LAND CONVERSION AND THE CONSERVATION RESERVE PROGRAM (CRP) IN NORTH CAROLINA

by

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Introduction

Agriculture is a multi-billion dollar business in North Carolina. According to the 2002 Agricultural Census, about 9 million acres of North Carolina are classified as “farmland,” comprising 29 percent of the state. Crops are planted and harvested on 4.3 million acres, or 14 percent of the state. North Carolina ranks 8th in the country for total agricultural receipts; in 2005, harvested crops earned $5.6 billion and farmers received an additional $1.2 billion in government payments.[1]

Of the total farmland in North Carolina, however, less than 2 percent (180,000 acres) was enrolled in the Conservation Reserve Program (CRP) in 2002.[2] CRP is a federal land-retirement program that provides annual payments and cost-share assistance to farmers who agree to provide long-term, resource conserving practices on eligible farmland.[3] As such, farmers receive a guaranteed stream of payments from the federal government, and the retired land provides environmental benefits that include decreased soil erosion, increased wildlife habitat, improved water quality, and recreational activities.[4] The Environmental Benefits Index (EBI)—which accounts for wildlife habitat benefits, air and water quality benefits from decreased erosion, long-term environmental benefits, and cost—determines the per-acre CRP contract for a given parcel.[5] Since CRP’s inception in the 1985 Farm Bill, the program has retired 36.7 million acres nationwide, or approximately 8% of U.S. cropland.[6] In 2005 alone, CRP provided landowners and operators $1.6 billion in rental payments.[7] In North Carolina, however, CRP comprised only 8% of total government payments in 2002, down from nearly 13% in 1997.[8]

1 North Carolina Department of Agriculture & Consumer Services, 2006.
2 USDA, 2006.
3 U.S. Farm Service Agency, 2006.
4 Feather, Hellerstein, & Hansen, 1999.
5 U.S. Farm Service Agency, 2006.
6 USDA, 2006; Lubowski & Roberts, 2003.
7 U.S. Farm Service Agency, 2007.
8 USDA, 2002; USDA, 1997.

This paper will explore the economic factors that influence a rural landowner's decision to either continue planting crops or to enroll land in CRP. Specifically, I will estimate the extent to which federal commodity subsidies encourage North Carolina farmers to continue producing crops on agricultural land that may otherwise convert to CRP. I will also devise hypothetical policy scenarios related to conservation and commodity government payments in the 2007 Farm Bill to predict land use conversion.

My hypotheses are:

1) Commodity subsidies promote inefficiency by encouraging farmers to till unproductive land that would otherwise convert to other uses such as CRP;
2) If the 2007 Farm Bill reduced commodity payments and/or expanded the CRP program, the amount of CRP-enrolled land would increase.

Methods

This section will describe the methods I employed in this study. I will discuss the theoretical model on which the study is based, data collection and methodology, the econometric model I devised for empirical analysis, and a hypothetical policy scenario based on the empirical results.

Theoretical Model

Land use decisions can be thought of as part of a dynamic optimization problem in which a landowner chooses land use *j* at time *t* that maximizes the present discounted value of the stream of expected net benefits. Lubowski (2002) models the situation as follows:

$$\max_{a_{jkt}} \int_{t=0}^{\infty} \left\{ \sum_{j=1}^{J} E_t\left[R_{jt}\right] s_{jt} - \sum_{j=1}^{J} \sum_{k=1}^{K} E_t\left[C_{jkt}\left(a_{jkt}\right)\right] \right\} e^{-rt} dt \qquad (1)$$

Subject to:

$$\overset{\bullet}{S}_{jt} = \sum_{k=1}^{K}\left(a_{kjt} - a_{jkt}\right) \qquad (2)$$

$$\sum_{k=1}^{K} a_{jkt} \leq S_{jt} \qquad (3)$$

$$a_{jkt} \geq 0 \qquad (4)$$

where:

$J = K$ = number of different land uses $(j=1,..., J)$, $(k=1,..., K)$;

S_{jt} = stock of land on the parcel in use j at time t $(t=0,...,\quad)$, as noted above;

a_{jkt} = number of acres converted from use j to k at time t;

R_{jt} = the instantaneous net benefits from an acre of land in use j at time t;

$C_{jkt}(a)$ = total costs of converting a acres of land from use j to use k at time t;

r = discount rate $(r>0)$.[9]

If $\mu_j(t)$ represents the shadow price for land use j=1,…,J, then the Hamiltonian equation to solve this dynamic optimization problem is described as follows:

$$\tilde{H} = \sum_{j=1}^{J} R_{jt}S_{jt} - \sum_{j=1}^{J}\sum_{k=1}^{K} a_{jk}(t)C_{jk}(t) + \sum_{j=1}^{J} \mu_j(t)\left\{\sum_{k=1}^{K}\left[a_{kj}(t) - a_{jk}(t)\right]\right\} \qquad (5)$$

The necessary first-order conditions for an optimum are:[10]

$$-\frac{\partial \tilde{H}}{\partial S_{jt}} = \overset{\bullet}{\mu} - r\mu_{jt} = -R_{jt}$$

[9] Lubowski, 2002.
[10] *ibid*.

