SLIPPAGE EFFECTS OF THE CONSERVATION RESERVE PROGRAM

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Each year, billions of dollars of public funds are expended to purchase conservation easements on farmland. One unintended impact of these programs is that they may bring non-cropland into crop production. Such a slippage effect can be caused by increased output prices and by substitution effects. This article shows that for each one hundred acres of cropland retired under the Conservation Reserve Program (CRP) in the central United States, twenty acres of non-cropland were converted to cropland, offsetting 9% and 14% of CRP water and wind erosion reduction benefits, respectively. Implications of these results for the design of conservation programs are discussed.

Key words: conservation programs, environmental benefits, land use changes, slippage effects.

Few programs in recent U.S. history have had such a large and sweeping effect on farmland use as the Conservation Reserve Program (CRP). Established under the Conservation Title of the 1985 Food Security Act and re-authorized in subsequent Farm Bills, the CRP contained approximately 33 million acres of cropland as of January 1997, with an annual cost of over $1.6 billion (Osborn and Ribaudo, p. 287). Annual erosion reduction on CRP land totaled 626 million tons as of January 1997, or about 19 tons/acre/year, generating substantial social benefits. For example, CRP wildlife recreation benefits alone were estimated to be $428 million per year (Feather, Hellerstein and Hansen, p. iii). Although the CRP was not intended specifically as a land use policy, the magnitude of its impact on farmland use and rural communities has been recognized (Young and Osborn).

One unintended impact of the CRP, which may compromise its primary objectives,[1] is that it may cause non-cropland to be converted into crop production. For example, the Economic Research Service's CRP database shows that 17.63 million acres of cropland were retired under the CRP in the Corn Belt, Lake States and Northern Plain by 1992, but total cropland acres were reduced by only 13.69 million acres in the region from 1982 to 1992 according to the 1982 and 1992 National Resources Inventories (NRI). This implies that at least 3.69 million acres of non-cropland were converted to cropland in the period of 1982–92.[2] Many factors may have contributed to the slippage effect, but cropland retirements under the CRP may be one of them.

Slippage effects may exist for at least two reasons. First, some non-cropland may be brought into production as a result of increased output prices associated with reduced production on CRP land. Price effects of conservation efforts have been documented. For example, Berck and Bentley estimated that governmental takings of old-growth redwood for inclusion in the Redwood National Park significantly increased redwood lumber prices. The 1978

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The author thanks two anonymous referees for their thorough review of this paper. Useful comments from Bill Boggess, David Zilberman, Bruce Babcock, and participants of the 1999 Rural Land Use Change Workshop at University of Maine are also gratefully acknowledged. Technical paper number 11672 of the Oregon Extension and Experiment Station.

[1] The original goals of the CRP were (P.L. 99–198): a) reducing soil erosion, b) protecting soil productivity, c) reducing sedimentation, d) improving water quality, e) improving fish and wildlife habitat, f) curbing production of surplus commodities, and g) providing income support for farmers. Also, see Feather, Hellerstein, and Hansen.

[2] Using the 1982 and 1987 NRI data, we estimated that 10.25 million acres of noncropland were converted to cropland from 1982 to 1992, 1.16 million acres of noncropland were converted to cropland and then to CRP land. Thus total acreage of noncropland converted to cropland is 11.41 million acres. During the same period, only 8.35 million acres of cropland were converted to noncropland (excluding CRP land). Thus, the net increase in total cropland is 3.06 million acres, which is smaller than the estimate of 3.94 million acres based on the ERS's CRP database. The discrepancy arises because the NRI underestimates the total CRP acreage by 0.88 million acres for the study region. In this analysis, the ERS's CRP database is used to estimate CRP acreage.

Amer. J. Agr. Econ. 82(4) (November 2000): 979–992

taking alone increased redwood lumber prices by 26%. Ironically, these price increases led to increased profits and harvesting of old-growth redwood on other lands.

Another possible reason for slippage is substitution effects. When some cropland is taken out of production, farmers may substitute other land for crop production because of scale economies and fixed input effects (see the detailed discussed in the next section). However, no CRP provision prohibits participating farmers from converting non-cropland to cropland. The "sodbuster" and "swampbuster" provisions of the 1985 Food Security Act prohibit farmers who convert highly erodible land or wetland into crop production from receiving price and income support payments under the commodity provisions. But temporal cycles in the agricultural economy, as well as definitional, implementation, and enforcement problems, have hampered the effectiveness of these provisions (Heimlich 1995; Miranowski and Cochran).

The primary objective of this article is to determine if a slippage effect was present in the CRP and, if so, how large was the effect. The objective is achieved by combining the Economic Research Service's county-level CRP file with data from the National Resources Inventories (NRI) and the Census of Agriculture. The 1982 and 1992 NRIs were used to estimate the land use changes from 1982 to 1992. The CRP database was used to estimate the acres retired during the period. The 1982 and 1992 Census of Agriculture was used to estimate changes in land value, farm size, and other farm characteristics affecting land use. Regression analysis was then used to determine if land retirements under the CRP increased conversions of non-cropland to cropland. To make the analysis more manageable, we focused on twelve states in the central United States where more than half of the CRP acres were concentrated.

Previous analyses of CRP efficiency have demonstrated that specific benefits from the CRP could have been achieved at a lower cost than what was actually incurred. Babcock et al. (1996) estimated that 90% of the available water erosion benefits could have been achieved with 50% of the CRP budget. Heimlich and Osborn compared two hypothetical enrollment patterns and found that selecting five million CRP acres to renew on the basis of maximizing soil erosion reduction per dollar would cost \$0.54 per ton of soil saved compared to \$1.01 under a targeting criterion of minimizing total cost. Reichelderfer and Boggess estimated that the cost per ton of soil erosion reduction could have been decreased by 15% if erosion benefits were maximized. Ribaudo showed how total benefits of the CRP could be increased if the off-site benefits were accounted for. Osborn and Thurman analyzed recent CRP signups and found that the CRP began to enroll land based on comparisons of environmental benefits and government costs with an objective of improving the environmental performance of the CRP. These studies, however, have not examined the slippage effects of the CRP.

In the next section, I model the slippage effects associated with output price increases and substitution effects and show that slippage reduces environmental gains of a conservation program, and in some cases, may make it counterproductive. Subsequent sections discuss data, empirical specifications, and land use changes for twelve states in the central United States. Empirical results and policy implications are discussed in the last two sections.

