41 (as described above) and the present water production (supply) to be 12.17 million cu.m, the price change is given by:

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Since the present price is 10 baht/cu.m, the optimal price should be set at 15.8 baht/cu.m in order to

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<sup>13</sup> In the report the value presented for this elasticity is 0.98. Even though this is more likely than the figure .01, it can not be obtained with the data available.

achieve the desired reduction in consumption. The resulting level of revenues from water sales would be 20% higher, even considering that 30% of water production is lost through leakages.

### Industrial water demand

The procedure to estimate industrial water demand was similar to the one used in BMR. The different demands for water were aggregated in just one equation, presenting demand ( $Q_I$ ) as a (translog) function of real minimum price ( $P_I$ ) and aggregate industrial output ( $M$ ).

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The elasticity functions are expressed as:

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The elasticity values were obtained through applying the average of the logarithm of observed data:

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These results point out that the industrial sector is more responsive to water pricing than the residential and service sectors. However, this result may not be a realistic one since the estimation did not consider values after 1981. Until 1981 the real prices of the Metropolitan Waterworks Authority (MWA) for piped water were declining, being more competitive with the cost of groundwater extraction. After that, the prices of the MWA water supply increased substantially, and further increased the difference with the costs of groundwater extraction. Therefore the costs of substituting pipewater for groundwater was very high, and the industry became relatively unresponsive to pipe water prices. If the observations also include the period 1982-86, the estimated price elasticity falls to just -0.18 and the industrial output elasticity becomes bigger than unity. (Sethaputra et al.1990: 71). Hence, these results indicate that (without institutional changes) pricing policies would be relatively ineffective, and that water demand will increase faster than industrial growth.

The results were used to show that the MWA forecasts about future industrial demand are underestimated. However, one important issue was not addressed in the exercise: the industrial use of recycled water. The TDRI study considered that additional demand for water is to be supplied through groundwater or (piped) surface water, but recent studies show that recycling of water is becoming increasingly common in the Thai industry.

### Agriculture water demand

Agriculture has the largest market share of water amongst its users, and its share is expected to

increase from the present figure of 22% to 72% in 2010 (Sethaputra et al. 1990: 22). However, there are no estimates of demand functions for agricultural use.

A possible way to model the agricultural demand for water is through CES equations. In that case water is considered a production factor like capital and labour, and the substitutability between them is given by a fixed parameter  $\tilde{\eta}$ .<sup>14</sup>

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click here to view equation.

#### Comparison of the results

Table A.1 presents the elasticities of demand for water in the residential, service and industry sectors as estimated by TDRI. They suggest that pricing policies have a potential role in improving efficiency of water use. However, as discussed before, the comparability of these results is questionable due to significant methodological differences.

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<sup>14</sup> This procedure was used by Goldin and Roland-Holst (1994) to estimate agricultural water demand in Morocco.

**Table A.1**

**Values of Elasticities of Demand for Water - Thailand**

|                   | BMR         |         | Pattaya    | Industry |         |
|-------------------|-------------|---------|------------|----------|---------|
|                   | Residential | Service | Res.+Serv. | 1970-81  | 1970-86 |
| Real min. price   | -0.28       | -0.31   | -0.41      | -0.49    | -0.18   |
| Income per capita | 0.48        |         |            |          |         |
| Total output      |             | 0.45    |            | 0.61     | > 1     |
| Number of users   | 0.79        | 0.01    |            |          |         |

Source: Sethaputra et al. (1990)

Main Problems Identified

Following are the main problems identified in the estimation procedures adopted by the TDRI study:

- The equations were presented in an *ad hoc* way, with no theoretical modelling.
- The equations were specified in different functional forms, making it difficult to compare results. It seems that the functional forms were chosen according to "best fit" criteria with no explanation of differences between equations.
- It is uncertain whether the demand equations were for ground water or surface water. (Clarify different types of water and their uses). Also, no consideration was given to industrial use of recycled water.
- Demand analysis uses real minimum price but water charges by MWA are set according to effective prices. This will have implications for pricing policies once we look at interactions between demand and supply.

Any new attempt to model the sustainable use of water in Thailand must address the problems presented above.

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