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Power Tariff Policy for Groundwater Regulation: Efficiency, Equity, and Sustainability*

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1. INTRODUCTION

Power tariff policy is frequently advocated as a means to influence the groundwater use and withdrawal decisions of farmers (*e.g.*, Shah, 1993). This suggestion is gaining in importance in recent years in view of the complete failure of existing well-spacing regulations implemented through credit and power connection policies and the supposed impossibility of instituting an enforceable property rights system in groundwater (Saleth, 1996). The main objective of this paper is to critically evaluate how effective is power tariff policy as an instrument of groundwater regulation based essentially on theoretical reasoning and practical considerations. In particular, it is aimed to demonstrate that the nature and magnitude of sustainability, efficiency, and equity effects of power tariff policy depend crucially on the nature and shape of the power demand curve--both individual and aggregate--that links power tariff and power consumption on the one hand and power consumption and groundwater withdrawal[1] on the other hand.

2. RATIONALE FOR POWER TARIFF AS A POLICY INSTRUMENT

The rationale for proposing power tariff as a tool for influencing groundwater withdrawal and use stems from the fact that the demand curve for power is continuous and presumably, its shape is convex throughout its entire range. Unfortunately, this assumption appears to be suspect at least for the following two reasons.

Firstly, the power demand curve is not continuous throughout its range but actually has a "kink", the exact position of which is determined, among other things, by a combination of economic, agronomic, hydrological, and even, technological factors.[2]

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[1] Since electric powered pumpsets are also used to lift water from surface water bodies like river, ponds, etc., surface water withdrawals could also be influenced by power tariff changes. To this extent, most of our arguments advanced in the context of the relationship between power tariff and groundwater withdrawal could also be generalized to the context of the relationship between power tariff and lift-based surface water withdrawal.

[2] Since these factors do not allow farmers to use power up to the point where its marginal cost and marginal value product are equalized, the farmers are forced to operate way above this marginal condition with the marginal value product of power far exceeding its marginal cost. Under such

And, secondly, if at all the farmers are responsive to tariff changes, there is a point in which they will switch to diesel pumpsets provided the groundwater table and diesel availability make such an energy switching technically and economically feasible. Notice that this kind of energy switching is certainly possible not only in the hydrologically better-endowed areas like the Indo-Gangetic and deltaic regions but also in other areas where power shortage reduces the utility of electric pumps for water lifting purposes. To the extent power tariff changes trigger energy switching, tariff changes become less effective in controlling groundwater withdrawal.

The kink in the power demand curve has important policy implications both for sustainability, efficiency, and equity in the utilisation of groundwater resources. This is so because the presence of the kink in the power demand function implies that within certain range of power tariff, power consumption (and hence, groundwater withdrawal) becomes insensitive to variations in power tariff. Obviously, the larger the size of the kink, the lesser will be the scope for making groundwater withdrawal sensitive to changes in power tariff. Therefore, in order to determine the extent power tariff policy can be effective in regulating groundwater use, it is important to determine the exact size and location of the kink in the power demand curve. While the precise size and location of the kink in the power demand function are basically an empirical issue, nevertheless, there are plausible theoretical reasons that suggest the probable region in the power demand curve within which the kink can occur.

The implications of the kink in power demand for groundwater withdrawal emerge from the fact that it also gets translated into a parallel kink in the water withdrawal curve and the accurate size and location of the latter kink depend on the exact form of the relationship between power supply and water withdrawal. Intuitively speaking, the functional form of this relationship is determined, among other things, by hydro-geological and technical factors like groundwater depth, efficiency of pumpsets, and the quality of power supply.

Apart from the problems emerging from the shape of the power demand curve, the efficacy of power tariff as an instrument of groundwater regulation is also fogged down by yet another major issue, i.e., could one instrument be sufficient enough for influencing three critical aspects of water management, *i.e.*, sustainability, efficiency, and equity, at the same time that too with the same level of effectiveness? Probably this may not be so especially when the policy instrument under consideration here has contradictory effects on the three policy goals noted above. Moreover, such contradictory effects also make the issue of trade-offs between different goals inevitable. It is often suggested to combine power rationing with the power tariff policy to maximise the effectiveness of the latter (*e.g.*, Shah, 1993). This, however, begs the following questions: could power rationing be itself effective in the first place? And, what sort of tariff structure should be considered--whether unit price or flat rate--for an effective tariff policy?

