Open access renewable resources, urban unemployment, and the resolution of dual institutional failures

Ichiroh Daitoh[1*] and Nori Tarui[2]

[1]Faculty of Business and Commerce, Keio University, Tokyo, Japan and
[2]Department of Economics, University of Hawaiʻi at Mānoa, Honolulu, HI, USA
[*]Corresponding author. Email: idaitoh@fbc.keio.ac.jp

ONLINE APPENDIX

1. Existence condition of Harris-Todaro equilibrium (for section 2)

We show how to solve the HT equilibrium under the export tax τ on the resource good. First, the urban manufacturing employment L_M^* is predetermined by (5). Then, rural income per capita in the steady state is $w^\tau = \frac{\alpha S(L_R)}{1+\tau}$. Combining this with (6), we have:

$$(1+\mu)\alpha S(L_R) = (1+\tau)w_M \; . \tag{A1}$$

Another relation between $(1+\mu)$ and L_R is the labor constraint (7) $L_R + (1+\mu)L_M^* = L$. By simultaneously solving these two equations, we can obtain the HT equilibrium. Figure A1 below shows the loci of $(1+\mu)$ and L_R that satisfy (A1) and (7). If the vertical axis intercept of (7) is higher than that of (A1), the HT equilibrium exists as an interior solution. This existence condition can be written as $(1+\tau)\left(\frac{w_M}{\alpha K}\right) < \frac{L}{L_M^*}$, which is equivalent to Assumption 1 under $\tau = 0$.

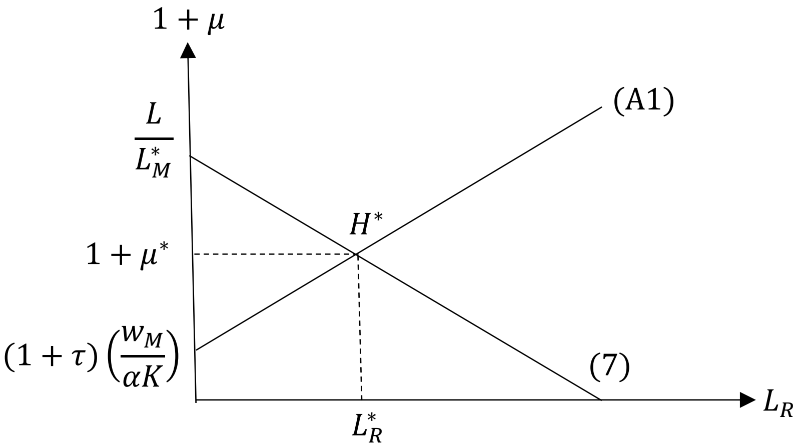

Figure A1. Existence of Harris-Todaro equilibrium.

2. Effects of export tax on the rural resource good along the transition path (for Proposition 1)

We investigate the effects of an export tax τ on the transition path. For this purpose, we first consider a general equilibrium at each instant: given S, w_M, p and L, the system of (1), (2'), (5), (6') and (7) determines the values of five endogenous variables $R, \mathrm{w}^{\tau}, L_R, L_M,$ and μ. Then, the resource dynamics equation determines the change in S over time.

An increase in τ at the initial steady state has opposing effects on urban unemployment at the initial instant and along the transition path. At the initial instant, $w^{\tau*}$ decreases by (2') and thus μ^* increases by (6').[1] This is qualitatively the same as what Abe and Saito (2016) identify as the instantaneous impact of an export tax on unemployment. Then, the decrease in L_R^* by (7) and thus in R^* by (1) makes $\dot{S} = G(S) - R^*$ positive. The increase in S raises $w^{\tau*}$ by (2') and reduces μ^* by (6') along the transition path. Recalling that the new steady state is associated with higher unemployment rate μ^*, the instantaneous effect turns out to dominate the effect along the transition path. The instantaneous effects of the export tax on the rural resource good and on urban unemployment, derived by Abe and Saito (2016), decrease in magnitude (but in the same direction) in the long run.

3. Sustainable yield and the dynamically efficient outcome (for footnote 15)

In section 4, we derived the first-best labor allocation in (9), where we apply:

$$\alpha K\left(1 - \tfrac{2\alpha}{r} L_R^E\right) = w. \tag{9'}$$

This corresponds to the first-order condition for the problem of deriving the efficient sustainable yield L_R that maximizes the rent $R(L_R) - wL_R$. Solving (9') for rural labor, we have:

$$L_R^E = \frac{r(\alpha K - w)}{2\alpha^2 K} = \frac{r}{2\alpha}\left(1 - \frac{w}{\alpha K}\right).$$

The above efficient outcome for the "sustainable yield" model is the (dynamically) efficient

[1] Because L_M^* remains unchanged, the level L_U^* of urban unemployment moves in the same direction as the rate μ^*.

