THE EFFICIENCY OF INSTITUTIONS REGULATING AGRICULTURAL WATER USE – THE CASE OF THE HAI-RIVER BASIN IN CHINA

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1 INTRODUCTION

Agriculture is the sector with the highest water demand all over the world. In 1995 it accounted for 69 % of the global water withdrawal (FAO 2002: 2). Still, in many regions it competes with industrialization. Due to the rapid economic development in the Hai-River Basin, which is examined in this research project, an enormous transfer of water resources has taken place. In 1980, 80.5 % of the overall water use was allocated to agriculture, whereas in 2000 only 58.5 % were assigned to agriculture. The rest went to the industrial and domestic sectors (Crook: 184). At the same time, as "[t]he importance of irrigation as a means of crop production has been recognized in China for centuries" (Bramall 2000: 133) and "China looks set to maintain more than 93% self-sufficiency even after 2005" (Rabobank 2002: 27), it is likely that irrigated agriculture in the water scarce Northern China will continue in future, especially due to the region's traditional importance as a producer of roughly half of China's grain, and therefore location of more than 65 % of China's cultivated land (Lohmar et al. 2003: 3). Nonetheless, conditions are rather disadvantageous in Northern China: 85 percent of the annual rainfall falls between June and September. In 2000, most of Northern China and part of Southern China suffered a severe drought, which hit 29 provinces and autonomous regions, destroyed one million hectares of farmland, and caused 300,000 tons in lost grain (PECC 2001: 20).

With the threatening water scarcity in the North China Plain, and the increasing conflict between population growth and limited resources of freshwater, as well as the transfer of water to other sectors, agricultural policies have to explore means to cope with the continuous reduction in agricultural water availability while maintaining the socio-economic conditions of the farmers, not to let them be the disadvantaged of the overall economic development in China. Water use efficiency (WUE) is considered a key-element for water policies. If one takes the term as defined by the FAO, the water use efficiency in China is 36 %[1], which is just a bit higher than the average WUE in East Asia which accounts for 34 %.

In the following, we develop a framework how to evaluate the efficiency of policy instruments addressing the increase of WUE. These "policy instruments" are themselves institutions[2] and as such a product of international discussion where general recommendations are developed. They have to be seen as concepts to be adapted to local conditions in order to enhance their acceptance and therewith efficiency. The policy instruments which are of interest here and under discussion in China are: 1) the devolution of irrigation management by establishing Water User Associations; 2) the distribution of water saving technologies and techniques; and 3) the introduction of a water pricing mechanism. In our view, they have to be developed in an intense

[1] (AQUASTAT / FAO's Information System on Water and Agriculture; viewed May 2003) Water use efficiency is described as the total irrigation water requirement for the country divided by the total agricultural water withdrawal.

[2] Institutions are understood as rules and norms which govern the behaviour of the society, - both as "informal" ("cultural", historical) institutions and as formal institutions like law. "Individuals come and go, but the concern goes on, if not in one form, then in another. Hence our 'institutions' are, in reality, 'going concerns'" (Commo0ns 1970: 34)

dialogue with farmers. If we know more about their strategies to deal with the policies, it is possible to predict the effective result of the policies more precisely including their potential side-effects. Additionally, new local policy options may evolve from the farmers´ indigenous knowledge, and therefore improve the design of the policy instruments. Thus, our research is guided by an interdisciplinary social science framework and stakeholder investigations (Pahl-Wostl, 2002).

Within the analysis of the policy instruments, we concentrate on the investigation of the attitudes and the behaviour of the farmers. There are two components of analysis: on the one hand the external environment is supposed to have an impact on the farmers' perception of the resource and their behaviour. The environment comprises natural and social factors. Regarding natural influences the distinction is made between "groundwater" and "surface water", and their state can be characterized by the values "scarce" and "not scarce". The state of the resource as well as the accessibility of the resource is supposed to affect the farmers' awareness of a water scarcity situation, as well as the interest for WUE. The influence of the resource has to be seen in relation to the existing institutions and in how far their way of administering the resource is perceived as offsetting the disadvantages of the source. Whereas the parameters of the natural context may be generalizable, the social determinants have to be developed in a close observation of the local society. They are captured by the terms "human-capita determinants" and "polit-economic determinants". The latter represent the local conditions of agriculture in China: they comprise attributes of land-ownership and the dependency on agriculture as a source of income. The "human capital"-determinants comprise the size of the family, the age of the family members as well as the education of the family members. They are supposed to interact with the institutions which regulate the use of the common pool resource.

