An Analysis of the Impacts of Electricity Subsidy Removal on Subsistence Rice Farmers in Tamil Nadu, India

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INTRODUCTION

There has been much talk amongst economists and policymakers regarding the pros and cons of agricultural input subsidies in developing countries. One view on the detrimental effect of subsidies is they can lead to an inefficient use of the subsidized, and other, inputs. A benefit of subsidies is they can serve as a weak substitute for poorly functioning credit markets. In Tamil Nadu, India, a subsidy on electricity for well pumping and other household uses is relatively popular. Currently, rice is the most prominent crop produced by subsistence farmers in Tamil Nadu, and farmers are charged a nominal price for electricity used in pumping water used in crop irrigation – the low price being the result of highly subsidized electricity prices. To date, it appears there have been no studies that examine the economic impact of removing input subsidies. This exercise examines the likely impact on subsistence farmers in Tamil Nadu, India, of removing electricity subsidies for pumping water used in rice irrigation.

Using household survey data, I first econometrically estimate a rice production function with the intention of constructing a restricted profit function using the estimated technology. I then implement data envelop analysis to examine the same question. By calculating the farmer's profit given the data, I am able to create a behavioral model that suggested how farmers would react when the price of electricity to pump water decreased from the initial subsidized price of about 3.5 rupee per unit of water to zero rupees per unit of water. As water price increases in 0.25 rupee increments, all 58 farming household's profits decreased, some more drastically than others. Thirteen of the 58 farmers with wells did not change the amount of water they pumped for crop irrigation and the remaining made varied decreases. In aggregate, the decrease in profit was not solely attributed to the increase in well water prices. One possible reason for the additional decrease in profit could be attributed to a reduced crop yield brought about by using a less than optimal quantity of water. Another explanation could be that the households chose to substitute water with a higher priced or less effective input that results in lower yield and possibly higher costs. However, the likely impact of subsidy removal is clear: removing the subsidy and charging rice farmers in Tamil Nadu the full cost of electricity used to pump water can result in drastically decreased farm income.

The next section provides an overview of agricultural production in India, with a primary focus on Tamil Nadu. The overview summarizes information related to the climate of the region and its governance, and summarizes what we know about the effects of electricity subsidies on farming communities. Section 3 lays out the economic model and the intuition behind the model. Section 4 describes the econometric and DEA analysis, and describes the data used in the empirical analysis. The last section summarizes the results of the study.

1. LITERATURE REVIEW

1.1 Trends in water supply and demand

All of India experiences a seasonal rainfall pattern – with a rainy (monsoon) and dry season. North Indian states have one monsoon season beginning in June and ending in September, with Karnataka and Tamil Nadu getting an additional rainy season in November. In most years, 50% of India's precipitation falls in a period of about 15 days. For centuries, households on the Indian subcontinent adapted to this "monsoon" agriculture by living near river banks, and creating water storage tanks both above and underground. Over the last one hundred fifty years, large investments in infrastructure have occurred that brings water to new, previously water-scarce areas. This created a large upward shift in water supply, with one result being the creation of new centers of economic growth (Briscoe & Malik).

Water availability in India has not kept up with increasing water demand, resulting in increasing scarcity for both drinking and irrigation demands. India water storage capacity is about 200 cubic meters per capita. Compare this to the water storage capacity of the United States, which averages over 5,000 cubic meters per capita, while the water storage capacity of middle-income countries like China and South Africa are approximately 1,000 cubic meters per capita (Briscoe & Malik). Also, India can store around 30 days of rainfall, whereas the arid regions of most developed countries can store approximately 900 days' worth of rainfall. To add to the already critical storage problem, studies reported in the Science Daily and BBC News suggest in the upcoming decades, global climate change will lead to a melting of the Himalayan Glaciers and cause increased rainfall variability in many regions of India .

Water demand from agriculture is influenced by the availability of highly subsidized electricity for pumping irrigation water (Dossani and Ranganathan). For example, the subsidy on electric power for rural pumpset usage in the fiscal year 2002-2003 was estimated at 1.1% of GDP, with an average of more than 85% of cost relief per farmer (Dossani & Ranganathan). The Indian government has most likely created these subsidies in an attempt to assist farmers that are credit constrained, but some suggest the subsidies lead to a wasting of water resources – leading to further decreases in the already scarce supply of water – and contributes to daily power shortages (Dossani & World Bank). Currently, the average household in rural Andhra Pradesh only receives about nine hours of (grid based) electricity per day.

1.2 The political economics of electricity subsidization

In order to fully understand why India is in its current position, it is useful to examine the political history of electricity in India. Shortly after India's independence in 1948, the electricity sector was organized around publicly owned State Electricity Boards (SEB). These SEBs were created with the idea that electricity was a benefit to society, and could be used as tangible evidence of one gain from British independence. In the late 1970's, a decision was made to provide farmers with inexpensive electricity, mostly used for pumping irrigation water. The subsidy was implemented largely as a response to the adoption of high yielding grain varieties by farmers across India: as these varieties required a much larger quantity of water to realize full yield potential. Less than ten years later, farmer's in many states received free electricity, or electricity charged at a very low flat rate. As a result, meters eventually were not needed, which caused a myriad of accounting problems and inefficiencies. At this point more than 50% of India's electricity was unaccounted for, and the issue of transmission and distribution losses arguably became one of India's largest regulatory problems (Dubash). Also, SEB's financed the farmer subsidy by imposing tariffs on industrial consumers. These "cross-subsidies" resulted in industrial electricity costs being over ten times that of electricity for agriculture, and led to many industrial users exiting the power grid and setting up individual power plants for their own use. Estimates suggest that in 2001-2002, SEBs recovered approximately 69% of their fixed and operating costs, and state-paid direct subsidies accounted for 20-30% of gross fiscal deficits (Dubash).

1.3 *Trends in electricity demand and supply*

Audinet and Verneyre (2002) observe that since India's independence in 1947, electricity consumption has increased about 7% per year. A major driver of this increased demand has been India's economic growth and the corresponding increase in electrical appliance use. In the year 2000, industry accounted for approximately 34% of total electricity use, agriculture for 30% and households accounted for 18% (Audinet & Verneyre). However, supply has not been keeping up with demand. Close to 90% of villages in India receive electricity, but only 50% of the population actually has access to it or can afford to pay for it. The "International Energy Agency's World Energy Outlook 2000" project electricity demand in India will increase faster than an assumed 4.9% annual rate of growth in India's GDP. This assumption, however, is at odds with actual World Bank data, which suggests GDP has been growing much faster than 4.9% (see Table 1).

Table 1 – India GDP Growth

Country	**Series Name**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
India	GDP growth (annual %)	5.21%	3.73%	8.39%	8.33%	9.23%	9.20%

* Statistics retrieved from http://web.worldbank.org

Indian electricity supply is dominated by coal production facilities. Dependence on hydroelectricity has fallen, gas has experienced increased usage, and nuclear power has seeing marginal growth and not expected to become widely used in the immediate future. Blackouts and brownouts are common across India, and forces commercial users to rely on standby/in-house technologies which raise commercial production costs.

India's electricity supply has been provided by the public sector since the Electric Supply act of 1948, which converted the existing electric utilities into 19 State Electricity Boards and 8 electricity departments. In 1999, the SEB's owned about 63% of electricity generation capacity and the rest was owned by Central Sector Utilities (CSU) which emerged after the 1975 Indian Company Act, with CSU controlled by the central Ministry of Power. CSU was originally set up to create economies of scale and lower electricity costs by pooling the electricity produced by hydroelectricity and coal, and redistributing it across users. Private utilities represent a very small portion of electricity supply. These include such licensees as Tata Electric Corporation, Bombay Suburban Electricity Supply Corporation and Calcutta Electricity Supply Corporation (Audinet & Verneyre).

