Water Markets and Third Party Effects

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Introduction

As water scarcity increases, so does the interest in using market mechanisms to allocate water. To date, market mechanisms have found an occasional home, with most trade occurring among users within a water district and within the same use category, e.g., farmer to farmer trades. In Chile water markets exist in select areas in the north and within small river basins (Bauer, 1998), and trading there has been mostly among irrigators. Limited trades between irrigators and the urban sector have occurred, but these trades did not involve fallowing or retiring land. Northern Colorado has an active market but most of the trading is among farmers in the same water district. Little trade has occurred among water districts or watersheds or among different types of uses (irrigation vs. urban use). Two notable exceptions are the California Water Bank and the Colorado/Big Thompson project (Easter and Archibald, 2001). Although the California Water Bank has moved large quantities of water over long distances and among different uses, it is not a true market in that prices are fixed by the government and do not adjust to supply and demand forces. Prices are determined by market forces in the Colorado/Big Thompson project, but the trading has involved small amounts of water as compared to California Water Bank trades.

One explanation for the dearth of water markets and trading is the belief that water market expansion engenders losses in local business income. The argument goes as follows. If water markets open up and water has a higher value outside of agriculture, then farmers will sell their water to urban users or to irrigators outside the local district. If a significant number of farmers export their water, irrigation falls, land retirement increases and agricultural production falls. The resulting drop in production causes a decrease in local demand for agricultural inputs and processing services, which reduces demand for local business services. In addition to finding disfavor among local businesses, farmers who remain in agriculture would likely not favor water trading because such trades are believed to have negative impacts on agricultural land prices (Haddad, 2000).

Given the beliefs above, it is not unusual to see local businesses voice opposition to water trading. Howitt and Vaux (1995) have suggested that because of the impacts of water trades on local business, California may need to limit water sold from each county. This would prevent sales from being concentrated in just a few counties. The State of California took the suggestion somewhat further and banned all water sales based on land fallowing. Such restrictions appeared to satisfy many local business concerns. However, wholesale resistance to water trading is not necessarily the best course of action to take. For instance, in the Westlands Water District in central California, irrigators first opposed interdistrict water transfers. As water trading developed, however, local markets expanded and revealed the potential benefits from water trading. Local resistance then turned to support (Easter and Archibald, 2001). The resistance to water trading by local businesses and farmers, combined with the Westlands Water District experience suggests we should examine more closely the potential impact of water trading on local/regional economies.

Past empirical papers have argued water trading has both improved and hurt local economies - see Howe and Goemans (2003). This paper attempts to tie these stories together with a common conceptual underpinning. We develop a formal analytical model that helps examine the (general equilibrium) economic impacts of water market creation on a small, but open, rural economy with heterogenous land quality. Given farmers have appropriative rights to a water resource, we consider the impact of placing – or removing -- water trading restrictions on: farmer and service sector income, and household welfare. The model assumes a subset of agents can potentially leave the region and take their income with them – income flight.

We show that with, or without, income flight, water trading unambiguously improves per capita regional welfare, but with income flight can lead to a decrease in aggregate regional income. The impact of water trading on service and land rental values is ambiguous. However, at least one stakeholder group (farmers or service providers) is always hurt with water trading. Likewise, someone always benefits. In other words, water trading triggers a natural conflict between farmer and service sector stakeholders. With no income flight, when the share of household income spent on services is large relative to the cost share of services in agricultural production, the service sector benefits from water trading: otherwise agriculture benefits. If income flight is an issue, and the share of agents migrating out of the region is large enough, the service sector likely looses with increased water trading. Hence, the model provides conceptual support for why agricultural service providers and farmers might, indeed, be concerned with water trading.

Section 2 presents the basic model and Section 3 examines the model's equilibrium properties. Section 4 calibrates the model to a social accounting matrix and examines the impact of water trading on agricultural and service sector income. The last section concludes.

The Model

Consider a small rural economy with two productive sectors: agriculture and services. Agriculture produces a traded composite good y^a, while the service sector produces a non-traded composite good y^s. Agricultural production requires land, water, services, and labor, while service production requires labor and region/sector specific capital K, where $K = 1$. Local production does not affect the agricultural good's price, p_a, which we normalize to 1. The service good is used either for (household) consumption in the region (e.g., restaurants, movies, health care, etc.), or as an input for agricultural production (implement repairs, fertilizer, pesticides, etc.). Being a non-traded good, the service good price p_s is endogenous.

