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Positive and Negative Externalities in Agricultural Production: The Case of Adena Springs Ranch

Charles B. Moss and Andrew Schmitz

Policy analysis is complicated by the myriad of benefits and costs generated by the use of natural resources. This study develops three benefits that must be considered in the granting of a consumptive use permit for water filed by Adena Springs Ranch, east of Ocala, Florida. This ranch is hoping to expand into grass-fat beef; but to do so, it needs additional water for irrigation. Specifically, our analysis considers the potential gain from the ranch, the potential negative effect on existing permit holders and environmental uses of water, and the possible positive value generated by the increased surface flow for other recreational users in eastern Marion County.

Key Words: grass-fat, hormone-free, water allocation, welfare analysis

JEL Classifications: C63, D62, Q25

The development of water resources has been an important economic issue for more than a century. In fact, in the first article of the *American Economic Review*, Coman (1911) presents the issues around using irrigation projects to develop the western United States. By the 1980s, the issues surrounding water allocation had changed dramatically. Reisner's (1993) book entitled, *Cadillac Desert: The American West and Its Disappearing Water*, described the water allocation in the western United States in terms of conflicts between higher-valued urban uses and environmental quality issues vs. entrenched agricultural uses, which produced lower-valued (and often subsidized) agricultural outputs. These water conflicts, however, are not limited to the western United States. Florida's urban growth

between the 1970s and the onset of the Great Recession of 2008 brought the state's historical water use for agricultural production into increasing conflict with growing urban demand for water and a concomitant recognition of the environmental consequences of water use.

Although the Economic Research Service of the U.S. Department of Agriculture classifies Florida as part of the Fruitful Rim, the state is a significant cow-calf producer (Schmitz, Moss, and Schmitz, 2003). In areas north of Orlando, traditional citrus acreage was replaced with cow-calf production after the freezes of the 1980s. The state's cattle industry has been dominated by the production of stocker cattle (sold at 400–600 pounds to backgrounders in the plains) with some feeder calves sold directly to feedlots. The profitability of backgrounding or feedlots in the state has been limited by the long distance to corn markets and by prolonged periods of heat and humidity.

This study analyzes the decision to permit additional agricultural water withdrawals by Adena Springs Ranch (Ranch) in Marion County,

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Florida. The Ranch requested the authority to pump 13.267 million gallons of water per day (mgd) in August 2012 as part of a plan to shift from traditional cow-calf production to supplying grass-fat, hormone-free beef to specialty markets. Although the pumping request was later reduced to 5.3 mgd, the Ranch’s request spawned a firestorm of controversy pitting the Ranch and its supporters against environmental groups and tourist concerns in the area. Within the context of cost–benefit analysis, the proposed pumping will have both negative and positive externalities. Specifically, pumping from the deep Floridian aquifer may reduce the output of Category 1 springs, which are those springs with an output of more than 64.6 mgd (Table 1). These springs represent significant economic value through environmental amenities along with a well-developed tourism industry around Silver Springs and the Rainbow River. However, additional pumping by the Ranch may create increased surface flows supporting additional recreational flows for canoeing and kayaking in eastern Marion County. This study incorporates both the negative and positive changes in environmental flows along with additional returns from the grass-fat cattle operation of the Ranch.

The primary issue raised in Adena Springs Ranch’s permit request involves the valuation of water under Florida’s Administrative Water Law. Under Florida’s Law, the state is divided into five water management districts, which are charged with the allocation of water to maximize the benefit to the state’s residents. This allocation is largely accomplished by the granting of consumptive-use permits. Once a permit is granted by the water management district,

the cost of water is simply the pumping and delivery expense; there is no market price for water itself. The water management district (in this case, the Saint Johns River Water Management District) then uses the permitting process to make tradeoffs between existing water users (current permit holders), environmental values for water, and the applicant.

Measuring the Costs and Benefits of Water Use

From an economic perspective, the charge to Florida’s Water Management Districts is consistent with the concept of an externality, specifically the case in which one individual’s action affects the utility of another individual outside the output or factor markets. Typically, an externality exists when the action of one person directly affects the utility of another individual in the absence of well-defined property rights. Examples include smoke from one person’s chimney that finds its way into a neighbor’s house, degradation of water from an upstream laundry affecting downstream users, and so on. Typically, the lack of a direct market linkage leads to the creation of an excessive amount of the offending output or an overuse of a common resource. Historically, this linkage has been used to justify a policy intervention to bring the marginal private benefit of the offending activity in line with its marginal social benefit (i.e., imposing a Pigouvian tax on wood that generates the chimney smoke). Florida’s creation of Water Management Districts provides an alternative mechanism for the direct allocation of water ostensibly to overcome potential negative externalities.