Modeling Slippage Effects

In this section, I first model the slippage effects associated with output price increases. I show that when the output demand is sufficiently inelastic, slippage may make a program counterproductive (resulting in negative net environmental benefits). Then I present a model to show that substitution effects also give landowners incentives to convert non-cropland to cropland when some cropland is retired under a conservation program.

Output Price Feedback Effects

I analyze the situation where some cropland is retired from crop production for environmental benefits (e.g., soil erosion reduction) in a nation or a large region. Land quality is differentiated by the output and environmental benefits per acre. Let y be the output per acre, and let b be the environmental benefit per acre if the land is retired. Across the landscape y and b vary and have a joint probability distribution function of $s(y, b)$, where y varies from 0 to $\bar{y}$ and b varies from 0 to $\bar{b}$. Production cost per acre is assumed to

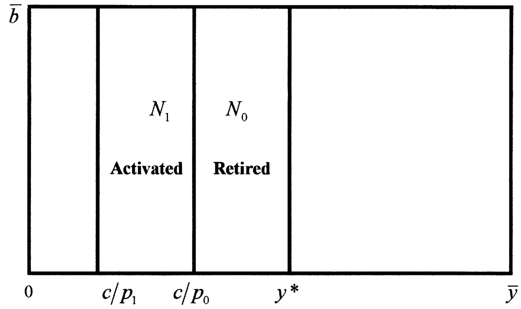

Figure 1. Slippage effects from output price increases

be constant and is denoted by c.[3] Without the land retirement program, all land with $\pi = p_0 y - c \geq 0$ or $y \geq (c/p_0)$ is assumed to be used in crop production (figure 1), where p_0 is the initial output price.

Suppose some cropland is targeted for conservation practices. Each targeting criterion corresponds to selecting a subset of (y, b) from the base resource set $R_0 \equiv \{(y, b); c/p_0 \leq y \leq \bar{y}; 0 \leq b \leq \bar{b}\}$. The first nine signups of the CRP, conducted under authority of the 1985 Food Security Act, were subject to mandatory minimum annual enrollment levels as established in the Act. In an effort to meet these enrollment levels, bids were accepted as long as land eligibility criteria were met and the rental rate requested by the producer did not exceed a USDA maximum acceptable rental rate (MARR) established for a multiple county area or state (Economic Research Service, pp. 294–95). Thus, the experience of CRP implementation before 1990 was consistent with acreage maximization (Reichelderfer and Boggess). Land with lower yields had greater incentives to enroll because the MARR offered a rental premium. Let y^* be the highest yield of lands accepted into the program. Then, land in N_0 will be retired from crop production (see figure 1). Because of the output reduction, the price of the output will increase.[4] As a result, the marginal land in N_1 will be put into production. The net reduction in cropland acreage equals

$$(1)\qquad \Delta A = A(N_0) - A(N_1) = \int_{c/p_0}^{y^*}\int_0^{\bar{b}} s(y, b)dydb - \int_{c/p_1}^{c/p_0}\int_0^{\bar{b}} s(y, b)dydb.$$

The net environmental gain equals

$$(2)\qquad \Delta B = B(N_0) - B(N_1) = \int_{c/p_0}^{y^*}\int_0^{\bar{b}} bs(y, b)dydb - \int_{c/p_1}^{c/p_0}\int_0^{\bar{b}} bs(y, b)dydb.$$

The output price p_1 after the land retirement is defined by the market equilibrium condition:

$$(3)\qquad \int_{y^*}^{\bar{y}}\int_0^{\bar{b}} ys(y, b)dydb + \int_{c/p_1}^{c/p_0}\int_0^{\bar{b}} ys(y, b)dydb = D(p_1),$$

where $D(p)$ is the market demand curve for the output.

To see that expressions (1) and (2) can both be negative, note that when the market is in equilibrium, the change in demand must equal the change in supply under the conservation program:

$$(4)\qquad A(N_0)E(y|N_0) - A(N_1)E(y|N_1) = D(p_0) - D(p_1),$$

where $E(y|N_i)$ is the average yield for land in N_i. As the demand for the output becomes more inelastic, both sides of equation (4) become smaller. Because $E(y|N_1) < E(y|N_0)$, $A(N_1)$ will eventually become greater than $A(N_0)$. Specifically, if the demand is perfectly inelastic, $A(N_0)E(y|N_0) - A(N_1)E(y|N_1) = 0$, which implies that $A(N_0) < A(N_1)$ and $\Delta A < 0$. In this case, more land will be activated for crop production than retired. Furthermore, if

[3] Relaxing this assumption would complicate our model, but would not change our basic result as long as the convertible land has a lower yield than the currently cropped land. Empirical evidence indicates that crop yields are generally lower on converted cropland than on other cropland. For example, the NRI data show that the average land capability class of the converted cropland is higher (i.e., has a lower quality) than the other cropland (see table 2). In addition, the USDA's Area Study Data show that crop yields and land capability classes are negatively correlated across fields. For example, the average corn yield in central Nebraska Basin is 143 bushel per acre on the first class land, but only 120 bushels on classes II and III land and 113 bushels on land with a capability class IV or higher.

[4] While reduced output would tend to raise the commodity price in a static setting, it may only serve to mitigate further price declines that may occur due to other market factors in a dynamic setting. We thank a referee for pointing this out.

environmental benefits and crop yields are negatively correlated, the net environmental gain ΔB is also negative.[5]

To provide further insights, we assume that (y, b) follows the bivariate normal distribution, $N(\mu_y, \mu_b, \sigma_y, \sigma_b, \rho)$, where μ_y and μ_b are the mean of crop yields and environmental benefits, σ_y and σ_b are their standard derivation, and ρ is the correlation coefficient. Under this normal distribution assumption, ΔA, ΔY, and ΔB have the following relationship (see the Appendix):

$$\sigma_y \Delta B = (\mu_b \sigma_y - \rho \mu_y \sigma_b) \times \Delta A - \rho \sigma_b \Delta Y, \tag{5}$$

where $\Delta Y = D(p_1) - D(p_0) \leq 0$. Equation (5), together with equation (4), indicates that if the demand is perfectly inelastic ($\Delta Y = 0$), both ΔA and ΔB are negative if $\rho < (\mu_b \sigma_y)/\mu_y \sigma_b$. In this case, more land will be put into production than retired, and the conservation program will be counterproductive. On the other hand, if $\rho > (\mu_b \sigma_y)/\mu_y \sigma_b$, $\Delta A < 0$ and $\Delta B > 0$, which implies that the conservation program will result in a positive environmental gain even if more land will be activated than retired.

