WATER MARKETS AND THIRD PARTY EFFECTS

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Abstract

This paper examines the potential effects of water trading on aggregate welfare and on the service sector of a small rural economy. The economy earns income producing an irrigated agricultural product and a non-agricultural (service) good, and possibly by selling water. Among other things, we show when none of the water income leaves the region (no income flight), water trading enhances regional welfare. We then show if income flight is "large enough", water trading has the opposite effect. Albeit, even under income flight, if the income flight problem is not too serious, water trading can enhance regional welfare.

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1 Introduction

With the increased scarcity of water there has come an increased interest in using market mechanisms to allocate water (Easter et al., 1998). And although market mechanisms have found an occasional home, to date, most trade has occurred 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 expansion of water markets will lead to losses in local business income. The argument goes as follows. With the opening up of water markets, water might have higher value outside of agriculture and farmers will sell their water to urban users or to irrigators outside the local district. If so, and if a significant number of farmers sell their water outside the production region, irrigation falls, land retirement increases and agricultural production falls. The resulting drop in production causes a decrease in local demand for inputs and processing services, which reduces demand for local business services. In addition to finding disfavor among local businesses, farmers planning to 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 (Easter and Smith, 2004). 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 which appeared to satisfy many of the 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 tended to oppose 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 that water trading has both improved and hurt local economies (see for instance, Howe and Goemans (2003)). This paper attempts to tie these stories together with a common conceptual underpinning. This paper develops a formal analytical model that can serve as a tool for examining the (general equilibrium) economic impacts of water market creation on a small, but open, rural economy with heterogenous land quality. We consider two types of possible policies. One scheme – often implemented in the Western U.S. – consists in assigning to farmers appropriative rights to the water resource. The second scheme – typical in European countries, e.g., France – presumes a water authority manages and sells the resource, and that farmers are subsidized for their water expenses. Among other things we show if all income from water proceeds remains in the region, then the rural economy expands with water trading. Also, the service sector as a whole benefits from water trading, but agricultural service providers can definitely lose as a result of such trades and the impact of water trading on land values is ambiguous. If water proceeds exit the region – income flight – the region may or not benefit from water trading.

Section 2 presents a model economy in which agents are given property rights on water and use their endowment of labor and (heterogeneous) land to produce either an irrigated agricultural product or a service good. Section 3 examines the equilibrium properties of the model when water income stays in the region. Section 4 compares this situation to a scheme where farmers are not assigned property rights on water but are subsidized for their water expenses. Section 5 examines the equilibrium properties of the property rights model when income leaves the region. The last section concludes and provides suggestions for further research.

2 The Model

Consider a small rural economy with two productive sectors: agriculture and services. The agricultural sector produces the traded composite good y^a, while the service sector produces the non-traded composite good y^s. Agricultural production requires land, water, services, and labor inputs, while services are produced using labor and sector specific capital K. Local production does not affect the agricultural commodity's price, and we normalize that price to 1. We view the service industry as performing two primary functions: (i) It provides (household) consumption services for the region (e.g., restaurants, movies, health care, etc.); and (ii) it provides the agricultural sector with support services (implement repairs) and intermediate inputs (fertilizer, pesticides, etc.). Being a non-traded good, the service good's price p is endogenous.

The economic agents in the region are represented by a continuum with total mass normalized to one. Each agent is endowed with one unit of labor, one parcel of land, and an equal share of capital K. They earn revenues by either producing the agricultural commodity, or by producing services and possibly selling water. Revenues are used to purchase the agricultural commodity, services, and a composite import good. Local consumption of the imported 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.

2.1 Consumption and production

Consumer welfare is indexed to the welfare of a representative consumer whose preferences are typified by the homothetic utility function $U(q^a, q^s, q^m)$, where q^a, q^s and q^m respectively denote the aggregate (regional) household consumption of services, food/agriculture, and the imported composite good. We assume $U(\cdot)$ is an increasing, concave function of the consumption bundle. The corresponding aggregate expenditure function is given by,

$$E(p, p_m, \bar{u}) \equiv \min_{q^s, q^a, q^m} \{q^a + pq^s + p_m q^m : U(q^s, q^a, q^m) = \bar{u}\},$$

where $E(\cdot)$ satisfies the following properties: (i) increasing in $\bar{u}$, (ii) increasing, homogenous of degree one, and concave in prices, and (iii) satisfies Shephard's lemma. Given $U(\cdot)$ is homothetic, we have

$$E(p, p_m, \bar{u}) = e(p)\bar{u}$$

where, suppressing the constant p_m, $e(p)$ is the unit expenditure function. Note that the unit expenditure function can be interpreted as a cost of living index.