Table 1. Marion County Springs Water Flow

	Spring Flow		Category
	Cubic Feet per Second	Million Gallons per Day	
Fern Hammock Springs	13	8.40	2
Juniper Springs	11	7.11	2
Orange Spring	3	1.94	4
Rainbow Springs	447	288.90	1
Salt Springs	81	52.35	2
Silver Glen Springs	102	65.92	1
Silver Springs	811	524.16	1

Most of the literature on externalities is concerned with negative externalities such as the effect of excess water withdraws on the flow of environmental services. However, it is also possible that an individual's actions may yield positive externalities (i.e., one person's actions may yield benefits to someone who is not a party to the transaction). One example from California is the removal of a tree on a homeowner's property. The homeowner may remove a tree to improve his or her view, which also improves the view of the owner of an adjacent property.

Figure 1 presents the economic impact of the additional pumping of water by Adena Springs Ranch. As a starting point, we hypothesize that the current water allocation among users in the region east of Ocala results in a supply of water...for environmental and consumptive uses. If the Saint Johns River Water Management District grants the Adena Springs Ranch a consumptive-use permit, the overall quantity of water available for environmental and consumptive uses will shift to S' . This shift will result in a loss of environmental services, assuming that the current level of pumping restricts the benefits from the environmental or consumptive use of water in the region (i.e., the last million gallons of water pumped affected the quantity of water flowing from the springs or the amount of water that could be withdrawn by another person). The economic value of this loss is depicted by $abQ_WQ'_W$ in Figure 1. If the current water use does not bind the level of

environmental flows and consumptive uses, then the additional water use does not have an economic cost. Thus, the shift from \hat{S} to \hat{S}' does not imply an economic cost.

An additional complication is that the new pumping may produce a positive externality. Florida has a complex water dynamic with deep and shallow aquifers. If Adena Springs Ranch pumps from a deep aquifer (i.e., Floridan), it may increase the surface flow of water by augmenting the shallow surficial aquifers. The additional flow in the shallow aquifers may provide new recreational opportunities such as canoeing in tributaries of the Saint Johns River or the old Cross Florida Barge Canal. As depicted in Figure 2, pumping may shift the water supply in the deep Floridan aquifer to the left, to S'_D ; alternatively, it may shift the supply in the shallow aquifer to the right, to S'_S . The net economic effect from environmental flows will then be $cdQ'_S Q_S - abQ'_D Q_D$. Although the graphical depiction in Figure 2 implies a net loss of $cdQ'_S Q_S - abQ'_D Q_D < 0$, it is clear that the positive externality of the surface flow partially attenuates the loss in the deep (Floridan) aquifer.

In quantifying the economic implications of water allocations, Young (2005) develops five categories for the valuation of water: 1) commodity benefits; 2) waste and assimilation benefits; 3) public and private aesthetic, recreational, and fish and wildlife habitat benefits; 4) biodiversity and ecosystem preservation benefits; and 5) social and cultural benefits.