1.4 *Estimates of social cost of subsidy*

One challenge policymakers is accurately anticipating the overall cost of a subsidy mechanism. The IEA proposed a targeted subsidy scheme in which households that consume less than 50 kwh per month would pay one Rupee per kwh, and all others would pay the full marginal cost of electricity (at least 3.4 Rupee per kwh). They estimated the maximum, annual direct cost of such a subsidy mechanism to be about 44.7 billion Rupees or approximately 1.1 billion U.S. dollars. The agency concluded the direct cost of the support mechanism would be at least four to five times less than the current cost of subsidies for electricity consumption, which amounts to 187 billion rupees or 4.5 billion U.S. dollars (Audinet & Verneyre).

The IEA examined the economic implications of completely eliminating Indian electricity subsidies? Using 1999-2000 data, they estimated the full cost-of-supply reference price amounted to 93% for agriculture and 58% for households (Audinet & Verneyre). They also concluded that a complete removal of electricity subsidies, especially for agriculture, would lead to a significant reduction in electricity consumption, and the derived demand for oil and coal from power plants would drop by

40%. The IEA study also suggested that an additional removal of certain coal subsidies would lead to a 105 million ton reduction in carbon dioxide emissions (See Appendix A for more details on the IEA study).

These results suggest a move to removing subsidies may be a sound policy agenda to pursue, however, one-third of India's population lives below the poverty line and subsidies might play to role of propping up the income of poor households. However, according to, Briscoe and Malik in the "Oxford Handbook of Water Resources in India", the way subsidies are being delivered often fails to truly help the poor. Raising prices by removing subsidies and creating a more competitive market would likely bring about two negative effects. First, consumers that cannot afford the price may be unable to access commercial energy. Second, in the future additional investments would most likely concentrate on profitable market segments, thus limiting access for credit constrained citizens. Some other benefits include improvements in health and hygiene through refrigeration and water heating, advantages of electric lighting, an increase in workers' productivity, and the narrowing of social gaps.

Perhaps the Indian government does not need to remove the subsidies but merely target the portion of the population that needs the most financial support. It is important to be able to identify the direct costs of a subsidy, and cross-subsidies can be very unclear in this respect, so direct government financing is usually recommended. *Ad hoc* subsidy schemes have been created by public utilities and private investors in developing countries at the request of local authorities or in response to political pressures. An example of this is the progressive electricity tariff (social tariff) that has been used in developing countries like Vietnam, South Africa and Cambodia. The underlying idea is to charge larger and typically affluent consumers a higher price than the smaller farmers through a system of cross-subsidies with the hopes that the utility will recover the cost of delivering the electricity service. However, it is often the case that electricity prices are set too low to recover costs and therefore an additional system of cross-subsidies is needed which puts the burden on industrial or commercial users (Briscoe & Malick). These schemes ultimately impose a financial burden on the utility and encourage consumers to remain in the lower-consumption groups. In 1998, the Indian government launched a project called the Kutir Jyothi Yojna program ("light for small houses"), which states that SEBs must connect households under the poverty line. The SEB's provide grants up to 1,000 rupees per connection with the installation of a meter. Sadly, the program has not been successful due to difficulties identifying eligible households and by the SEB's severe financial problems.

Dossani and Ranganathan conducted a study using survey data from Andhra Pradesh, India to analyze farmer's willingness to pay for power. Their research concludes that 81% of the farmer's marginal willingness to pay for power is currently at zero, despite subsidies averaging around 88.9% of costs. However, the wealthiest group of farmers makes up the other 19%, and they are willing to pay up to 51% more for power. Since this wealthy group is responsible for 40.6% of the total revenue, a discriminatory pricing strategy which increases the price they pay for power by 50% would raise state revenues by 20.3%. However, farmer's cost-to-income ratios average around 135% which could be the result of exceedingly low prices having caused overexploitation of unproductive land (Dossani & Ranganathan).

A recent study by V. Ratna Reddy analyzed three separate farming villages in India which represent good, average, and scarce groundwater statuses. In these villages, household income is dependent on the status of groundwater since the primary livelihood activity is cultivation and the main source of irrigation is wells. For purposes of analysis, the villages were split up into groups depending on the size of the farms, i.e. large, medium, and small/marginal farms. A major finding in this study is the smaller farms bear almost the entire burden arising from water scarcity. These farms have to dig the most wells and have to bore deeper into the ground in order to reach the low water table. This requires higher horse-power engines and much more time, which on a per acre basis, causes very high operating costs. The smaller farms also have the largest amount of dry wells. The "good" water status village is in such a position mainly due to its percolation tank. Percolation tanks are structures that recharge ground water, and dramatically reduce the probability of depletion. This tank seems to be crucial to water sustainability.

There is another problem in that the prominent farmers in India seem to have more access to working wells in areas with higher water tables. This creates inefficient and unequal markets where struggling farmers purchase water from affluent farmers. Since water is essentially free, the farmers with wells are making excess profits at the expense of the government, the environment and their fellow village farmers.

Paddy, or rice, has been the predominant crop harvested in India. However, the crop is highly dependent on irrigation (Reddy). Therefore, recent shortages in water have forced farmers to switch to less water intensive crops or suffer severe losses due to decreased yield and continued ground-water depletion. Many farmers are set in their ways and still feel that paddy is the most profitable crop, which currently appears to be true. Gingelly, similar to sesame, the second most preferred crop, has comparable cost-return ratios, but is not quite as remunerative. It appears that paddy will remain popular until something drastically changes. Perhaps some type of incentive is needed that would convince farmers to switch to dry crops or at least a combination of the two.

2. EMPIRICAL MODELS

2.1 Basic Conceptual Model

Let $y \in \Re_+$ denote the level of rice produced by each household and let $\mathbf{x} \in \Re_+^N$ denote a vector of N inputs with x_i representing the level of input-i used to produce y. The farmer's technology is given by the set:

$$T = \{(\mathbf{x}, y) : \mathbf{x} \in \mathbb{R}_+^N \text{ can produce } y \in \mathbb{R}_+\}$$

We assume T satisfies free disposability of input and outputs, which means households can choose not to use all of an available input. Given free disposability, consider the production function

(1) $$f(\mathbf{x}) = \max_y\{y: (\mathbf{x}, y) \in T\}$$

Here, $\mathbf{x} = (\mathbf{x}_{\mathrm{V}}, \mathbf{x}_{\mathrm{F}})$: $\mathbf{x}_V = (x_1, x_2, \dots, x_V)$ represents a vector of variable inputs and $\mathbf{x}_F = (x_{V+1}, x_{V+2}, \dots, x_N)$ represents a vector of fixed inputs.

Let p represent output price and $\mathbf{w} = (x_1, x_2, \dots, x_V)$ represent the vector of input prices corresponding to the variable inputs. Given the technology (1), rent to land and other household assets is defined as

$$\Pi(p, \mathbf{w}, \mathbf{x}_F) \equiv \max_{\mathbf{x}_V}\{py - \mathbf{w}\mathbf{x}_V: f(\mathbf{x}) \geq y\}$$

If $f(\mathbf{x})$ is a Cobb-Douglas production function, the rental function is continuous in input and output prices, and continuous in fixed inputs $\mathbf{x}_F$. Furthermore, a well behaved rental function will be increasing in p and $\mathbf{x}_F$, decreasing in w, and satisfy Hotelling's lemma.

