



E.ON Energy Research Center
FCN | Institute for Future Energy
Consumer Needs and Behavior

FCN Working Paper No. 11/2009

Do Baseline Requirements hinder Trades in Water Quality Trading Programs?

Gaurav Ghosh, Marc Ribaudó and James Shortle

November 2009

**Institute for Future Energy Consumer
Needs and Behavior (FCN)**

Faculty of Business and Economics / E.ON ERC

RWTHAACHEN
UNIVERSITY

FCN Working Paper No. 11/2009

Do Baseline Requirements hinder Trades in Water Quality Trading Programs?

November 2009

Authors' addresses:

Gaurav Ghosh
Institute for Future Energy Consumer Needs and Behavior (FCN)
Faculty of Business and Economics / E.ON Energy Research Center
RWTH Aachen University
Mathieustrasse 6
52074 Aachen, Germany
E-mail: gghosh@eonerc.rwth-aachen.de

Marc Ribaudó
Economic Research Service
U.S. Department of Agriculture
1800 M Street NW,
Washington D.C. 20036, U.S.A.
E-Mail: mribaudó@ers.usda.gov

James Shortle
Director, Environmental and Natural Resources Institute
Department of Agricultural Economics and Rural Sociology
Pennsylvania State University
112C Armsby,
University Park, PA 16802, U.S.A.
E-mail: jshortle@psu.edu

Publisher: Prof. Dr. Reinhard Madlener
Chair of Energy Economics and Management
Director, Institute for Future Energy Consumer Needs and Behavior (FCN)
E.ON Energy Research Center (E.ON ERC)
RWTH Aachen University
Mathieustrasse 6, 52074 Aachen, Germany
Phone: +49 (0) 241-80 49820
Fax: +49 (0) 241-80 49829
Web: www.eonerc.rwth-aachen.de/fcn
E-mail: post_fcn@eonerc.rwth-aachen.de

Do baseline requirements hinder trades in water quality trading programs?

Gaurav Ghosh ^{a,*}, Marc Ribaud ^b and James Shortle ^c

^a *Institute for Future Energy Consumer Needs and Behavior (FCN),
Faculty of Business and Economics, E.ON Energy Research Center,
RWTH Aachen University, Mathieustrasse 6, 52074 Aachen, Germany.*

^b *Economic Research Service,
U.S. Department of Agriculture, 1800 M Street NW, Washington D.C. 20036, U.S.A.*

^c *Environmental and Natural Resources Institute,
Department of Agricultural Economics and Rural Sociology,
Pennsylvania State University, 112C Armsby, University Park, PA 16802, U.S.A.*

November 2009

Abstract: The Environmental Protection Agency and the U.S. Department of Agriculture are promoting point/nonpoint trading as a way of reducing the costs of meeting water quality goals while giving nonpoint sources a larger role in meeting those goals. Farms can create offsets or credits in a point/nonpoint trading program by implementing management practices such as conservation tillage, nutrient management, and buffer strips. To be eligible to sell credits, farmers must first comply with baseline requirements. The EPA defines a baseline as the pollutant control requirements that apply to a seller in the absence of trading. EPA guidance recommends that the baseline for nonpoint sources be management practices that are consistent with the water quality goal. A farmer would not be able to create credits until the minimum practice standards are met. An alternative baseline is those practices being implemented at the time the trading program starts. The selection of the baseline has major implications for which farmers benefit from trading, the cost of nonpoint source credits, and ultimately the number of credits that nonpoint sources can sell to regulated point sources. We use a simple model of the average profit-maximizing dairy farmer operating in the Conestoga (PA) watershed to evaluate the implications of baseline requirements on the cost and quantity of credits that can be produced for sale in a water quality trading market, and which farmers benefit most from trading.

Key words: nonpoint pollution, emissions trading, management practices

* Corresponding author: Tel. +49 241 80 49 840, Fax. +49 241 80 49 829, gghosh@eonerc.rwth-aachen.de

1. Do baseline requirements hinder trades in water quality trading programs?

Water quality trading is currently of much interest as a mechanism to improve the efficiency of water pollution control allocations among and between point and nonpoint sources in the U.S. Under the Clean Water Act, point sources (e.g. factories, sewage treatment plants) are regulated through a non-tradable permit system. A permit specifies how much of a particular pollutant the permit holder can discharge. Traditionally, permittees were required to meet their permit obligations through their own effluent reductions. New U.S. Environmental Protection Agency (EPA) policy guidelines on water quality trading now allow points sources to meet their Water Quality Based Effluent Limitation requirements through offsets from other sources (US EPA 2004). Under the EPA policy guidelines, those sources may be regulated point sources, or unregulated nonpoint sources. The guidelines encourage States to consider agriculture as a source of offsets in water quality trading programs, and many states are either implementing or considering water quality trading programs that allow point-nonpoint source trading (Environmental Trading Network, 2009; U.S. EPA, 2009).

The U.S. Department of Agriculture (USDA) is also very interested in water quality trading. In 2006, the Department announced a new policy on market-based environmental stewardship with the goal of broadening the use of market-based mechanisms for providing environmental and ecosystem services, such as credit trading (USDA, 2006). Such markets could provide a source of income to farmers and reward them for engaging in conservation activities. Farms can create offsets or credits for the market by implementing management practices such as conservation tillage, nutrient management, and buffer strips. Since the price is determined in the marketplace, payments are not limited to the cost or a fraction of the costs of the practice, as in most conservation programs. Farmers can also receive a payment for a much longer period of time than the 2 to 5 years of a standard conservation program contract.

Point/nonpoint trading has not been very successful to date, at least in terms of the participation of potential traders and the number of trades between regulated sources and farms (Breetz et al., 2004). Much has been written about various issues related to point/nonpoint trading, including uncertainty, trading ratios, and validation issues (Hoag and Hughes-Popp, 1997; King, 2005; King and Kuch, 2003; Woodward and Kaiser, 2002; Ribaudo and Nickerson, 2009). One area of program design that has not received much attention is the establishment of a baseline for

calculating credits. To be eligible to sell credits, farmers must first comply with baseline requirements. The selection of the baseline has major implications for the cost of nonpoint source credits in the market, and ultimately the number of credits that nonpoint sources can sell to regulated point sources.

In this paper, we use a simple model of the dairy farms operating in the Conestoga watershed (Pennsylvania) to evaluate the implications of baseline participation requirements on the cost and quantity of credits that can be produced for sale in a point/nonpoint water quality trading market. The Conestoga is a major source of nutrients entering the Susquehanna River, which is in turn a leading source of nutrients entering the Chesapeake Bay (Belval and Sprague, 1999). Reducing agricultural nutrient loads in the Conestoga has long been an objective of water quality agencies concerned with water quality in Pennsylvania and the Chesapeake Bay. Since 2007, farmers in the watershed have had the opportunity to participate in a nutrient credit trading program established by the Pennsylvania Department of Environmental Protection for the Susquehanna Basin in 2007. Although the program has received much attention as innovation in point/nonpoint trading, analogous to other programs, participation and trade volumes are limited. In this paper, we examine how baseline decisions affect the prices at which different types of farms, defined by pre-program practice adoption and soil resource base, will enter a market and offer credits.