Natural resource agencies tend to target resources for conservation based on biological, agronomic or hydrologic criteria. For example, the U.S. Fish and Wildlife Service, in its Wetland Reserve and similar programs, targets wetlands and other water resources based primarily on biological criteria. In recent signups, the CRP began to enroll land based on comparisons of environmental benefits and contract costs. By using a similar model, it can be shown that these criteria may also cause slippage.

Substitution Effects

Another possible cause of slippage is substitution effects, which can be understood by considering a farmer's land use decisions. Suppose a farm has three types of land: high-quality, medium-quality, and low-quality land. Suppose all high-quality land is devoted to crop production, and all low-quality land is devoted to a non-cropping activity. The medium-quality land is divided between crop production and the non-cropping activity, and the allocation depends on the output prices and production costs. Let A_H, A_M, and A_L be the total acreage of high, medium, and low quality land, respectively. Let $\pi_C(A_H, A_{MC})$ and $\pi_N(A_L, A_{MN})$ be the total profit functions for crop production and the non-cropping activity, where A_{MC} and A_{MN} are acres of medium-quality land allocated to crop production and the non-cropping activity. It is assumed that $\partial^2 \pi_C / \partial A_{MC}^2 \leq 0$ and $\partial^2 \pi_N / \partial A_{MN}^2 \leq 0$. Without the CRP, the medium-quality land would be allocated such that

$$\frac{\partial \pi_C(A_H, A_{MC})}{\partial A_{MC}} = \frac{\partial \pi_N(A_L, A_{MN})}{\partial A_{MN}}. \tag{6}$$

If the left-hand side is greater than the right-hand side, more land would be allocated to crop production, and vice versa. This condition is shown in figure 2, where the distance between the two vertical axes equals the total acreage of the medium quality land. Thus, graphically, A_{MN} equals the distance between 0' and A_{MC}.

Now, suppose A_{CRP} acres of medium-quality cropland are enrolled into the CRP. As a result, $\partial \pi_C(A_H, A_{MC} - A_{CRP})/\partial A_{MC} > \partial \pi_N(A_L, A_{MN})/\partial A_{MN}$. Because the marginal profit from crop production is greater than the marginal profit from the non-cropping activity, the farmer would have an incentive to convert some medium-quality land from the non-cropping activity into crop production. Without government restrictions, the farmer would switch A_S acres of medium-quality land from the non-cropping activity to crop production such that

$$\frac{\partial \pi_C(A_H, A_{MC} - A_{CRP} + A_S)}{\partial A_{MC}} = \frac{\partial \pi_N(A_L, A_{MN} - A_S)}{\partial A_{MN}}. \tag{7}$$

Thus, in equilibrium, the total cropland acreage would be reduced by $(A_{CRP} - A_S)$ instead of A_{CRP}. Graphically, the land between $(A_{MC} - A_{CRP})$ and A_{MC} is retired, land between A_{MC} and $(A_{MC} + A_S)$ is converted to crop production, and the land

[5] Empirical evidence indicates that the correlation between an environmental benefit and crop yields can be positive, negative, or zero, depending on the specific environmental benefit considered. For example, Babcock et al. (1997) found that CRP rental rates are negatively correlated with wind erosion (with a correlation coefficient of −0.26), but are positively correlated with water erosion and wildlife habitat benefits (with a correlation coefficient of 0.19 and 0.14, respectively). The correlation between the CRP rental rate and the groundwater vulnerability index is negative, but is close to zero (with a correlation coefficient of −0.02). In another study, Heimlich (1989) compared the distributions of crop yields on highly erodible land and other land and found that the two distributions are almost identical, indicating that retiring highly erodible, physically marginal cropland is not synonymous with retiring less productive, economically marginal cropland.

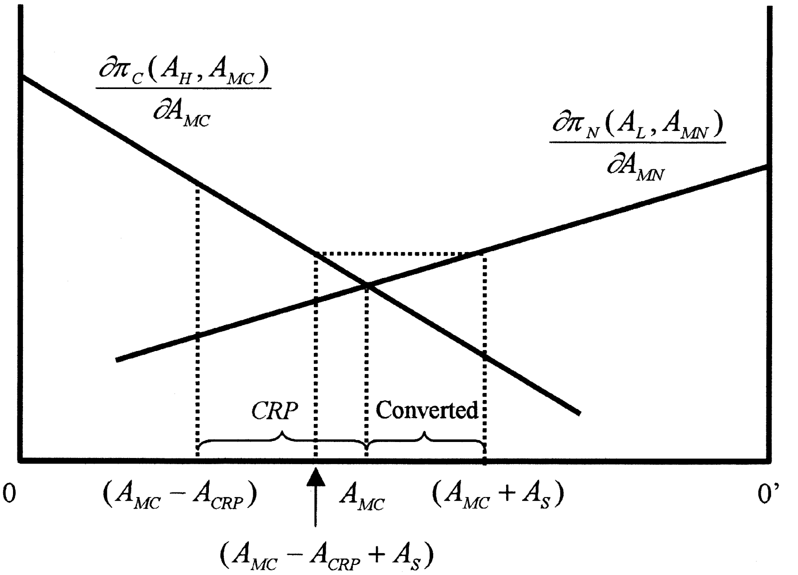

Figure 2. Slippage effects from land substitution

between $(A_{MC} - A_{CRP} + A_s)$ and A_{MC} is the net reduction in total cropland acreage (see figure 2).

Up to now, we have shown that both output price increases and substitution effects can cause slippage effects. The question is whether a slippage effect exists in the CRP, and if so, how large is the effect.

An Empirical Analysis of Slippage Effects in the CRP

This section discusses the data and empirical model that we used to analyze the slippage effects in the CRP. The empirical analysis focuses on twelve states in the Corn Belt, Lake States and Northern Plains (figure 3), a region that accounted for over 50% of total CRP acreage and experienced large land use changes in many areas during 1982–92 (figure 4). Overlaying figure 3 upon figure 4 reveals that counties with large CRP acreage tend to have more non-cropland converted to cropland. In this section, we use regression analysis to estimate the acreage of non-cropland converted to cropland as a result of land retirements under the CRP.

Empirical Specification and Data

A multivariate regression model is used to examine the impact of the CRP on the acreage of non-cropland converted to cropland:[6]

$$\Delta A_i = \alpha + \beta CRP_i + X_i\gamma + \varepsilon_i, \tag{8}$$

where i is an index of Agricultural Statistics Districts (ASD) as defined by the National Agricultural Statistics Service, ΔA_i is the acreage of non-cropland converted to cropland between 1982 and 1992 as a proportion of the total land area in ASD i, CRP_i is the acres of cropland enrolled in the CRP by 1992 as a proportion of the total land area in ASD i, and X_i is a vector of other land and farm characteristics that affect land use conversions, including changes in farm size and population. The empirical model was specified at the ASD level because reliable estimates of land use changes for the whole study region were not available at a more disaggregate level, as will be discussed.