2.2 *Model I – Cobb-Douglas Production Function*

In this study, the empirical analogue of $f(\mathbf{x})$ is the Cobb-Douglas production function:

$$f(\mathbf{x}) = \alpha_0 \prod_{i=1}^{N} x_i^{\alpha_i}$$

where α_i are production parameters. This function is twice continuously differentiable, and to be consistent with profit maximization or cost minimization, $f(\mathbf{x})$ must also be non-decreasing and strictly concave in each input. One implication of these restrictions is the marginal product of $f(\mathbf{x})$ is positive, and decreases with increased applications of the varying input – diminishing returns to each factor. A sufficient condition for f being nondecreasing and strictly concave is for $\alpha_i \in (0,1), i = 1, \dots, N$.

One of the reasons for appealing to the production function, is it lets us impose restrictions (translation) on the technology that ensure an estimated production technology is well behaved. The estimated technology can then be used to calculate economic values of interest like the marginal value product of an input. Or, as in the case examined here, one can in principle, calculate the rent a farmer would lose if electricity subsidies were removed.

2.3 Model II - Piecewise Linear Technology / DEA

As noted in the prior section, the parametric, Cobb-Douglas approach implicitly assumes farmers are optimizing agents. To allow for non-optimizing behavior, we now consider the non-parametric, piecewise linear (PL) technology:

$$T = \left\{(\mathbf{x}, y) \colon \sum_{j=1}^{J} \lambda^j y_j > y\,, \sum_{j=1}^{J} \lambda^j x_{i,j} < x_i\,, i = 1, \ldots, N, \lambda^j \geq 0, \sum_{j=1}^{N} \lambda^j = 1\right\}$$

We employ data envelope analysis (DEA), a linear programming methodology, to identify the profit maximizing input-output combinations as a function of fixed demand and water endowments and exogenous input and output prices. By varying well water price, we can uncover the well water demand function of each (well access) farmer, and measure the implicit impact of changing subsidy levels on water price and farmer rent.

Finally, to indentify the well water demand curve for each well access farmer, we increase well water price in 0.25 rupee increments, and observe the corresponding input demand response for each farmer.

3. DESCRIPTION OF THE DATA

To estimate the underlying production technology, we use a set of 1998 survey data from Tamil Nadu, India. Out of the 30 districts in the state, 11 are tank intensive: of these districts, four southern districts -- Madurai, Sivaganga, Ramnad and Virudhunagar -- were selected for the study, as they are homogeneous in terms of soil, crops and rainfall and tank water storage patterns. The block in each district with the highest concentration of tanks was selected and from the list of tanks in the block, five tanks were randomly selected. Of the total number of farmers in the selected five tanks, 10 percent formed the sample for the study. Accordingly 226 farms were selected randomly. The farmers were further post stratified according to the possession of wells which is also an indication of credit availability.

Of the 226 farms, 58 supplemented their tank water supplies with well water. We focused on the following variables: (i) cultivated area of farm (acres); (ii) human labour (in man-days) which included the number of male and female labourers used in rice production; (iii) fertilizer, manure, chemical and pesticide applications; (iv) total cubic meters of tank water used; and (v) total well water used (in cubic meters), with quantity approximated by the number of hours of pumping and pump size. The volume of tank water used was calculated by multiplying the irrigation depth by the area of the rice field, with irrigation depth measured by inserting marked stakes in the farmer's field during different irrigations.

Table 1 shows the production and net rent characteristics of the sample farmers. Yield per acre is larger for the farms with well access, with an average rice yield of 1,899.0 kg per acre. Farmers having no well access had an average yield of 1468.6 kg per acre. As for input use, farmers with well access had a tendency to use more labour per acre than farms without well access. Seed, chemical fertilizer and manure use per acre were higher among no-well farmers. Well access farmers were able to allocate 20 percent more water to their paddy fields than the counterparts without well access. Combining water from wells and tanks, well-access farmers utilized over 2.7 times as much water per acre than farmers without well. Actual profit (i.e., land and tank-water rent) per acre is 40 percent larger for well access farmers.

Table 1 – Descriptive Statistics

	Well				No Well			
	Average	Max	Min	SD	Average	Max	Min	SD
production (kg)	5,732.5	41250	990	6,036.8	2,536.4	1,4400	240	2,263.2
rice area (acres)	3.1	25	0.5	3.4	1.9	15	0.2	1.7
yield (kg/acre)	1,899	3,300	594	617	1,468.6	3,173.3	300	652
price (Rs/kg)	5.26	0.65	4.17	7.11	5.11	0.65	3.57	7.04
labour (days/acre)	70.7	204	7.8	35.5	62.4	158.9	7	27.5
price (Rs/day)	42.5	0	0	42.5	42.5	0	0	42.5
seed (kg/acre)	33.4	50	20	6.1	34.7	65	16	7.8
price (Rs/kg)	11.09	1.85	7.5	20	10.56	2.01	5	20
N (kg/acre)	34	134	0	26.7	37.1	115.3	3.7	25.3
price (Rs/kg)	10	0	10	10	10	0	10	10
P (kg/acre)	18.6	92	0	14.1	19.7	92	0	13.9
price (Rs/kg)	18.75	0	18.75	18.75	18.75	0	18.75	18.75
K (kg/acre)	7.5	40	0	8.6	7.6	80	0	10.5
price (Rs/kg)	7.25	0	7.25	7.25	7.25	0	7.25	7.25
manure (kg/acre)	1,256.6	6,000	0	1,550.3	1,468.7	12,000	0	2,203.5
price (Rs/kg)	0.26	0	0.26	0.26	0.26	0	0.26	0.26
chemicals (Rs/acre)	74.9	320	0	75.1	78.1	360	0	81.6
tank water: m³/acre	4,282.8	12,000	0	2,451.6	3,502.4	12,800	640	19,88.1
well water: m³/acre	5,290.9	38,400	100	7,129.2	0	0	0	0
profit (total Rs)	14,040	15,2358	-8,509	2,2524	54,32.3	49,881	-4,953	8,067.5
profit (Rs/acre)	3,749.2	12,468	-7,293	3,999.4	26,96.3	11,596	-6,604	3,017.2
# tank irrigations	11.1	30	0	6.3	10.3	34	2	5.5

The data used for our analysis, is household survey data collected by A. Sakurai. The data consists of 226 observations of rice farming households in Tamil Nadu, India, which gives us a one year snapshot of their crop production in the year 1996. The data provide us with values for each households rice yield (kg) for the year, how many acres each farmer owns, and the amount of human labor days used to produce the crop. It also tells us the various other inputs used in the process, such as potassium (K), phosphorus (P), manure and chemicals. Perhaps the two most important values are tank water use and well water use. With these data, we are able to tell how much water was used to produce the rice crop and whether or not the farmer has access to a well. Table 3 below shows the mean, median, maximum, minimum and standard deviation for each of the above mentioned variables. The average rice crop yield per farmer is 1,902.50 kg with a maximum of 41,250 and minimum of 240 kg. Most of the farms have an approximate size of 1.5 to 2 acres and the households use on average 8,586.67 cubic meters of tank water. The average amount of well water used by each farmer is approximated at 2,140.51 cubic meters, however 168 of the farmers do not have access to wells, therefore the observations for these households would all have values of zero. The median quantity of well water used for all farmers with well access is 8,340.61 cubic meters per household, with a maximum of 44,800.00. The average amount of labor days paid for in a year equates to 121.60 with a minimum of 18.43 days and a maximum of 591.86.