$$\frac{\partial \tilde{H}}{\partial a_{jkt}} = -C'_{jkt}(a_{jkt}) + \mu_{kt} - \mu_{jt} \leq 0 \qquad (6)$$

$$a_{jkt} \frac{\partial \tilde{H}}{\partial a_{jkt}} = a_{jkt}\left[C'_{jkt}(a_{jkt}) + \mu_{kt} - \mu_{jt}\right] = 0 \qquad (7)$$

where:

μ_{jt} = expected return from use *j* at time *t*;

μ_{kt} = expected return from use *k* at time *t*;

These conditions imply that if marginal conversion costs (C'_{jkt}) are constant or decreasing, the following "bang-bang" solutions will be optimal:

$$a_{jkt} = \begin{Bmatrix} 0 \\ a^{*}_{jkt} \\ a^{\max}_{jkt} \end{Bmatrix} whenever \frac{\partial \tilde{H}}{\partial a_{jkt}} = -C'_{jkt}(a_{jkt}) + \mu_{kt} - \mu_{jt} \begin{Bmatrix} < \\ = \\ > \end{Bmatrix} 0 \qquad (8)$$

Rearranging Equation 8, the condition for conversion from use *j* to *k* becomes

$$\mu_{kt} - C'_{jkt}(a_{jkt}) > \mu_{jt} \qquad (9)$$

Through the preceding dynamic optimization solution, Lubowski shows that the optimal policy is to convert all land in use *j* to use *k* when the shadow value of land for use *k*, less the cost of conversion, exceeds the shadow value of land in use *j*. In the steady-state condition (defined as $\dot{\mu}_{jt} = 0$),

$$\mu_{jt} = \frac{R_{jt}}{r} \qquad (10)$$

Equation 10 states that in the steady-state, the total return from use *j* at time *t* is equal to the present discounted infinite stream of expected net returns R_{jt} from use *j*. Rearranging once again, Lubowski shows that conversion from use *j* to use *k* is optimal if and only if the present discounted value of the infinite stream of expected net returns from use *k*, minus conversion costs, exceeds the present discounted value of the infinite stream of expected net returns from use *j*. In mathematical terms:

$$\frac{R_{kt}}{r} - C'_{jkt}\left(a_{jkt}\right) > \frac{R_{jt}}{r} \qquad (11)$$

With respect to agriculture, the expected net benefits, or land rents, are functions of the costs and revenues of planting and harvesting a particular crop, as well as any government payment a farmer may receive. Farmers have the option to continue planting the same crop, switch to a different crop, enroll the land in CRP, or switch to another land use such as forest, pasture, or urban. Generally, urban land rents far exceed any other land use; if a farmed plot of land that borders an urban area is no longer profitable as agricultural land, it will almost certainly switch to urban use. In some areas, however, it is likely that government commodity payments bolster agricultural rents enough to prevent land use changes that would otherwise occur in an open market.

It should be noted that Lubowski's model is overly simplistic because it does not take into account behavioral tendencies that can prevent a farmer from switching to another land use despite the fact that doing so would increase land rents. For example, a farmer might be hesitant to switch to another crop if he lacks experience raising the crop. Additionally, some farmers view CRP negatively because it removes farmland from production. One Montana farmer described the problem as such: "[CRP] takes away all the opportunity for young farmers to get a start in the community…it's killing local communities [by] taking everything out of production while the people are retiring and going to town."[11] Schatzki (2003) discusses the implications of variable uncertainty; in the face of uncertain expectations of net benefits, landowners will be less likely to convert land to

[11] Abbott, 2006.

other uses.[12] In addition, Lubowski's model does not take into account the so-called "option" value of delaying a conversion decision; Schatzki finds that land use conversions are less likely when option values are considered.[13] For the purposes of this analysis, however, I will ignore the uncertainty and option value aspects of the dynamic optimization problem and focus only on expected net benefits that arise from land rents for various crops in North Carolina counties. This assumption may tend to inflate the optimal amount of land conversion predicted in the model.

The remainder of this paper will explore the extent to which commodity subsidies shift the profitability margin and consequently prevent marginally-productive agricultural land from switching to other uses, namely CRP.

Data

Using 1991-2003 data, I constructed a database comprised of the following: county-level crop production estimates for North Carolina crops; average county-level cost data for each crop; county-level average yearly prices for each crop; county-level direct federal government payments estimates for 1992, 1997, and 2002; and county-level CRP payment and enrollment data. With this database, I estimate agricultural land rents—both with and without government aid—for ten major crops in each North Carolina county.

Other studies that have used county-level data to model agricultural land use have demonstrated the importance of accounting for heterogeneous factors such as land quality and nearby urban development.[14] I will measure a county's suitability for agriculture by using Land Capability Class (LCC) data from the Natural Resources Conservation Service's Soil Survey Geographic (SSURGO) database. "The LCC system is based on a ranking of twelve different soil

[12] Schatzki, 2003.
[13] *ibid*.
[14] See Lubowski, 2002; Lubowski, Plantinga, and Stavins, 2003; Stavins & Jaffe, 1990; Bernard et. al, 1997.

characteristics that are critical for crop production. The overall LCC score consists of the lowest ranking given to any of these twelve soil features based on the principle that this factor will be limiting for crop production."[15] Additionally, I will measure urban pressure on agricultural land using Population-Interaction Zones for Agriculture (PIZA) ratings developed by USDA's Economic Research Service (ERS). PIZA classifications represent areas of agricultural land use in which urban-related activities (residential, commercial, and industrial) affect the economic and social environment of agriculture. In these zones, interactions between urban-related population and farm production activities tend to increase the value of farmland, change the production practices and enterprises of farm operators, and elevate the probability that farmland will be converted to urban-related uses.[16]

For more detailed information regarding data collection, see Appendix A.