2. Baseline rules in water quality trading programs

The EPA defines a baseline participation requirement (BPR) as the pollutant control requirements that apply to a seller in the absence of trading (U.S. EPA, 2007). A seller must meet its baseline requirements to be eligible to generate credits. EPA guidance recommends that where a Total Maximum Daily Load (TMDL) is in place, the “load allocation” for nonpoint sources should serve as the threshold for nonpoint sources to generate credits (U.S. EPA, 2007). A load allocation defines the nonpoint source load reductions necessary to achieve water quality standards, and where available, can be applied to individual nonpoint sources or, more commonly, to the sector as a whole. EPA guidance states that it would not support a trading program that allows nonpoint sources to sell credits if the discharge is contributing to water quality impairments (U.S. EPA, 2007). However, EPA recognizes that there are difficulties associated with estimating loads from nonpoint sources.

In watersheds where a TMDL does not exist, or where the load allocation is uncertain, the program can establish alternative baseline requirements, including practices existing at the time the trading program was established, or implementation of a minimum set of best management practices defined by the State. The majority of point-nonpoint trading programs use a date-based baseline. The rest, including the Lower Boise, Kalamazoo, and Conestoga programs, specify a minimum practice standard (Breetz et al., 2004).

The potential for a baseline to require something other than current practices presents an interesting dilemma for program managers. Under the Clean Water Act, there are no requirements for nonpoint sources to adopt a best management practice (BMP), even in the presence of a TMDL. By requiring a minimum practice standard (MPS) as the BPR to participate in the trading program, the regulatory agency may be disqualifying the “lowest hanging fruit”; the least costly reductions cannot be offered as offsets. It is thus possible that the expected income from an offset market will be insufficient to induce farms that have not already voluntarily adopted the minimum set of practices, so called “poor stewards,” to incur the cost of meeting the BPR. This entry cost would therefore potentially limit participation and adversely affect the efficiency of the market.

One set of beneficiaries of a MPS is prior adopters of best management practices, or so-called “good stewards”, who have a competitive advantage over farms that can actually provide pollution abatement at a lower cost. This would result in higher credit prices for point sources, and fewer credits being purchased from agriculture. If nonpoint source participation is a secondary goal of the program, then the minimum-standard baseline would appear to work against it. Water quality problems associated with “poor stewards” will remain unaddressed, at least through the trading program.

3. Pennsylvania Water Quality Trading Program

The Pennsylvania Department of Environmental Protection (PADEP) has clear criteria for point source and nonpoint source participation in nutrient trading programs specific to the Chesapeake Bay watershed (PADEP, 2008a). The criteria for agricultural nonpoint sources take the form of baseline and threshold requirements. The baseline requirement is that on-site operations must be in compliance with Chapter 102 Erosion & Sedimentation Regulations, Section 91.36 (Agricultural Operations), Act 38 Nutrient Management Regulations, and Chapter 92 (CAFOs), as

applicable. Compliance is determined by a site visit by PADEP staff or a PADEP approved entity and verified by PADEP, the Conservation District or other PADEP-approved entity.

A farm is in compliance when one of three conditions is met. The first condition is that a 100 foot mechanical setback or equivalent is implemented on-site. It either requires that no surface waters exist within 100 feet of the farm *or* that manure is not mechanically applied within 100 feet of surface water *or* that manure is not applied at all and that commercial fertilizer application rates are below Penn State recommended agronomic rates. The second condition is that a 35 foot buffer or equivalent is planted between the field and surface water. The buffer is a swathe of permanent vegetation maintained between the field and surface water. Common types of buffer are riparian forest buffers and riparian grass buffers. The third condition is that the farm's overall nutrient balance be reduced by 20% below what is required by the baseline requirement presented earlier. For the purposes of our analysis, and for the sake of simplicity, we assume that all simulated farms meet their threshold requirements by satisfying the second condition, i.e. a 35 foot strip of permanent vegetation is planted between the field and surface water.

4. Analytical model

The numerical analysis uses a model of agricultural production and pollution control based on characteristics of the Conestoga River watershed in Lancaster Co., PA. Reducing agricultural nutrient loads in the Conestoga has long been an objective of water quality agencies concerned with water quality in Pennsylvania and the Chesapeake Bay. The model simulates nitrogen pollution loads from agricultural sources from sub-watersheds of the Conestoga. The model is not intended to be a highly explicit representation of agricultural production in the watershed. Instead it is intended to serve as a platform for testing the effects of alternative specifications of BPRs on the efficiency and equity of water quality trading.

Agricultural nutrient loads in the watershed are especially associated with livestock agriculture. Dairy production is very important in the Conestoga watershed in terms of land use, farm income, and nutrient loads. The Conestoga watershed is located primarily in Lancaster County, PA (figure 1). The 2002 Census of Agriculture (USDA, NASS, 2002) reported that sales of livestock related products accounted for approximately 89% of the total market value of production for the county. Generating baselines for dairy farms is also important because to a greater extent than

poultry and hog operations, dairy farms participate in farm programs that may affect incentives to participate in trading. Accordingly, we focus our model on dairy production.

The dairy production model is highly stylized and simplified to maintain focus on the mass flow of nutrients and the management of manure and runoff, which are the main concerns for water quality management, water quality trading, and conservation programs. The nutritional needs of dairy herds are met through nutrients in purchased feeds, nutrients from crops produced on the farm, and from pasturing. Dairy herds are poor processors of nutrients with 50-75 percent of the nutrients in the feed ending up in the manure (CAST, 2002). Traditionally, manure is spread on crop land. Nitrogen applied to crop land can have several fates. Some is taken up by crops, some is lost to the atmosphere through volatilization or denitrification, some leaches into ground waters, and some runs off into surface waters. In the Conestoga watershed, the volume of nutrients applied is substantially in excess of what is taken up in crops, leaving a large pool of nutrients to move into air and water.

In the stylized model, profits from milk production are described by a restricted profit function conditioned on herd size or number of cows, K , and corn produced onsite, C . The herd's feed requirement is completely met by corn grown onsite. All corn is assumed to be fed, thus there is no marketing of corn. This is consistent with the structure of Lancaster Co. farming, where corn is produced mainly as an animal feed. The animal manure (M) is spread on crop land and, supplemented by purchased fertilizer (N), to provide nutrients to the corn crop. The size of all representative dairy farms, in terms of land, is fixed at 80 acres. This is close to the mean size for Conestoga dairy farms, which is 78 acres (U.S. Census of Agriculture, 2002). In the baseline model (without trading), the continuous production variables in the stylized farm models are the herd size, onsite corn production, and purchased fertilizer. The proportion of pasture land versus crop land is fixed at 50 percent. This number reflects 2005 land use patterns in the Conestoga watershed where 24 percent of all land is crop land and 25 percent is pasture (PASDA, 2008). Land in corn production is continuous up to an upper bound. Discontinuous variables are manure management practices and runoff control practices.

Nutrient losses to the water resources from a farm can be reduced by:

- (1) *Reducing the volume of nutrients applied to crop land.* This can be accomplished through feeding strategies that reduce the volume of nutrients in manure, storage strategies that increase the volatilization of nitrogen, disposing of nutrients off-site, reducing the volume of manure production, and thus the herd size, and reducing applications of commercial fertilizer.

- (2) *Increasing the utilization of nutrients.* This can be accomplished by developing crop strains that have higher nutrient absorption capabilities, changing soil chemistry, and changing manure chemistry to facilitate nutrient uptake.
- (3) *Reducing nutrient runoff.* This can be accomplished by implementing on-field tillage practices and off-field interception practices. Reduced tillage reduces surface runoff, allowing water and associated nutrients to percolate into the soil profile. Filter strips absorb nutrients not absorbed by the crop and so reduce runoff.

In our analysis we focus on three best management practices (BMP): conservation tillage, nutrient management plan (NMP), and riparian grass buffers (RGB).