Our analysis of the efficiency of policy instruments aims at providing scenarios about the change in total water use, as well as the distribution of yield and agricultural income under the regime of the respective policy. In a latter phase the scenarios will be backed up with a computational model that allows exploring different development paths.

2 DEFINITION AND MEASUREMENT OF THE EFFICIENCY OF POLICY INSTRUMENTS ADDRESSING WUE

The general definition of WUE as water used (to produce yield) in relation to the yield (per unit area) is enhanced by the various levels at which to improve water use efficiency. We will focus on one part of the term of overall WUE: the "irrigation efficiency", which is the ratio between the estimated irrigation water requirements and the actual irrigation water withdrawal[3]. "Irrigation efficiency" comprises the most important variables of WUE which are influenced by the management of irrigation: the conveyance efficiency, the farm irrigation efficiency and the field irrigation efficiency. "Conveyance efficiency" captures the relation of water which comes from the source to the amount which arrives at the farm level. "Farm Irrigation Efficiency" addresses the farm distribution networks, the loss of water due to its design, management and operation. "Field irrigation efficiency", or "application efficiency" looks at the irrigation and emitter system used (furrow irrigation, trickle irrigation etc.), the grading of land as well as at the amount and timing of water applied relative to soil water storage. These kinds of efficiency will be affected by the policy instruments in different ways.

[3] (FAO http://www.fao.org/ag/agl/aglw/aquastat/water_use/index5.stm, viewed May 2003); in the following, we refer to E.J. Schmidt

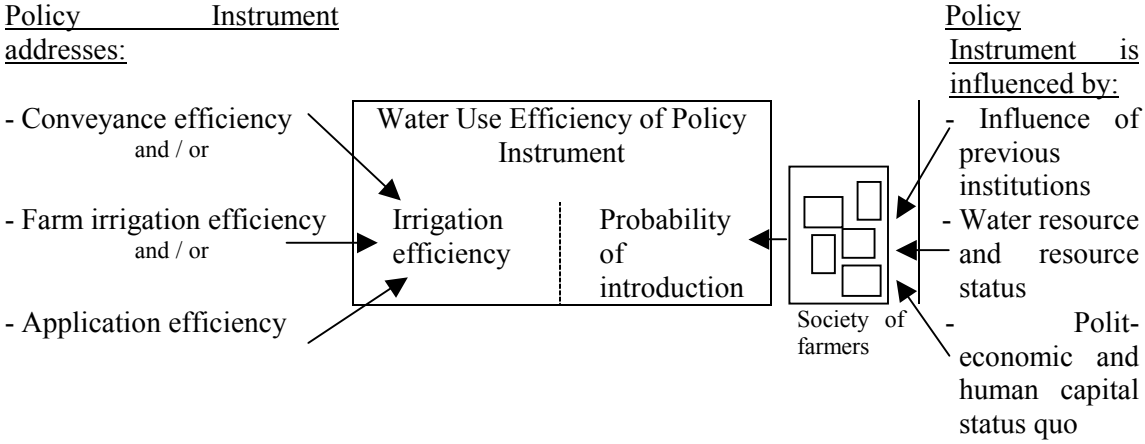

Figure 1. WUE of the Policy Instruments as the composition of Irrigation efficiency and the probability of its introduction

The technical term of WUE has to be considered in the context whether the respective policy instrument is likely to be implemented by the local society. Efficiency in this sense means that a high proportion of farmers would implement the policy by comprehending and further developing its rationale, so that it will easily get introduced in and will be an institution of the local society.