The land use data for this analysis were derived from the 1982 and 1992 National Resource Inventories (NRI). The NRI is conducted every five years by the Natural Resource Conservation Service (NRCS) to determine the status, condition, and trend of the nation's soil, water, and other related resources at more than 800,000 sites across

[6] This specification precludes us from separating the substitution effect from the output price effect. Ideally, we would like to examine how the CRP affected output prices and how changes in output prices in turn affected land conversions. However, because of lack of time-series data on land conversion and little variations in output prices across counties, we are unable to include output prices in our land conversion model.

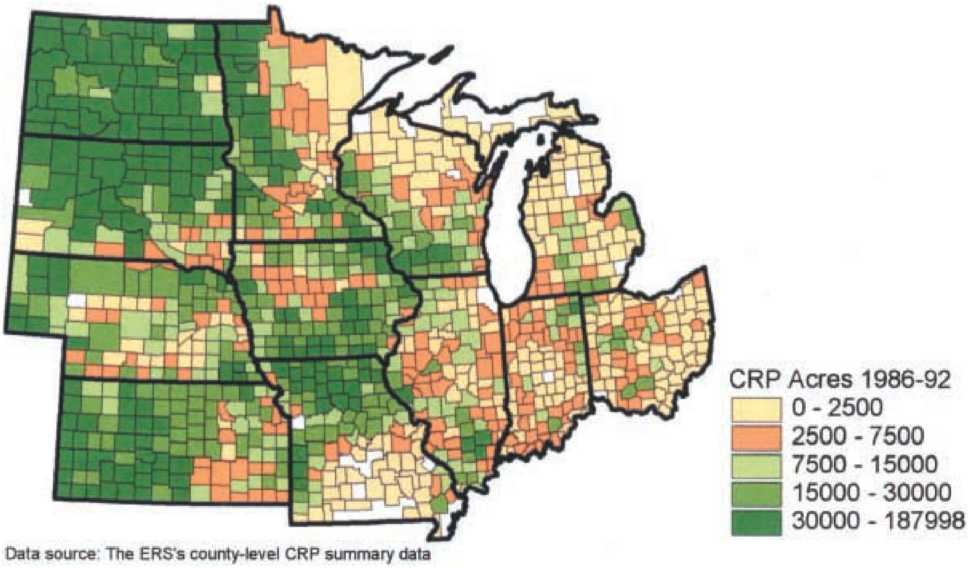

Figure 3. Total CRP acres enrolled from 1986–92 by county

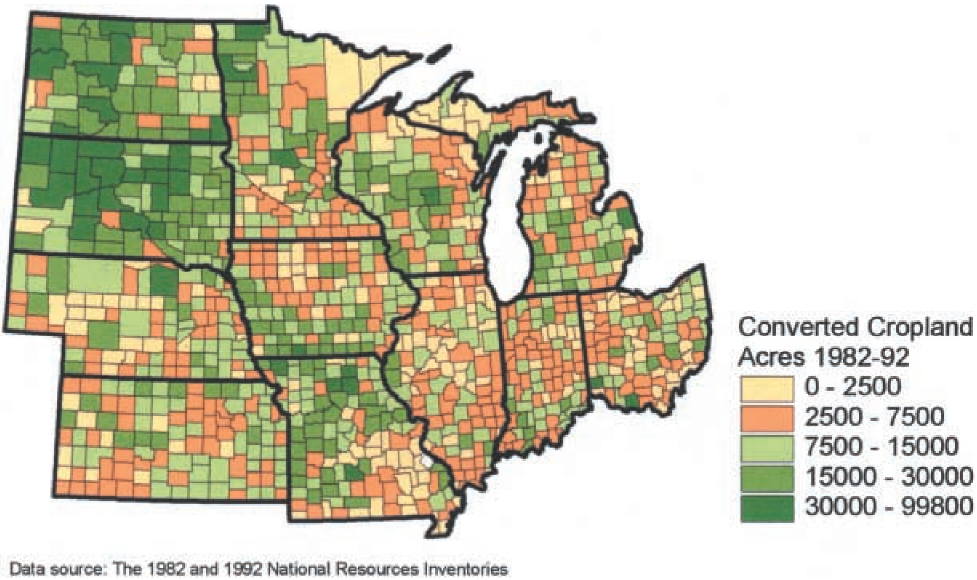

Figure 4. Acres of non-cropland converted to cropland from 1982–92 by county

the continental United States. Each NRI site is assigned a weight (called the expansion factor) to reflect the acreage it represents. For example, the summation of expansion factors for all sites planted to crops in a region gives an estimate of cultivated cropland acreage in the region. The sampling design of NRI ensures that inferences at the national, regional, state, and substate levels are made in a statistically reliable manner.

There were 336,462 NRI sites in the study region. At each NRI site, information on nearly 200 attributes was collected, which include land use and cover, cropping history, irrigation type, tillage and conservation practices, topography, and soil type. NRI divides land use into twelve major categories (cultivated cropland, non-cultivated cropland, pastureland, rangeland, forest land, urban and built up land, and six other categories). NRI recorded land use at each NRI site in 1982 and 1992. By comparing land use in 1982 and 1992 at each NRI site, I estimated acres of non-cropland converted to cropland from 1982 to 1992. As shown in figure 4, there were large variations in the number of acres converted across the study region. A comparison of figure 4 with figure 3 indicates that counties with more converted cropland tend to have more CRP acres.

Although the NRI data can be used to show spatial patterns of land use change at the county level, point estimates from the NRI (e.g., acres of non-cropland converted to cropland) are generally reliable only at a more aggregate geographic level. For this reason, I aggregated the NRI data to Agricultural Statistics Districts (ASD). Each state in our study region has nine ASDs, except Nebraska (which has eight). On average, each state falls into ten Major Land Resource Areas (MLRAs). Thus, the average size of an ASD is comparable to the average size of a MLRA within a state, a level of aggregation reliable for point estimates according to the NRCS.