Econometric Model

Using the panel data described above, I will estimate agricultural land use patterns using the following fixed-effects model:

$$\begin{aligned}\log CRP_t &= \beta_0 + \beta_1(\log ACRES_{ag})_{t-1,t-6} + \beta_2(RENT_{ag})_{t-1,t-6} \\ &+ \beta_3(\log ACRES_{crp})_{t-1,t-6} + \beta_4(\log RENT_{crp})_{t-1,t-6} \\ &+ \beta_5(\log GOVPAY)_{t-1,t-6} + \beta_6(LCC) + \beta_7(PIZA\_LOW) \\ &+ \beta_8(PIZA\_HIGH) + K_c + \varepsilon_{ct}\end{aligned} \qquad (12)$$

where:

$\log CRP_t$ = natural log of CRP acreage in a given year;

$\log ACRES_{ag}$ = natural log of mean acres in agricultural production over previous five years;

$RENT_{ag}$ = mean land rent for agricultural land over previous five years;

15 USDA, 1973.
16 USDA ERS, 2005.

log $ACRES_{crp}$ = natural log of mean acres enrolled in CRP over previous five years;

log $RENT_{crp}$ = natural log of mean rent for land enrolled in CRP over previous five years;

log $GOVPAY_{year}$ = natural log of direct government payments (other than CRP payments) per acre;[17]

LCC = dummy variable representing the weighted average Land Capability Class rating for a county's soil;[18]

PIZA_LOW = indicator variable representing the rural portion of a county with zero or low urban-related population interaction;

PIZA_HIGH = indicator variable representing the portion of a county with moderate, high, or very high urban-related population interaction;[19]

K_c = county-level fixed-effects dummy variable.

The regression model outlined above will estimate the change in the number of acres enrolled in CRP using prior CRP enrollment, crop acreages, free-market agricultural rents, government commodity payments, urban influence, and soil quality as explanatory variables. I employ a five-year "lagged" model to represent the assumption that farmers' decisions on crop production and CRP enrollment in a given year are based on returns over the previous five years. To adjust for inflation, I converted price, cost, and government payment data to 2003 dollars using USDA's Prices Paid and Received Indexes and the Bureau of Labor Statistics' Consumer Price Index Inflation Calculator. The model assumes that all social, economic, and other differences between individual counties that are not included in the model are *constant over time*; as long as this assumption holds, the fixed-effects variable for each county will control for differences between counties.

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17 Direct government payments include federal farm programs (except CRP and the Wetlands Reserve Program) and commodity credit corporation loans. Government payment data are only available for census years (1992, 1997, and 2002); data for all other years is linearly interpolated from census year data.

18 Counties with average LCC ratings less than 4 (good soil) are coded as 0; counties with average LCC ratings greater than 4 (bad soil) are coded as 1. The LCC dummy variable is interacted with a time trend to avoid absorption by the fixed effect variable.

19 Both PIZA_LOW and PIZA_HIGH are interacted with a time trend to avoid absorption by the fixed effect variable.

Past studies have also used econometrics to analyze agricultural land use change. Lubowski, Plantinga, and Stavins (2003) find a significant positive relationship between government commodity payments and total crop acreage on a national scale. This relationship, however, is of smaller magnitude than the effect of changes in crop rental rates on total crop acreage. In a similar study, Lubowski and Roberts (2003) determine that the probability of CRP-enrolled land returning to cropland depends critically on the profitability of crop production. Claassen and Tegene (1999) establish that land conversion depends on relative returns, land quality, and government polices such as CRP and government commodity payments. Their results also support Schatzki's theory that land can become "fixed" in a given use due to conversion costs and option values; this rigidity is more pronounced for cropped land than for land enrolled in CRP. Similarly, Stavins and Jaffe (1990) find that while landowners respond to economic incentives in their land-use decisions, their adjustments are relatively gradual. Only 38 percent of agricultural land which "should" have been abandoned or converted to other uses was actually abandoned or converted after five years. Bernard *et al* (1997) measure the extent to which non-conservation government payments are capitalized into cropland values. They find that in eastern North Carolina, 20-40 percent of agricultural land values are attributed to government commodity payments rather than crop markets.

Policy Scenario

Finally, I will examine a hypothetical shift in federal agricultural policy. Specifically, I will simulate a scenario in which the portion of federal agricultural payments awarded in the form of commodity subsides is halved and the portion awarded for conservation efforts is doubled. This scenario is particularly relevant given the scheduled passage of the 2007 Farm Bill. According to Environmental Defense, legislators from both political parties are considering commodity payment cuts in the 2007 Farm Bill due to budget necessities and anti-subsidy lobbying pressure from groups on both sides of the political divide.[20] I will use the beta coefficients from the econometric model to predict the future change in CRP enrollment in selected counties that would result if the Farm Bill increased per-acre CRP payments and decreased per-acre commodity payments. This analysis is limited due to a lack of more recent data, and by the fact that changes in CRP enrollment may not occur in the year immediately following the policy scenario. Nevertheless, it can give an indication of the extent to which CRP enrollment across North Carolina would change should the federal government adopt a more conservation-minded approach to government payments in the 2007 Farm Bill.