3 DETERMINANTS OF THE BEHAVIOUR AND THEIR INTERACTION WITH THE INSTITUTION – EFFICIENCY

Research needs to investigate what determines farmers' acceptance of the policy-instruments. The variables taken into consideration cover polit-economic conditions as well as natural resources settings and the influence of existing institutions regulating irrigation management.

3.1 Polit-economic determinants and human capital

Decisions about agricultural water use are one part of the overall decision-processes in agricultural practice which itself is dependent on the polit-economic conditions for agriculture. What is of interest in this section is in how far the economic development taking place in the North will also have impacts on agricultural practices carried out in a changing rural society. The boundary conditions of "polit-economic parameters" are themselves "institutions", like the rules for land distribution or the job market. However, they are assumed to remain unchanged and are thus not part of the policy instruments. Their existence impacts the implementation of institutions aiming at regulating water use efficiency, and it is this interrelationship which will be addressed in research.

The societal parameters result from a first analysis of intense discussions with farmers about the perceived barriers to introduce higher water use efficiency, and from the analysis of expert interviews about what might affect the probability of the policy instrument implementation. The parameters strongly depend on the conditions of the society under investigation[4].

[4] To show why farmers do not maximize their profits in grain production, Kalirajan and Huang took the following variables which are similar to those employed here: formal education, main profession, total arable land, size of household, and ratio of non-crop income to total income. These variables were assumed to directly influence decisions about the method of applying inputs, which shapes the level of efficiency;

An important influence on agriculture, considering decision making in irrigation, is the characteristic of land ownership and land allocation in the PRC. Land is not owned by the farmers but contracted per member of the household. Land reallocation adjusts the agricultural area per family to the natural growth within the family; therefore land can be subtracted as well as given to the households. The key of how much is allocated per capita depends on the availability of land in the region. The dispersion of land as well as the intervals of land-contracting are relevant for irrigation: the more the land is scattered, the less the return from investment in water saving technologies will be, and the shorter the contracting phase, the less infrastructure investment will be reimbursed. According to Chen et al. (1991), the government suggested prolonging the time of the contract to a minimum of 15 years to encourage the peasants to make long-term investments. In reality, two neighbouring villages in the Luancheng District of the Hebei Province even showed differences in contract durations, in that in one it was set at three, in the other at ten years. It is up to the village committee to determine the interval.

We assume a negative correlation between land size and investment in irrigation facilities as well as a negative correlation between contracting intervals and investment in irrigation facilities.

Besides the influences deriving from the polit-economic framework, in literature education proved to be an important parameter for analysing conduct in agriculture in general and especially for the efficiency of crop-production. It is closely interlinked with the parameter of off-farm employment. The opportunity for the rural population to work in off-farm employment is another important polit-economic parameter as the opportunity to work in the non-agricultural sector increasingly plays a role for rural life in the North China Plain. Rural underemployment seems to be a large problem in China (see for example: The 1990 Institute p. 53 ff). This goes together with "the rapid development of rural off-farm activities [that] has attracted many young people with more education"; "[a]s a result, relatively older farmers with more farming experience but less education are left to the farm land" (Yang 1999: 201). Whereas education is an important factor for household production efficiency, farming experience is of minor importance. Kalirajan and Huang (1999) showed that education increases the income-generating opportunities for farmers in the non-agricultural sector and therefore appears significantly to reduce profit-maximizing behaviour in the production of grain. For them, a reason for this might be that farmers are less interested in efficient grain production. "With more and more opportunities to earn income from non-agricultural activities, farmers have fewer incentives to apply the technology effectively" (Kalirajan and Huang 1999: 215).

It is therefore assumed that education increases the interest for water use efficiency in agriculture if there are well-educated family members living in the household, whereas with increasing off-farm income (and old members of the families participating in agriculture mainly), the likelihood of no interest in efficient water use increases.

According to Kalirajan and Huang, maximizing behaviour appeared to increase with increasing family size, but farmers with a large agricultural area according to them do not maximize profits (Kalirajan and Huang 1999: 214), whereas Yang found out that "the bigger the plot size, the more productive the plot" (Yang 1999: 202). We think that the importance of family size as well as plot size is determined by the fact if the household is a main-income or side-income farmer household.