The service good is produced using labor and the sector specific asset K. Let l^s denote the aggregate amount of labor devoted to service production. Then net service sector revenue (rents to capital K) is given by

$$G^s(w, p) \equiv \max_{y^s, l^s} \{py^s - wl^s : y^s = f(l^s, K)\}.$$

Here w denotes the wage rate, and $f(\cdot)$ is a differentiable, non-decreasing function, that is concave in both arguments and satisfies constant returns to scale. Given the properties of $f(\cdot)$, the indirect function $G^s(\cdot)$ is continuous and convex in w and p. Using Hotelling's lemma, labor demand from the service sector is given by

$$l^s(p, w) = -G^s_w(p, w),$$

and the total supply of services is given by

$$y^s(p, w) = G^s_p(p, w).$$

Land quality is heterogeneous and is indexed by the location/quality index $\alpha \in [0, 1]$: the worst quality land is located at $\alpha = 0$, while the best quality land is located at $\alpha = 1$.

Nature randomly assigns a unique land quality to each agent, and in what follows we index each agent by the parameter α. The agricultural technology is "Leontief-like" in the sense that farming a parcel of land requires a unit of labor, a unit of water, and a fraction ρ of the service good. Such an application of inputs to land at location α yields output $\phi(\alpha) = \alpha$. By "Leontief-like" we mean, if a farmer applies to his parcel of land, a unit of labor, a unit of water, and 2ρ units of the service good, he or she would still realize only $\phi(\alpha) = \alpha$ units of output. On the other hand, combining 0.5ρ units of the service good with a single unit of the other inputs yields zero output. Note, given there is only unit of each quality land, the output at location α is either equal to 0 or α.

The economic rent of farming the land located at α is given by

$$\pi(\alpha) = \alpha - \rho p - w - p_w, \tag{1}$$

and corresponds to the market value of production at location α less the market value of the productive inputs.

2.2 Water managment practices: quantity restrictions and subsidies

In what follows an agent either farms his or her parcel, or abandons the land to join the manufacturing sector. The resulting labor allocation across agricultural and service production depends on incentives given by public regulations and particularly 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. To introduce the possibility that agents may or may not be able to sell water outside the region, or if water trading is allowed but restricted, define the exogenous water trading parameter $\sigma \in [0,1]$. If $\sigma = 0$ water trading is not allowed, and if $\sigma = 1$ full water trading is allowed. A value of $\sigma \in [0,1]$ is a crude attempt to capture institutional limitations on water trading. For example, if $\sigma = 0.5$ only half of the available water is tradeable. Then, the effective per-unit value of water is given by σp_w.

Under such a scheme, as a farmer the type-α agent's income is equal to $\alpha - \rho p$. This follows because the farmer is self-employed and does not have to pay for water. On the other hand, as a laborer, the agent sells what water she can and earns wage w. In such a case, the agent's income is equal to $w + \sigma p_w$. Then the type-α agent exits agriculture if $\alpha - \rho p \leq w + \sigma p_w$,or

$$\alpha \leq \alpha_I \equiv \rho p + w + \sigma p_w, \tag{2}$$

where α_I denotes the agent who is indifferent between farming or working in the manufacturing sector. The farmer's income, $\alpha - \rho p$, is different from the (true) economic rent from farming $\pi(\alpha)$ and condition (2) is equivalent to

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

i.e., the true profit from farming augmented by a per-unit water subsidy, $\tau p_w = (1 - \sigma) p_w$, is positive. Hence, a policy of granting appropriative use rights to all agents in the region combined with restrictions on water sales has the same effect on labor allocations as a subsidy-taxation scheme with an unrestricted water market. In particular, the labor allocation under appropriative use with no water trades (i.e. $\sigma = 0$) is the same as that of assigning the water to a water authority (a benevolent regulator), removing all water trading restrictions, and having farmers pay for the water – but subsidizing the farmers' water expenses. We refer to the scheme with appropriative use rights and water trading restrictions as the appropriative use (AU) policy, and refer to the second scheme as a pure subsidy (PS) policy. The AU policy with unrestricted water markets ($\sigma = 1$) has a labor allocation equivalent to a PS policy where farmers receive no water subsidies and pay the true economic cost of water. For $\sigma > 0$, the farmers' revenue is greater under an AU policy than a PS regulation since individuals who farm their plots have no water expenses if they are assigned property rights on the resource, while they incur the expense σp_w under PS.

The same is true at the aggregate level: although the AU and PS policies generate the same labor allocations across the agricultural and service sector, their effects on the aggregate revenue are different. Consider first the revenue generated by the AU policy: 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. It follows that the total water revenue under an AU policy is $p_w [1 - (1 - \sigma) \alpha_I]$. Then, for given levels of p, w, and water trading restrictions σ, regional aggregate income under the AU policy is

$$G^{AU}(p, w, \sigma) = G^s(p, w) + \int_{\alpha_I}^{1} \pi(\alpha) d\alpha + w + p_w [1 - (1 - \sigma) \alpha_I], \tag{3}$$

where income is derived from services, agricultural production, and water sales. Under a PS policy, the revenue generated by the water authority selling the water is p_w, regardless of who pays for it. Such subsidies are simply transfers from taxpayers to farmers, and have no effect on aggregate revenue. Consequently, for given p, w and σ, the aggregate income under the PS policy is

$$G^{PS}(p, w, \sigma) = G^s(p, w) + \int_{\alpha_I}^{1} \pi(\alpha) d\alpha + w + p_w. \tag{4}$$

3 Analysis of AU and PS Policies

We now examine the impact of water trading on regional welfare and income distribution under the AU and PS policy on: (i) aggregate regional income, and its distribution across agricultural and service providers, (ii) the labor shares across agricultural and service production activities, and (iii) the service price and land rental values. In what follows 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 $\bar{w}$.