The county-level CRP summary data from the Economic Research Service were used in this analysis. This data included CRP acreage by enrollment year, annual rental rates, soil erosion reduction, corn and wheat base acres retired by the CRP, and a number of other variables. The percentage of cropland enrolled into the CRP varies from zero to over 80% among counties, with an average of 8.6% for all counties in the study region. There were also large variations in CRP rental rates and soil erosion reduction among counties (see figures 5 and 6). The average CRP rental rate varied from \$12 to \$113 per acre. On average, CRP rental rates in the Corn Belt were the highest in the nation, with almost all counties having an average annual rental rate above \$70 per acre. In contrast, CRP rental rates in the western Dakotas and northern Lake States were the lowest, with almost all counties having an average annual rental rate below \$40 per acre. Although the average soil erosion reduction per CRP acre was generally higher in the Corn Belt than in the Dakotas, the average soil erosion reduction per dollar expended was relatively low in the Corn Belt.

The 1982 and 1992 Census of Agriculture provides information on farm characteristics in 1982 and 1992. From these census data, several variables that may affect land use changes were derived, including changes in farm size and average market value of land and buildings from 1982 to 1992. Some of these variables were not included in the final model because they were statistically insignificant. Equation (8) was estimated using the ordinary least square procedure in SAS.

Results and Implications

Three steps are involved in the estimation of the slippage effects of the CRP. The first one involves a statistical evaluation of the relationship between the CRP and the converted cropland acreage based on the specification presented in equation (8). The relationship allows us to estimate the

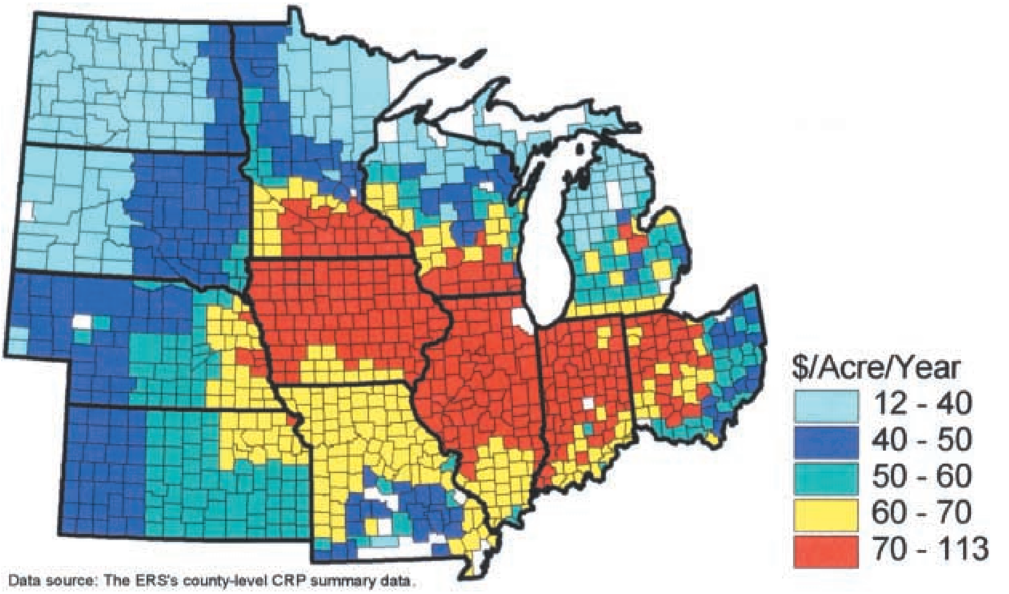

Figure 5. CRP rental rates by county

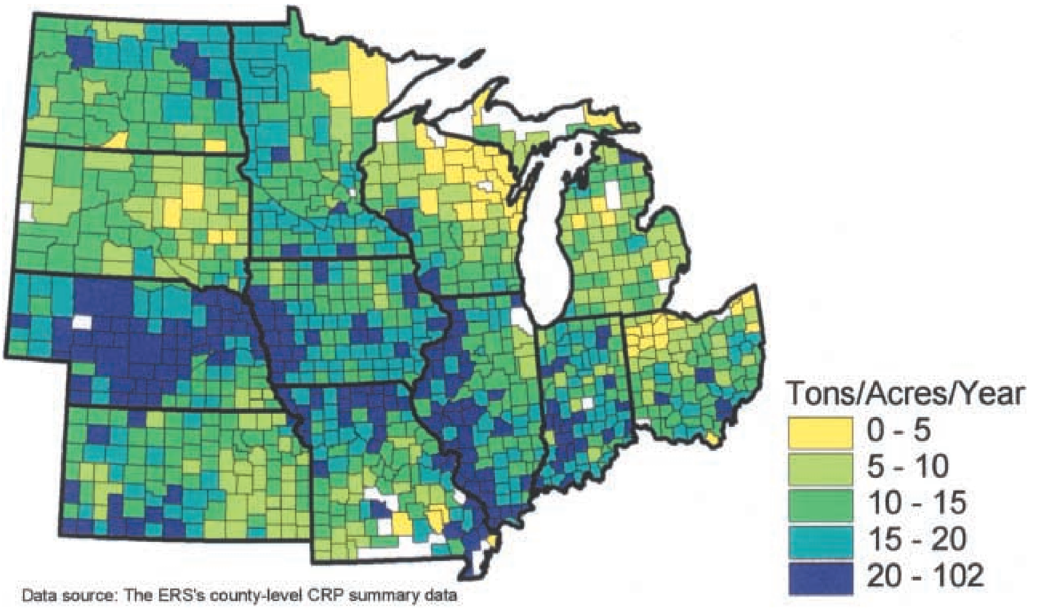

Figure 6. Annual soil erosion reduction per CRP acre

acreage of non-cropland converted to cropland as a result of land retirements under the CRP. The second step involves estimation of environmental benefits offered by CRP land and the converted cropland. In the final step, we combine results from the first two steps to determine the magnitude of the slippage effects. The results from these three steps are reported in tables 1–3, respectively.

Table 1 presents the statistical results from the estimation of the relationship between the CRP and the converted cropland acreage. As is evident from the table, all variables except changes in population and average farm size are statistically significant at the 10% level. These variables explain 45% of the variation in converted cropland acreage across ASDs. Coefficients of particular interest to this analysis are those on CRP acreage as a proportion of the total land area and its interaction terms with regional dummy variables. These coefficients indicate that land retirements under the CRP had a strong and highly significant impact on the acreage of non-cropland converted to cropland. In the Corn Belt, each one hundred acres of cropland retired under the CRP resulted in thirty acres of non-cropland converted to cropland. The slippage effect is smaller in the Lake States and Northern Plains, but still significant. Each one hundred acres of land retired under the CRP resulted in sixteen and fifteen acres of non-cropland converted to cropland in these two regions, respectively.