5. Mathematical Structure: No trading – no explicit representation of BMPs

Farm behavior is modeled using a dual approach that allows the number of choice variables to be limited to the policy relevant set. The restricted profit function for the profit maximizing dairy farm is

$$\pi(C,K) = R(C,K) - C_C(C,K) - P_K K - Q(B) \quad (1)$$

where $R(C,K)$ represents revenues from milk sales, $C_C(C,K)$ is the corn production cost function, P_K is the unit cost of herd maintenance and $Q(B)$ is the cost of implementing conservation practice B . P_K captures all non-feed costs and includes the costs of acquiring and housing cattle. The linear form implies that the marginal herd maintenance cost is constant. This specification reflects our focus on long run equilibrium responses. We expect farm profits to be increasing and concave in both C and K .

The revenue function for milk sales is approximated by a second order Taylor's Series expansion about the pre-trading levels of C and K .

$$R(C,K) = a + b_C C + b_K K + \lambda_C C^2 + \lambda_K K^2 + \lambda_{CK} CK \quad (2)$$

where a , b_C , b_K , λ_C , λ_K and λ_{CK} are parameters associated with the Taylor's Series expansion. The second order Taylor's Series expansion allows flexibility in modeling revenue response to the

input variables, C and K . Differentiating $R(C,K)$, the first order conditions with respect to C and K are $b_C + 2\lambda_C C$ and $b_K + 2\lambda_K K$ respectively. The signs on the first order conditions will determine the marginal response of revenue to the inputs respectively. *Ex ante* we expect corn production and herd size to have positive effects on farm revenue: we expect that $b_C + 2\lambda_C C \geq 0$ and $b_K + 2\lambda_K K \geq 0$.

We assume that the only feedstuff fed to the herd is corn.¹ We also assume that all feedstuff necessary for herd sustenance is grown onsite. The farmer does not buy any corn on the open market. The corn production cost function $C_C(C,K)$ is determined analytically by solving an expenditure minimization problem (EMP), where expenditure is on market inputs needed for corn production. It is assumed that the only input needed for corn production is nitrogen, as a nutrient. Some of the nitrogen is obtained from manure produced onsite by the herd. The rest is bought from the market. The relationship between corn, C , and nitrogen, N , is often modeled as quadratic or as a linear plateau (Fox and Piekielek, 1983; Dillon and Anderson, 1990). Following the recommendation in Ghosh (2004), the relationship between C and N is captured by a bounded exponential function (3), which retains salient features of the quadratic and linear plateau functions. The initial response of corn yield to nitrogen is similar to the quadratic formulation and the asymptotic response is similar to the linear plateau.

$$C(N) = \beta_0 + \beta_1[1 - \exp(-\beta_2 N)] \quad (3)$$

β_0 , β_1 and β_2 are model parameters, the values of which are determined through calibration and presented in Ghosh (2004). The parameters vary by land capability class (LCC). Since there are four LCCs in the Conestoga watershed, there are four sets of values for the β s.

The nitrogen (N) needed for corn production is obtained from two sources: from manure obtained onsite and from fertilizer purchased in the open market at price P_N . If N_M is the nitrogen content of onsite manure and N_F is the nitrogen content in the fertilizer bought in the market, then total nitrogen input $N = N_M + N_F$. Let M be the manure produced by the herd and let ζ be the proportion of nitrogen in manure. It follows that the nitrogen content in manure, $N_M = \zeta M$. If ϕ is the quantity of manure produced by each cow and K is the number of cows then $M = \phi K$. Let H be farm size. The farmer minimizes corn production costs by minimizing expenditure on N_F , the only

¹ Or it can be assumed that non-corn feed units are transformed into equivalent corn feed units, allowing all nutrient calculations to be made in terms of corn

market input. If C is the minimum amount of corn needed to feed the herd, then the farmer faces the constraint $C(N) \geq C$. The farmer's constrained EMP for food production is set out in (4) and (5) and the farmer optimizes over N_F . The optimum level of fertilizer purchase per hectare, N_F^* , is given in (6).

$$\min_{N_F} P_N N_F H \quad (4)$$

$$\text{subject to } \beta_0 + \beta_1 \left[1 - \exp\left(\frac{\beta_2}{H}(N_F + \zeta\phi K)\right) \right] \geq \frac{C}{H} \quad (5)$$

$$N_F^* = -\frac{1}{\beta_2} \ln\left(\frac{\beta_0 + \beta_1 - C/H}{\beta_1}\right) - \zeta\phi K \quad (6)$$

By substituting N_F^* into the objective function of the EMP, the minimized cost function for corn production is

$$C_C(C^*, K^*) = P_N N_F^* H = -\frac{P_N H}{\beta_2} \ln\left(\frac{\beta_0 + \beta_1 - C/H}{\beta_1}\right) - P_N H \zeta\phi K^* \quad (7)$$

As is common in the literature, $\frac{\partial C_C}{\partial C}$ and $\frac{\partial C_C}{\partial K}$ are interpreted as the shadow or implicit prices of corn (S_C) and herd size (S_K) when considered as inputs in corn production. S_C and S_K are calculated by taking the partial derivative of C_C , as defined in (6), with respect to K and C :

$$S_K = \frac{\partial C_C(C, K)}{\partial K} = -P_N H \zeta\phi \quad (8)$$

$$S_C = \frac{\partial C_C(C, K)}{\partial C} = \frac{P_N H}{\beta_2(H\beta_1 + H\beta_0 - C)} \quad (9)$$

Specific values of S_C and S_K , which are necessary for the calibration, will be known if the optimal values of C , K , P_N , ζ , ϕ , and the β s are known. If the farmer is an optimizer then $S_K K^* + S_C C^*$ can be substituted into (1). Calibration of the model is discussed below.

6. Calibration

The model is calibrated so that the choice variables (C , K , N) when optimized “without” trading correspond to a pre-trading baseline. Herd size on all modeled farms is set to 56, which is the average size of milk cow herds in Lancaster County as per the 2002 Agricultural Census (USDA, 2003). We assume that the herd is composed of Holsteins, which implies that the average herd size is 62.2 animal equivalent units (AEU). The adjustment costs for herd size, P_K , is \$3600 (Bailey 2008). The total variable costs for no-till is \$4-\$8 per acre higher than for conventional till (Pennsylvania State University, 1996). For the purposes of the simulation it is assumed that the cost of conservation or no-till is \$6 per acre. Since there are 40 acres under corn production, the total cost of conservation till is $Q(CT) = \$240$.

The manure generated per cow per year is $\phi = 19.45$ tons and the nitrogen proportion in manure is $\zeta = 4.54$ kg / ton. These statistics are obtained from the 2007-2008 Agronomy Guide (Penn State, 2007b). The market price for nitrogen fertilizer, P_N , is set to the official April 2007 price (USDA, 2008). These parameter values and their data sources are summarized in Table 2 below.

The values assigned to β_0 , β_1 and β_2 and total nitrate use, N , are taken from Ghosh (2004). The β s vary across LCCs to reflect heterogeneity in soil quality and fertility. C is obtained by substituting the optimal values of the β s and N into (3). C varies by LCC because the β s, as calibrated in Ghosh (2004), vary by LCC.