Results

Table 1 displays the results of the regression model from Equation 12. As expected, urban population pressure and soil quality are significantly correlated with CRP enrollment. Low levels of urban-related population interaction (PIZA_LOW) are coupled with increased CRP enrollment, while increased population pressure (PIZA_HIGH) indicates decreased CRP enrollment.[21] Counties with poor soil quality (LCC_dummy = 1) have less CRP acreage than counties with good soil quality. Contrary to my original hypothesis, however, the results do not indicate that government payments over the preceding five years are statistically correlated with CRP enrollment. Similarly, agricultural rents and CRP rents are also statistically insignificant. Table 1 also shows that the acreage variables (log CRP acres and log Ag acres) have the largest coefficients and are thus the most important components of CRP enrollment in a given year. The intercept term, within which the county-level fixed-effect variables are embedded, is also statistically significant. The rho statistic

[20] McNaught, 2007.
[21] Recall that PIZA_LOW and PIZA_HIGH are inversely related; if 70% of a county is classified in the PIZA_LOW category, then 30% is classified in the PIZA_HIGH category.

indicates that of the 67 percent of the variance in log CRP acres that is explained by Equation 12, 58% is due to the fixed-effect variables.

Table 1: Coefficients for fixed-effect regression using log CRP acres as dependent variable (see Equation 12)

Variable	Coeff.	Std. Error	t	P>|t|	{95% Conf. Interval}	
Ag. rental rate[1]	-0.00001	0.00018	-0.04	0.972	-0.00035	0.00034
Log Ag.acres[1]***	-0.53783	0.17349	-3.1	0.002	-0.87829	-0.19738
Log CRP rent[1]	-0.06739	0.07200	-0.94	0.350	-0.20869	0.07391
Log CRP acres[1]***	0.84496	0.06514	12.97	0.000	0.71712	0.97279
Log Gov.payments[1]	-0.02157	0.08308	-0.26	0.795	-0.18460	0.14146
LCC dummy**	-0.06727	0.03030	-2.22	0.027	-0.12672	-0.00782
PIZA_LOW dummy***	0.00062	0.00023	2.62	0.009	0.00015	0.00108
PIZA_HIGH dummy***	-0.00144	0.00027	-5.24	0.000	-0.00197	-0.00090
Intercept***	5.30327	1.55330	3.41	0.001	2.25516	8.35138

[1] variable created using 5-year lagged mean
R-squared = 0.674
rho = 0.575 (rho represents the fraction of variance explained by the fixed-effect variables)
**Significant at 5% level
***Significant at 1% level

I examined five other models in addition to Equation 12 (hereafter Model *I*). Model *II* is identical to Equation 12 in form, but I used the Economic Research Service's "Total Cost" estimates, which include all fixed and variable costs and are more all-inclusive than the Lubowski method's cost calculation, to determine agricultural rents. Model *III* is similar to Model *I* but omits CRP acreage as an independent variable; Model *IV* includes CRP acreage but omits CRP rents; Model *V* includes CRP acreage and rents, but excludes government payment data; and Model *VI* is a "parsimonious" model that includes only the historical acreage variables as determinants of current CRP acreage.

Table 2 presents the results of these five alternative models, as well as the original coefficients from Table 1. The results for Models *II-VI* generally mirror those for Model *I.* The soil quality and population-interaction variables are highly significant in each model in which they are included, although the coefficients' relative size suggests that they contribute only marginally to CRP acreage. The agricultural acreage and CRP acreage variables are always highly significant when included in the model, while agricultural rents and government payments are never statistically significant. Although CRP payments are not significant in Model *I*, they are significant at the 1 percent level when historical CRP *acreage* is omitted (Model *III*). However, the R^2 statistic for Model *III* suggests that the explanatory variables account for only 7 percent of the variance in CRP acreage. The other five models, all of which include historical CRP acreage, have R^2 values 10 times larger than Model *III*.

Table 2: Coefficients for alternate fixed-effect models (log CRP acres = dependent variable)