In addition to the CRP acreage, the characteristics of CRP land also affected the slippage effects. The larger the corn and wheat base acres retired under the CRP, the more likely the farmers will replace them by converting non-cropland to cropland. However, both the CRP rental rate and the soil erosion reduction per CRP acre are negatively correlated to the converted cropland acreage. This result may reflect that areas with higher CRP rental rates tend to have few acres of non-cropland suitable for crop production. The correlation coefficient between CRP rental rates and non-cropland acreage across counties is -0.52. The coefficient on the change in the average farm size indicates that the larger the increase in the average farm size, the more likely non-cropland will be converted to cropland. Likewise, the larger the increase in population in a county, the more likely that urbanization is proceeding, and the less likely non-cropland will be converted to crop production. Although these results make sense, the coefficients on both changes in farm size and population are statistically insignificant at the 10% level.

To determine the magnitude of slippage effects of the CRP, we also need to estimate the total environmental benefits offered by CRP land and the converted cropland. Table 2 shows the use of CRP land and the converted cropland before their retirements or conversions and the changes in water and wind erosion rates on these lands

Table 1. The Impact of the Conservation Reserve Program on the Acreage of Non-Cropland Converted to Cropland from 1982–92 in the Central United States

Variable[a]	Coefficient[b]	T-Statistic
Intercept	0.0361***	6.70
Acres of CRP land enrolled by 1992 as a percent of the total land area (CRP)	0.3041***	6.81
CRP * a dummy variable for lake states	−0.1355**	−2.23
CRP * a dummy variable for northern plains	−0.1514***	−2.70
CRP rental rate ($/acre)	−0.0003***	−3.54
Average annual erosion reduction per CRP acre (tons/acre/year)	−0.0003*	−1.86
Corn base acres retired per CRP acre	0.0321***	2.86
Wheat base acres retired per CRP acre	0.0256**	2.42
Percent change in population 1982–92	−0.0119	−0.92
Change in average size of farm 1982–92	0.00003	1.41
Total land area (million acres)	−0.0019***	−4.02
R-square	0.45	

[a]The dependent variable is the acreage of non-cropland converted to cropland from 1982-92 as a proportion of the total land area. The unit of the cross-sectional analysis is Agricultural Statistics Districts (ASD) as defined by the National Agricultural Statistics Service.
[b]One, two and three asterisks indicate statistical significance at the 10%, 5% and 1% level, respectively.

from 1982 to 1992. These measures were estimated based on the comparison of water and wind erosion rates in 1982 and 1992 at each CRP and converted cropland site in the NRI sample.

Before their retirements, 19.4% of CRP acres were planted to corn in the region, 10.8% to soybeans, 27.9% to wheat, and 41.9% to other crops or summer fallow in 1982. The average water and wind erosion rates on these lands were 6.56 and 4.51 tons/acre/year, respectively. However, conservation practices under the CRP on these lands reduced the average water and wind erosion rates to 0.52 and 0 tons/acre/year, respectively, in 1992.

In contrast, before their conversions, 63.4% of the converted cropland acres were pastureland, and 22.3% were rangeland in 1982.[7] Cropping practices on these lands increased the average water and wind erosion rates for the whole region from 1.44 and 0 tons/acre/year in 1982 to 4.12 and 3.11 tons/acre/year in 1992. The largest water erosion increase occurred in the Corn Belt (from 1.34 ton/acre/year in 1982 to 6.99 tons/acre/year in 1992), while the largest wind erosion increase occurred in the Northern Plain (from zero in 1982 to 4.10 tons/acre/year in 1992).

The average water erosion rate on other cropland was slightly reduced in all three regions, with the largest reduction in the Corn Belt (by 1.65 tons/acre/year). The reduction may reflect the increased adoption of conservation tillage and other conservation practices from 1982 to 1992. For example, the percentage of cropland cultivated with conservation tillage was increased from 13.5% to 23% in the Corn Belt from 1982 to 1992. One important factor that contributed to the increased adoption of conservation tillage is the reduced production costs associated with the use of conservation tillage (Martin et al.). In addition, the conservation compliance and lower commodity prices might also be a factor. The conservation compliance required adoption of conservation tillage and other conservation practices as a condition of continued receipt of farm program payments. Lower commodity prices tended to cause producers to reduce the intensity of crop production, primarily through reduced tillage and less intensive crop rotations.[8]

The last three rows of table 2 show the average land capability class of CRP land and converted and non-converted cropland as well as the percentage of each type of land in capability classes I–II. On average, the converted cropland has a slightly lower land capability class (higher land quality) than the CRP land, but both have lower land quality than the other cropland.

[7] Since a large percentage of the converted cropland was pastureland or rangeland before the conversion, an interesting extension of this study is to look at how the CRP affected the cattle industry.

[8] I thank a referee for pointing this out.

Table 2. Land Use, Soil Erosion Rates, and Land Quality of CRP Land and Converted Cropland Before and After Conversions, by Region

Variables	Corn Belt	Lake States	N. Plains	The Region
Use of CRP Land in 1982 (Before Retirements) (Percent)				
Corn	45.5	46.0	11.5	19.4
Soybeans	22.8	2.4	8.2	10.8
Wheat	6.9	0.5	34.5	27.9
Other	24.8	51.1	54.2	41.9
Use of Converted Cropland in 1982 (Before Conversions) (Percent)				
Pastureland	80.0	81.1	56.9	63.4
Rangeland	0	0	30.5	22.3
Forestland	8.8	5.5	3.3	4.1
Other	10.4	13.4	9.3	10.2
Soil Water Erosion Rate in 1982 (Tons/Acre/Year)				
CRP land	12.02	6.77	5.18	6.56
Converted cropland	1.34	0.42	1.56	1.44
Other cropland	6.09	4.00	3.17	4.07
Changes in Soil Water Erosion Rates 1982–92 (Tons/Acre/Year)				
CRP land	−11.42	−6.09	−4.69	−6.04
Converted cropland	5.65	3.68	1.75	2.68
Other cropland	−1.65	−0.81	−0.67	−0.97
Soil Wind Erosion Rate in 1982 (Tons/Acre/Year)				
CRP land	0.56	0.05	5.72	4.51
Converted cropland	0	0	0	0
Other cropland	0.48	0.08	3.81	2.65
Changes in Soil Wind Erosion Rates 1982–92 (Tons/Acre/Year)				
CRP land	−0.56	−0.05	−5.72	−4.51
Converted cropland	0.51	0.17	4.10	3.11
Other cropland	0	0	0	0
Average Land Capability Class (% in Land Capability Classes I–II)				
CRP land	3.2	3.5	3.3	3.3
	(33%)	(27%)	(30%)	(30%)
Converted cropland	2.9	3.3	3.2	3.1
	(49%)	(38%)	(38%)	(40%)
Other cropland	2.3	2.7	2.5	2.5
	(71%)	(58%)	(61%)	(64%)