The revenue function $R(K,C)$ has five parameters needing calibration, λ_C , λ_K , λ_{CK} , b_C , b_K . We use a system of five equations to calibrate these five parameters. The final unknown parameter a acts as a scaling variable and is calculated when the other parameter values are known. The first and second equations in the system are obtained from the first order necessary conditions for profit

maximization, which are obtained by differentiating (1) with respect to C and K . Rearranging these first order conditions demand functions for C and K are

$$K^* = \frac{\lambda_{CK}b_C - 2\lambda_C b_K + 2\lambda_C(S_K + P_K) - \lambda_{CK}S_C}{4\lambda_C\lambda_K - \lambda_{CK}^2} \quad (10)$$

$$C^* = \frac{\lambda_{CK}b_K - 2\lambda_K b_C + 2\lambda_K S_C - \lambda_{CK}(S_K + P_K)}{4\lambda_C\lambda_K - \lambda_{CK}^2} \quad (11)$$

As (10) and (11) indicate, optimal levels of C and K are linear in S_C and S_K , which are the marginal implicit prices of corn and herd size in the production of corn and are given by (7) and (8). P_K is the unit non-feed cost of the herd and hence $S_K + P_K$ is the total unit cost of herd maintenance.

The last three equations in the system are derived from the farmer's own and cross price supply elasticities. The elasticities are derived from the demand functions for K and C in (10) and (11) and shown below.

$$\varepsilon_{K,P_K} = \frac{\partial K}{\partial P_K} \frac{S_K + P_K}{K} = \frac{2\lambda_C}{4\lambda_C\lambda_K - \lambda_{CK}^2} \frac{S_K + P_K}{K} \quad (12)$$

$$\varepsilon_{C,P_C} = \frac{\partial C}{\partial P_C} \frac{S_C}{C} = \frac{2\lambda_K}{4\lambda_C\lambda_K - \lambda_{CK}^2} \frac{S_C}{C} \quad (13)$$

$$\varepsilon_{C,P_K} = \varepsilon_{K,P_C} = \frac{\lambda_{CK}}{4\lambda_C\lambda_K - \lambda_{CK}^2} \frac{S_K + P_K}{C} \quad (14)$$

The own price elasticity of dairy production with respect to corn costs, ε_{C,P_C} , was obtained from Chavas and Klemme (1986), who estimate short-run, medium-run and long-run elasticities. Their numbers for medium-run elasticity – the medium-run is defined as ten years – are used, which implies that $\varepsilon_{C,P_C} = -1.5$. We were unable to find estimates of the own price elasticity of dairy production with respect to herd costs and the cross price elasticities. We set $\varepsilon_{K,P_K} = -0.5$. ε_{K,P_K} is

negative because it is assumed that K is a normal good and hence *ceteris paribus* herd size will diminish as costs increase. Also, since $|\varepsilon_{K,P_K}| < 1$, herd size is relatively inelastic in its response to price; there are fixed and variable costs associated with the herd. The fixed costs, associated with the physical infrastructure needed to maintain the herd, are sunk and unchanging in the medium-run. The physical infrastructure will maintain a herd of a given size, and to use this infrastructure to the maximum, the farmer will try to keep his herd as large as he can. Variable cost changes in the medium-run, hence ε_{K,P_K} measures the effect that changes in variable costs have on milk supply. A rise in variable cost will exert a downward pressure on herd size and milk supply, but this pressure is mitigated by the incentive that the farmer has to not reduce herd size and to utilize his physical infrastructure optimally. These conflicting incentives will manifest in a relatively inelastic herd size response to increases in medium-run herd maintenance costs.

We set $\varepsilon_{C,P_K} = \varepsilon_{K,P_C} = -1.0$ because it is assumed K and C are complements rather than substitutes. The magnitude of the cross price supply response is unknown, but sensitivity analysis did not reveal significant variation in the calibration results when $\varepsilon_{C,P_K} = \varepsilon_{K,P_C}$ was varied about -1. We solve the system of five equations [(10)—(14)] to calibrate the five unknown parameters, b_C , b_K , λ_C , λ_K , and λ_{CK} .

7. Pre-market conditions

For the purposes of this analysis, we define a farm as having 40 acres of arable land with a lake or stream adjacent to the field. Prior to the trading program, a farm can be one of 12 general types, each given a unique identifier (in brackets):

- plant on all 40 acres, using conventional tillage (Q), conservation tillage (QC), a NMP (QN), or both conservation tillage and a NMP (QNC);
- have a riparian grassed buffer around a lake, taking two acres out of production, and using conventional tillage (S1), conservation tillage (S1C), a NMP (S1N), or both conservation tillage and a NMP (S1NC);

- have an riparian grassed buffer on both sides of a stream, taking four acres out of production, and using conventional tillage (S2), conservation tillage (S2C), a NMP (S2N), or both conservation tillage and a NMP (S2NC).

Farms with riparian grassed buffers (RGBs) are defined as good stewards, since they are meeting the PADEP minimum standards. Farms without RGBs are defined as poor stewards. Even though they may be using conservation tillage or nutrient management; they have not adopted the riparian buffers required to meet the PADEP guidelines.

The farms in the Conestoga watershed are on one of four land capability classes (LCCs), which measure land quality. LCC1 land has the highest quality and LCC4 has the lowest quality. We modeled each farm type on each LCC, giving us 48 farm types before market entry. The potential for each farm type to participate in the market under the two baseline scenarios is evaluated with the economic model.

For the remainder of this paper we refer to farm types before and after market entry by their LCC and BMP codes. For example, an LCC4 farm with a riparian buffer around a lake and using conservation tillage prior to market entry is referred to as L4S1C. If this farm adopts nutrient management after market entry, its designation is L4S1CS1CN.

8. Minimum Standard Baseline

Under the Minimum Standard Baseline (MSB), farmers with RGBs (S1 or S2-type farms) prior to market entry are eligible to sell credits on any additional changes in management they make. Farms without RGBs (Q-type farms) cannot enter the market until RGBs are installed. For the purposes of this analysis, farmers are not allowed to discontinue a conservation practice (conservation tillage or a nutrient management plan) they are using in the pre-market situation.

Table 2 summarizes the trading possibilities. All farm types designated by a “Q” before market entry are the “poor” stewards. There are 16 in all, accounting for the four LCCs. Those farm types designated by “S1” or S2” are the good stewards. There are 32 of these. Those actions that result in tradable credits are denoted by a “y” in the cells; 40 by good stewards and 40 by poor stewards (4 LCCs for each cell). The table also shows acres in production before and after market entry. The shaded cells show the baseline for calculating credits. For example, a farm planting on all 40 acres and using conventional tillage (Q) can enter the market only by installing an RGB and then

adopting another conservation practice (conservation tillage or nutrient management). No credits are earned by simply adopting the RGB. Note that QNC, S1NC, and S2NC type farms cannot take any actions to produce credits.

Figure 2 shows the estimated market entry price for each farm type. It reflects the minimum credit price at which each of the original farm types will adopt practices necessary to create and market credits, as well as the practice that was adopted. The results from the model are as expected. Almost all the good stewards (designated with a “G” in front of the farm-type code) can enter the market at a lower price than poor stewards (designated with a “B”). Poor stewards are at a distinct disadvantage in the MSB, even though they can actually reduce nitrogen losses at a lower cost than good stewards. The lowest poor steward entry price (for farm type BL4QS1NC) is much higher (\$34.85) than for almost all the good-steward types. Depending on the actual mix of farms in the watershed, and the demand for credits from regulated sources, poor stewards may not be able to enter the market at all.

9. Timed baseline

The alternative to the MSB is a baseline based on the status quo; farms can enter the market and earn credits by adopting conservation practices, regardless of whether they were meeting the PADEP guidelines before or after market entry. This means that so-called poor stewards under the MSB can enter the market and create credits by adopting conservation practices other than RGBs. Table 3 summarizes all the trading possibilities.