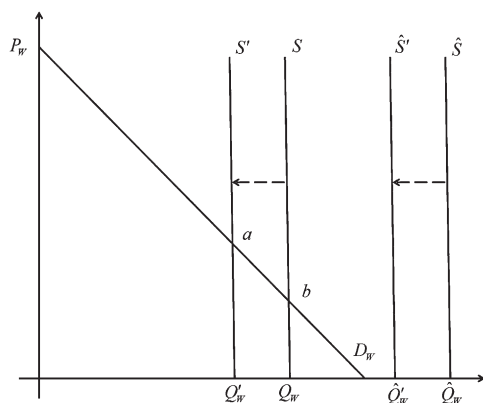


Figure 1. Effect of Additional Water Withdraws on Environmental Flows

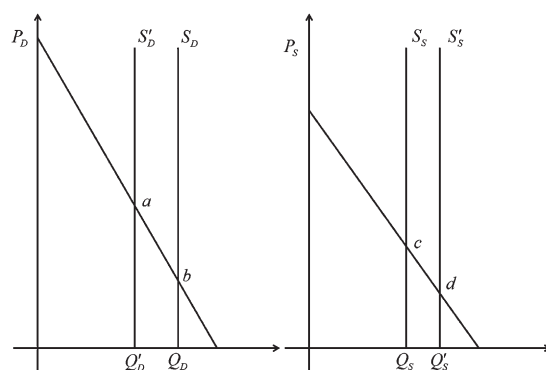


Figure 2. Attenuating Effect of Positive Externality

Thus, we envision the demand for water as the horizontal summation of five different demand curves (Figure 3):

(1)
$$D_T(p) = \sum_{i=1}^5 D_i(p),$$

where $D_T(p)$ is the total demand for water, $D_1(p)$ is the commodity demand for water, $D_2(p)$ is the waste assimilation demand for water, $D_3(p)$ is the demand for water from environmental amenities, $D_4(p)$ is the demand for water for biodiversity and ecosystem preservation, and $D_5(p)$ is the demand for water for social and cultural purposes. The method of valuation of each component of this demand structure raises different challenges. The commodity demand for water and the demand for waste assimilation are revealed by the choices of consumers and producers. The demand for environmental amenities may be revealed partially by consumer decisions (e.g., we can use the travel-cost method to infer the demand for recreational demand on the Silver River in Marion County). However, some aspects of this demand must be derived from expressed preferences: “Expressed preference (or stated preference) methods involve asking people directly about the values placed on proposed or hypothetical improvements or reductions in environmental services” (Young, 2005, p. 118). For example, some could suggest estimating the demand for environmental services by interviewing individuals who recreate at

Marion County springs (i.e., using a direct travel-cost method) or by phone surveys that ask individuals what they would be willing to pay for wildlife habitat, biodiversity, and so on in Marion County.

Effects of Grass-Fat Beef Expansion

Given the economic cost of the reallocation of water presented previously, we estimate whether the permit will increase the economic benefits to Marion County by estimating the economic benefits from Adena Springs Ranch’s expansion into the grass-fat, hormone-free beef production. Figure 4 presents an economic framework for analyzing the costs and benefits of a traditional cow-calf operation such as that operated by Adena Springs Ranch before the proposed expansion. In this scenario, the producer receives a constant price for its calves of P_S . This price is determined by the cost of feeding cattle (typically using grains) to slaughter weight. In this example, we depict this cost using an upward sloping marginal cost of feeding, $MC_F(Q)$; however, given a large number of competitive feedlots, we could also depict the cost of feeding cattle as a constant (MC_K). The sum of the price of stocker cattle in Florida plus the cost of feeding the same stocker cattle to slaughter weight equals the price of fat cattle ($P_S + MC_F(Q) = P_S + MC_K = P_F$). The producer surplus accruing to the operation of Adena Springs Ranch under the traditional cow-calf operation is then $P_S ab$.