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condition, therefore, a marginal change in power tariff fails to influence power consumption and hence, water withdrawal.

3. POWER DEMAND CURVE: NATURE AND IMPLICATIONS

Consider Figure 1 depicting the possible relationship between power tariff and power use. The power demand curve so far assumed by researchers is convex and continuous as shown by the curve ACB. Under this assumption of continuity, an increase in power tariff will lead to a reduction in power consumption and hence, groundwater withdrawal. Given the assumption of convexity, a marginal increase in power tariff will have a more than proportionate reduction in power consumption in the initial stages but, as we move along the curve, each subsequent increase in power tariff brings lesser and lesser reduction in power consumption (and hence, groundwater withdrawal). That is, the convexity of the power demand curve implies that the price elasticity of the curve is more than unity initially but becomes less than unity in its upper reaches.[3]

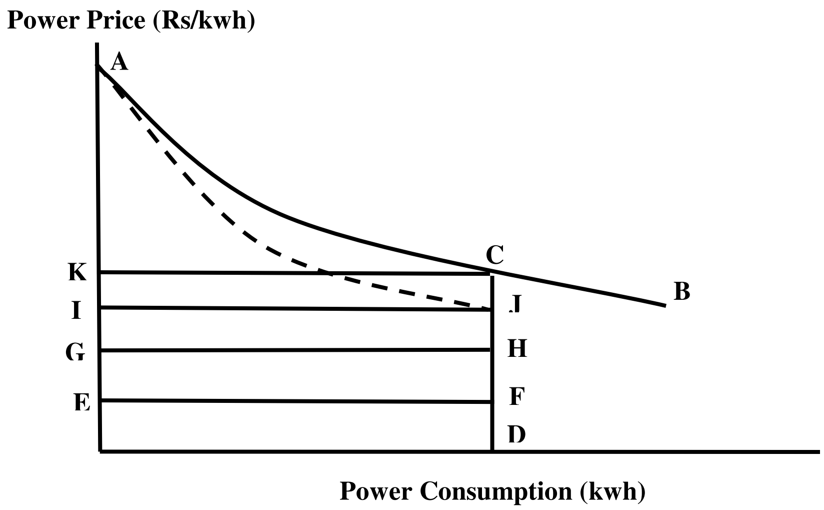

Figure 1
The Nature and Shape of Power Demand Curve

Now, the major issues before us are: what is the shape of the power demand curve—whether the curve is continuous or not in its whole range? What are the implications of this discontinuity, i.e., the presence of the kink, in the power demand curve for the efficacy of power tariff as a policy tool to influence groundwater withdrawal decisions of farmers? Returning to Figure 1, we argue that instead of the continuous curve ACB, the actual curve will be ACD with a kink at point C. The emergence of the kink is mainly due to the following two factors.

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[3] Notice that the convexity of the power demand curve emerges from the concavity evident in the relationship between power use and crop output--the latter itself emanates from the usual concave shape of the water-yield function.

Firstly, energy supply in terms of hours of power availability is fixed at the farm level.[4] That is, power supply at the farm level becomes a constraint and the farmers will tend to operate their pumps and withdraw water up to that limit provided groundwater supply in the well is not a limiting factor. Else, groundwater availability will itself determine the location of the kink.

Secondly, given the cropping pattern as determined by the relative prices of farm products, groundwater supply position, farm-specific agronomic characteristics, etc., as long as the margin between energy cost and the net value of output per unit of power is high, the farmers will not reduce power consumption unless the whole value of the additional output is appropriated as electricity charge. Consequently, with the actual power demand curve being ACD, any increase in tariff below that level (i.e., K in Figure 1) will not induce farmers to reduce power consumption and hence, groundwater withdrawal.

A closer look at the two factors noted above reveals that actually, it is the combination or interplay of both that determines the exact location of the kink in the power demand curve. If the net value, i.e., the excess of power productivity over power cost at the margin, is high, then, the first factor (i.e., power supply constraint) determines the kink. Else, the second factor (i.e., the marginal value productivity of power) has the determining role in specifying the exact location of point C.

We also note that the second factor noted above depends basically on the cropping pattern as determined by the relative output prices, groundwater conditions, farm size and farm technology, production efficiency, etc. If a high-value crop is cultivated, the marginal value product of a unit of power will be higher as compared to a low-value crop. As a result, unlike the power supply at the farm level which the farmers could not influence much, the marginal value productivity of power can be influenced to a greater extent by farmers through effective strategies (e.g., by switching to high-value crops).