The number of scenarios that could result in tradable credits has increased to 132. All the additions are from so-called poor stewards who were limited in what they could do to generate credits under the MSB. Not only can poor stewards enter the market without having an RGB, implementing an RGB will now generate saleable credits. Previously, an RGB would only allow entry into the market; credits were generated only with the implementation of additional practices. Unit costs for reducing N runoff are much lower for many of the poor stewards, enabling them to enter the market at a lower price than most good stewards (figure 2). For example, under the MSB, farm type BL4Q would adopt an RGB and both nutrient management and conservation tillage to enter the market (BL4QS2NC). Its market entry price is \$73.15. Under the TB, the same farm would

enter the market by simply adopting nutrient management (BL4QQN). Its market entry price is now only \$2.23.

It is worth noting that under the TB, the only poor stewards to adopt RGBs, would be those that have already adopted nutrient management and conservation tillage prior to market entry; the only step remaining to these farm types to create credits. These farm types had the highest market entry prices of all the farm types under TB.

10. Market supply

The previous analysis demonstrated the impact of different baseline requirements on individual farm types, namely so-called good and poor stewards. The impact on market supply for the watershed depends on the distribution of the different farm types.

There are 43 agricultural sub-watersheds in the Conestoga watershed. Their location and the location of all water bodies in the Conestoga are shown in Figure 4. The map is constructed from data obtained from PASDA, 2008. The sub-watersheds are filled with the representative 80-acre dairy farms. This yields 1818 dairy farms for the Conestoga. A comparison of farm locations to streams implies that 831 face setback requirements. The remaining 987 farms do not, but can create credits by adopting conservation tillage or nutrient management. These farms are unaffected by the baseline requirements as we defined them. Of the 831 farms facing setback requirements, we assume that half are good stewards and the other half are poor stewards. The good and poor stewards are distributed across the 4 LCCs in the same proportion in which the larger population of all dairy farmers is distributed across LCCs.

The market supply curves under the MSB and TB are shown in Figure 5. As expected, the supply curve under the TB is shifted to the right, indicating more credits available for a given price. Whatever the demand from point sources, the equilibrium price will be lower under the TB. This result is obtained even though less than one quarter of all farms in our analysis is assumed to be poor stewards.

Taking a closer look at which farms supply credits under the two scenarios further demonstrates the implications of the baseline requirements. Assuming that regulated point sources will offer \$30 per credit (and assuming away trading ratios), 46,442 credits (pounds of N reduction) will be purchased under the MSB. None of the credits will be supplied by our so-called poor

stewards, 18 percent by good stewards, and 82 percent by farms not falling under the baseline requirements (no water bodies on the farms). Under the TB, for the same number of credits purchased by point sources, the price drops to \$23.80 per credit. Poor stewards now supply 16 percent of the credits, and good stewards only 12 percent. Good stewards benefit most from the MSB.

11. Conclusions

Baseline conditions in a water quality trading program could have a profound impact on the make-up of farm types that will likely succeed in a market. A baseline that requires a minimum level of stewardship prior to market entry will benefit those good stewards who had already adopted those practices. Poor stewards are at a distinct competitive disadvantage, and would most probably not find it in their interest to enter the market.

Under a timed baseline, where there are no practice pre-conditions for market entry, farm types that were labeled poor stewards in the MSB can now readily compete with the good stewards, and would likely supply a major share of the credits in a market. Good stewards are not eliminated from the market; however, as some farm types can still produce credits for a low cost by adopting nutrient management or conservation tillage.

The analysis shows that selecting the MSB eliminates many low cost credits from the market. While this might benefit prior-adopting good stewards, it raises the overall cost of credits and likely reduces the number of credits traded in the market. It also fails to provide an adequate incentive for poor stewards to adopt best management practices. If one of the goals of point/nonpoint trading is to encourage trades and enable farms most in need of conservation to adopt BMPs, then this goal is better served by the timed baseline. If the MSB is used in a trading program, then there is a role for conservation programs such as EQIP to assist poor stewards reach the level of management that is required to allow them to trade in the market.

Table 1: Model Parameter Values

Parameter	Value	Definition	Data Source
K	62.2 AEU	Herd size	2002 Census of Agriculture
ϕ	19.45 tons / head / year	Manure generated	Penn State Agronomy Facts #54, Table 1
ζ	4.54 kgN / ton	Nitrogen proportion in manure	Penn State Agronomy Facts #54, Table 1
P_N	\$1.02 / kg	Nitrogen Price	National Agricultural Statistics Service, 2007
Q(CT)	\$240	Cost of CT	PSU, 1996
P_K	\$3600/head	Unit cost of herd maintenance	Bailey, 2008

Table 2 - Minimum Standard Baseline scenarios

		After market entry												
		ACRES	40	40	40	40	38	38	38	38	36	36	36	36
ACRES			Q	QC	QN	QNC	S1	S1C	S1N	S1NC	S2	S2C	S2N	S2NC
Before market entry	40	Q	n	n	n	n	n	y	y	y	n	y	y	y
	40	QC	n	n	n	n	n	n	n	y	n	n	n	y
	40	QN	n	n	n	n	n	n	n	y	n	n	n	y
	40	QNC	n	n	n	n	n	n	n	n	n	n	n	n
	38	S1	n	n	n	n	n	y	y	y	-	-	-	-
	38	S1C	n	n	n	n	n	n	n	y	-	-	-	-
	38	S1N	n	n	n	n	n	n	n	y	-	-	-	-
	38	S1NC	n	n	n	n	n	n	n	n	-	-	-	-
	36	S2	n	n	n	n	-	-	-	-	n	y	y	Y
	36	S2C	n	n	n	n	-	-	-	-	n	n	n	y
	36	S2N	n	n	n	n	-	-	-	-	n	n	n	y
	36	S2NC	n	n	n	n	-	-	-	-	n	n	n	n

Shaded cells are the after-entry baselines for calculating credits

y = credit generation allowed

n = credit generation not allowed

Table 3 – Timed Baseline scenarios

		After market entry												
		ACRES	40	40	40	40	38	38	38	38	36	36	36	36
ACRES			Q	QC	QN	QNC	S1	S1C	S1N	S1NC	S2	S2C	S2N	S2NC
Before market entry	40	Q	n	y	y	y	y	y	y	y	y	y	y	y
	40	QC	n	n	n	y	n	y	n	y	n	y	n	y
	40	QN	n	n	n	y	n	n	y	y	n	n	y	y
	40	QNC	n	n	n	n	n	n	n	y	n	n	n	y
	38	S1	n	n	n	n	n	y	y	y	-	-	-	-
	38	S1C	n	n	n	n	n	n	n	y	-	-	-	-
	38	S1N	n	n	n	n	n	n	n	y	-	-	-	-
	38	S1NC	n	n	n	n	n	n	n	n	-	-	-	-
	36	S2	n	n	n	n	-	-	-	-	n	y	y	Y
	36	S2C	n	n	n	n	-	-	-	-	n	n	n	y
	36	S2N	n	n	n	n	-	-	-	-	n	n	n	y
	36	S2NC	n	n	n	n	-	-	-	-	n	n	n	n