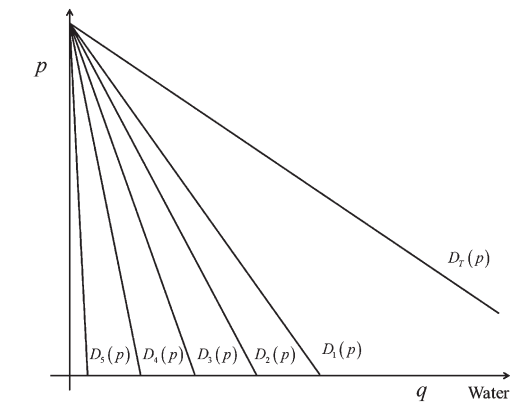


Figure 3. Composite Demand for Water

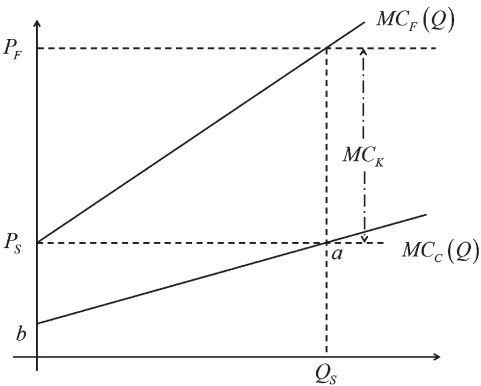


Figure 4. Producer Surplus from Traditional Cow-Calf Production

Figure 5 presents the effect of a new production structure for Adena Springs Ranch. In addition to the market for stocker cattle in Figure 4, Figure 5 depicts the demand curve for grass-fat, hormone-free beef in North Florida, $D_B(Q)$. We assume that Adena Springs Ranch will be able to market this specialized product in Orlando and Tampa at a premium over standard grain-fed beef. To model this premium, we hypothesize a downward-sloping demand curve with a nearly perfect substitute. In addition, we assume that the price of grain-fed beef provides a lower bound for the specialty beef. Based on these assumptions, the level of specialty beef produced maximizes the profit to the Ranch where the marginal cost of producing the good equals the marginal revenue derived from the downward sloping demand curve, $MR_B(Q)$. As depicted in Figure 5, the marginal cost of producing grass-fat, hormone-free beef is the sum of the cost of growing the cattle to weight on pasture, $MC_{GF}(Q)$, plus the cost of processing live cattle into beef (with the sum of the cost being depicted as $MC_B(Q) + MC_{GF}(Q)$). For a detailed discussion of economic rents in a vertically integrated market channel, see Schmitz and Moss (2001). The cost of production equals the marginal revenue at point d in Figure 5, the optimal quantity is Q_{GF} , which is less than the quantity of cattle produced by Adena Springs Ranch as a cow-calf operation. This reduction can be traced to two factors. First, the cost of producing grass-fat cattle is higher than the cost of producing

stocker cattle, $MC_{GF}(Q) > MC_S(Q)$. Pasturing cattle to finished weight will reduce the total number of cattle that can be produced on a fixed amount of land. The fixed amount of land can be offset partially by the use of additional inputs such as irrigation water. However, the possible market power in the specialty beef market also reduces the quantity of grass-fat cattle produced. In Figure 5, consumers pay a price of P_B for beef, whereas the cost of producing and processing beef is \tilde{P}_B . This difference generates the monopoly rent of $P_Bcd\tilde{P}_B$ in Figure 6. The marginal cost of producing Q_{GF} of grass-fat cattle is depicted in Figure 5 as P_{GF} . The producer surplus from this activity is depicted in Figure 6 as $P_{GF}ef$. Similarly, the profit from processing the grass-fat cattle into specialty beef is depicted in Figure 6 as \tilde{P}_BdP_{GF} . The overall return to the production of specialty beef is $P_Bcd\tilde{P}_B + P_{GF}ef + \tilde{P}_BdP_{GF}$.

Although it is apparent that the firm is now making a larger profit than before, some care needs to be taken when comparing apples to apples. First, the profit of processing cattle into beef cannot be used as part of the comparison of farm returns. It is an additional activity beyond the cow-calf operation depicted in Figure 6 that occurs on the Great Plains or in the Midwest. From a societal point of view, the rents to processing beef may simply be shifted from the Midwest to Ocala, Florida. In this analysis, we separate out the economic rents to processing so that the decision-maker may