3.1 AU Policies

Definition 1. A *competitive equilibrium* with quantity trading restrictions σ is characterized by a service price p^* and welfare level $\bar{u}^*$ such that

(i) the service good market clears

$$G_p^s(p^*, \bar{w}) = E_p(p^*, \bar{u}^*) + \rho(1 - \alpha_I) \tag{5}$$

and

(ii) aggregate income is equal to aggregate expenditures (Walras law holds)

$$E(p^*, \bar{u}^*) = G^s(p^*, \bar{w}) + \int_{\alpha_I}^{1} \pi(\alpha) d\alpha + \bar{w} + p_w [1 - (1 - \sigma) \alpha_I] \tag{6}$$

where the farm labor threshold α_I is given by (2) with $p = p^*$.

When characterizing the effect of a AU policy on the market equilibrium, it proves convenient to define the household share of income spent on the service good (for given service good price p) by $s(p) \equiv pq^s/E$. We have the following result:

Claim 1 . *As water trading restrictions ease, i.e., as σ increases:*

(i) *regional welfare increases, i.e.;*

$$\frac{d\bar{u}}{d\sigma} > 0,$$

and

(ii) *the price of the service good increases if the consumers' share of the budget spent on services is sufficiently high, i.e.;*

$$s(p) \geq \frac{\rho p}{\rho p + \bar{w}}.$$

Proof. See Appendix A. ■

The obvious implication of Claim 1 part (i) is, under AU, a complete removal of water trading restrictions yields maximal regional welfare. Of course, the model as presented here assumes no income leaves the region, and as such, provides theoretical support for one of the case studies discussed in Howe and Goemans (2003).

Part (ii) of Claim 1 tells us the impact of water trading on service good prices is ambiguous and gives a sufficient condition for the service price to increase. This result reflects the fact that an increase in water trading has both demand and supply side impacts on the service sector. On the demand side, with the sale of water, regional income increases, and as income increases the household demand for services increases, with the importance of household service demand indexed by $s(p)$. On the supply side, as water leaves agriculture, labor leaves agriculture and joins the service sector. Also, as the input demand for services by agriculture falls, labor already in the service sector begins producing the household service good, and the rate at which this occurs is proportional to ρ. Hence, increased water trading leads to an increase in household service good production.

Whether the supply or demand side effect dominates depends on the relative size of $s(p)$, ρ and the service price adjusted wage, $\bar{w}/p$. If the adjusted wage is small compared to ρ, the supply side effect dominates and the service price falls. If the adjusted wage is large compared to ρ, the exodus of labor to the service sector is dampened enough for demand side effects to dominate service sector expansion, and the service price increases. In the extreme case where $\rho = 0$, services are consumed only by the household. In such a case, as regional income increases with water sales, the increase in aggregate demand dominates the increase in service production, and the service price increases.

We now show that if the household spends any income on service good consumption, then as water trading increases, household service consumption increases. We show this using the properties of the expenditure function, $e(p)\bar{u}$, and the aggregate service supply function G_p^s. The demand for services is given by $x^c(p, \bar{u}) = e'(p)\bar{u}$. Taking the total derivative of $x^c(\cdot)$ gives

$$\frac{dx^c}{d\sigma}(\cdot) = e''(p)\bar{u}\frac{dp}{d\sigma} + e'(p)\frac{d\bar{u}}{d\sigma}.$$

where $e'' < 0, e' > 0$, and $\frac{d\bar{u}}{d\sigma} > 0$. Consequently, when the service good price falls, $\frac{dx^c}{d\sigma}$ is positive and household service consumption increases. On the other hand, if the service good price increases, we have

$$\frac{dy^s}{d\sigma}(\cdot) = G_{pp}^s(p, \bar{w})\frac{dp}{d\sigma} > 0.$$

Since agricultural production falls, we know the demand for services coming from the agricultural sector falls. Hence, if aggregate service output increases it must follow that household service consumption increases. This also tells us that when the service price increases, $e'(p)\frac{d\bar{u}}{d\sigma} > -e''(p)\bar{u}\frac{dp}{d\sigma}$, i.e., the welfare effects of increased water trading, $e'\frac{d\bar{u}}{d\sigma}$, dominate the price effects $-e''\bar{u}\frac{dp}{d\sigma}$.