Shaded cells are the after-entry baselines for calculating credits

y = credit generation allowed

n = credit generation not allowed

Figure 1 – Study area

Conestoga Watershed and County Boundaries

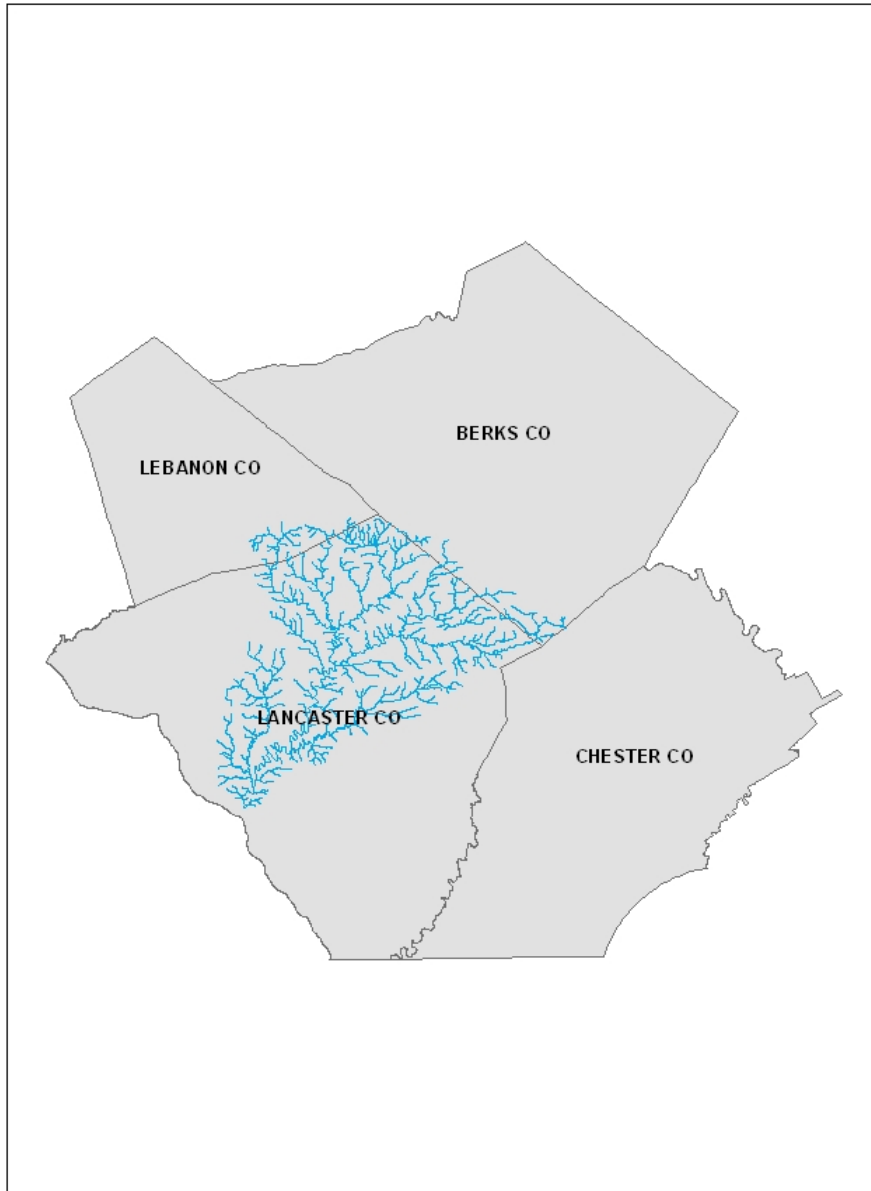


Figure 2 – Minimum Standard Baseline