Coefficient (std error)	Model					
	original I	Alt. cost measure[2] II	Omit CRP acres III	Omit CRP rent IV	Omit gov't payments V	Parsimonious VI
Ag. rental rate[1]	-0.00001 (.00178)	0.00011 (.00013)	0.00011 (.00019)	5.07e-07 (.00018)	-0.00001 (.00018)	-
Log Ag.acres[1]	**-0.53783***** **(.17350)**	**-0.52841***** **(.17193)**	**-0.94288***** **(.18456)**	**-0.55010***** **(.17298)**	**-0.44394***** **(.15081)**	**-0.45209***** **(.14683)**
Log CRP rent[1]	-0.06739 (.07200)	-0.07013 (.07200)	**0.35850***** **(.06930)**	-	-0.07984 (.07075)	-
Log CRP acres[1]	**0.84496***** **(.06514)**	**0.84041***** **(.06525)**	-	**0.81716***** **(.05797)**	**0.83894***** **(.06383)**	**0.84029***** **(.05599)**
Log Gov.payments[1]	-0.02157 (.08308)	-0.01595 (.08321)	-0.02937 (.03277)	-0.01895 (.08302)	-	-
LCC dummy	**-0.06727**** **(.03030)**	**-0.07220**** **(.03035)**	**-0.06706**** **(.03277)**	**-0.06740**** **(.03030)**	**-0.05948**** **(.02959)**	-
PIZA_LOW dummy	**'0.00062***** **(.00023)**	**0.00727***** **(.00027)**	**0.00148***** **(.00024)**	**0.00067***** **(.00023)**	**0.00056**** **(.00022)**	-
PIZA_HIGH dummy	**-0.00144***** **(.00027)**	**-0.00140***** **(.00028)**	**-0.00134***** **(.00030)**	**-0.00138***** **(.00027)**	**-0.00147***** **(.00026)**	-
Intercept	**5.30327***** **(1.55328)**	**5.24622***** **(1.51075)**	**11.16933***** **(1.60707)**	**5.28834***** **(1.55310)**	**4.54672***** **(1.29940)**	**4.15815***** **(1.23248)**
R-squared (rho)	0.674 (0.575)	0.677 (0.572)	0.068 (0.878)	0.664 (0.584)	0.708 (0.544)	0.701 (0.522)

[1] Variable created using 5-year lagged mean

[2] Model II uses the Economic Research Service's "Total Cost" estimates to calculate agricultural rents. These estimates are higher than the Lubowski Method estimates and therefore result in lower agricultural rents estimates.

**Significant at 5% level

***Significant at 1% level

Discussion

<u>Urbanization (PIZA) variables</u>

The urban influence variables (PIZA_HIGH and PIZA_LOW) are statistically significant in all model variations in which they are included. However, they influence CRP enrollment in opposite ways. Model *I* indicates that if a county experiences a 10 percent increase in moderate/high urban influence, CRP enrollment will *decrease* by 1.4 percent; a 10 percent increase in land classified as having zero/low urban influence leads to a 0.6 percent *increase* in CRP enrollment.[22] These results are not surprising; urban rents tend to be far higher than rents from any other land use type, so counties with more urban influence should tend to have fewer acres available for agricultural purposes (e.g., cropped land or CRP land). By the same token, counties with low or zero urban pressure will tend to have more land available for agriculture and CRP. Although both variables are significant, the coefficients are quite small and I therefore conclude that urban influence contributes only marginally to CRP enrollment.

<u>Soil quality (LCC) variable</u>

Soil quality, as measured by a county's weighted average Land Capability Class rating, has a significant negative effect on CRP enrollment in all model variations. After inverting the log function from Model *I*, I conclude that counties with poor soil quality have 7 percent fewer acres enrolled in CRP than counties with good soil quality. This result is somewhat counterintuitive. It is more difficult to grow crops on land with poor soil quality, so farmers should tend to convert these marginally-productive lands to other uses (such as CRP).

[22] Since the dependent variable (CRP acres) is log-transformed, it is first necessary to back-transform the PIZA coefficients using the inverse-log function: for PIZA_LOW, exp(10*-0.00062) = 1.0062; for PIZA_HIGH, exp(10*-0.00144 = 0.986 (refer to Ramsey & Schafer [2002] for more information). Note that, due to the inverse relationship of PIZA_HIGH and PIZA_LOW, the effects on CRP enrollment would occur in tandem (i.e., a 10% increase in PIZA_LOW necessitates a subsequent 10% decrease in PIZA_HIGH, both of which significantly affect CRP acreage).

The reason for this surprising result is likely due to data limitations. The SSURGO database from which the original LCC ratings originate contains approximately 30-100 sample areas per county. In most cases, SSURGO also lists the acreage for each sample area, which facilitated constructing a weighted average for each county. However, due to the lack of spatial data for North Carolina, I was unable to determine the prevailing land use for each sample area.[23] It is entirely possible that large sample areas with high LCC scores (and therefore poor soil quality) are located in non-agricultural areas. In fact, one would *expect* non-agricultural areas to have poorer soil quality if the land were efficiently used. However, a county's LCC score should ideally include only agriculture or forest land since these are the most plausible land uses that would convert to CRP. When urban land is also included, county-level LCC scores are likely inflated by large non-agricultural sample areas with poor soil quality.

With a score of 2.52, Granville County has the lowest LCC average—and consequently the best soil quality—in North Carolina. However, according to NRCS soil definitions, an LCC score of 2.5 indicates moderate to severe soil limitations that reduce plant choice and require conservation practices for effective tillage.[24] Of the 100 North Carolina counties, 43 have average LCC scores above 4.0, which the NRCS defines as having severe limitations that are impractical to remove and that prevent farmers from growing crops of any kind.[25] However, in 2002 alone, crops were planted and harvested on 170,000 acres of land in these 43 counties. Based on this discrepancy, I believe using a weighted average comprised of plot-level LCC scores to construct one LCC rating for an entire county is fundamentally flawed. Future studies should attempt to account for soil quality using LCC data from sample plots *devoted only to agricultural uses* to construct a more valid estimate of county-wide LCC scores.