Table 2 – Input & Output Statistics

	Output	Acres	Labor	P	K	Manure	Tank Water	Well Water
Mean	3,193.97	2.19	121.60	31.75	14.93	2,028.86	8,586.67	2,140.51
Median	1,902.50	1.50	85.74	23.00	8.50	600.00	5,500.00	0.04
Max	41,250.00	25.00	591.86	186.50	154.00	12,500.00	90,000.00	44,800.00
Min	240.00	0.20	18.43	0.00	0.00	0.00	0.03	0.00
Standard Deviation	3,685.81	2.30	102.15	26.57	20.95	2,595.57	11,707.76	8,995.17

The data also contain the associated input prices for each of these variables. The land rental value is fixed at 2,200 rupees/acre in the region of Tamil Nadu that was surveyed. The price of labor, phosphorus, potassium and manure are also fixed as you can see in Table 4 below. Both of the prices associated with the water variables are however, not fixed. The average tank irrigation fee is 38.98 rupees per year and the average well irrigation cost is at 308.04 rupees per year. The price farmers are receiving for their rice can range from 1.00 to 7.11 rupees per kilogram.

Table 3 – Price Statistics

	Output Price (paddy)	Land Rental Value (rupees/ acre)	Price of Labor	Price P	Price K	Manure Price	Tank Fee	Well Costs
Mean	5.12	2,200	42.50	18.75	7.25	0.26	38.98	308.04
Median	5.17	2,200	42.50	18.75	7.25	0.26	37.06	0.00
Max	7.11	2,200	42.50	18.75	7.25	0.26	98.70	4,500
Min	1.00	2,200	42.50	18.75	7.25	0.26	0.00	0.00
Standard Deviation	0.70	0.00	0.00	0.00	0.00	0.00	16.85	741.38

4. ECONOMETRIC RESULTS

4.1 *Cobb-Douglas Results*

Using OLS regression techniques, we have come up with the following Cobb-Douglas estimation results. The function used is as follows:

$$Y_j = (\alpha_0 + D_j) \prod_{i=1}^{6} x_{i,j}^{\alpha_i} \qquad (2)$$

where:

Output (kg) = Y
Rice Area (acres) = x_1
Human Labor (days) = x_2
nitrogen (kg) = x_3
K (kg) = x_4
Pesticide (kg) = x_5
Total water (m^3) = x_6
Dummy (well = 1) = D
Error term = ε_i

Table 4 presents the results of an ordinary least squares estimation of the parameters in equation (2). The R^2 is equal to 0.77, and all but the K coefficient was statistically significant at the 99% level: that coefficient was significant at an 89% level. The factor coefficients sum to 0.954, suggesting the farmers could, on average, increase output if they had more land to work with.

Table 4 – OLS Estimation Results

Parameter	Parameter Estimate	Standard Error	t Value
α_0	4.2306*	0.3896	10.86
α_1	0.3752*	0.0672	5.58
α_2	0.2347*	0.0641	3.66
α_3	0.1329*	0.0308	4.32
α_4	0.0104**	0.0064	1.63
α_5	0.0194*	0.0053	3.63
α_6	0.1972*	0.0453	4.35

Results Created in STATA © statistical analysis software

*Statistically significant at the 99% level

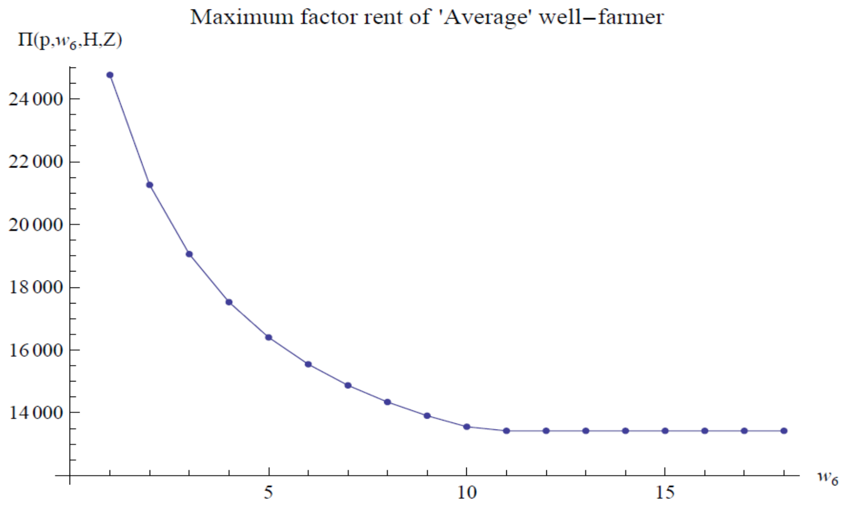
** Statistically significant at the 89% level

Given the output price, well water price, and tank water endowment, the restricted profit function associated with the parameter estimates in table 4 is

$$\Pi(p, w_6, H) = \frac{108.416p^{2.4676}}{(\mathrm{w}_6)^{0.4866}} + \mathrm{w}_6 H$$

Given an average farm size of 2.1 acres, rice price equal to 6.1 Rupee per kg, and tank water endowment of 8,586 m^3, predictions of farmer rent began at 28,520 Rupee when electricity was fully subsidized (well water about 0.1 Rupee per cubic meter) and fell to about 16,700 Rupee when the subsidy was decreased by about 53 Rupee per KWH, at which point well water demand was driven to zero. This is equivalent to a 41% fall in farmer income (see graph 1 below).

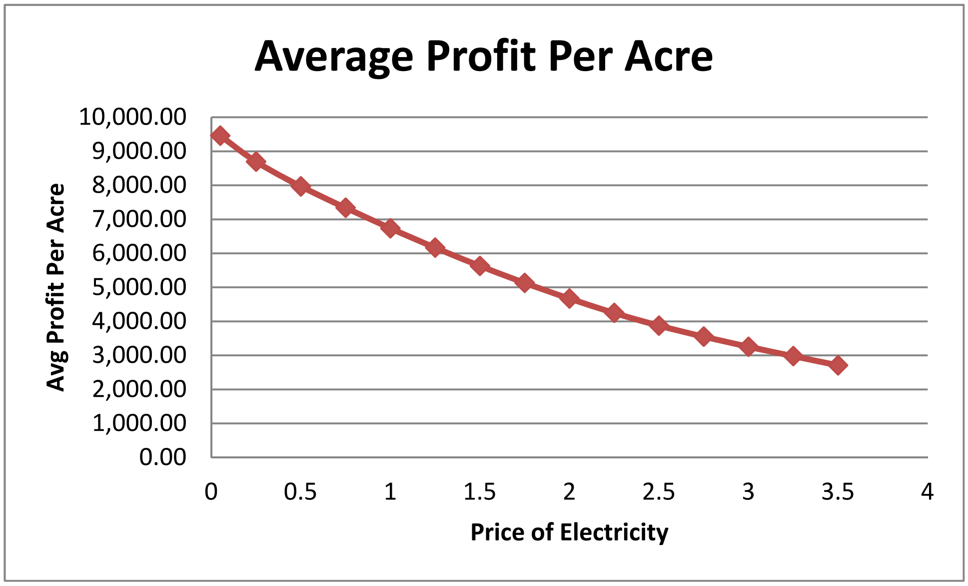
Graph 1



4.2 *Data Envelope Analysis Results*

Although only well access farmer data was used here, the linear programming analysis produced similar results to the Cobb-Douglas specification. Total profit per acre started out at 9,458 Rupees when the price of electricity was 0.05 Rupees per cubic meter and dropped to 2,706 when we increased the electricity price to 3.5, which is a 71% decrease in average profit by acre. Total profit per acre started at 482,335 rupees and dropped to 138,012. Below is a graph showing the steady decrease in average profit per acre as the electricity subsidy is incrementally reduced.