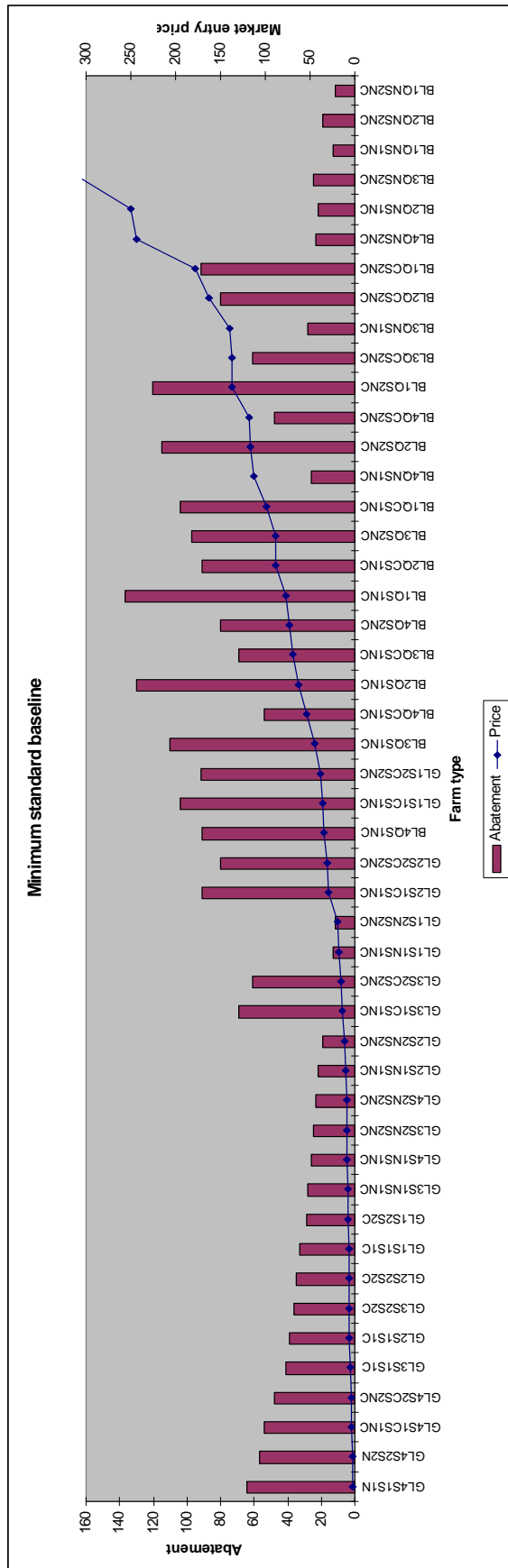


Figure 3 – Timed Baseline

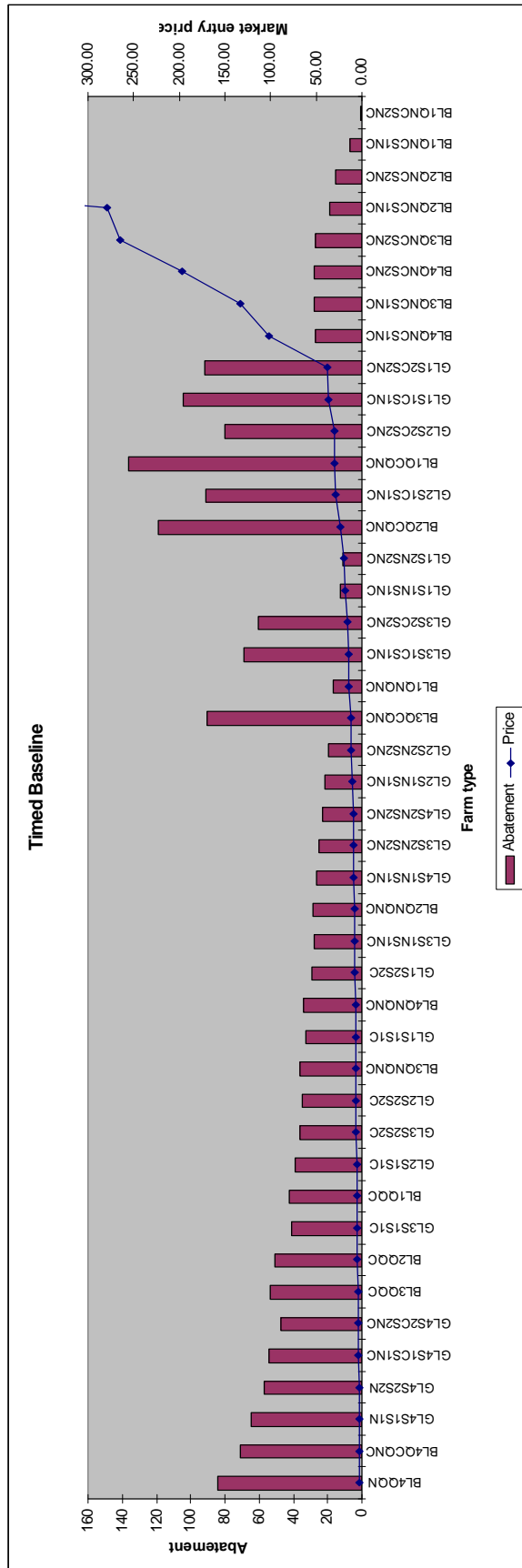


Figure 4 – Agricultural Sub-watersheds and Streams in the Conestoga

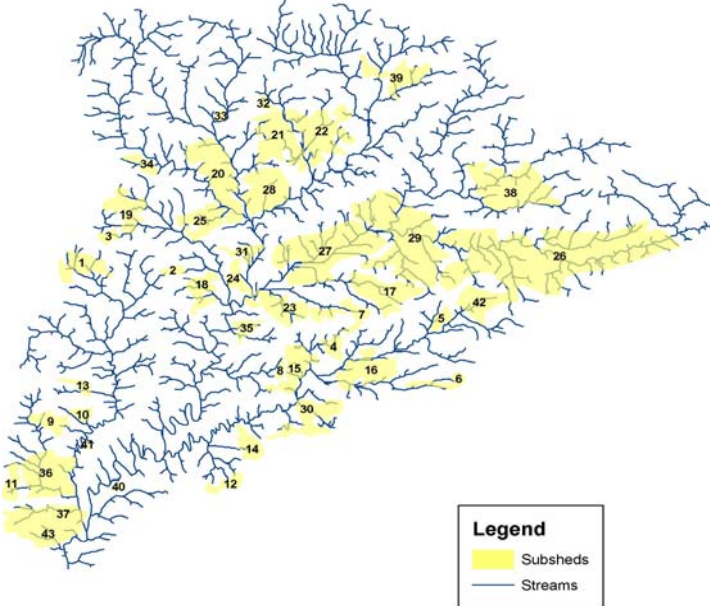
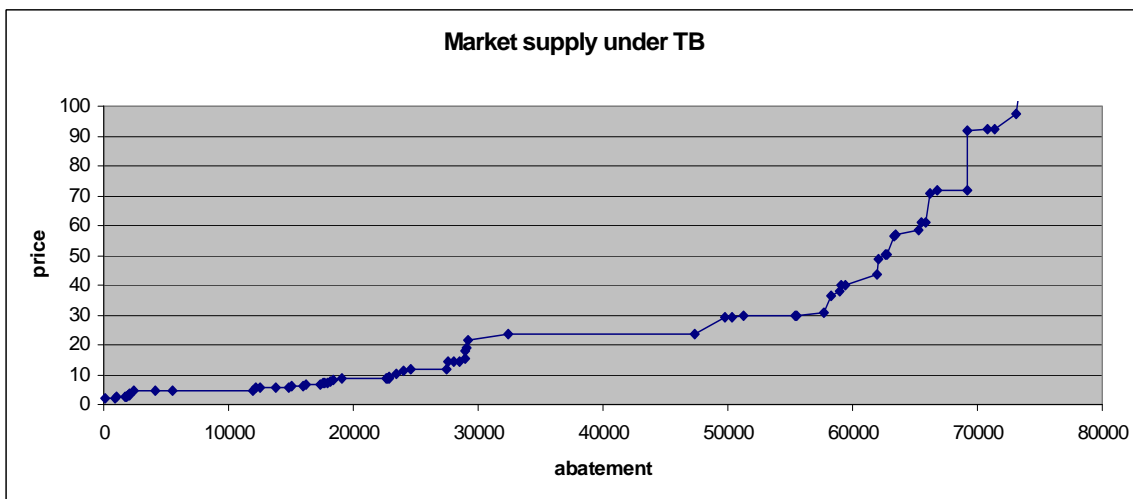
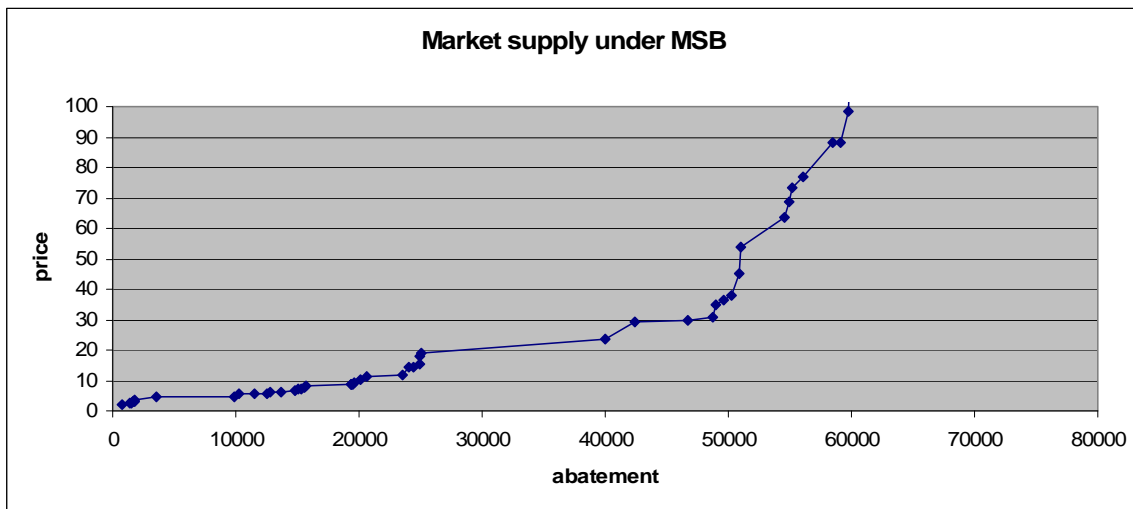