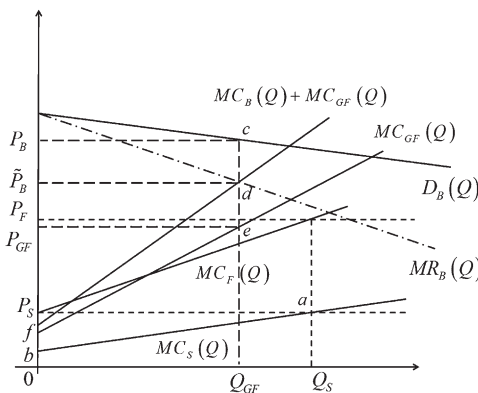


Figure 5. Market Equilibrium for Grass-Fat Cattle Operation

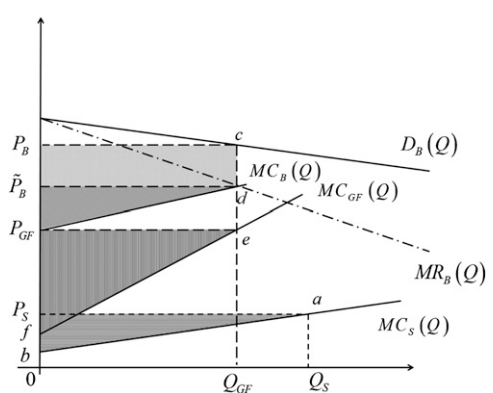


Figure 6. Producer and Consumer Surplus for Grass-Fat Beef

choose to consider these returns. In addition, it is unclear how much of the monopoly rent should be considered as part of the restructuring of Adena Springs Ranch. The graphical results in Figure 6 indicate that the farm returns from grazing cattle to finished weights will exceed the returns to traditional stocker operations, $P_{GFef} > P_{Sab}$. However, as demonstrated subsequently, this result is conditioned on the effect of monopolistic pricing of grass-fat, hormone-free beef. Specifically, as the monopolistic profits ($P_{Bcd}\tilde{P}_B$) increase, the gains in producer surplus from the farming operation (P_{GFef}) declines given a fixed marginal cost function (i.e., to extract monopolistic rents, the quantity produced declines).

However, the increased profit from the pasture operation is only part of the story. It is clear that the cost of production has also changed as depicted in Figure 6 (i.e., the area below each marginal cost of production— baQ_S0 for the traditional cow-calf operation and $feQ_{GF}0$ for the grass-fat beef operation). The debate in the Florida Saint Johns River Water Management District involves the fact that some of the additional cost of these changes are not borne by the producer (i.e., included in $feQ_{GF}0$ in Figure 6). Namely, the proposed expansion requires additional groundwater withdraws. Although Adena Springs Ranch will bear directly the pumping costs associated with the groundwater withdraws, there will be externalities involved, because additional costs will be incurred or reduced benefits to individuals who are not directly a party to the transaction will occur.

In this study, we estimate the value of water to Adena Springs Ranch using the producer surplus methodology (Just et al., 2004). As a starting point for our numerical analysis, we express prices in terms of \$/head of cattle. The price for a stocker calf is then taken at $P_S = 5.50\text{cwt} \times \$164.91/\text{cwt} = \$907.01$. We assume the original level of production to be 2500 head of stocker cattle. Assuming a choke price of \$467.50/head, we parameterize the marginal cost curve for stocker cattle as

$$(2) \quad MC_S(Q) = 467.50 + 1.96 \times 10^{-7} Q^{2.75},$$

which is a form of a translog cost function in which we restrict the elasticity of the marginal

cost function to be 0.75 at the Q_S . Using similar assumptions, we derive the cost of grass-fat production:

$$(3) \quad MC_{GF}(Q) = 690.00 + 8.45 \times 10^{-6} Q^{2.39},$$

assuming a choke price of \$690.00/head for grass-fat cattle and an elasticity of the marginal cost function of 0.80 at the grain-fed fat cattle price of \$1446.70/head. The cost function for processing cattle into beef is computed to be:

$$(4) \quad MC_B(Q) = 23.00 + 4.87 \times 10^{-20} Q^{6.76},$$

assuming that at fat-cattle prices, the required margin for processing is 10% with a choke price for processing of \$23.00/head. To complete the production model, we assume a fairly elastic demand for grass-fat, hormone-free beef:

$$(5) \quad D(P_B, P_F) = \exp(8.16 - 2.75 \ln[P_B] + 2.70 \ln[P_F]),$$

where P_B is the price of grass-fat, hormone-free beef and P_F is the price of grain-fed beef.

To solve for the optimum level of grass-fat cattle produced, we compute the total cost function $TC_B(Q)$ as the integral of the sum of the marginal cost functions:

$$(6) \quad TC_B(Q) = \int_0^Q [MC_{GF}(z) + MC_B(z)] dz.$$

Next, we define the inverse function for price as a function of quantity based on the demand curve:

$$(7) \quad \begin{aligned} P_B(Q, P_F) &= P \Leftrightarrow D(P_B, P_F) \\ &= Q \Rightarrow P_B(Q, P_F) \\ &= \frac{19.4357}{\left(\frac{Q}{P_F^{2.70}}\right)^{0.36}}. \end{aligned}$$

Using these two functions, we then specify the profit function as:

$$(8) \quad \pi(Q, P_F) = P_B(Q, P_F)Q - TC_B(Q).$$

Solving this problem numerically using *Mathematica 8.0* yields an optimum quantity of grass-fat cattle produced of 1431.69. The price of cattle for this quantity taken from the inverse demand curve is \$1753.61/head, which is

\$306.91/head (or \$26.69/cwt) more than standard grain-fed cattle.