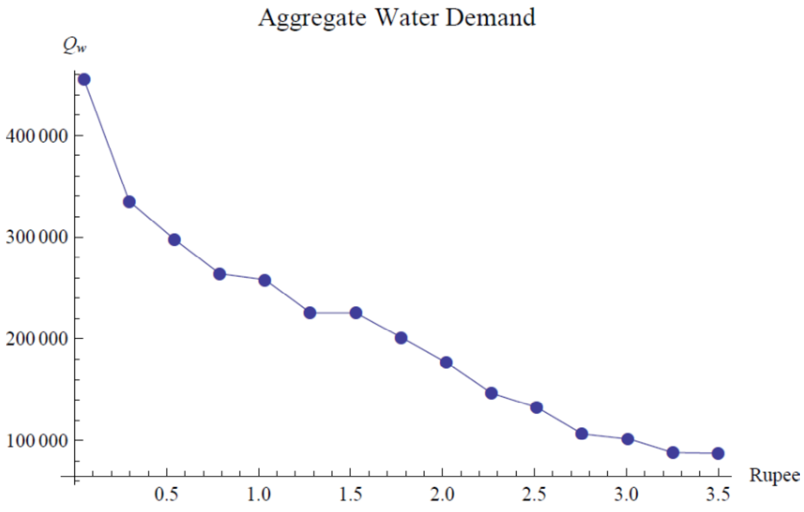
Graph 2



Of the 58 well access farmers, five of them actually experienced a negative profit when the price of electricity increases to 3.5 rupees per cubic meter. These five households would likely look at other forms of generating household income or revise their farming technology.

Aggregate water demand decreased rapidly when increasing the price of electricity in .25 Rupee increments. At the current subsidized rate where farmers pay approximately 0.05 Rupees per cubic meter, the aggregate water demand was 455,390 cubic meters for well access farmers. Aggregate water demand dropped by 42% or 263,976 cubic meters only after increasing the price of electricity to 0.75. At the completely unsubsidized rate of 3.5 rupees, water demand dropped to 87,497 cubic meters, a staggering 81% decrease (see Graph 3 below).

.**Graph 3**



Looking at an individual household’s rent, however, reveals that for some endowments, per unit increase in electricity price of 55 Rupee leads to a 34% drop in land-water rent.

5. CONCLUSION

Electricity subsidies in India have been in existence since the late 1970’s and the suggested effects of these subsidies vary. Some believe the subsidies harm industrial users in order to benefit those using electricity to pump water for farming. Although one of the primary reasons subsidies exist is to give aid to credit constrained households, others believe the subsidies to cause pollution and over-exploitation of the already scarce natural resource known as water. However, research relating to the impacts of removing subsidies on electricity used for crop irrigation in India is limited. This paper used data from 226 farming households located in a state called Tamil Nadu in Southeastern India. The results of both the OLS Cobb-Douglas estimation and a non-parametric analysis of profit, suggests that by charging subsistence farmers in Tamil Nadu, India, the full price of electricity used to pump water, their agricultural income will decrease significantly. Also, as the price of electricity increased in 0.25 rupee increments, profit decreased for each farmer every step of the way – suggesting limited input substitution opportunities for these farmers.

A close look at the behavioral changes amongst these farmers shows an overall decrease in the quantity of water used for irrigation as the electricity prices increased, but it would be difficult to suggest that this benefit outweighs that of the drastic profit reductions. In summary, our analysis suggests that removing the current subsidy placed on electricity used to pump water for rice crop irrigation in Tamil Nadu, India would result in significantly reduced subsistence farmer income, with some of these reductions being severe. Given this result, one might question the wisdom of removing fully, electricity subsidies to agricultural households.

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Appendix

A. IEA Study on Subsidy Removal

A big challenge policy makers run into is accurately anticipating the overall cost of the subsidy mechanism. Some believe that access by the poor to electricity must be addressed by instruments of social policy rather than electricity pricing, and the state budget has to make up for what the poor cannot afford. The IEA attempted to estimate the direct cost of demand-side support to electricity access and the following depicts their process and results.

First, the assumption made was that the government will give poor households a lifeline system, which covers the consumption of a fixed monthly quantity of power as well as the actual connection to the grid. Next they assumed that the average low-income household in an urban area of India was approximately 50 kWh per month. Then they asked, "What would be the total cost of such a system?" There are two main components involved in providing a targeted population with electricity. The first component is connection cost, through either the central or local grid {C}, which is a non-recurrent expenditure. The second is the cost of poor households' daily consumption of power {E}, which is a recurrent expenditure. As for how the money will be provided, it could be directly to the service provider or to the final consumer (deducted from the monthly electricity bill). The total cost of the subsidy will be {C} + {E} where: {C} = (C * P) / H and {E} = (S * P) / {H * (K*(1-B))} with:

C = average connection cost (per household)

E = cost of poor household's daily consumption of power

H = number of persons per household

S= marginal supply cost of power for residential consumption

P = estimated poor population

K = chosen lifeline consumption level

B = fixed chosen percentage of electricity billed and paid for

{E} is based on a simple lifeline rate system and consumers are billed for their electricity according to the marginal cost, but this does not include recipients with consumption below the chosen lifeline level as they are charged a fixed proportion of the actual marginal production cost of the electricity service. This strategy gives management of the transfer to households and it avoids giving away the service which could lead to exploitation. The cost of supply for household consumption was estimated at 3.4 rupees per kWh, and the assumption was made that one third of existing customers and half of the additional households connected each year will benefit from the lifeline rate. The price charged to this category will be one rupee per kWh, and an estimated four million households will be connected each year. With all of these assumptions, the maximum direct expenditure to be borne by the economy per year would be 44.7 billion rupees or approximately 1.1 billion U.S. dollars: 28 billion rupees for poor households' consumption and 11 billion rupees for new connections. Again, this is considered the maximum since it is based on the assumption that each household consumes their 50kWh per month, and actual average consumption would more than likely be lower.