In general, the change in aggregate revenue received by the service sector given a change in water trading restrictions is given by

$$\frac{dG^s}{d\sigma} = G_p^s(p, \bar{w})\frac{dp}{d\sigma} = y^s\frac{dp}{d\sigma},$$

the sign of which increases (decreases) as the service price increases (decreases). Revenue received by agricultural service providers is equal to $\rho p[1 - \alpha_I]$. Taking the total derivative of $\rho p[1 - \alpha_I]$ and rearranging terms gives

$$\frac{d}{d\sigma}\{\rho p[1 - \alpha_I]\} = \rho\left\{\frac{dp}{d\sigma}[1 - \alpha_I] - p\frac{d\alpha_I}{d\sigma}\right\}.$$

Then if the service price falls agricultural service income necessarily falls. If the service price increases, then the impact of water trading on agricultural service income is ambiguous. It is obvious, however, that although service sector revenues might increase, agricultural service revenue can definitely fall.

To examine the impact of water trading on land rental rates, take the total differential of the land rental function $\pi(\alpha) = \alpha - \rho p_s - w - p_w$. Then the change in land rental rates given changes in per-unit water values is

$$\frac{d\pi}{d\sigma} = -\rho \frac{dp_s}{d\sigma}.$$

If the service price increases, land rental values fall and the opposite occurs with a decrease in the service price.

3.2 PS policies

We now examine the impact of a PS policy on aggregate welfare and compare the relative merits of both policies. In this section we assume the entire water endowment is sold at price p_w by the benevolent regulator. A market equilibrium under a PS policy is defined as follows:

Definition 2. A competitive equilibrium with subsidization at rate $\tau = 1 - \sigma$ is characterized by a service price p^* and welfare level $\bar{u}^*$ such that

(i) the service good market clears

$$G_p^s(p^*, \bar{w}) = E_p(p^*, \bar{u}^*) + \rho(1 - \alpha_I)$$

and

(ii) aggregate income is equal to aggregate expenditures (Walras law holds)

$$E(p^*, \bar{u}^*) = G^s(p^*, \bar{w}) + \int_{\alpha_I}^{1} \pi(\alpha) d\alpha + \bar{w} + p_w \tag{7}$$

where the farm labor threshold α_I is given by (2) with $p = p^*$.

The following result shows that – when compared to the zero subsidy case – a small farmer water subsidy increases service sector revenue.

Claim 2 . *A small level of subsidization increases the price of the service good.*

Proof. See Appendix B. ■

This can be easily understood observing that a small subsidy only has second order-effects on the aggregate income (4) (and thus on the welfare level of the representative consumer), but a first-order effect on the farmers' demand for service goods. Hence a small farmer water subsidy leads to an increase in service sector revenues with only a negligeable impact on the overall welfare. However, farmer water subsidies are costly in terms of aggregate welfare losses when the financial support provided to farmers becomes non neglegible. Besides, as the next result reveals, large water subsidies may also hurt the service sector

Claim 3 *A marginal increase in the water subsidy increases the service sector price if and only if*

$$s(p^*) \leq \frac{\rho p^*}{\tau p_w}. \tag{8}$$

Proof. See Appendix C. ■

Consequently, if the household share of income spent on the service good is high, then increasing farmers' subsidies leads to a fall of the service sector price. The threshold level given by (8) is simply the relative proportion of the farmer's service cost over the water subsidy. Since $s(p) < 1$, the water subsidy will not trigger a decrease in the price of the service sector good as long as the water subsidy is smaller than the farmer's cost of services. One can also deduce from claim 3 that the service sector price will be greatest when the farmer subsidy satisfies (assuming concavity)

$$\tau p_w = \rho p^* / s(p^*).$$

The reader can verify that if expression (8) holds, as τ increases, the service price increases and (i) household service consumption decreases,

$$\frac{dx^c}{d\tau}(\cdot) = e''(p)\,\bar{u}\frac{dp}{d\tau} + e'(p)\frac{d\bar{u}}{d\tau} \leq 0,$$

(ii) nominal service sector revenue increases,

$$\frac{dG^s}{d\tau} = G^s_p(p, \bar{w})\frac{dp}{d\tau} \geq 0,$$

(iii) agricultural service income increases

$$\frac{d}{d\tau}\left\{\rho p\left[1-\alpha_I\right]\right\}=\rho\left\{\frac{dp}{d\tau}\left[1-\alpha_I\right]+p\frac{d\alpha_I}{d\sigma}\right\}>0,$$

and (iv) land rental values decrease

$$\frac{d\pi}{d\tau}=-\rho\frac{dp}{d\tau}\leq 0.$$

3.3 Aggregate welfare comparisons under the AU and PS schemes

As mentioned above, for given p and w, *ceteris paribus*, the AU and PS policies generate the same labor allocations across the agricultural and service sector but their impact on individual and aggregate income is different. At the aggregate level, using (3) and (4), we obtain that for given p, w and $\sigma < 1$

$$G^{PS}\left(p,w,\sigma\right)-G^{AU}\left(p,w,\sigma\right)=p_w\left(1-\sigma\right)\alpha_I>0,$$

where $p_w\left(1-\sigma\right)\alpha_I$ is the amount of water income the region loses under the AU water trading restrictions. However, just because aggregate income under the PS scheme is greater than that under the AU scheme, one must be careful in making direct comparisons of aggregate welfare under the two schemes, as the service good price under the two schemes are likely to differ. However, we now show the service good price is higher under the PS scheme, as is the level of regional welfare.