As presented in Table 2, the total profit for feeding grass-fat, hormone-free beef is \$1,345,461. This represents a return (Figure 6) to the production operation of \$297,225 ($P_{GF}ef$), which is a return of \$135,290 from the processing facility ($\bar{P}_B dP_{GF}$), and monopoly returns of \$912,946 ($P_{Bcd}\bar{P}_B$).

The total commodity consumption of water in Marion County (based on Young's definitions) is 50.761 mgd of ground water and 59.131 mgd of surface water (Table 3). The original Adena Springs Ranch proposal involved a water withdraw of 13.267 mgd. This would have represented a 26.1% increase in the consumptive use of water in Marion County. Recently, Adena Springs Ranch amended their proposal to withdraw 5.3 mgd, which represents a 10.4% increase in permitted water in the county. To value this flow, we use the \$34.75/acre-foot value of water in Northwest Florida estimated by Moss and de Bodisco (1998). Given that each acre-foot contains 325,851 gallons of water, this price translates into \$106.54/million gallons of water. We acknowledge that this is probably a lower bound for the value of water. As a starting point, we assume that this demand is very price inelastic at -0.10 .

Attempting to value the environmental flows is far more problematic. Table 1 presents water flows from Marion County's major springs.

Table 2. Gains and Losses to Adena Springs Ranch

Gains to Cattle Operation (\$/year)		
Cow-calf rents	297,225	
Processing rents	135,290	
Monopoly rents	912,946	
Grass fat beef—total rents		1,345,461
Gains (losses) from Environmental Flows		
	Value/Day	
Value of ground water	(952.186)	(347,548)
Value of return flow	3.066	1119
Net Gains (losses)		
Net rents change		999,032
Original rents		(805,884)
Value of Change		193,148

Table 3. Water Use in Marion County

	Million Gallons per Year	Million Gallons per Year
Marion County Currently Permitted		
Ground water	18,527.65	50.761
Surface water	21,582.79	59.131
Total	40,110.44	109.892
Adena Ranch request		
Original		13.267
Amended		5.300

These springs and associated state parks represent tourist destinations. The linkage between groundwater withdraws and spring flow is sketchy. Although Marion County's Category 1 springs may be significant tourist destinations, little is known about the tourist demand for minor springs. In addition, although there is evidence that the quantity of water flowing from each spring has declined over time, a direct relationship between additional groundwater withdraws and spring flow is unavailable. Given the lack of information, we simply assume that the environmental demand for environmental services is 10% of the commodity demand. Again, this may be an underestimate of the true demand for the environmental services generated by the water.

Given these assumptions, we solve for the parameters of the demand function:

$$(9) \quad \begin{aligned} D_W(p) &= \exp[\alpha_0 + \alpha_1 p] \\ \Rightarrow \left\{ \begin{aligned} D_W(106.54) &= 55.84 \\ \epsilon &= \frac{\partial D_W(p)}{\partial p} \frac{p}{D_W(p)} \bigg|_{p=106.54} = -0.10 \end{aligned} \right. \end{aligned}$$

yielding $\alpha_0 = 4.122$ and $\alpha_1 = -0.001$. The reduction in consumer surplus from the reduced water flow associated with the Adena Springs Ranch's permit is then:

$$(10) \quad \begin{aligned} W_C(q_U, q_L) \\ = - \int_{q_L}^{q_U} [-1065.40 \ln(0.02q)] dq, \end{aligned}$$

where $q_L = 50.030$ and $q_U = 55.837$, which yields $W_C(q_U, q_L) = -952.186$ (in dollars per day — $abQ_DQ'_D$ in Figure 2). The question is then: How many days per year will Adena

Springs Ranch pump at maximum flow? If the Ranch pumps water at maximum flow for 365 days per year, the value of the water diverted from other uses is \$347,548, resulting in a societal loss of \$192,029 (i.e., the gain of \$539,577 from feeding grass-fat cattle less \$347,548).