4. Criteria for Power Tariff Fixation

Up to what level power price is to be increased to make it binding on farmers? There are two alternative bases for fixing power tariff under present condition. Firstly, power price can be determined based on its cost of generation and distribution. And, second, power price can be equated with that of its next best alternative, *i.e.*, diesel. Determining power tariff in terms of the supply cost of power requires clear-cut estimates of the cost of power generation and distribution.[5]

Under the first approach, we could certainly achieve full-cost pricing and ensure that the losses of the State Electricity Boards (SEBs) due to power price subsidisation are eliminated completely. But, in so far as the current power supply is maintained and the marginal productivity of power in the reckoning of farmers is still

[4] In most states, power supply for farm purpose is limited only to 4-6 hours per day.

[5] The average generation and supply cost per kilo watt hour (kwh) of power is calculated to be Rs. 1.19 during 1991-92 whereas the actual sale income realized per unit was only Rs. 0.96.

higher than the full-cost price of power, increasing tariff could not effectively control power consumption and hence, groundwater withdrawal. In this case, it is to be noted that though the farmers' share of the marginal value product of power at the margin is reduced, it is not eliminated altogether. Consequently, any increase in power tariff below the kink could not be expected to generate the much sought after sustainability effect. It needs to be recognized, however, that there will be some minimal efficiency effects to the extent higher power cost may induce farmers to use energy more efficiently through marginal improvements in watering practices leading to a higher output per unit of energy than that at present. Also, to some extent, higher power cost could lead to crop pattern shifts as the farmers will go for high-value crops so as to raise the kink above point C.

The second option for fixing power tariff based on diesel price has been suggested, among others, by Samanta, *et al*. (1982). It needs to be noted that this suggestion has been originally proposed more as a means for enhancing the revenue of SEBs than as a route for groundwater regulation. When electricity is priced in terms of the price of diesel, farmers could very well shift from electric to diesel pumps.[6] We also recognise the fact that diesel pumps have an advantage over electric pumps especially in areas with erratic power supply and load shedding problems and also in terms of their mobility especially in the context of surface water-based lift irrigation systems. But as we know, such a switching can happen only when: (a) the farmers' capital position is such as to enable them to internalise the economic loss due to either the temporary or permanent abandonment of electric pumpsets, (b) groundwater condition is such as to lend technical viability to diesel engine, and (c) the farmers owning electric pumps also have diesel pumps as a kind of standby arrangement.

One can also add here the difficulty and the associated real costs in getting adequate and timely diesel supply. In those circumstances, where the three points noted above are binding, the "switch point" between electric and diesel pumps occurs at a price level much higher than the diesel price as such.[7] If at all such a switch occurs, it will occur, therefore, at the point in the demand curve corresponding to the unit price of diesel plus an amount equal to the amortised capital loss of abandoning electric pumps. In Figure 1, this possibility has been shown by the broken curve AJ assuming I represents such an unit price. We also notice that the revised energy (i.e., diesel) demand curve has shifted downwards. Regarding the possibility for the kink to occur at J, it depends upon whether the net value point noted earlier also coincides with I or not.

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[6] Power cost-induced energy switching is not just a theoretical proposition as it has been actually observed in many parts of India. As for instance, in Andhra Pradesh when the government raised the pro rata power tariff to 0.16/kwh in 1975, many farmers have switched to diesel engines. But, in 1982, when power cost became cheaper with the adoption of the flat rate of Rs. 50/horse power (HP)/year, most of these farmers have decommissioned their diesel engines (see Shah and Raju, 1988).

[7] The switch point price is higher than diesel price as the former has also to account for the economic loss from the abandonment or non-use of electric pumps and structures.

What are the sustainability, efficiency, and equity effects of power tariff being fixed at the diesel price? Naturally, there will be a tendency among farmers to switch to diesel pumps, of course, within the financial and technical constraints noted above. When farmers rely exclusively on diesel pumps, it has been observed that farmers normally use less number of irrigation than the case when electric pumps are used for irrigation. There will also be a tendency among farmers relying on diesel pumpsets to better utilise available soil moisture through conjunctive use of rain/surface water with the available groundwater. This does not necessarily and exclusively reflect that farmers are cost-conscious. One should also consider here the phenomenon of a kind of "credit card effect" as farmers have to spend out-of-pocket every time they buy diesel as well as to go through the trouble of obtaining and transporting diesel. Such is not the case with electricity even when it is priced at diesel price as the farmers do not feel the pinch immediately.