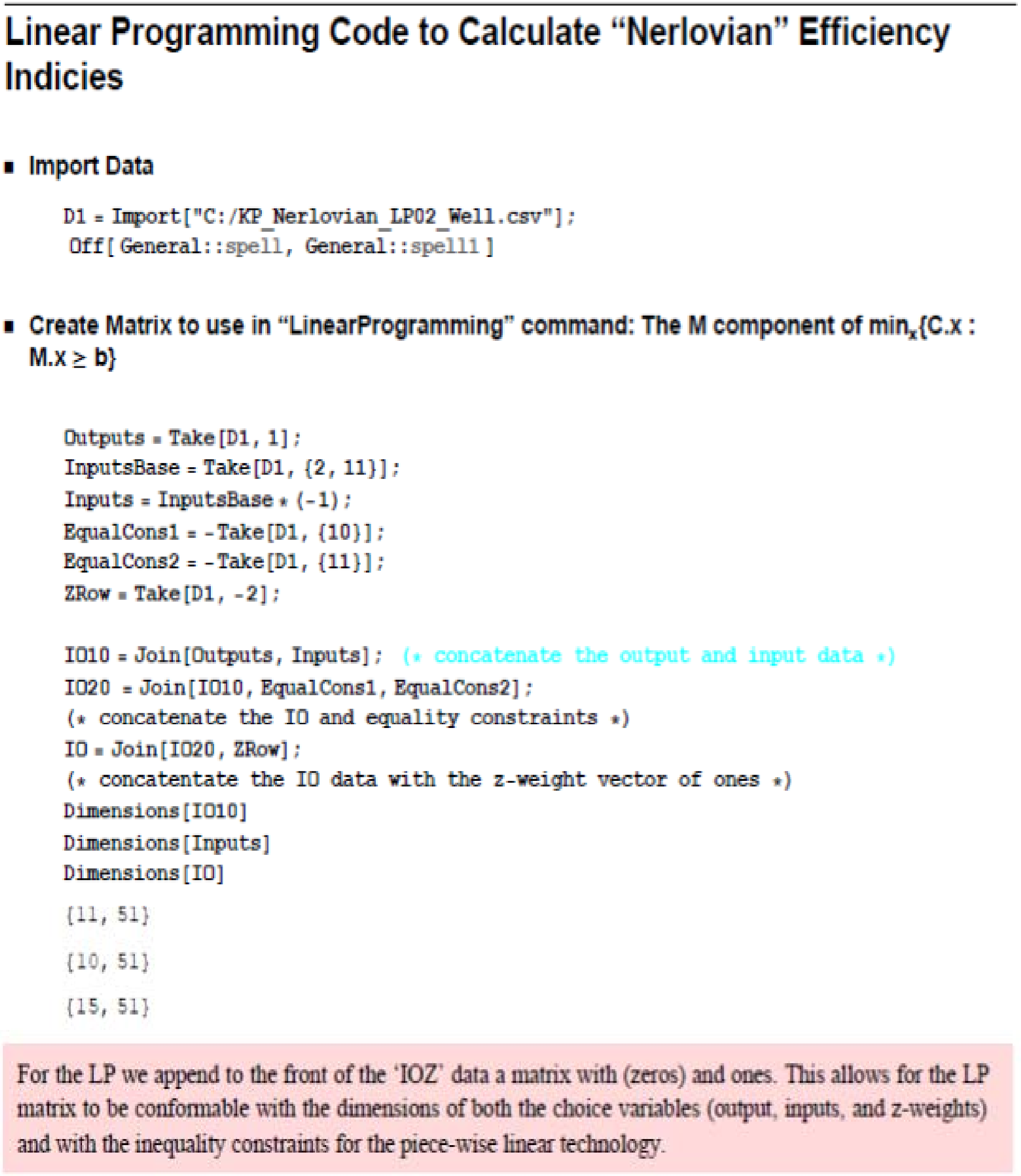
As an end result, the IEA estimated that the direct expenditure or cost of this support mechanism would be at least four to five times less than the current cost of subsidies for electricity consumption, which amounts to 187 billion rupees or 4.5 billion U.S. dollars (Audinet & Verneyre). *SEE TABLE 2 BELOW FOR A SUMMARY OF THE DATA USED.*

Data Used In IEA Estimation

Indian Population (millions)	980
Number of households (millions)	163
Households living in electrified zone (%)	90
Number of household living in electrified zones (millions)	147
Domestic Customers (millions)	70
Domestic customers in the total number of households (%)	43
Overall domestic consumption (TWh)	59
Average annual observed consumption (kWh)	846
Distribution lines 500 kV and under (km)	3,108,830
Meter cost: purchase + installation for 1 phase electromagnetic kWh in rupees	583
Connection cost per customer (rupees)	2,783
Assumptions:	
Number of persons per household	6
Length of line to be installed per new customer (m)	20

Sources: CEA, 1998a; CMIE, 2001; IEA, 1999; RSEB, 1999 and IEA calculation.

B. Linear Programming Methematica © Code



Linear Programming Code to Calculate “Nerlovian” Efficiency Indicies

- **Import Data**

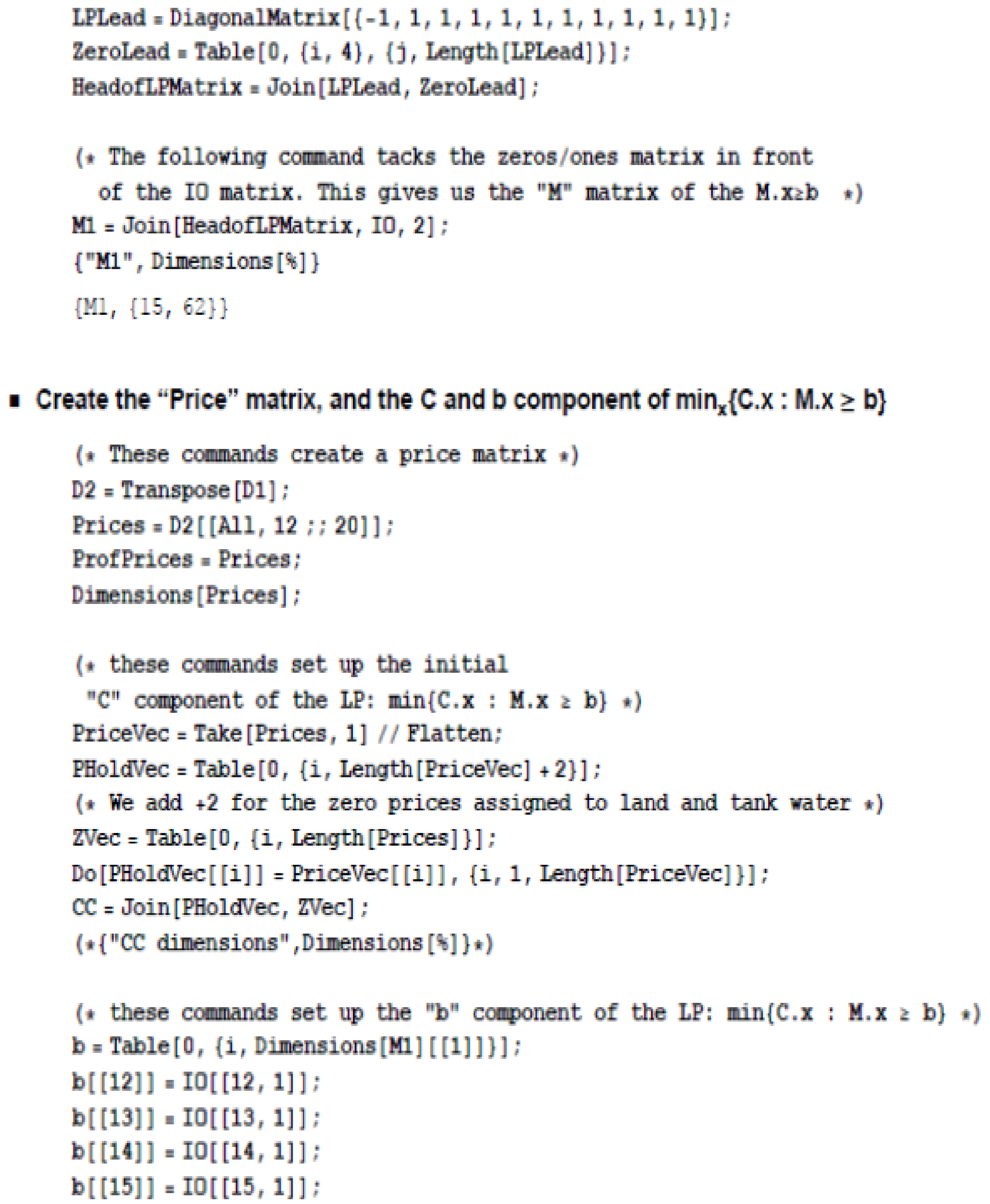
```
D1 = Import["C:/KP_Nerlovian_LP02_Well.csv"];
 Off[ General::spell, General::spell1 ]
```