In case of a main-income farmer , productivity and the interest to reduce costs (like for water) or to manage the supply of water as an important input increases with the size of the family and the plots, whereas they are to be seen relative to the side-income if there are off-farm income sources.

Another variable which is assumed to be important for the introduction of water use efficiency is the kind of crop grown. In households with no side-income, "[t]he produce is for self-consumption, for feeding farm livestock, and about 20 per cent of it is sold on the market" (Chen et al. 1991: 220).

Due to the high dependency on water as a major agricultural input, the sensitivity for restrictions in water use is higher and therefore the launch of water use efficiency more likely for main income farmers.

All in all, the following system of human capital and polit-economic variables are important for the analysis:

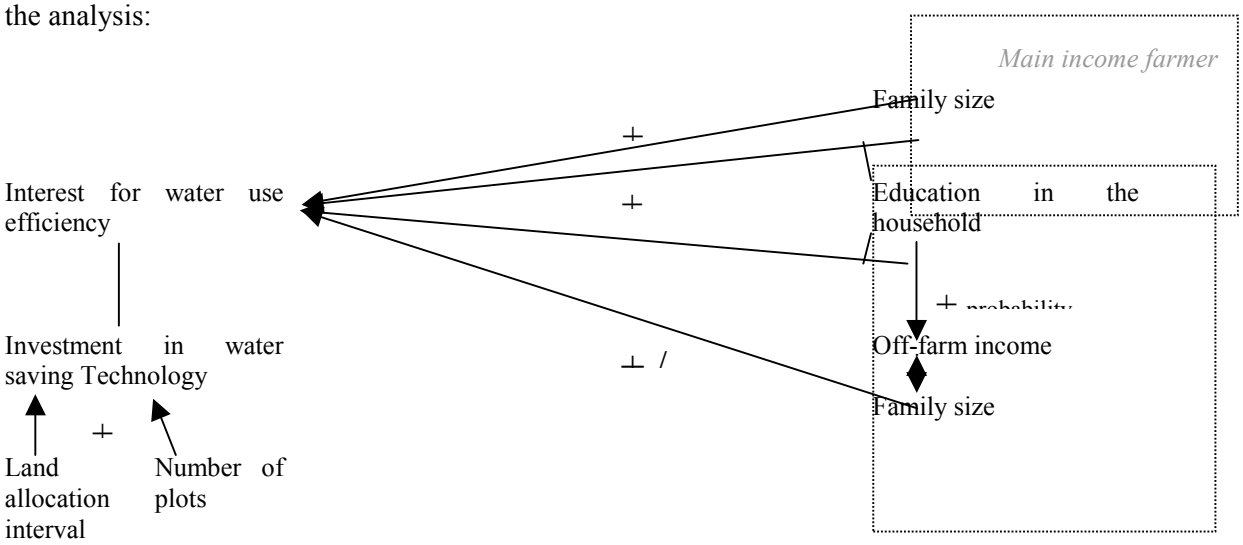

Figure 2. Diagram of polit-economic and human capital parameters affecting the interest in water use efficiency

3.2 Resource conditions

Whereas the accessibility to water is foremost a natural condition, the access to water is administered by society: in the following section we will first describe the common understanding in how far the accessibility to the resource water, groundwater and surface water influences irrigation. Afterwards, the access to the resource is discussed. Here the influence of existing institutions is of importance, as they are the rules and regulations how the access to the resource is administered.

Parameters affecting the choice for the source / Source	Timing in relation to crop growth stages	Reliability	Water amount	Matters of expenses
Groundwater	Just in time	High	Flexible	Energy; depending on shallow or deep aquifer
Surface water	Dependent on management	Depending on management	Arranged per crop and area	Infrastructure operation and maintenance