Although tariff fixation based on the price of diesel will certainly have some efficiency effects both in terms of energy and water use, it can, nevertheless, foment some unfavourable equity and welfare effects both across farms as well as across geographical regions. The adverse impacts of diesel price-based power tariff on small and marginal farmers' income and access to groundwater especially in water scarce regions hardly need any elucidation. While farmers in the hydrologically better-endowed regions can go for diesel pumps, farmers in the hard-rock regions could not easily go for such an energy switch mainly due to the technical infeasibility of installing diesel pumps as there is a physical limit beyond which diesel pumps may not have efficient discharge. This is not to deny, however, the use of heavy duty diesel pumps in hardrock areas with no or erratic power supply.

The diesel pump option is also ruled out completely in regions where submersible pumps are being used which, under current pumping technology, are essentially electricity-based. From the point of view of groundwater sustainability, diesel price-based power tariff cannot have much effect as long as power price is still inadequate to appropriate fully the marginal value productivity of power. Moreover, given the practice of using diesel pumps as stand-by, the sustainability implication of even power rationing gets diluted substantially. In all contexts where diesel pumps are used either as a stand-by or as an exclusive arrangement, even the use of a policy based on a combination of both power tariff and supply restriction as a counter to groundwater depletion cannot be expected to have the desired level of impact.

5. BINDING POWER TARIFF FOR SUSTAINABILITY

None of the two criteria for determining agricultural power tariff discussed above will have much influence on the groundwater withdrawal decisions of farmers. Here, we argue that unless a third criterion is adopted to determine power tariff (and also, diesel price), our ability to ensure groundwater sustainability remains largely limited. The third criterion for power price fixation, in fact, requires the determination of power (also, diesel) price in such a way as to completely expropriate the net marginal value product due to a unit of power (or, diesel).

To illustrate how the third criterion can be operationalized, let us use the input and output data pertaining to wheat cultivation in a 0.4 acre farm in Amrapur village, Junagadh district, Gujarat as reported in Bhagwat (1993). While total input costs other than power (i.e., seeds, fertiliser, and labour) were observed to be Rs. 917, power cost for the crop season (90 days) came to Rs. 48 (i.e., one-fourth of the annual flat rate of Rs. 192 for a 3 HP pump). With an observed wheat yield of 600 kg and a wheat price of Rs. 80 for a 20 kg bag, the total gross income for the season has been Rs. 2400. Even if we allow Rs. 1000 to cover imputed land rent and management costs, the income net of all costs other than power comes to Rs. 463. Given the observed total power consumption of 37.5 kwh for the season, the net income noted above implies an average of Rs. 12.58 of additional income for each unit of power used.

Although the marginal productivity of power will not only be lower than its average productivity but also tend to decline, it will still be far higher than the marginal cost of power which becomes zero under the flat rate system. As a result, our third criterion that requires the fixation of power tariff so as to completely appropriate the difference between the marginal productivity and marginal cost of power will make power rates to be very high. While this criterion could certainly take us in the responsive region of the power (diesel) demand curve that will alter power (diesel) consumption and hence, groundwater withdrawal, it is necessary to appreciate certain practical problems involved in applying this criterion. These problems are as follows:

First of all, there will be a formidable resistance from farm groups for its applications. Farmers would even agree to fix power price in accordance with the supply cost of power or diesel but, they will definitely resist any attempt at fixing power price based on the third criterion suggested here.

Secondly, the political risk apart, there are also theoretical and practical issues that could seriously undermine the practical utility of the third criterion for fixation of energy prices. For instance, as we have noted already, the size and position of the kink at point C depends on a host of factors including power supply, farm size, cropping pattern, and groundwater supply condition. In other words, the point C is specific to farmers, crop patterns, and hydrological conditions. Therefore, identification of the exact position of the kink which is crucial for determining the power tariff under the third criterion is difficult to be generalized. As a result, the level of power price that will take us into the responsive region of the power demand curve will vary across farmers, crop groups, and hydro-geological regions. Thus, instead of a single and uniform power tariff policy, we will end up having a multiple and discriminatory tariff structure.