- **Create Matrix to use in “LinearProgramming” command: The M component of min$_x${C.x : M.x ≥ b}**

```
Outputs = Take[D1, 1];
InputsBase = Take[D1, {2, 11}];
Inputs = InputsBase * (-1);
EqualCons1 = -Take[D1, {10}];
EqualCons2 = -Take[D1, {11}];
ZRow = Take[D1, -2];

IO10 = Join[Outputs, Inputs]; (* concatenate the output and input data *)
IO20 = Join[IO10, EqualCons1, EqualCons2];
(* concatenate the IO and equality constraints *)
IO = Join[IO20, ZRow];
(* concatentate the IO data with the z-weight vector of ones *)
Dimensions[IO10]
Dimensions[Inputs]
Dimensions[IO]
```

```
{11, 51}

{10, 51}

{15, 51}
```

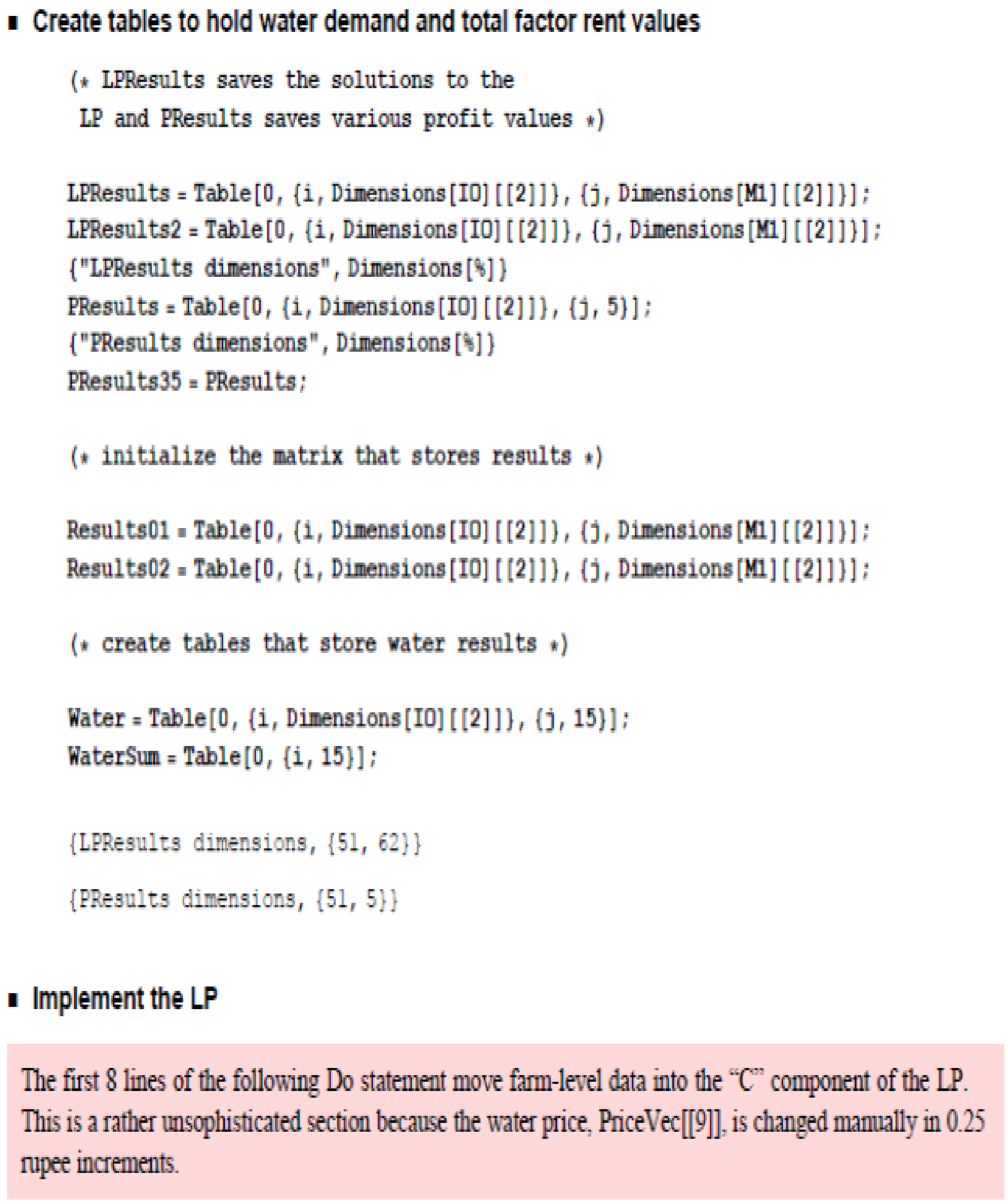
For the LP we append to the front of the ‘IOZ’ data a matrix with (zeros) and ones. This allows for the LP matrix to be conformable with the dimensions of both the choice variables (output, inputs, and z-weights) and with the inequality constraints for the piece-wise linear technology.



```
LPLead = DiagonalMatrix[{-1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1}];
ZeroLead = Table[0, {i, 4}, {j, Length[LPLead]}];
HeadofLPMatrix = Join[LPLead, ZeroLead];

(* The following command tacks the zeros/ones matrix in front
  of the IO matrix. This gives us the "M" matrix of the M.x≥b  *)
M1 = Join[HeadofLPMatrix, IO, 2];
{"M1", Dimensions[%]}
{M1, {15, 62}}
```

Create the “Price” matrix, and the C and b component of $\min_x\{C.x : M.x \geq b\}$

```
(* These commands create a price matrix *)
D2 = Transpose[D1];
Prices = D2[[All, 12 ;; 20]];
ProfPrices = Prices;
Dimensions[Prices];

(* these commands set up the initial
 "C" component of the LP: min{C.x : M.x ≥ b} *)
PriceVec = Take[Prices, 1] // Flatten;
PHoldVec = Table[0, {i, Length[PriceVec] + 2}];
(* We add +2 for the zero prices assigned to land and tank water *)
ZVec = Table[0, {i, Length[Prices]}];
Do[PHoldVec[[i]] = PriceVec[[i]], {i, 1, Length[PriceVec]}];
CC = Join[PHoldVec, ZVec];
(*{"CC dimensions",Dimensions[%]}*)

(* these commands set up the "b" component of the LP: min{C.x : M.x ≥ b} *)
b = Table[0, {i, Dimensions[M1][[1]]}];
b[[12]] = IO[[12, 1]];
b[[13]] = IO[[13, 1]];
b[[14]] = IO[[14, 1]];
b[[15]] = IO[[15, 1]];
```