outcome, i.e., the solution to the associated dynamic optimization that maximizes the present value of rents over time if the discount rate is (close to) zero. To see this, consider the following dynamic optimization problem:

$$\max_{\{E_t\}_{t\geq 0}} \int_0^\infty e^{-\rho t}[\alpha S_t E_t - wE_t]dt$$

$$s.t. \quad \dot{S}_t = rS_t(1 - S_t/K) - \alpha S_t E_t \quad t \geq 0,$$

given S_0, where E_t is labor effort and $\rho > 0$ is the discount rate (we let $E_t \equiv L_{Rt}$). Let H be the associated current-value Hamiltonian:

$$H_t = \alpha S_t E_t - wE_t + \lambda_t \left\{ rS_t \left(1 - \frac{S_t}{K}\right) - \alpha S_t E_t \right\},$$

where λ_t is the co-state variable associated with S_t. The condition for optimality is given by

$$\frac{\partial H_t}{\partial E_t} = \alpha S_t - w - \lambda_t S_t = 0$$

(at the singular solution) and the following adjoint equations:

$$\dot{\lambda}_t - \rho \lambda_t = -\frac{\partial H_t}{\partial S_t} = -\left\{ \alpha E_t + \lambda_t (r - \frac{2rS_t}{K} - \alpha E_t) \right\}.$$

At the steady state, we have $\dot{S}_t = 0$ and a harvest equal to natural resource growth: $\alpha SE = rS(1 - S/K)$ (the time subscript t is omitted here). It then follows from the adjoint equation that

$$\rho \lambda = \alpha E + \lambda(-rS/K).$$

As $\rho \to 0$, we have

$$\alpha E = \frac{\lambda r S}{K}, \quad i.e., \quad \lambda = \frac{\alpha E K}{rS}.$$

Plug this into the first-order condition (for the singular solution) and we have

$$\alpha S - w - \frac{\alpha^2 E K}{r} = 0.$$

Because the harvest equals natural resource growth in the steady state, we have $\alpha E = r(1 -$

S/K), i.e., $S = K - \frac{\alpha EK}{r}$. Substitute this into the last expression, and we have

$$\alpha K\left(1 - \frac{2\alpha}{r} L_R\right) = w.$$

Therefore,

$$E = \frac{r(\alpha K - w)}{2\alpha^2 K} = \frac{r}{2\alpha}\left(1 - \frac{w}{\alpha K}\right).$$

This is the same as the efficient outcome for the sustainable yield model derived from (9').

4. Effects of the parameters on the first-best rural policy (for Proposition 2 *(ii)*)

We investigate the effects of changes in K, r and α on the right-hand side of equation (10) in subsection 4.2. By differentiating (9), we obtain:

$$\left\{\alpha K\left(\frac{2\alpha}{r}\right) - pF''\right\} dL_R = \alpha\left(1 - \frac{2\alpha}{r} L_R\right) dK + \alpha K\left(\frac{2\alpha}{r^2} L_R\right) dr - F' dp + K\left(1 - \frac{4\alpha}{r} L_R\right) d\alpha.$$

It follows that $\frac{dL_R^E}{dr} > 0$, $\frac{dL_R^E}{dp} < 0$, and $\frac{dL_R^E}{dK} > 0$ (because $1 - \frac{2\alpha}{r} L_R^E > 0$). The sign of $\frac{dL_R^E}{d\alpha}$ is ambiguous. We now return to the expression for the optimal rural subsidy rate, $s_R = w_M - \alpha K\left(1 - \frac{\alpha}{r} L_R^E\right)$. The derivation above indicates that $\frac{ds_R}{dw_M} > 0$ and $\frac{ds_R}{dp} = \frac{\alpha^2 K}{r}\,\frac{dL_R^E}{dp} < 0$. Hence, the condition $s_R < 0$ holds if w_M is low enough or if p is high enough. In both cases, the institutional failure of the urban labor market is small relative to the distortions due to rural resource open access, and hence, the first-best rural policy is to tax rural income. We also have

$$\frac{ds_R}{d\alpha} = -K\left(1 - \frac{2\alpha}{r} L_R^E\right) + \frac{\alpha^2 K}{r}\frac{dL_R^E}{d\alpha} = -K\left(1 - \frac{2\alpha}{r} L_R^E\right) + \frac{\alpha^2 K}{r}\frac{K\left(1 - \frac{4\alpha}{r} L_R^E\right)}{\alpha K\left(\frac{2\alpha}{r}\right) - pF''(L_M^E)}$$

$$= \frac{-rK\left(1 - \frac{2\alpha}{r} L_R^E\right)\left\{\alpha K\left(\frac{2\alpha}{r}\right) - pF''(L_M^E)\right\} + \alpha^2 K^2\left(1 - \frac{4\alpha}{r} L_R^E\right)}{r\left\{\alpha K\left(\frac{2\alpha}{r}\right) - pF''(L_M^E)\right\}} = \frac{-\alpha^2 K^2 + rK\left(1 - \frac{2\alpha}{r} L_R^E\right) pF''(L_M^E)}{r\left\{\alpha K\left(\frac{2\alpha}{r}\right) - pF''(L_M^E)\right\}} < 0.$$