[23] Spatially-related SSURGO data is available for parts of North Carolina, but not the entire state (Duvall, 2006).
[24] NRCS, 1997.
[25] *ibid*.

Crop and CRP acreage

Both acreage variables are significant in all model variations, and their large coefficients indicate that they have a strong relationship with CRP enrollment. The results from Model *I* suggest that doubling a county's historical agricultural acreage would decrease CRP enrollment by 31 percent, while doubling the historical CRP enrollment would increase CRP enrollment in the current year by 80 percent.[26] Both results are intuitive; if a large amount of agricultural land in a county has historically been devoted to planting crops, then one would expect less land to be enrolled in CRP. By the same token, if a county has a large amount of land enrolled in CRP over the previous five years, then these prior enrollments will largely determine the amount of land that is *currently* enrolled. The overwhelming dominance of the CRP acreage variable relative to all other explanatory variables reflects the long-term nature of CRP contracts. That is, land that has been enrolled in CRP over the preceding five years is highly likely to still remain in CRP in the current year.

Agricultural rents

Agricultural rents—which are determined by the amount of crop produced, the average selling price, and the cost of planting and harvest the crop—were insignificant in all model variations. Model *II* indicates that the lack of relationship between historical agricultural rents and current CRP enrollment is not sensitive to a particular cost calculation methodology (for a description of cost calculation methodologies, see Appendix A). Although the coefficient's sign is inconsistent (negative in Models *I* and *V*, positive in Models *II*, *III*, and *IV*), it is very close to zero in all models and clearly plays no role in determining CRP enrollment. One would expect agricultural rents to have a significant negative relationship with CRP enrollment. Farmers who earn

[26] Recall from Equation 12 that the acreage variables are based on five-year lagged averages. Thus, the model predicts CRP enrollment in a given year based on CRP and agricultural acreages from the preceding five years.

high rents from planting and harvesting crops will likely continue to actively farm the land, while land that does not produce high rents is more likely to convert to CRP.

One explanation for the lack of a negative relationship between agricultural rent and CRP enrollment concerns the way in which I calculated rents. As described in Appendix A, ERS separates the United States into cropping regions and estimates the cost of growing a given crop in a given region. According to agricultural economists at North Carolina State University, however, production costs can vary greatly from county to county due to issues such as transportation, soil type, and rainfall.[27] Farming skill can also affect the cost of production at the sub-county level.[28] As a result, the accuracy of ERS regional cost estimates is uncertain.

Additionally, I calculated gross agricultural revenue by multiplying the amount of each crop grown in a county by the crop's average yearly selling price in that county. This method assumes that all harvested crops are sold on the market. However, many North Carolina farms harvest crops for the purpose of feeding livestock or hogs. North Carolina ranks 2nd in the country in hog production and 6th in livestock production, and many farms grow crops primarily to feed their animals.[29] The methodology I employed in this study will deflate agricultural rents by incorrectly assuming that these farms are earning negative profits. One can observe this problem in the database itself; approximately one-fifth of agricultural rent observations have negative values, indicating that farmers are losing money by harvesting crops. Future studies should attempt to account for livestock and hog operations by, at the very least, including a variable that indicates hog and livestock prevalence in each county.

Finally, agricultural rents might be insignificant indicators of CRP enrollment because farmers may not view CRP as a profit-maximizing alternative to harvesting crops. In areas with high

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27 Piggott & Brandt, 2005.
28 *ibid.*
29 North Carolina Department of Agriculture & Consumer Services, 2005.

CRP enrollment, some landowners rely on CRP for retirement income or simply don't want to bother with farming the land or renting it to a farmer.[30] The decision to enroll land in CRP, therefore, may have more to do with behavioral tendencies (e.g., not wanting to farm, opting for a guaranteed source of income, etc) than with profit maximization.

<u>CRP rents</u>

CRP rents were surprisingly insignificant in all model variations except the model in which CRP acreage is omitted (see Table 2). Furthermore, the coefficients are negative for most variations (including Model *I*) which would suggest that higher per-acre CRP payments lead to *lower* CRP enrollments. This conclusion draws into question the model's theoretical basis. Increasing CRP payments is an obvious way to encourage farmers to enroll more land in the program, yet the model predicts that higher per-acre payments have the opposite effect.

A closer examination of the data and model results reveals the reason for this counterintuitive result. In Model *III*—which omits historical CRP enrollment as an explanatory variable—historical CRP rents are highly significant and positively correlated with CRP acreage, while in all other model variations the opposite is true. Data diagnostics reveal that historical CRP acreage and historical CRP rents are highly collinear (r = 0.8). The effect of historical CRP rents on current CRP enrollment is masked by the effect of historical CRP enrollment on current CRP enrollment. When historical CRP enrollment is omitted (as in Model *IV*), historical CRP rents influence current CRP enrollment as expected. A doubling of historical CRP rents corresponds to an increase in median CRP enrollment of 28 percent. However, Model *IV* explains less than 7 percent of the variance in CRP enrollment, indicating that it would be more appropriate to omit historical CRP rents than historical CRP acreage in a regression model.

[30] Abbott, 2006.