And, finally, although power price based on a multiple and discriminatory tariff structure could be much more effective in addressing the equity, efficiency, and sustainability issues, the practical management of such a tariff structure could be a real administrative challenge. For, the policy not only requires the fixation of farm and crop group-specific power tariff but also the revision of tariff structure as and when there are changes in the underlying cropping pattern and relative prices. The information requirements and monitoring needs are also too heavy to make such a discriminatory tariff policy practicable.

Yet, without fixing power price in accordance with the third criterion, the equity, efficiency, and sustainability issues in groundwater utilisation could never be addressed effectively *via* power tariff policy. In the responsive region of power demand (*i.e.*, the AC segment), power tariff could be manipulated to alter power consumption and water withdrawal. This will not only improve sustainability but also enhance efficiency both in the use of power and water. Such efficiency effects will be quite substantial and have the capacity of inducing farmers not only to apply water saving technologies and water conserving crop pattern but also to resort to supplemental irrigation and conjunctive use of groundwater and surface water.

The efficiency gains achieved in the region CF of the demand curve ACD, on the other hand, will be only marginal, although, in this region, the revenue of the SEBs could certainly be increased and the power subsidy can be done away with. But, we have noted already the unfavourable equity effects of such a non-binding power tariff policy on small and marginal farmers. A discriminatory tariff structure (*i.e.*, fixing tariff in accordance with farm size and crops, for instance) could enhance the smaller farmers' access to groundwater and power while, at the same time, regulating power use and groundwater withdrawal of well-to-do farm groups and regions.

6. CERTAIN POTENTIAL SIDE-EFFECTS

Against the favourable sustainability and efficiency effects of a binding power tariff policy noted above, now, let us also note just for the sake of theoretical curiosity what other unfavourable side-effects would happen if we operate in the responsive region of the power demand curve. By juxtaposing its unfavourable effects against its favourable effects, we could indicate whether or not a discriminatory power tariff policy will have positive effects on balance.

First of all, power consumption and water withdrawal could be reduced for sure enhancing thereby both the sustainability and efficiency of groundwater utilisation. However, it is essential to remember that even the magnitude of the overall sustainability effect of a binding power tariff policy depends upon commensurate begging up of the diesel price also. Else, energy substitution will happen making thereby groundwater withdrawal less responsive to power tariff changes. This is especially so in areas where the switch to diesel pumps is technically and economically feasible. In this case, due to the lower relative price of diesel and the attendant possibility of making, at the margin, a surplus over the energy cost, farmers may be economically well placed to internalise capital loss due to the abandonment of electric pumpsets altogether.

From the viewpoints of resource sustainability and efficiency as well as inter-regional equity, it is necessary to have an integrated energy price policy covering both electric power and diesel. It is only under such an integrated policy, there will emerge powerful economic incentives for the widespread application of water saving technologies and an impetus for their development by national agricultural engineering laboratories. In contrast, a mere power tariff policy--whether binding or otherwise--can generate unfavourable inter-personal and inter-regional inequality in groundwater use as long as such a policy is biased against regions and groups exclusively relying on electric power.

Secondly, consequent upon a binding power tariff policy, the existing cropping pattern could also undergo a substantial change with considerable unfavourable implications for food production. The growth rate of food output can be negative at the aggregate level as the crop pattern will shift towards high-profit items which are, by nature, mostly commercial or non-food crops. As noted already, the switching to diesel pumps and shifting of crop pattern towards cash crops are few among many strategies the farmers will resort to in their attempt to raise and maintain the kink in power (or energy) demand curve as it is in their economic interest to do so.

While economically well-endowed large and medium farmers could insulate themselves from the economic stress caused by stringent power tariff, the resource-poor small and marginal farmers will be the ultimate losers. Since access to groundwater could become inequitable under the power tariff based on the third criterion, the increasing tendency towards marginalisation of poor farm groups could not be ruled out completely. The issue as to whether the equity loss can get counterbalanced by efficiency gains in a given regional context depends not merely on the relative magnitude of these effects but equally also on the relative weights the society places on these two contrary effects.

And, finally, the stringent tariff policy, if at all feasible and successful, will definitely create an artificial excess supply of power for alternative uses other than that for irrigation. The most fundamental question is: what are we going to do with the power saved in the process? Are we going to divert to industries or to the domestic consumption both in urban and rural areas? If power productivity is the criterion for inter-sectoral power allocation, naturally, industrial sector will get the top priority, followed by agriculture and domestic sectors. On the other hand, if the prevailing power price structure is the criterion, agricultural sector will be at the bottom of the priority scale. More often than not, inter-sectoral allocation and tariff fixation are also done for other considerations such as food security and welfare. When power tariff policy is used with an exclusive focus on controlling groundwater withdrawal, some of these equity and self-sufficiency effects may obviously get distorted. This adds another dimension to the equity issue in terms of sectoral and regional distribution of power.