Table 3 presents estimates of the slippage effects of the CRP and some of the data used in the estimation. The first row of table 3 shows total CRP acreage enrolled in each region by 1992 based on the ERS's county-level CRP summary data. The reduction in water and wind erosion on CRP land was estimated by multiplying the total CRP acreage by the change in average water and wind erosion rates on CRP land as reported in table 2. The fourth row of table 3 shows the total acreage of non-cropland converted to cropland from 1982 to 1992. The acreage converted as a result of the CRP was estimated using the estimated relationship between the CRP and the converted cropland acreage as reported in table 1. Specifically, I first estimated the acreage of non-cropland that would be converted without the CRP by assuming a zero CRP acreage in the relationship and then subtracted it from the total converted acreage. The result was then multiplied by the change in average water and wind erosion rates on the converted cropland to give an estimate of the increase in total water and wind erosion on the land converted by the CRP. The percentage of CRP soil erosion benefit offset by the slippage effect was then estimated based on the reduction in soil erosion on CRP land and the increase in soil erosion on the cropland converted by the CRP.

The results in table 3 show that a slippage effect was present in the CRP. For the

Table 3. Slippage Effects of the CRP on Cropland Acreage and Soil Erosion Benefits

Variables	Corn Belt	Lake States	N. Plains	The Region
Total acres of cropland enrolled in CRP by 1992[a]	5,204,923	2,847,611	9,576,646	17,629,180
Reduction in soil water erosion on CRP land (tons/year)[b]	−59, 440, 221	−17, 341, 951	−44, 914, 470	−106, 480, 247
Reduction in soil wind erosion on CRP land (tons/year)[b]	−2, 914, 757	−142, 381	−54, 778, 415	−79, 507, 602
Total acres of non-cropland converted to cropland 1982–92	2,117,100	544,000	7,493,600	10,254,700
Acres of non-cropland converted to cropland by the CRP	1,582,817	480,107	1,462,354	3,525,278
Increase in water erosion on converted cropland by the CRP (tons/year)	8,942,917	1,766,795	2,559,119	9,447,745
Increase in soil erosion on converted cropland by the CRP (tons/year)	807,237	81,618	5,995,651	10,963,615
Acres of non-cropland converted for each CRP acre	0.30	0.17	0.15	0.20
Percent of soil water erosion benefit offset by the slippage effect	15%	10%	6%	9%
Percent of soil wind erosion benefit offset by the slippage effect	28%	57%	11%	14%

[a] Estimated based on the Economic Research Service's county-level CRP summary data.
[b] The water and wind erosion reductions are estimated by multiplying total CRP acreage by the average water and wind erosion reduction rates as shown in table 2. The sum of the water and wind erosion reductions is lower than the estimate of soil erosion reduction based on ERS's county-level CRP summary data. The estimates of water and wind erosion reduction rates are used here for consistency because ERS's county-level CRP summary data do not separate water and wind erosion and include no information on soil erosion on the converted cropland.

entire study region, each one hundred acres of land retired under the CRP resulted in twenty acres of non-cropland converted to cropland. This slippage effect offset 9% of water erosion benefits and 14% wind erosion benefits offered by the CRP. The slippage effect on acreage was the largest in the Corn Belt; each one hundred acres of land retired under the CRP resulted in thirty acres of non-cropland converted in the region. This slippage offset 15% of CRP water erosion benefits and 28% of CRP wind erosion benefits. The slippage effect on acreage was smallest in the Northern Plains; each one hundred acres of land retired under the CRP resulted in fifteen acres of non-cropland converted in the region, offsetting 6% of CRP water erosion benefits and 11% of CRP wind erosion benefits. The slippage effect on water erosion benefits was smaller than the slippage effect on acreage in all three regions because the increase in the average water erosion rate on the converted cropland was smaller than the reduction in the average water erosion rate on the CRP land. A large portion of CRP wind erosion benefit (57%) was offset by the slippage effect in the Lake States because the increase in the wind erosion rate on the converted cropland was much larger than the decrease in the wind erosion rate on the CRP land. Fortunately, the average wind erosion rate was minimal on all types of land in the Lake States.

Concluding Remarks

Each year, billions of dollars of public and private funds are expended to purchase easements on farmland for resource conservation and environmental protection. One unintended impact of these conservation programs is that they may bring non-cropland into crop production. Such a slippage effect can be caused by increased output prices and/or by substitution effects. In this study, we found that substantial slippage effects were present in the CRP. For each one hundred acres of land retired under the CRP in the central United States, twenty acres of non-cropland were converted to cropland, offsetting 9% and 14% of CRP water and wind erosion benefits, respectively.

The USDA estimated that the CRP provided \$9.7–14.5 billion of net social benefits (Osborn and Ribaudo, p. 294). The results of the present analysis suggest that these benefit estimates may be over stated because the slippage effects were not incorporated into the estimation. For the twelve states in the central United States, ignoring slippage effects would result in an overestimation of acreage control benefits by 20% and an overestimation of water and wind erosion related benefits by 9% and 14%. The overestimation of other environmental benefits may be even larger if the converted cropland, prior to conversion, provides the same or higher level of these benefits per acre than the CRP land.

The results of this analysis have implications for the design and implementation of land retirement programs. The substantial slippage effect identified in this analysis suggests that it should be considered in the targeting of conservation efforts. Currently, the CRP targets only cultivated cropland. Non-cropland is ineligible for the CRP. Relaxing program rules to allow targeting of non-cropland that offers large environmental benefits but would otherwise be converted into crop production would reduce the slippage effects and improve the environmental performance of conservation programs (Wu, Zilberman and Babcock). Although enrolling non-cropland would not provide any supply control benefit, it would be consistent with the objective of maximizing environmental benefits per dollar expended, as specified for the Environmental Quality Incentives Program (EQIP) and other conservation programs.

A good part of the rationale for land retirement as a national policy since the 1930s is that it achieves both conservation/environmental objectives and supply control/farm income support objectives. But if conversions of non-cropland to cropland as a result of land retirement are not recognized and prevented, the effect of land retirement on supply control is reduced, and the objective of maintaining commodity prices, farm income and asset values would also be compromised. Thus, reducing slippage effects not only improves the environmental performance of a land retirement program, it increases supply control although supply control has not been universally agreed upon to be beneficial from a societal standpoint.