Government payments

In all model variations, no significant relationship exists between non-conservation government payments and CRP enrollment. As expected, the coefficient is consistently negative, but without statistical significance I must conclude that commodity subsidies do not affect CRP enrollment at the county level. However, this result may stem from insufficient data. As described in Appendix A, I obtained government payments estimates from the U.S. Agricultural Censuses. These estimates, however, are prone to error. The census relies on farmers to accurately report federal payment information; in some cases, farmers may not distinguish federal conservation payments from state conservation payments. In counties with relatively few agricultural operations, the Census may not release data due to confidentiality concerns. As a result, the Census is a low-end estimate of the actual government payments that farmers from each county receive. Additionally, the USDA conducts the Agricultural Census every five years. I estimated subsidy payments for missing years using linear interpolation, further contributing to data uncertainty. While these concerns do not by themselves invalidate the regression results, they are nevertheless worth noting.

Policy scenario

Due to the insignificance of the CRP rent, agricultural rent, and government payment variables, any policy scenario that adjusts agricultural or CRP rents will have a statistically negligible effect on CRP enrollment. Model *I* predicts that the only factors that are significantly related to current CRP enrollment are past CRP enrollment and past agricultural acreage. However, it is quite possible that the lack of significance is due to collinearity concerns (as with CRP rents) and data limitations (as with government payments). Consequently, I have used the coefficients from Model *I*, irrespective of their significance, to simulate a scenario in which the 2007 Farm Bill doubles CRP payments and halves government commodity payments. The simulation results should illustrate the possible impacts of policy changes in the Farm Bill.

I ran the scenario for six counties that represent high, medium, and low levels of CRP enrollment and varying degrees of urban influence. The results are presented in Table 3. The policy shift has a small negative effect on CRP enrollment, which reflects the relative sizes of the coefficients (the CRP rent coefficient is three times larger than the government payments coefficient, so its negative effect dominates the positive effect that decreasing government payments has on CRP enrollment). Model *I* predicts that changing the structure of government agricultural payments to a more conservation-minded approach in the 2007 Farm Bill would make little difference in CRP enrollment in the subsequent year. However, the policy scenario estimates the change in CRP enrollment for only the year immediately following the policy shift. It is quite possible that CRP enrollment would be more sensitive to the policy shift if farmers have more time to adjust their behavior to the altered incentives.

Table 3: Model I predictions for CRP enrollment in 2004, with and without policy scenario

County	Actual 2003 acreage	2004 acreage (with policy shift)	2004 acreage (without policy shift)
Anson	9,946	9,067	9,360
Catawba	3,758	261	270
Cleveland	10,071	862	890
Davidson	3,466	426	439
Davie	694	402	415
Hertford	2,041	693	715

Policy shift involves doubling CRP payments and halving government commodity payments
Model *I* coefficients used to determine acreages. All coefficients used (regardless of statistical significance) to facilitate policy shift simulation.

The 2004 enrollment estimates in Table 3 are troubling because, with the exception of Anson County, they differ substantially from 2003 enrollment figures. Unless large quantities of CRP land dropped out of the program after 2003, Model *I* appears to underestimate 2004 CRP enrollment. Some of the error is explained by the use of insignificant variables from Model *I* to predict CRP enrollment. In Table 4, I present alternate estimates of CRP enrollment using only the significant coefficients from Model *I*.[31] The CRP enrollment estimates for 2004 are closer to the actual 2003 enrollment figures, but large variations still persist in Cleveland, Catawba, and Davidson Counties. These three counties are also dominated by moderate or high urban influence as measured by the PIZA_HIGH variable. Model *I* appears to estimate CRP enrollment more accurately for areas with little to no urban influence such as Anson County and Hertford County.

Table 4: Model I predictions for 2003 and 2004 CRP enrollment, using only significant coefficients

	Model *I* (Equation 12) using only significant coefficients			
County	**Pred. CRP (2003)**	**Actual CRP (2003)**	**|pred. - actual|**	**Pred. CRP (2004)**
Anson	12,531	9,946	2,585	13,293
Catawba	297	3,758	3,461	1,265
Cleveland	1,731	10,071	8,341	362
Davidson	556	3,466	2,910	582
Davie	137	694	557	563
Hertford	615	2,041	1,425	1,115
Predictions are based on Model *I* coefficients for historical CRP enrollment, historical agricultural acreage, soil quality, urban influence, and the intercept term.				

Table 5: Model VI predictions for 2003 and 2004 CRP enrollment

	Model *VI* (Parsimonious)			
County	**Pred. CRP (2003)**	**Actual CRP (2003)**	**|pred. - actual|**	**Pred. CRP (2004)**
Anson	6,336	9,946	3,610	6,317
Catawba	1,446	3,758	2,312	4,648
Cleveland	5,706	10,071	4,366	2,038
Davidson	2,112	3,466	1,355	2,494
Davie	549	694	145	563
Hertford	311	2,041	1,729	530
Predictions are based on Model *VI* coefficients for historical CRP enrollment, historical agricultural acreage, and the intercept term.				

31 Recall that the CRP rent and government payment variables are statistically insignificant. Simulating the policy shift, therefore, has no effect on future CRP enrollment when only significant coefficients are included.