Figure 3. Sources of Water and their influences on irrigation

From the perspective of the farmer, many arguments are in favour of using groundwater irrigation: as an important input for crop-production it can be extracted just in time, whereas the supply of surface water depends on the irrigation district management. Additionally, the reliability of supply in groundwater is of course high, whereas in the case of surface water, especially plots downstream of the lateral always are under the risk of not being irrigated as water may be over-extracted by upstream farmers. And the impact on water stress is severe: Lack of adequate water supply during the flowering stage of maize for example can reduce yields by 60 percent even when water supply is adequate throughout the rest of the crop season. Therefore, yields in groundwater-irrigated areas are said to be higher (often twice as much)

compared to those in canal-irrigated areas (FAO 2003: 7). As groundwater availability has enabled farmers to invest in complementary inputs, the overall increase in crop yield is substantial. Reliable water supplies enable farmers to take other, often non-agricultural employment.

Concerning costs, infrastructure provision costs are lower in groundwater irrigation districts than in large surface water irrigation districts. Additionally, the maintenance costs are relatively low. With the need for administration of supply and distribution of surface water, this administration became the most cost-intensive post for irrigation water supply in China (Yang et al. 2003).

Besides these parameters, an additional "soft" variable influencing the irrigation decision of farmers may be considered: The "hydrological regime" also has indirectly an effect on the awareness for water scarcity and the behaviour of the farmers concerning irrigation. In a groundwater context, farmers tend to irrigate more.

From all the above differences between groundwater and surface water we presume that there is a preference for groundwater if both resources are available. Due to direct access without the involvement of society, less risk and costs seem to be involved.

Still it is advisable not to generalize this assumption for every situation. Resource characteristics itself may be overshadowed by other institutions as for example the electricity price regulations: although the advantages of groundwater use are clear concerning scheduling and the amount of appliance, if in areas with a deep groundwater level the price of electricity is too high, it would not be cost-efficient to pump groundwater if there are alternative accesses to surface water.

3.3 Pre-existing institutions

Under optimal conditions policy concepts might produce the expected results, under local conditions they might hardly get implemented, resulting in less overall water use efficiency. Therefore, in this section we ask in how far pre-existing institutions affect the behaviour of the farmers and the efficiency of the implementation of new policy instruments. *W*hich common understanding of the use of the resource did they put into effect? Which rules and regulations are enforced, which may already be internalized by the farmers? Are farmers familiar with the rationale of the new policy instrument or can adapt to it without high costs?

For the analysis of the main existing institutions administering irrigation water supply, the ADICO framework is applied (Ostrom et al 1995). In a comparison with the policy instruments, the differences of their characteristics can be examined. The criteria are:

- to whom the institutions address
- what their degree of requirements, their deontic is;
- to which aims the deontic is assigned
- under which conditions, that means when, where, how and to what extent an aim is permitted, obligatory or forbidden, - according to the deontic
- and which sanctions are carried out by whom in case of the refuse of rule-following. These sanctions again need rules to be backed up and enforced by the monitoring entity.

To reveal the significance of the existing institutions for the farmers, the degree of internalisation of the rules has to be examined (Schimank 200: 49). Two variations are distinguished: external norms which need to be backed up with a rule-set for sanctioning, as well as an entity which sanctions in case of non-compliance; and norms which are internalised

and become part of the intrinsic value system and are therefore followed without external enforcement. Whether the norms of previous institutions have been internalised or not impacts the introduction of new regulations to a major extent.

The following assumptions are given for analysis:

If the policy instruments follow the same rationale as the previous institutions there is a high probability that it may be carried by the local society. If the rules and regulations of the previous institution have been internalized, less external monitoring and sanctioning mechanisms may be necessary to implement the new institution. Variations will occur in the implementation.

If the policy instruments follow the same rationale as the previous institutions, but the previous institutions required monitoring and sanctioning, there may be a chance for a self-regulation as farmers are familiar with the institutional set-up.

A lot of transaction costs (Williamson) will be involved if the previous institutions have set incentives for actions which are internalized by the farmers but counteract new rules and regulations. If the previous institution used monitoring and sanctioning as means of enforcement, there is a chance for a welcomed change of the new regularities.

4 CONCLUSIONS AND OUTLOOK

The frame of analysis developed in the preceeding sections is represented in Figure 4.