Finally, we consider the possible effects of the positive externality from the surface returns of groundwater to surface water flows. In the derivation of equation (10), we assumed that the nonmarket demand shifted the total quantity of demand out by 10%. This shift represented the demand for recreation at major tourist destinations like the Category 1 springs in Marion County. The return flows contribute to a lowered value recreational alternative such as canoeing and kayaking in the eastern part of Marion County on the tributaries of the old Cross Florida Barge Canal. Hence, we assume that the demand curve for these services is 10% of the demand for the environmental services from all the major tourist destinations. The demand for water in these uses, $D_{W'}(p)$, can then be computed as:

$$(11) \quad D_{W'}(p) = \exp[-0.48 - 0.001p].$$

Hence, at a water price of \$106.54/million gallons, the quantity of water used in this secondary recreation use is 0.558 million gallons. The question then becomes, how much additional surface water for secondary recreation will be generated from Adena Springs Ranch? As a starting point, we assume that the Adena Springs Ranch project will increase the surface water recreation by 10%, implying a gain of 3.066 (in dollars per day— $cdQ'_S Q_S$ in Figure 5):

$$\begin{aligned} W_{C'}(0.56, 1.09) \\ = \int_{0.56}^{1.09} [-1065.4 \ln(1.62q)] dq. \end{aligned}$$

Again, if we assume this value occurs every day of the year, the gain from the positive externality is \$1119.

As depicted in Table 2, the net environmental cost of Adena Spring Ranch's additional ground water withdraws is \$346,429 (i.e., \$347,548 – \$1119). The total rents for the

additional pumping becomes \$999,032. Subtracting the original rents from the cattle operation of \$805,884 yields a net change in producer and consumer surplus in Marion County of \$193,148. Thus, the change meets the compensation principle for policy analysis. The gainer (in this case, Adena Springs Ranch) could pay off the losers (in this case, the existing "commodity" and environmental users of water). However, without such compensation, the proposed change represents a significant equity effect.

Summary and Further Research

This study examines the costs and benefits associated with the proposed increased water allocation to Adena Springs Ranch east of Ocala, Florida. In general, the increased allocation of water generates a substantial increase in profit to the ranch, part of which comes from increased prices from the segmentation of the beef market (i.e., a market premium for grass-fat, hormone-free beef). From an environmental perspective, the project implies a significant reduction in the consumer welfare of the environmental flows from deep aquifers. However, these negative effects are, in small part, offset by increased environmental services from increased surface water flows.

The analysis must be regarded as preliminary and raises several issues for future timely research, because no decision has yet been reached on granting the requested water allocation for the Adena Springs Ranch. On December 14, 2012, the ranch requested that its application be amended to an allocation of 5.3 mgd and provided additional information regarding the amended application. District staff on January 11, 2013, determined that additional technical information was needed and sent the ranch a Request for Additional Information (RAI) letter. The ranch has until May 11, 2013, to respond to the RAI or to request an extension to their response timeframe. When the application is considered complete, district staff will determine if the requested allocation of water meets district-permitting criteria.

First, the commodity value of water is computed based on the value of water to agriculture

in northwest Florida. More work on the water demand in Marion County is required. From an agricultural perspective, the crops in Marion County are somewhat different than the crops in northwest Florida. However, more to the point of the analysis in this study, the estimation of the demand for environmental services is highly problematic. The literature contains two approaches to the estimation of the value of environmental services from water. First, revealed behavior such as the decision to recreate can be used to estimate the demand for rural amenities. Although this approach appears straightforward, it does not provide information on the effect of additional pumping on the quantity of water demanded (i.e., we still require information on how the increased pumping will affect the quality of the recreational experience). The second approach is to allow consumers to express their preferences (typically through a survey). This procedure allows for a more direct linkage between changes in the quality of environmental amenities and the demand for them. The results of this study could be improved by obtaining better estimates of negative externalities: 1) the reduced demand associated with reduced groundwater flow from Marion County's Category 1 springs; and 2) the positive externalities of the value of increased recreation from the increased surface water flow.

In our analysis, we have assumed an "all or nothing" change in agricultural production (i.e., either Adena Springs Ranch produces stocker calves or grass-fat beef). However, this monopolistic solution can be extended to

consider whether Adena Springs Ranch will continue to produce a reduced quantity of stocker cattle. Intuitively, the question is whether the marginal value of the last grass-fat animal produced (including the effect of monopoly pricing) is greater than the marginal value of stocker cattle. If the optimal level of grass-fat cattle does not use all the pasture generated under expanded pumping, the ranch may choose to continue production of stocker cattle.

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