It is essential to answer and resolve all these critical questions and issues before contemplating power tariff as a policy instrument for groundwater utilisation. It is not just an issue of reducing power consumption and groundwater withdrawal alone as other equally critical issues are intimately inter-linked. Agricultural sustainability does not end up with mere groundwater sustainability as such. It also requires, at the same time, to sustain the ability of the production system to meet the food and other livelihood needs of a growing population. Under the current policy of power subsidisation, power subsidy becomes, in fact, the price we need to pay for achieving and maintaining higher agricultural growth as well as rural income and employment.

While one may argue about the relative size and location of the points K, I, G and E, the fundamental issues raised here still remain to be reckoned with in so far as the relative ordering of these points remains the same. It is possible to argue that the marginal value of power may be lower so that a slight increase in power price could lead to a substantial reduction in power consumption. But, the fact of the matter is that farmers are not permitted to reach the marginal level in view of water and power supply constraints. That is, since farmers are operating way above the marginal condition, the pitch to be raised to make power price as a binding constraint on their groundwater withdrawal decisions is substantially higher.

What about the efficacy of power rationing? Power rationing could definitely reduce power consumption and water withdrawal. The dual effect of sustainability and efficiency will be achieved. We have already noted, however, that power rationing that makes the diesel pumpset option quite attractive could still lead to groundwater depletion depending upon the hydrology of the region. The tendency for groundwater depletion is further accentuated by the possibility of installing higher horse power engines and multiple wells to fully utilise available power supply (Saleth and Thangaraj, 1993). The depletive effects--whether generated by power tariff policy or otherwise--also have an equity dimension as receding water table could drive many small and marginal farmers especially those relying on traditional water lifting mechanisms out of farm business (Dhawan, 1990; Saleth, 1992). This point reveals that while there is an inherent conflict between sustainability and intra-generational equity, there is also a synergy between groundwater sustainability and inter-generational equity.

In our discussion so far, we have concentrated our attention only on the power demand at the farm level. What would be the nature of the aggregate power demand curve? Will the aggregate demand curve also have the kink? The aggregate power demand curve will certainly have the kink, not just one but, in fact, many. That is, the curve will look very much like a step-function. The steps in the aggregate power demand function emerge due to our aggregating the power demand curves of many farmers each of which will have the kink in different location in view of our argument that the location of the kink is specific to farms, crops, hydrology, scale of operation, farm and water lifting technologies, etc.

7. Concluding Remarks

There is no way we can avoid either the kink in the power demand both at the individual and aggregate contexts or its multifarious implications for water withdrawal and use. The persistence of the kink under current power tariff structure and power supply conditions clearly suggests how ineffective could power tariff be as an instrument of groundwater regulation. While we have certain theoretical expectations about the location of the kink, it will be good to empirically estimate the level at which the kink appears at standardised conditions and evaluate its implications for equity, efficiency, and sustainability. This policy-wise most relevant issue is an area for further empirical research.

The contradictory effects of power tariff policy in the domains of equity, efficiency, and sustainability suggest that this policy, even if it is coupled with power rationing, cannot be an effective instrument for simultaneously achieving the three policy goals, *i.e.*, equity, efficiency, and sustainability. Current arguments in favour of power tariff as a policy instrument appear to miss both the technical gap in the relationship between power use and groundwater withdrawal as well as the effects of power tariff on aspects other than groundwater withdrawal.

Instead of looking for hypothetical, ineffective, or short-run-oriented options, we need to look for harder but long-lasting options like the institution of a water rights system that specifies limits for individual and collective water withdrawals and use. Even an imperfect system of water rights will have much more sustainable benefit than the most perfectly designed but ineffective instruments (see Saleth, 1996). Since groundwater sustainability could be ensured by limiting the overall withdrawal, equity could be achieved at the stage of distributing individual water rights, and efficiency in water use could be enhanced by permitting the exchange of water rights, water right system will be one of those rare policy instruments that could address all the three issues, *i.e.*, sustainability, efficiency and equity, simultaneously and effectively.

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