Similarly, we have

$$\frac{ds_R}{dK} = -\alpha\left(1 - \frac{\alpha}{r} L_R^E\right) + \frac{\alpha^2 K}{r}\frac{dL_R^E}{dK} = -\alpha\left(1 - \frac{\alpha}{r} L_R^E\right) + \frac{\alpha^2 K}{r}\frac{\alpha\left(1 - \frac{2\alpha}{r} L_R^E\right)}{\alpha K\left(\frac{2\alpha}{r}\right) - pF''(L_M^E)}$$

$$= \frac{-\alpha r\left(1-\frac{\alpha}{r}L_R^E\right)\left\{\alpha K\left(\frac{2\alpha}{r}\right)-pF"(L_M^E)\right\}+\alpha^3 K\left(1-\frac{2\alpha}{r}L_R^E\right)}{r\left\{\alpha K\left(\frac{2\alpha}{r}\right)-pF"(L_M^E)\right\}} = \frac{-\alpha^3 K + r\left(1-\frac{\alpha}{r}L_R^E\right)pF"(L_M^E)}{r\left\{\alpha K\left(\frac{2\alpha}{r}\right)-pF"(L_M^E)\right\}} < 0.$$

An intuition behind these two results is that as α or K increases, the sustainable yield of the rural resource good increases, and thus the distortion due to open access increases. If these parameters have sufficiently large values, the first-best policy involves taxing rural income. The effect of a change in r is ambiguous (but if $r \geq 1$, $\frac{ds_R}{dr} < 0$ holds):

$$\frac{ds_R}{dr} = -\frac{\alpha^2 K}{r^2} L_R^E + \frac{\alpha^2 K}{r}\frac{dL_R^E}{dr} = -\frac{\alpha^2 K}{r^2} L_R^E + \frac{\alpha^2 K}{r}\frac{\alpha K\left(\frac{2\alpha}{r^2}L_R^E\right)}{\alpha K\left(\frac{2\alpha}{r}\right)-pF"(L_M^E)} = \frac{\frac{2\alpha^4 K^2}{r^3}L_R^E(1-r)+\frac{\alpha^2 K}{r}pF"(L_M^E)L_R^E}{r\left\{\alpha K\left(\frac{2\alpha}{r}\right)-pF"(L_M^E)\right\}}.$$

5. Institutional changes under an export tax on the rural resource good (for Proposition 3 *(i)*)

We derive the condition (11) for increasing the incentive for rural institutional change in subsection 5.1. The change in the maximum sustainable rent, $\pi^* = \frac{R(L_R^*)}{1+\tau} - w_R L_R^*$, is:

$$\frac{d\pi^*}{d\tau} = -\frac{R(L_R^*)}{(1+\tau)^2} + \left[\frac{R'(L_R^*)}{1+\tau} - w_R\right]\frac{dL_R}{d\tau} + \frac{w_M L_R^*}{{\lambda^*}^2}\frac{d\mu^*}{d\tau}.$$

Using the first-order condition for rural firms' profit maximization, $w_R = \frac{R'(L_R^*)}{1+\tau}$ and $w_R = \frac{w_M}{\lambda^*}$, the above formula becomes:

$$\frac{d\pi^*}{d\tau} = -\frac{R(L_R^*)}{(1+\tau)^2} + \frac{w_R L_R}{\lambda^*}\frac{d\mu^*}{d\tau}.$$

With $\frac{d\mu^*}{d\tau} > 0$, the necessary and sufficient condition for $\frac{d\pi^*}{d\tau} > 0$ is:

$$\frac{R(L_R^*)}{w_R L_R} < (1+\tau)^2 \frac{d\lambda^*/d\tau}{\lambda^*} \quad . \tag{11}$$

6. An increase in an import tariff on the urban manufactured good (for subsection 5.2)

Comparative statics (Proposition 4)

The effects of a tariff can be derived from the system (1), (2), (3), (5'), (6) and (7), where the domestic price is $p = (1 + t)\bar{p}$ and thus (5) is replaced with (5') $w = (1 + t)\bar{p}F'(L_M)$. An increase in t increases $L_M^* = L_M(w_M/(1 + t)\bar{p})$, which is predetermined. Totally differentiating $\lambda\alpha S(L_R) = w_M$ and (7), the comparative-static results are:

$$\frac{dL_R^*}{dL_M^*} = \frac{\lambda[1-(\alpha/r)L_R]}{-[1-(\alpha/r)L_R]-L_M^*\lambda(\alpha/r)} < 0, \qquad \frac{d\mu^*}{dL_M^*} = \frac{d\lambda^*}{dL_M^*} = \frac{\lambda^2(\alpha/r)}{-[1-(\alpha/r)L_R]-L_M^*\lambda(\alpha/r)} < 0.$$