Economic agents in the region are represented by a continuum with total mass normalized to one. Each agent is endowed with a single unit each of labor, land and water, and an equal share of capital *K.* Agents earn revenues by either producing the agricultural commodity, or by producing services and possibly selling water outside the region. Households use revenue to purchase the agricultural commodity, services, and a composite import good. Local consumption of the composite good does not affect its price, denoted p_m. The total water endowment of the region is normalized to one and if sold outside the region, is sold at the ongoing price p_w.

Production and consumption 1

The service good is produced using labor and capital *K*. Let l^d denote the region's aggregate demand for service labor. Then net service sector revenue (rents to capital) is given by

$$G^s(w, p_s) \equiv \max_{y^s, l^d} \{p_s y^s - w l^d \ : \ y^s = f(l^d)\},$$

where w is the wage rate, and $f(\cdot)$ is a differentiable, non-decreasing and concave function. Given the properties of $f(\cdot)$, the indirect function $G^s(\cdot)$ is continuous and convex in w and p_s. By Hotelling's lemma, service sector labor demand is

$$l^d(p_s, w) = -G^s_w(p_s, w),$$

and the supply of services is

$$y^s(p_s, w) = G^s_{p_s}(p_s, w),$$

where $G^s_w = \frac{\partial}{\partial w} G^s(p_s, w)$ and $G^s_p = \frac{\partial}{\partial p_s} G^s(p_s, w)$.

Land quality is heterogeneous and indexed by $\alpha \in [0,1]$: the worst quality land is indexed $\alpha = 0$, the best quality land is indexed $\alpha = 1$. Nature randomly assigns a unique land quality to each agent, and we index each agent by the parameter α.

Irrigated agricultural production requires the following inputs in fixed proportion: a unit of labor, a unit of water, ρ units of the service good and a unit of land. Such an application of inputs to the unit of land at location α yields output $f(\alpha) = \alpha$. Since there is only unit of each quality land, agricultural output at location α is either 0 or α.

Let p_a represent the per-unit price of the agricultural good. The economic rent of land at location α is

$$\pi(\alpha) \equiv p_a \alpha - (\rho p_s + w + p_w)$$

and is the market value of irrigated agricultural production of land quality α less the market value of the productive inputs. [1]

Consumer preferences are typified by the homothetic utility function $U(q_a^i, q_m^i, q_s^i)$, where $q = (q_a^i, q_m^i, q_s^i)$ is the vector of agent-i's consumption of agriculture q_a, the imported composite good q_m, and services q_s. Assume $U(\cdot)$ is an increasing, concave function of q. Agent-i's expenditure function is

$$E(p_a, p_m, p_s, \bar{u}^i) \equiv \min_{q_i^a, q_i^s, q_i^m} \{ p_a q_a^i + p_m q_m^i + p_s q_s^i : U(q_a^i, q_m^i, q_s^i) \geq \bar{u}^i \},$$

where $E(\cdot)$ is increasing in $\bar{u}^i$; increasing, homogenous of degree one, and concave in prices; and satisfies Shephard's lemma. Given $U(\cdot)$ is homothetic, we also have

$$E(p_s, p_m, \bar{u}^i) = e(p_s)\bar{u}^i$$

[1] Alternatively, one could view land as having two possible uses: it can be irrigated to produce a high valued product with per-unit price p_a, or it can be used to produce a dry-land agricultural product with per-unit price $p_a^d < p_a$. Dry-land agricultural production only requires land, while irrigated agriculture requires land, labor, water, and a service input. In such a case setting $p_a^d = 0$ will not change any of the results that follow.

where, suppressing the constant prices p_a and p_m, $e(p_s)$ is the unit expenditure function, typically interpreted as a cost of living index.

Water management practices: quantity restrictions and subsidies

An agent either farms his or her parcel, or abandons the land to join the service sector. The resulting labor allocation across agricultural and service production depends on incentives given by public regulations, and on the allocation of water property rights. In the Western U.S., water rights are typically appropriative use, with a first in time, first in right clause. As noted above, here, farmers have appropriative water rights.

Consider a policy that restricts the share of water a farmer can sell outside the region. Represent the level of this policy by the exogenous water trading parameter $\sigma \in [0,1]$. When $\sigma = 0$ water trading is not allowed, and when $\sigma = 1$ full water trading is allowed. If $\sigma = 0.5$, only half of the available water is tradeable and the effective per-unit value of water in trade is σp_w.