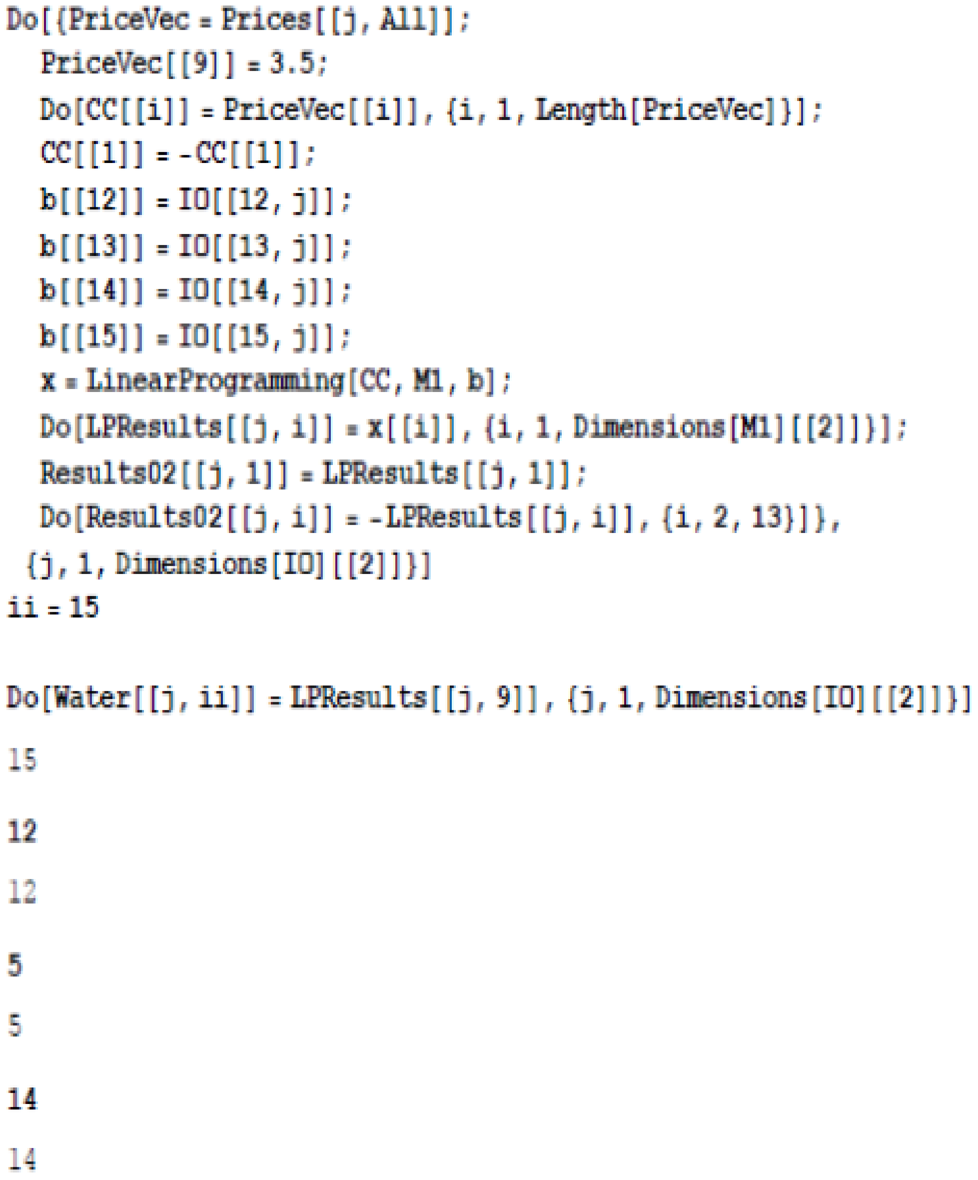
▪ Create tables to hold water demand and total factor rent values

```
(* LPResults saves the solutions to the
 LP and PResults saves various profit values *)

LPResults = Table[0, {i, Dimensions[IO][[2]]}, {j, Dimensions[M1][[2]]}];
LPResults2 = Table[0, {i, Dimensions[IO][[2]]}, {j, Dimensions[M1][[2]]}];
{"LPResults dimensions", Dimensions[%]}
PResults = Table[0, {i, Dimensions[IO][[2]]}, {j, 5}];
{"PResults dimensions", Dimensions[%]}
PResults35 = PResults;

(* initialize the matrix that stores results *)

Results01 = Table[0, {i, Dimensions[IO][[2]]}, {j, Dimensions[M1][[2]]}];
Results02 = Table[0, {i, Dimensions[IO][[2]]}, {j, Dimensions[M1][[2]]}];

(* create tables that store water results *)

Water = Table[0, {i, Dimensions[IO][[2]]}, {j, 15}];
WaterSum = Table[0, {i, 15}];
```

```
{LPResults dimensions, {51, 62}}

{PResults dimensions, {51, 5}}
```

▪ Implement the LP

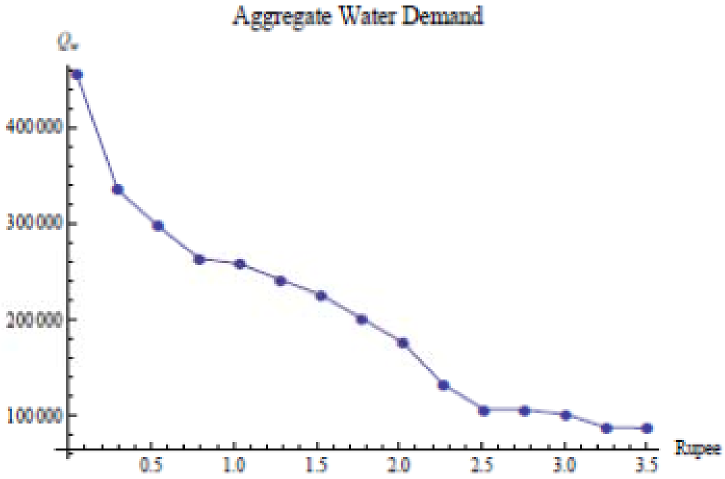
The first 8 lines of the following Do statement move farm-level data into the "C" component of the LP. This is a rather unsophisticated section because the water price, PriceVec[[9]], is changed manually in 0.25 rupee increments.



```
Do[{PriceVec = Prices[[j, All]];
  PriceVec[[9]] = 3.5;
  Do[CC[[i]] = PriceVec[[i]], {i, 1, Length[PriceVec]}];
  CC[[1]] = -CC[[1]];
  b[[12]] = IO[[12, j]];
  b[[13]] = IO[[13, j]];
  b[[14]] = IO[[14, j]];
  b[[15]] = IO[[15, j]];
  x = LinearProgramming[CC, M1, b];
  Do[LPResults[[j, i]] = x[[i]], {i, 1, Dimensions[M1][[2]]}];
  Results02[[j, 1]] = LPResults[[j, 1]];
  Do[Results02[[j, i]] = -LPResults[[j, i]], {i, 2, 13}]},
 {j, 1, Dimensions[IO][[2]]}]
ii = 15

Do[Water[[j, ii]] = LPResults[[j, 9]], {j, 1, Dimensions[IO][[2]]}]

15

12

12

5

5

14

14
```

- **Water demand summary and plots**

```
Do[WaterSum[[i]] = Sum[Water[[j, i]], {j, 1, 50}], {i, 1, 15}]
xx = {0.05, 0.25, 0.50, 0.75, 1.0,
   1.25, 1.50, 1.75, 2.0, 2.25, 2.50, 2.75, 3.0, 3.25, 3.5};
ListPlot[WaterSum, DataRange → {0.05, 3.5}, AxesOrigin → {0, 65000},
 AxesLabel → {Rupee, Qw}, PlotMarkers → {Automatic, Small},
 {Joined → True}, PlotLabel → "Aggregate Water Demand"]
```



```
WaterSum
```

```
{455390., 335182., 297699., 263976., 258165., 241762., 225595.,
 201493., 176727., 132592., 106775., 106775., 101892., 88183.1, 87497.4}
```

- **Calculate, farm-level, unrestricted and actual profit**

```
ProfPrices005 = ProfPrices;
Do[ProfPrices005[[i, 9]] = 0.05, {i, 51}]
                             9
Do[PResults[[i, 1]] = ∑ Results02[[i, j]] * ProfPrices005[[i, j]];
                            j=1
                         9
 PResults[[i, 4]] = ∑ IO[[j, i]] * ProfPrices005[[i, j]],
                        j=1
 {i, 1, Dimensions[IO][[2]]}]
MatrixForm[PResults]
```