To see this, consider the system of equations formed by (2), (5) and

$$E\left(p^*,\bar{u}^*\right)=G^s\left(p^*,\bar{w}\right)+\int_{\alpha_I}^{1}\pi(\alpha)d\alpha+\bar{w}+p_w\left[1-\left(1-\sigma\right)\alpha_I\right]+k, \qquad (9)$$

where $k\in\left[0,p_w\left(1-\sigma\right)\alpha_I\right]$. Here, a value of $k=0$ corresponds to the AU scheme and a value of $k=p_w\left(1-\sigma\right)\alpha_I$ corresponds to the PS scheme. Intermediate values of k correspond to a subsidy policy where the water authority sells only a fraction of the surplus of water over domestic usages. Differentiating the system (2), (5) and (9) with respect to $p,\bar{u}$ and k gives the effects of a marginal increase in the selling of water on the service price and on the welfare. Differentiating gives

$$d\alpha_I = \rho dp$$

$$G^s_{pp}dp = E_{pp}dp + E_{pu}d\bar{u} - \rho d\alpha_I \tag{10}$$

$$E_p dp + E_u d\bar{u} = G^s_p dp - \pi(\alpha_I)d\alpha_I - \int_{\alpha_I}^1 \rho dp d\alpha - p_w(1-\sigma)d\alpha_I + dk. \tag{11}$$

Expression (10) reduces to

$$\frac{dp}{dk} = \frac{E_{pu}/E_u}{G^s_{pp} - E_{pp} + \rho^2} > 0,$$

while substituting $\pi(\alpha_I) = -(1-\sigma)p_w$ and $\int_{\alpha_I}^1 \rho dp d\alpha = \rho(1-\alpha_I)dp$ into (11), using expression (5), and simplifying yields

$$\frac{d\bar{u}}{dk} = \frac{1}{E_u} > 0.$$

As these results hold for all k and σ, we can conclude that PS schemes yield a higher level of regional welfare than the AU scheme, and a higher service price.

4 Third party effects with income flight

This section takes a preliminary look at the potential impact of third party effects on regional welfare, given income flight – the exact definition of which follows shortly. The objective of this section is not to examine all of the impacts of water trading on regional equilibrium, e.g., the impact of water trading on land rental rates and service income. Instead we set out only to show that when a simple version of income flight is introduced into the open labor market model, water trading no longer leads to an unambiguous improvement in regional welfare.

Figure 1 presents a graphical representation of labor market equilibrium when the labor market is open. In Figure 1 the exogenous wage rate is $\bar{w}$ and the region's labor endowment is 1. The service labor supply function is given by the upward sloping line $l^s = w + \rho p^* + \sigma p_w$, and the service sector's inverse labor demand function is given by the downward sloping function $W^s(p^*, l)$. Given $\rho, \sigma, \bar{w}$, and p_w, if the equilibrium price of services is p^*, then the equilibrium level of labor supplied to the service sector is l^{s*}, the amount of service sector labor demanded by the region is $l^{s*}_d = W^s(p^*, l)$, and $l^{a*} = 1 - l^{s*}$ units of labor remain 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 to the city). On the other hand, if the equilibrium service price were $p^{**} > p^*$, then the regional service labor demand curve might be the dashed function $W^s(p^{**}, l)$,while the service supply function would shift out to $l^s = w + \rho p^{**} + \sigma p_w$. In this case there would be an excess demand for service labor and urban residents would commute to the countryside. Of course, our current analysis implicitly assumes commuting costs are zero.