With the policy parameter set at σ, the type-α agent's income as a farmer is $p_a - \rho p_s$ (a self-employed farmer who does not pay for water). As a laborer, the agent earns σp_w in water income and w in wages. Then, the type-α agent exits agriculture if $\alpha - \rho p_s \leq w + \sigma p_w$, or if

(1) $$\alpha \leq \alpha_I \equiv \rho p_s + w + \sigma p_w.$$

Here α_I denotes the agent who is indifferent between farming and working in the service sector. One result of expression (1) is agriculture uses $1 - \alpha_I$ units of labor, and the remaining agents work in the service sector.

The farmer's income, $\alpha - \rho p_s$, is different from the (true) economic rent from farming $\pi(\alpha)$, and condition (1) is equivalent to

$$\pi(\alpha) + (1 - \sigma) p_w > 0,$$

i.e., the true profit from farming augmented by a per-unit water subsidy, $(1 - \sigma) p_w$.

Aggregate revenue under the above policy comes from three sources: land rents, service sector profits, and water income. Define aggregate land rents by

$$G^a(p_s,\sigma) \equiv \int_{\alpha_I}^{1} \pi(\alpha)\,d\alpha.$$

A fraction $1-\alpha_I$ of agents use their share of water for farming and thus their true economic profit is increased by p_w, the cost of water they do not pay. The other fraction of agents α_I are only entitled to sell a fraction σ of their water endowment, which corresponds to each seller earning σp_w on the water market. Then aggregate water rents are

$$WR(p_s,\sigma) = p_w(1-\alpha_I) + p_w\sigma\alpha_I.$$

Then, for given levels of p_s, w, and water trading restrictions σ, regional aggregate income is equal to

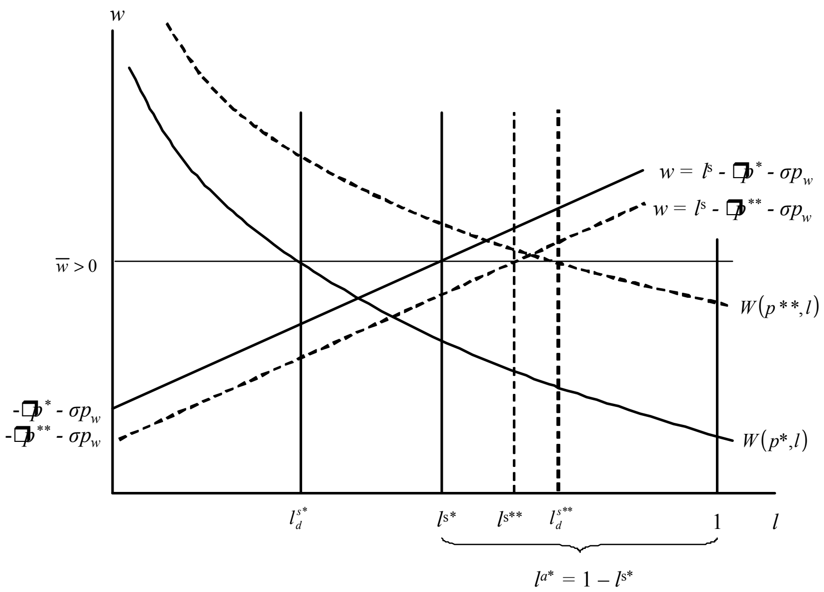
(2) $$G(p_s,w,\sigma) \equiv G^s(p_s,w) + G^a(p_s,\sigma) + w + WR(p_s,\sigma).$$

Policy Analysis

This section examines the impact of water trading on: regional welfare; aggregate regional income and its distribution across agricultural and service providers; labor shares across agricultural and service production; and the service price and land rental values. We assume labor moves freely in and out of the region, and from the standpoint of the region, the equilibrium wage rate is exogenous and equal to $\overline{w}$.

Figure 1 depicts labor market equilibrium with exogenous wage $\overline{w}$. Here, the region's labor endowment is normalized to 1. For $p_s = p_s^*$, the service labor supply function is the upward sloping line $w = l^s - (\rho p_s^* + \sigma p_w)$, and the service sector's inverse labor demand is $w = W(p_s^*, l)$. Given $(\rho, \sigma, \overline{w}, p_w)$, if the equilibrium service price is p_s^*, then the equilibrium level of service labor supply is l^{s*}, the level of service labor demand is $l^d = l_d^{s*} = W^s(p_s^*, l)$, while

$l^{a*} = 1 - l^{s*} = 1 - \alpha_l^*$ is the amount of labor in agriculture.