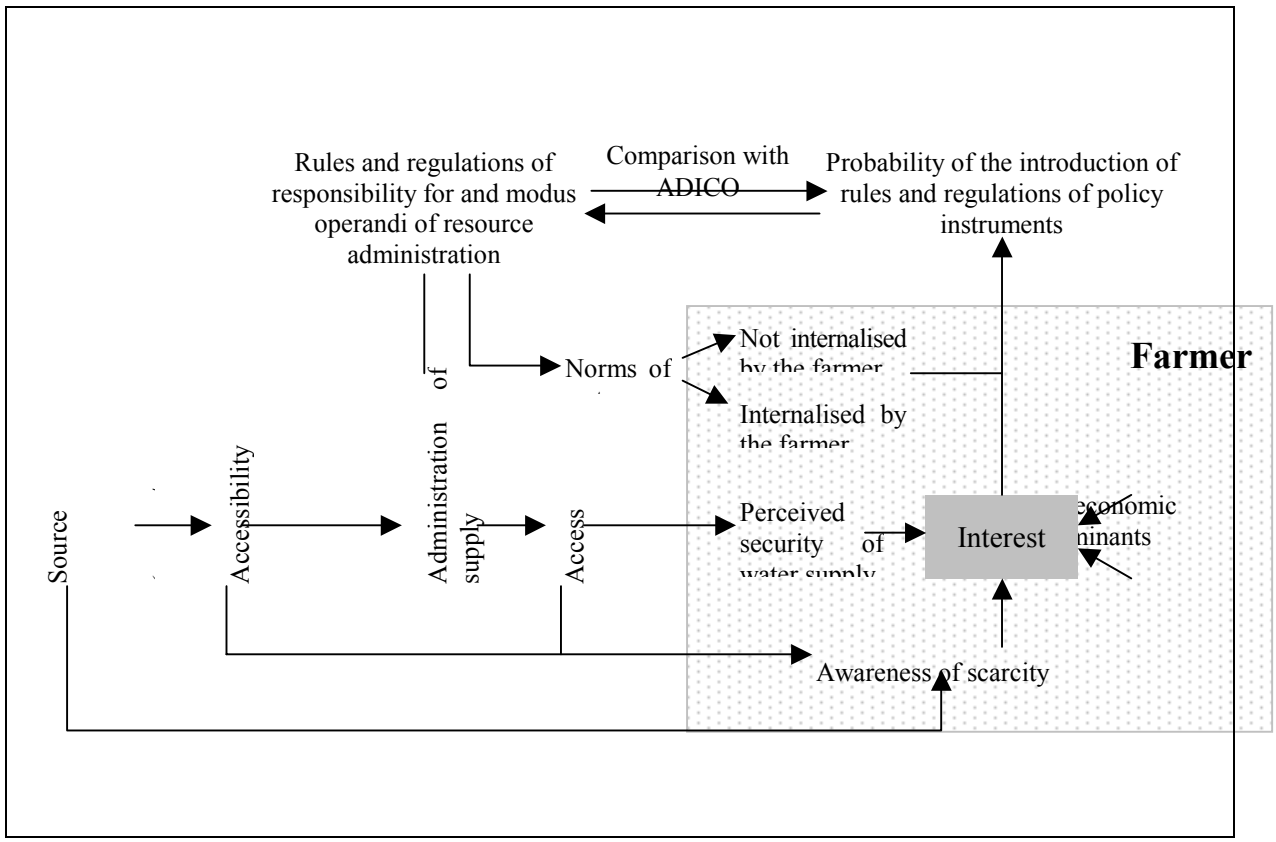

Figure 4. Frame of analysis to investigate the efficiency of institutions affecting water use efficiency

First results of the analyses lead to specific hypotheses about the probability for a successful introduction of Water User Associations in China. The usefulness of the framework's

application will be explored based on the results of field trip data in a groundwater irrigation district in Luancheng County, Hebei, China.

Given the importance of adapting policy instruments to the local conditions it is crucial to develop and apply participatory techniques in irrigation management. We will explore the usefulness of novel approaches combining knowledge elicitation techniques and participatory model development and application.

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