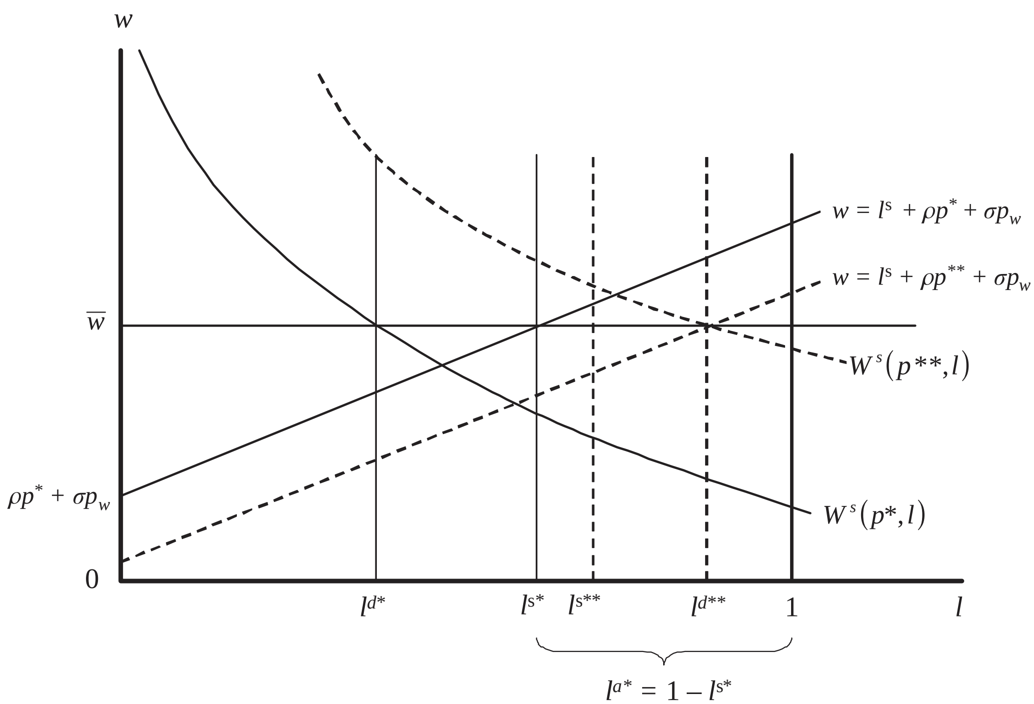

Figure 1. Labor market equilibrium

In what follows we focus on the case where labor leaves the region.[1] In such a case we can define commuter income as $(\bar{w} + \sigma p_w)\left[G_w^s(p, \bar{w}) - \alpha_I\right]$.

To introduce income flight we first assume a fraction $\gamma \in [0, 1]$ of commuter income is

[1] We have shown the region is better off with water trading with no income flight. With more income flowing into the region aggregate welfare should improve even more. In this sense, the case where urban labor flows into the region is uninteresting.

spent outside the region. Then the value of income leaving the region is equal to

$$\gamma\left(\bar{w}+\sigma p_w\right)\left[G_w^s\left(p,\bar{w}\right)-\alpha_I\right]\leq 0$$

A simple way to introduce income flight is by appending this term to the Walras condition in Definition 1.[2] This gives the following definition.

Definition 4. A competitive equilibrium with income flight, quantity trading restrictions, and open labor markets is characterized by a service price p^* and welfare level $\bar{u}^*$ such that

(i) the service good market clears, i.e. expression (5) holds

$$G_p^s\left(p^*,\bar{w}\right)=E_p\left(p^*,\bar{u}^*\right)+\rho(1-\alpha_I^*),$$

and

(ii) aggregate expenditure is equal to aggregate income (Walras law holds)

$$E\left(p^*,\bar{u}^*\right)=G^s\left(p^*,\bar{w}\right)+\int_{\alpha_I^*}^1\pi(\alpha)d\alpha+\bar{w}+p_w\left[1-\left(1-\sigma\right)\alpha_I^*\right] \qquad (13)$$
$$-\gamma\left(\bar{w}+\sigma p_w\right)\left[\alpha_I^*-G_w^s\left(p^*,\bar{w}\right)\right]$$

where the farm labor threshold is $\alpha_I^*\equiv\rho p^*+\bar{w}+\sigma p_w$.

We now show that with income flight, regional welfare does not necessarily improve with water trading. From Claim 1, when $\gamma=0$ (no income flight) welfare is increasing. It is proven in appendix that

[2] Strictly speaking, in the income flight model aggregate welfare should be reinterpreted by assuming there are a continuum of (equally weighted) households indexed by i, each having preferences

$$u^i\left(x^i\right)=\left(x_s^i\right)^{\beta_s}\left(x_a^i\right)^{\beta_a}\left(x_m^i\right)^{1-\beta_s-\beta_a}. \qquad (12)$$

Then rural expenditures should be defined as

$$E\left(p,\bar{u}\right)\equiv\min\left\{px_s+p_ax_a+p_mx_m:\bar{u}\leq\int_\gamma^1u^i\left(x^i\right)di\right\}$$

decomposed into rural and urban expenditures. The reader can verify that the qualitative results below, however, do not change.

Claim 4 . *If*

$$\gamma > \frac{\alpha_I\left(\rho^2 - E_{pp} + G^s_{pp}\right)}{\left[G^s_w - \alpha_I - (\bar{w} + \sigma p_w)\right]\left(\rho^2 - E_{pp} + G^s_{pp}\right) - \rho\left(\bar{w} + \sigma p_w\right)\left(G^s_{pw} - \rho\right)},$$

then regional welfare falls with water trading.

Proof. See Appendix D. ■

Hence, if a "large enough" share of income leaves the region, we get the much feared result that water trading hurts the local economy. In such a case even side payments (from within the region) offers no remedy to the problem. One final comment on Claim is warranted. The Claim holds only for a given (σ, γ) pair. Hence, even if income flight occurs, it is still possible that a nonzero level of water trading exits that will improve regional welfare. In other words, for the sake of argument, say $\gamma = 0.1$ and at $\sigma = 0.3$ Claim 4 holds. It is quite possible that if instead $\sigma = 0.1$, Claim 4 would not hold. If so, then compared to the case where water trading were completely prohibited, regional welfare would be higher if 10 percent of the water could be traded.