In this case there is an excess supply of service labor in the region, and $l^{s*} - l_d^{s*}$ units of labor obtain employment outside the region (e.g., rural residents commute or move to the city). If, however, the equilibrium service price were $p_s^{**} > p_s^*$ and the corresponding regional service labor demand and service supply functions were given by the dashed functions $W(p_s^{**}, l)$ and $w = l^s - \rho p_s^{**} - \sigma p_w$ respectively, then there is an excess demand for service labor and urban residents would commute/move to the countryside. **In what follows, we ignore the latter case.** Of course, our current analysis implicitly assumes commuting costs are zero.

As noted above, we focus only on the case where there exists an excess supply of labor in the rural sector, and that a share of the agents not finding employment there, leave and find employment elsewhere. *When agents leave the region they take their labor and water income with them*. The amount of labor that potentially leaves the region is equal to

$$ES(p_s, \sigma) = \alpha_l + G_w^s(p_s, \overline{w}) = \rho p_s + \overline{w} + \sigma p_w + G_w^s(p_s, \overline{w}),$$

where $ES(p_s)$ is the excess supply of service labor for the region. Assume *an exogenous* fixed proportion, $\gamma \in [0,1]$, of the excess service labor supply leaves the region. Then the value of income leaving the region is equal to

(3) $$-\gamma(\bar{w}+\sigma p_w)ES(p_s,\sigma) \leq 0.$$

Regional expenditures when $\gamma ES(p_s,\sigma)$ agents leave the region is now equal to

(4) $$e(p_s)\int_{\gamma ES}^{1} \bar{u}^i g(i : \gamma)di = e(p_s)\bar{u}_\gamma [1-\gamma ES(p_s,\sigma)]$$

where $g(i : \gamma) = \frac{1}{1-\gamma ES}$ is the uniform density over the interval $[\gamma ES, 1]$, and

$$\int_{\gamma ES}^{1} \bar{u}^i g(i : \gamma)di = \bar{u}_\gamma (1-\gamma ES(p_s,\sigma))$$

is the expected value of regional utility. The variable $\bar{u}_\gamma$ is the average utility of a typical agent remaining in the region.

With income flight, aggregate demand for consumption services is given by

(5) $$x^c(p_s,\bar{u}_\gamma) = e'(p_s)\bar{u}_\gamma [1-\gamma ES(p_s,\sigma)].$$

Given expressions (2) – (5), a competitive equilibrium is:

Definition *A competitive equilibrium with potential income flight, water trading restrictions* σ, *and open labor markets is characterized by a service price* p_s^* *and welfare level* $\bar{u}^*$ *such that (i) the service good market clears, i.e.*

$$G_p^s(p_s^*, \bar{w}) = e'(p_s^*)\bar{u}_\gamma^*[1-\gamma ES(p_s^*,\sigma)] + \gamma\alpha_I(p_s^*),$$

holds, and (ii) aggregate expenditure is equal to aggregate income

$$e(p_s^*)\bar{u}_\gamma^*[1-\gamma ES(p_s^*,\sigma)] = G(p_s, w, \sigma) - \gamma(\bar{w}+\sigma p_w)ES(p_s^*,\sigma)$$

where $\alpha_I(p_s^*) \equiv \rho p_s^* + \bar{w} + \sigma p_w$.

Due to space restrictions, we skip a formal presentation of the impact of relaxing water trading restrictions on per capita utility, the service price and income distribution. Instead, we summarize the major results.

Results:

(i) Nominal regional income can decrease with increased water trading: especially with income flight; Per capita welfare increases with increased water trading: with or without water trading;

(ii) The service price can increase or decrease with water trading. The general rule of thumb is: if the share of regional income spent on consumer based services is large (small) enough relative to the cost share of services in agricultural production, the service price increases (decreases) with increased water trading;

(iii) Typically farmers win (lose) when the service price falls (increases); service providers lose (win) when the service price falls (increases); agricultural service providers almost always lose. Thus, a natural conflict emerges between farming and service sector stakeholders;

(iv) Aggregate land rents can increase or decrease with water trading, as can individual land rents. Indirect service price effects influence greatly this result.

A Calibrated Version of the Model

The above model, combined with calibration techniques yield an empirical model with great potential for assessing the likely impact of water trading on a small regional economy.[2] The results above suggest without income flight, the impact of water trading on stakeholders depends on whether the service price increases or decreases with water trading. The Appendix provides a modified social accounting matrix (SAM), of an undisclosed country, for which the share of household income spent on services is large relative to service's share of cost in producing

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[2]Details of the calibration process are available upon request.

agricultural outputs. Table 1 presents equilibrium parameter values and stakeholder income associated with the SAM in the appendix assuming no income flight. The table introduces two additional variables: agricultural based services, $G^{sa}(\cdot)$, and household based services, $G^{sh}(\cdot)$.