Figure 5 – Market supply curves under MSB and TB



References

- Bailey, K., 2008, Personal Communication
- Belval, D.L., and L.A. Sprague. 1999. *Monitoring Nutrient in the Major Rivers Draining to Chesapeake Bay*. Water-Resources Investigations Report 99-4238, U.S. Geological Survey, U.S. Department of the Interior, Reston, VA.
- Breetz, H.L., K. Fisher-Vander, L. Garzon, H. Jacobs, K. Kroetz, and R. Terry. 2004. *Water Quality Trading and Offset Initiatives in the U.S.: A Comprehensive Survey*. Hanover, NH: Dartmouth College.
(<http://www.dartmouth.edu/~kfv/waterqualitytradingdatabase.pdf>).
- Council for Agricultural Science and Technology (CAST). 2002. *Animal Diet Modification to Decrease the Potential for Nitrogen and Phosphorus Pollution*. Issue Paper 21, July.
- Chavas, J-P. and R.M. Klemme, 1986, Aggregate Milk Supply Response and Investment Behavior on U.S. Dairy Farms, *American Journal of Agricultural Economics*, 68(1): 55-66.
- Dillon, J. L. and J. R. Anderson, 1990, *The Analysis of Response in Crop and Livestock Production*, Pergamon Press, UK.
- Environmental Trading Network, 2009. *Water Quality Trading: State Programs and Rules*. www.envtn.org/wqt/stateprograms_page.html#usprograms . Accessed 4/14/2009.
- Fox, R. H. and W. P. Piekielek, 1983, *Response of Corn to Nitrogen Fertilizer and the Prediction of Soil Nitrogen Availability with Chemical Test in Pennsylvania*, Technical Report, The Pennsylvania State University, University Park, PA.
- Hoag, D.L. and J.S. Hughes-Popp. 1997. "Theory and practice of pollution credit trading in water quality management." *Review of Agricultural Economics* 19:252-262.
- King, D.M. 2005. Crunch Time for Water Quality Trading. *Choices* 20:71-76.
- King, D.M., and P.J. Kuch. 2003. Will Nutrient Credit Trading Ever Work? An Assessment of Supply and Demand Problems and Institutional Obstacles. *Environmental Law Reporter* 33:10352-10368.
- PADEP, 2008a, *Final Trading of Nutrient and Sediment Reduction Credits – Policy and Guidelines, Appendix A*, Doc. No. 392-0900-001, Retrieved from <http://www.dep.state.pa.us/river/Nutrient%20trading.htm#Calculation> on 2/25/2009

- PADEP, 2008b, *Final Trading of Nutrient and Sediment Reduction Credits – Policy and Guidelines, Appendix A, Attachment 3*, Doc. No. 392-0900-001, Retrieved from <http://www.dep.state.pa.us/river/Nutrient%20trading.htm#Calculation> on 2/25/2009
- Pennsylvania Association of Spatial Data Access, 2008, *Pennsylvania Land Use Land Cover 2005*, Office for Remote Sensing of Earth Resources, University Park
- Pennsylvania State University (2007), *2007-2008 Agronomy*, Crop Management Extension Group (CMEG), University Park.
- Pennsylvania State University (1996), *Economics of Conservation Tillage, Conservation Tillage Series No. 6*, College of Agricultural Sciences, Cooperative Extension, University Park, <http://cropsoil.psu.edu/extension/ct/uc130.pdf>.
- Ribaudo, M.O. and C.J. Nickerson. 2009. “Agriculture and water quality trading: Exploring the possibilities,” *Journal of Soil and Water Conservation* 64(1):1-7.
- Shortle, J. and Ghosh, G., 2008c, *Baseline Rules and their Importance to Nonpoint Sources in Water Quality Trading Programs, Third Quarter Report*, Prepared under USDA Cooperative Agreement No. 58-6000-7-0094
- Tietenberg, T.H. 2006. *Emissions Trading: Principles and Practice*. Washington, DC: Resources for the Future.
- United States Department of Agriculture (2008), *Quickstats Database*, National Agricultural Statistics Service, Washington, DC.
- United States Department of Agriculture (2005), *Soil Survey Geographic (SSURGO) Database*, Natural Resources Conservation Service, Fort Worth, TX.
- U.S. Department of Agriculture, National Agricultural Statistics Service. 2003. *2002 Census of Agriculture*. Washington, DC.
- U.S. Department of Agriculture, Natural Resources Conservation Service. *USDA Roles in Market-Based Environmental Stewardship*, Departmental Regulation 5600-003, December 20, 2006.
- U.S. Environmental Protection Agency. 2004. *Water Quality Trading Assessment Handbook: Can Water Quality Trading Advance your Watershed’s Goals?* EPA 841-B-04-001. Washington, DC: Office of Water.
- U.S. Environmental Protection Agency. 2007. *Water Quality Trading Toolkit for Permit Writers*, EPA-833-R-07-004, Office of Water Management, Water Permit Division, Washington DC.

- U.S. Environmental Protection Agency. 2009. *Water Quality Trading*.
www.epa.gov/owow/watershed/trading.htm . Accessed 4/14/2009.
- Woodward, R.T., and R. A. Kaiser. 2002. Market Structures for U.S. Water Quality Trading.
Review of Agricultural Economics 24:366-383.



E.ON Energy Research Center



List of FCN Working Papers

2009

- Madlener R., Mathar T. (2009). Development Trends and Economics of Concentrating Solar Power Generation Technologies: A Comparative Analysis, FCN Working Paper No. 1/2009, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, November.
- Madlener R., Latz J. (2009). Centralized and Integrated Decentralized Compressed Air Energy Storage for Enhanced Grid Integration of Wind Power, FCN Working Paper No. 2/2009, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, November.
- Kraemer C., Madlener R. (2009). Using Fuzzy Real Options Valuation for Assessing Investments in NGCC and CCS Energy Conversion Technology, FCN Working Paper No. 3/2009, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, November.
- Westner G., Madlener R. (2009). Development of Cogeneration in Germany: A Dynamic Portfolio Analysis Based on the New Regulatory Framework, FCN Working Paper No. 4/2009, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, November.
- Westner G., Madlener R. (2009). The Benefit of Regional Diversification of Cogeneration Investments in Europe: A Mean-Variance Portfolio Analysis, FCN Working Paper No. 5/2009, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, November.
- Lohwasser R., Madlener R. (2009). Simulation of the European Electricity Market and CCS Development with the HECTOR Model, FCN Working Paper No. 6/2009, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, November.
- Lohwasser R., Madlener R. (2009). Impact of CCS on the Economics of Coal-Fired Power Plants – Why Investment Costs Do and Efficiency Doesn't Matter, FCN Working Paper No. 7/2009, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, November.
- Holtermann T., Madlener R. (2009). Assessment of the Technological Development and Economic Potential of Photobioreactors, FCN Working Paper No. 8/2009, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, November.
- Ghosh G., Carriazo F. (2009). A Comparison of Three Methods of Estimation in the Context of Spatial Modeling, FCN Working Paper No. 9/2009, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, November.
- Ghosh G., Shortle J. (2009). Water Quality Trading when Nonpoint Pollution Loads are Stochastic, FCN Working Paper No. 10/2009, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, November.
- Ghosh G., Ribaud M., Shortle J. (2009). Do Baseline Requirements hinder Trades in Water Quality Trading Programs?, FCN Working Paper No. 11/2009, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, November.

2008

- Madlener R., Gao W., Neustadt I., Zweifel P. (2008). Promoting Renewable Electricity Generation in Imperfect Markets: Price vs. Quantity Policies, FCN Working Paper No. 1/2008, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, July (revised May 2009).
- Madlener R., Wenk C. (2008). Efficient Investment Portfolios for the Swiss Electricity Supply Sector, FCN Working Paper No. 2/2008, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, August.

- Omamm I., Kowalski K., Bohunovsky L., Madlener R., Stagl S. (2008). The Influence of Social Preferences on Multi-Criteria Evaluation of Energy Scenarios, FCN Working Paper No. 3/2008, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, August.
- Bernstein R., Madlener R. (2008). The Impact of Disaggregated ICT Capital on Electricity Intensity of Production: Econometric Analysis of Major European Industries, FCN Working Paper No. 4/2008, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, September.
- Erber G., Madlener R. (2008). Impact of ICT and Human Skills on the European Financial Intermediation Sector, FCN Working Paper No. 5/2008, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, September.