5 Conclusion

There has been growing concern with 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 examined two basic cases. In one case all income stayed in the region – no income flight – and in the other case some of the agents with low quality land sold their water, left the region, and earned wage income in, say, a large urban wage market. In the model with no income flight, the following analytical results were obtained: Water trading leads to (i) an expansion in aggregate service provision, an increase in household service consumption, and a contraction of the agricultural sector and hence, the input demand of services by agriculture; (ii) the price of services and land rental rates can either increase or fall and (iii) water trading yields an unambiguous improvement in regional welfare. In general, one cannot tell what effect water trading will have on nominal, aggregate GDP, or on nominal service income. Real income, however, increases with water trading. The paper also examined the possible impact that water subsidies can have on regional welfare, and showed that water subsidies can have a negative impact on aggregate regional welfare. The second model introduces income flight. We focused only on the impact of water trading on regional welfare, and showed that with income flight, regional welfare can definitely fall. – a result that does not occur without income flight.

Fears of water trading are potentially justified if water trading triggers an exodus of labor, and its income, from the region. The analysis here suggests that with income flight, aggregate regional GDP will fall and the residents can be worse off after opening the market to water trades. On the other hand, if income stays in the community, fears that water trading will trigger a decline in the regions' economic health are understandable, but such an event is not likely to happen. In fact, it is likely that water taxes combined with income transfers could improve the living standards of all in the region. Also, although we do not examine the economics of such a case, a decline in regional welfare would not likely occur if producers sold water and used the proceeds from water sales to purchase water saving irrigation technologies. The "fixed-proportion type" technology used in the analysis precluded an easy investigation of the economics of such choices.

The simple model presented here can serve as a point of departure to examine several 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.

Appendix

A Proof of Claim 1

(i) Taking the total derivative of expressions (2), (6) and (5) with respect to p and σ yields

$$d\alpha_I = \rho dp + d\sigma p_w \tag{14}$$

$$G^s_{pp} dp = E_{pp} dp + E_{pu} d\bar{u} - \rho d\alpha_I \tag{15}$$

$$E_p dp + E_u d\bar{u} = G^s_p dp - \pi(\alpha_I) d\alpha_I - \int_{\alpha_I}^1 \rho dp d\alpha - p_w(1-\sigma) d\alpha_I + p_w \alpha_I d\sigma. \tag{16}$$

Using $\pi(\alpha_I) = -(1-\sigma)p_w$, $\int_{\alpha_I}^1 \rho dp d\alpha = \rho(1-\alpha_I)dp$ and (5), (16) simplifies to

$$E_u d\bar{u} = p_w \alpha_I d\sigma.$$

Hence, we have

$$\frac{d\bar{u}}{d\sigma} = \frac{p_w}{e(p)} \alpha_I > 0.$$

(ii) Substituting (14) into (15), dividing through by $d\sigma$, and rearranging terms yields

$$\left[G^s_{pp} - E_{pp} + \rho^2\right] \frac{dp}{d\sigma} = \left[\frac{E_{pu}}{E_u}\alpha_I - \rho\right] p_w$$

or

$$\frac{dp}{d\sigma} = p_w \frac{\left[\rho p + \bar{w} + \sigma p_w\right] s(p)/p - \rho}{G^s_{pp} - e'' \bar{u} + \rho^2}$$

where we have used

$$\frac{E_{pu}}{E_u} = \frac{e'(p)}{e(p)} = \frac{pe'(p)\bar{u}}{pe(p)\bar{u}} = \frac{s(p)}{p}$$

Since e is concave and $G^s_{pp} > 0$, we have $dp/d\sigma > 0$ for all $\sigma > 0$ if

$$s(p) \geq \frac{\rho}{\rho + \bar{w}/p} > \frac{\rho}{\rho + \bar{w}/p + \sigma p_w/p}.$$

B Proof of Claim 2

Take the total derivative of expressions (2), (7) and (5) with respect to p and σ to get:

$$d\alpha_I = \rho dp + d\sigma p_w \tag{17}$$

$$G_{pp}^s dp = E_{pp} dp + E_{pu} d\bar{u} - \rho d\alpha_I \tag{18}$$

$$E_p dp + E_u d\bar{u} = G_p^s dp - \pi(\alpha_I) d\alpha_I - \int_{\alpha_I}^1 \rho dp d\alpha. \tag{19}$$

Next, substitute $\pi(\alpha_I) = -(1-\sigma)p_w$ and $\int_{\alpha_I}^1 \rho dp d\alpha = \rho(1-\alpha_I)dp$ into (19) and rearrange terms to get

$$\frac{d\bar{u}}{d\sigma} = \left(p_w + \rho \frac{dp}{d\sigma}\right) \frac{(1-\sigma)\, p_w}{E_u}. \tag{20}$$