Table 1. Equilibrium parameter values and stakeholder income: No income flight

Going from no water trading to allowing 50% water trading can increase the service price by as much as 9.9%, while aggregate regional income aggregate income G increases as much as 10.3%. The service price increase occurs because the percentage increase in household service demand is greater than the percentage decrease in agricultural service demand. Given the price increases, aggregate service sector profits increase by 1.6% with full water trading, while agricultural service providers lose up to 33.1%. Finally, observe that for $\sigma = 0.05$ the region gains about 5327 in income. With homothetic preferences, consumer based service income increases by 0.44*5327=2343.9, while the value of household imports increase by 1331.8. Agricultural service providers lose 1938, yielding a net gain to the service sector of 209. The agricultural sector gains 129.

Table 2 presents equilibrium parameter values and stakeholder income associated with the appendix SAM under partial income flight, with $\gamma = 0.5$.

Table 2. Equilibrium parameter values and stakeholder income: ? = 0.5

Here, the service price falls, and accordingly, the agricultural sector benefits, while agricultural service providers lose. Also, the loss in agricultural service revenues dominate the increased income realized by providers of consumption based services. Overall, however, the region gains 1.15% in nominal aggregate revenue. In Table 3, similar results hold, with the significant difference relative to Table 2 being nominal aggregate income falls by 4.8%. Simulations show that with full income flight, nominal aggregate income would fall by more than 11%.

Table 3. Equilibrium parameter values and stakeholder income: ? = 1

Conclusion

There has been growing concern about the health of rural economies, and with impact of policies designed to address concerns in one sector, but affecting others, e.g., the impact of water trading on service sector income. This paper develops a model where the rural economy is endowed with labor, water and heterogeneous land, and uses these inputs to produce a tradeable agricultural commodity and a non-traded composite service good. Here, the service good can be consumed directly or used as an intermediate input in agricultural production.

The model generated the following analytical results: (i) with no income flight the direct effect of water trading on nominal regional income was always strictly positive, while with income flight the direct effect could be negative. Income flight increases the chance that water trading will trigger a decrease in the service price, and hence, likely benefits the agricultural sector. (ii) Water trading can lead to an increase or decrease in the service good price. (iii) If the service price falls: (iii.a) the sector providing household consumption services may or may not benefit from water trading, while agricultural service providers definitely lose with increased levels of water trading and (iii.b) aggregate agricultural rents increase. (iv) Irrespective of the impact of water trading on the service price, per capita regional welfare improves with increased water trading, and nominal income likely increases. Hence, with water trading at least one group of regional stakeholders will be hurt by increasing water trading levels.

Water trading can certainly lead to a decrease in nominal regional income, but its presence does not automatically signal disaster for the region. In fact, the per capital welfare of those remaining in the region increases with increased water trading. Third party fears of water trading, however, are justified: Farmers should welcome water trading if such trading leads to a decrease in their input costs. Service sector providers should welcome water trading if it leads to an increase in the service price. If income flight is of concern, however, the service sector would have cause for concern if the share of migrants leaving the region is significantly greater than one half: in this case, service prices are likely to fall as would service sector income . If income flight is a concern, water taxes combined with income transfers could slow the exodous of income from the region.

The simple model presented here can serve as a point of departure to examine several other questions. For example, what is the effect of water trading on service income and environmental quality, or what policy instruments could/should be used to minimize losses to the service sector and minimize losses in environmental quality and biodiversity.

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Appendix

Social Accounting Matrix:

	Manuf.	Ag.	Serv.
Labor Share	0.649	0.46	0.4217
Capital Share	0.351		0.5783
Land Share		0.1506	
Water Share		0.1249	
Service share		0.2645	

Household Expenditure Shares	
	1993
Food	0.3071
Manuf.	0.2515
Services	0.4414
	1

		Factors of												Total
		Production Activities			Commodities			Production					ROW	Receipts
Prod. Activities	Manuf	Ag	Serv	Manuf	Ag	Serv	Labor	Captial	Land	Water	Household	Capital		
Manuf.														0
Ag					45637									45636.6
Serv						59976								59976
Commodities														0
Manuf.											27299			27299
Ag											33331.6		12305	45636.6
Serv		12071									47905			59976
Factors														0
Labor		20992	25292										14994	61277.1
Capital			34685											34684.5
Land		6874												6874
Water		5700											0	5700
Households							61277	34684.5	6874	5700				108536
Capital														0
Trade				27299										27299
Total Expenditures	0	45637	59976	27299	45637	59976	61277	34684.5	6874	5700	108535.6	0	27299	482894