Rural population L_R^* and the rate of urban unemployment μ^* both decrease.[2] This implies that the import tariff on the urban manufactured good can make a mitigation of rural resource overuse and a reduction in urban unemployment compatible. In addition, by (6), rural income w^* increases, which means an improvement of income inequality between urban and rural areas. The resource good production R^* may or may not decrease because of $S'(L_R) < 0$.

Welfare analysis (for footnote 19)

To derive the welfare effects of the import tariff on an urban manufactured good, we follow the same procedure as in section 3. Given the domestic price of the urban manufactured good, $p = (1 + t)\bar{p}$, the representative consumer's budget constraint in terms of the domestic price is:

$$E(1, p, \bar{u}) = R + pM + t\bar{p}\big(E_p - M\big), \tag{A2}$$

where $E_p \equiv \frac{\partial E}{\partial p} = c_M$ is the compensated demand for the manufactured good. The tariff revenue $t\bar{p}(E_p - M)$ is distributed to consumers in a lump-sum fashion. Total differentiation

[2] The *level* of urban unemployment may increase or decrease. It can be shown that an increase in the tariff rate on the manufactured good decreases the *level* of urban unemployment if and only if the country's initial domestic price p of the urban manufactured good is sufficiently high. The proof is available on request.

of (A2) yields:

$$E_u du = dR + pdM + (M - E_p)dp + \{\bar{p}(E_p - M)dt + t\bar{p}(E_{pp} - M_p))dp\}.$$

Using $dp = \bar{p}dt$, $dM = F'(L_M)dL_M$ and $dR = wdL_R + L_R dw$ derived from the zero-rent condition $R = wL_R$, we obtain:

$$E_u du = wdL_R + L_R dw + pF'(L_M)dL_M + t\bar{p}^2(E_{pp} - M_p)dt.$$

Substituting $dw = -\left(\frac{w}{1+\mu}\right)d\mu$ and $dL_R = -(1+\mu)dL_M - L_M d\mu$ derived from (6) and (7) and using (5) yields:

$$E_u du = w\{-(1+\mu)dL_M - L_M d\mu\} - L_R\left(\frac{w}{1+\mu}\right)d\mu + pF'(L_M)dL_M$$

$$+t\bar{p}^2(E_{pp} - M_p)dt$$

$$= -\left(\frac{w}{1+\mu}\right)[L_R + (1+\mu)L_M]d\mu + t\bar{p}^2(E_{pp} - M_p)dt.$$

By substituting (7), we obtain:

$$E_u \frac{du}{dt} = -\left(\frac{wL}{1+\mu}\right)\frac{d\mu}{dt} + t\bar{p}^2\left(E_{pp} - M_p\right), \quad \text{(A3)}$$

where $E_{pp} \equiv \frac{\partial E_p}{\partial p} = \frac{\partial c_M}{\partial p}$, $M_p \equiv \frac{\partial M}{\partial p}$, and $E_{pp} - M_p$ represents the change in the quantity of imports. We can explain the welfare effects in further detail by rewriting the equation as:

$$E_u du = -\left(\frac{w - R'(L_R)}{1+\mu}\right)L_R d\mu - \left(\frac{R'(L_R)L_R + w_M L_M}{1+\mu}\right)d\mu + t\bar{p}^2(E_{pp} - M_p)dt\ .$$

The right-hand side of this expression represents three welfare effects of the import tariff. The first term is the "resource overuse effect" due to open access, the second is "the (pure) urban unemployment effect," and the third is the "trade reducing effect" (negative due to the decrease in the import of the manufactured good $E_{pp} - M_p < 0$).

It follows from (A3) that the social welfare will improve if the effect of reducing the urban unemployment rate is sufficiently large and/or when the country's trade volume ($E_p -$

M) decreases to a sufficiently small extent. Furthermore, if this country initially engages in free trade ($t = 0$), then welfare unambiguously improves after introducing an import tariff on the urban manufactured good.

Proposition A3: *An increase in the import tariff rate of the urban manufactured good improves the steady-state welfare if the effect of reducing the urban unemployment rate is sufficiently large and/or when the tariff increase reduces the country's trade volume to a sufficiently small extent. Furthermore, if the country initially engaged in free trade, a marginal increase in the import tariff rate will improve welfare in the steady state.*

References

Abe K and Saito M (2016) Environmental protection in the presence of unemployment and common resources. *Review of Development Economics* **20**, 176–188.