The advent of the 1985 Food Security Act signaled a significant change in the USDA's agricultural and environmental policy (Johnson, Wolcott, and Aradhyula). The sodbuster and swampbuster provisions were included in this and all subsequent farm bills to restrict conversion of wetland and highly erodible land. The incarnation of the CRP in the farm bill represents a significant improvement over previous land retirement programs by limiting enrollment to highly erodible land. The evidence presented in this article, however, suggests that both the environmental and supply control benefits of the CRP could be increased if the slippage effects were explicitly recognized and controlled. We recognize the conceptual and practical limitations on accounting for the secondary effect of land retirement and the considerable difficulties imposed by budget constraints and institutional strictures. However, we are optimistic that the environmental and economic performance of conservation programs will continue to improve with the increasing availability of data and economic analysis and the growing public demand for more accountable government policies.

This cross-sectional analysis is more likely to uncover the substitution effects causing slippage than the price effects and thus may underestimate the slippage effects. An important extension of this study is to determine the magnitude of the price-related slippage. If substitution effects are the main cause, then focusing on participating farmers should be sufficient to prevent the slippage effect. On the other hand, if output price increases are the main cause of the slippage effect, focusing on participating farmers alone will not solve the slippage problem. Because crop prices are determined in national and international markets, the CRP would affect crop prices by similar propositions across the study region. Thus, time-series data on CRP participation and land use changes are needed to identify the price-related slippage. Finally, this study addresses only one issue associated with the optimal design of conservation programs. Many other issues have been identified in the literature, including the choice of targeting criteria, the importance of offsite benefits, problems of asymmetric information, interrelations between alternative environmental benefits, and cumulative effects. Optimal design of conservation programs must consider these issues as well. In addition, U.S. conservation policy is at a crossroads between more coercive regulatory policies, more costly voluntary programs, and more facilitative market-oriented policies (Heimlich and Claassen). More research is needed to identify the pitfalls, advantages, and tradeoffs along these different paths.

Appendix: Derivation of Equation (5)

Let $f_1(y)$ and $f_2(b)$ denote the marginal density functions of y and b. Under the assumption that (y, b) follows the bivariate normal distribution $N(\mu_y, \mu_b, \sigma_y, \sigma_b, \rho)$,

$$f_1(y) = \frac{1}{\sigma_y}\varphi\left(\frac{y-\mu_y}{\sigma_y}\right),$$
$$f_2(b) = \frac{1}{\sigma_b}\varphi\left(\frac{b-\mu_b}{\sigma_b}\right),$$

where $\varphi(\cdot)$ is the probability density function of the standard normal distribution. Similarly, the cumulative distribution function of y and b are

$$F_1(y) \equiv \Phi\left(\frac{y-\mu_y}{\sigma_y}\right),$$
$$F_2(b) \equiv \Phi\left(\frac{b-\mu_b}{\sigma_b}\right),$$

where $\Phi(\cdot)$ is the cumulative distribution function of the standard normal distribution.

The changes in total acreage of cropland, environmental benefits and total output equal

$$\text{(A1)} \quad \begin{aligned}\Delta A &= \int_{c/p_0}^{y^*}\int_{-\infty}^{+\infty} s(y,b)\,dydb - \int_{c/p_1}^{c/p_0}\int_{-\infty}^{+\infty} s(y,b)\,dydb \\ &= \int_{c/p_0}^{y^*} f_1(y)dy - \int_{c/p_1}^{c/p_0} f_2(y)dy \\ &= [F_1(y^*) - F_1(c/p_0)] - [F_1(c/p_0) - F_1(c/p_1)] \\ &= [F_1(y^*) + F_1(c/p_1) - 2F_1(c/p_0)],\end{aligned}$$

$$\text{(A2)} \quad \begin{aligned}\Delta B &= \int_{c/p_0}^{y^*}\int_{-\infty}^{+\infty} bs(y,b)\,dydb - \int_{c/p_1}^{c/p_0}\int_{-\infty}^{+\infty} bs(y,b)\,dydb \\ &= \int_{c/p_0}^{y^*} f_1(y)\int_{-\infty}^{+\infty} b\frac{s(y,b)}{f_1(y)}dydb - \int_{c/p_1}^{c/p_0} f_1(y)\int_{-\infty}^{+\infty} b\frac{s(y,b)}{f_1(y)}dydb \\ &= \int_{c/p_0}^{y^*} f_1(y)\left[\mu_b + \rho\left(\frac{\sigma_b}{\sigma_y}\right)\times(y-\mu_y)\right]dy - \int_{c/p_1}^{c/p_0} f_1(y)\left[\mu_b + \rho\left(\frac{\sigma_b}{\sigma_y}\right)\times(y-\mu_y)\right]dy \\ &= \{\mu_b[F_1(y^*) - F_1(c/p_0)] - \rho\sigma_b[f_1(y^*) - f_1(c/p_0)]\} \\ &\quad - \{\mu_b[F_1(c/p_0) - F_1(c/p_1)] - \rho\sigma_b[f_1(c/p_0) - f_1(c/p_1)]\} \\ &= \mu_b\Delta A - \rho\sigma_b[f_1(y^*) + f_1(c/p_1) - 2f_1(c/p_0)],\end{aligned}$$

$$\text{(A3)} \quad \begin{aligned}\Delta Y &= \int_{c/p_1}^{c/p_0}\int_{-\infty}^{+\infty} ys(y,b)\,dydb - \int_{c/p_0}^{y^*}\int_{-\infty}^{+\infty} ys(y,b)\,dydb \\ &= \int_{c/p_1}^{c/p_0} yf_1(y)dy - \int_{c/p_0}^{y^*} yf_1(y)dy \\ &= \{\mu_y[F_1(c/p_0) - F_1(c/p_1)] - \sigma_y[f_1(c/p_0) - f_1(c/p_1)]\} \\ &\quad - \{\mu_y[F_1(y^*) - F_1(c/p_0)] - \sigma_y[f_1(y^*) - f_1(c/p_0)]\} \\ &= -\mu_y\Delta A + \sigma_y[f_1(y^*) + f_1(c/p_1) - 2f_1(c/p_0)].\end{aligned}$$

Multiplying (A2) by σ_y and (A3) by $\rho\sigma_b$ and then adding them together gives equation (5).

[Received July 1999; accepted April 2000.]

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