Then, substitute (17) into (18), divide through by $d\sigma$, and use (20) to get

$$G_{pp}^s \frac{dp}{d\sigma} = E_{pp} \frac{dp}{d\sigma} + \left[\frac{E_{pu}}{E_u}(1-\sigma)p_w - \rho\right] [\rho \frac{dp}{d\sigma} + p_w]$$

or

$$\left[G_{pp}^s - E_{pp} + \rho^2 - \rho \frac{E_{pu}}{E_u}(1-\sigma)p_w\right] \frac{dp}{d\sigma} = \left[\frac{E_{pu}}{E_u}(1-\sigma)p_w - \rho\right] p_w.$$

Rearrange terms to get

$$\frac{dp}{d\sigma} = -p_w \frac{(1-\sigma)p_w E_{pu}/E_u - \rho}{G_{pp}^s - E_{pp} + \rho^2 - \rho(1-\sigma)p_w E_{pu}/E_u}.$$

Finally, define $\tau = 1 - \sigma$, and substitute into the above expression to get

$$\frac{dp}{d\tau} = \frac{p_w}{\rho} \frac{\rho^2 - \tau \rho p_w s(p)/p}{G_{pp}^s - e''\bar{u} + \rho^2 - \tau \rho p_w (p)/p}.. \tag{21}$$

Since e is concave and $G_{pp}^s > 0$, we have

$$\left.\frac{dp}{d\tau}\right|_{\tau=0} = \frac{\rho p_w}{G_{pp}^s - e''\bar{u} + \rho^2} > 0$$

hence a small water subsidy increases the service sector price.

C Proof of Claim 3

Substitute (21) into (20) to get

$$\frac{d\bar{u}}{d\tau} = -\frac{\tau p_w^2}{e(p)} \left[\frac{G_{pp}^s - e''\bar{u}}{G_{pp}^s - e''\bar{u} + \rho^2 - \rho \tau p_w s(p)/p}\right]. \tag{22}$$

Since $d\bar{u}/d\tau \leq 0$ for all $\tau \in [0,1]$, the sign of $dp/d\tau$ only depends on the numerator of (21), which leads to condition (8).

D Proof of Claim 4

From computations developed in the proof of claim 1, it is easy to obtain that the total derivative of (13) and (5) simplifies to

$$\left(G^s_{pp} - E_{pp} + \rho^2\right)\frac{dp}{d\sigma} - E_{pu}\frac{d\bar{u}}{d\sigma} = -\rho p_w \tag{23}$$

and

$$\begin{aligned} E_u d\bar{u} &= p_w \alpha_I d\sigma + \gamma\left(\bar{w} + \sigma p_w\right)\left(G^s_{wp} dp - d\alpha_I\right) + \gamma p_w \left(G^s_w - \alpha_I\right) d\sigma \\ &= p_w \left[\rho p + (1-\gamma)\left(\bar{w} + \sigma p_w\right) + \gamma\left(G^s_w - \alpha_I\right)\right] d\sigma + \gamma\left(\bar{w} + \sigma p_w\right)\left(G^s_{pw} - \rho\right) dp \end{aligned}$$

or

$$-\gamma\left(\bar{w} + \sigma p_w\right)\left(G^s_{wp} - \rho\right)\frac{dp}{d\sigma} + E_u \frac{d\bar{u}}{d\sigma} = \Delta, \tag{24}$$

where $\Delta = p_w \left[\rho p + (1-\gamma)\left(\bar{w} + \sigma p_w\right) + \gamma\left(G^s_w - \alpha_I\right)\right]$, the sign of Δ being ambiguous.

The reader can verify the system of equations (23) and (24) has solution

$$\frac{dp}{d\sigma} = -\frac{\Delta E_{pu} + \rho p_w E_u}{H} \tag{25}$$

$$\frac{d\bar{u}}{d\sigma} = \frac{\Delta\left(\rho^2 - E_{pp} + G^s_{pp}\right) - \rho\gamma p_w\left(\bar{w} + \sigma p_w\right)\left(G^s_{pw} - \rho\right)}{H}, \tag{26}$$

where $H = \left(G^s_{pp} - E_{pp} + \rho^2\right) E_u - \gamma\left(\bar{w} + \sigma p_w\right)\left(G^s_{pw} - \rho\right) E_{pu} > 0$. Given H is positive, the sign of both $dp/d\sigma$ and $d\bar{u}/d\sigma$ depend on the sign of their respective numerator. Rearranging terms in the numerator of expression (26) reveals that $d\bar{u}/d\sigma < 0$ if

$$\frac{\alpha_I\left(\rho^2 - E_{pp} + G^s_{pp}\right)}{\rho\left(\bar{w} + \sigma p_w\right)\left(\rho - G^s_{pw}\right) + \left(\alpha_I - G^s_w + \bar{w} + \sigma p_w\right)\left(\rho^2 - E_{pp} + G^s_{pp}\right)} < \gamma.$$

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