Finally, Table 5 presents CRP enrollment estimates based on the Model *VI* coefficients. Model *VI* is the most parsimonious model in that it uses only two explanatory variables (historical CRP acreage and historical agricultural acreage) to explain 70 percent of the variance in CRP enrollment in a given year. Although the 2003 predicted CRP enrollment figures are still prone to error when compared to the actual 2003 enrollment data, Model *VI* is more accurate than Model *I* in predicting enrollment for counties with higher levels of urban influence (e.g., Catawba, Cleveland, Davidson, and Davie Counties).

Conclusion

In this paper, I explored the economic factors that influence land use decisions in North Carolina. Using an econometric model based on the concept of dynamic optimization, I estimated the extent to which a county's CRP enrollment in a given year is affected by historical agricultural rents and acreages; historical conservation payments and enrollments; government commodity payments; soil quality; and urban influence. My results show that CRP enrollment over the previous five years has a significant positive relationship with current CRP enrollment, while agricultural acreage over the previous five years has a significant negative relationship with current CRP enrollment. These results are not surprising; long-term CRP contracts ensure that most CRP land in year $n - 5$ will remain enrolled in CRP in year n, while counties that historically have large amounts of cropland will tend to have less rural land available for CRP enrollment.

Soil quality and urban influence are also significantly related to CRP enrollment, although the magnitudes of their effects are far smaller than historical CRP and cropland acreages. Poor soil quality detracts from CRP enrollment, which is consistent with the findings of Claassen and Tegene (1999). High levels of urban influence correspond to lower CRP enrollment, which is consistent with the conclusion of Lubowski, Plantinga, & Stavins (2003) that once urban development becomes feasible, development returns are so much higher than the returns from any other land use that non-urban returns are no longer relevant.

Surprisingly, my hypothesis that government commodity subsidies encourage farmers to till unproductive land that would otherwise convert to CRP is not supported by the data. This may due to data limitations, as the quality of my government payment data relies on the accuracy of the U.S. Agricultural Census, which in turn relies on the ability of farmers to accurately self-report their subsidy receipts. Nevertheless, I cannot conclude that government commodity subsidies inadvertently discourage farmers from enrolling in CRP.

To test my second hypothesis that adjusting the way in which federal payments are awarded in the 2007 Farm Bill would increase CRP enrollment, I devised a hypothetical policy scenario in which CRP payments were doubled and government commodity payments were halved. Due to the insignificance of both variables, however, my model predicts that such a policy shift would have no effect on CRP enrollment. Although this result is somewhat disheartening, Bernard *et al* (1997) conclude that landowners do indeed respond to economic incentives when making land use decisions, but they adjust to changing economic conditions gradually. My estimates are based on five-year lagged averages, but Bernard *et al* find that only 38% of agricultural land conversions that "should" have occurred actually *did* occur after five years. Schatzki (2003) also finds that in the face of uncertain future returns, landowners place a positive value on the option to delay conversion decisions. Thus, it is possible that a longer lag period would better represent landowners' decisions.

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Appendix A: Data Collection Methods

Production data

I obtained production data from USDA's National Agriculture Statistics Service (NASS).[32] Production datasets include crop type, acres planted, acres harvested, yield, and total production. I included ten crops (barley, corn, cotton, oats, peanuts, sorghum, soybeans, burley tobacco, flue-cured tobacco, and wheat) in my analysis. I did not include other crops (e.g., hay, potatoes, sweet potatoes, apples, winter wheat) due to cost and/or price data limitations. In some cases, it was necessary to convert production units (e.g., pounds, bushels) to ensure consistency with price and cost units.

Cost data

Due to unavailability of county-level agricultural costs differentiated by crop, I used regional-level cost data from the Economic Research Service (ERS). I used yearly regional cost estimates for each crop for all counties in a particular region.[33] Most of North Carolina is in the "Southern Seaboard" region, although parts of western North Carolina reside in the "Eastern Upland" region. ERS subdivided southeastern cropping regions in the 1990s; prior to regional reclassification, I used the "Southeast" regional estimates which comprised all of North Carolina. However, I used national cost estimates for barley, oats, and burley & flue-cured tobacco due to the unavailability of regional data. Cost estimates for burley and flue-cured tobacco in 1995 were unavailable from ERS; consequently, I averaged the 1994 and 1996 cost estimates to interpolate the missing data.

32 Available online at http://www.nass.usda.gov/Data_and_Statistics/Pre-Extracted_Data/Year/.
33 For a visual representation of ERS crop regions, see http://www.ers.usda.gov/publications/aib760/aib760.pdf.

I used four cost estimates in my analysis (which in turn led to four estimates for net crop revenue for each county). The first estimate is modeled after Ruben Lubowski's methodology in a 2002 publication (the Lubowski Method).[34] This method uses the measures of cash (as opposed to economic) costs and returns, and includes expenditures on seed; fertilizer, lime and gypsum; chemicals; custom operations; fuel, lube and electricity; repairs; hired labor; other variable cash expenses; general farm overhead; taxes and insurance; and interest.[35] The second cost estimation method adds the opportunity cost of unpaid labor to the Lubowski Method. The third cost estimation method adds depreciation and capital recovery to the second method. The final method uses the ERS "Total Cost" calculation which includes all fixed and variable costs. The Lubowski Method provides the lowest-cost estimate and, based on its use and acceptance in the academic literature, is the preferred cost estimation method in my analysis.

Government payments data: Commodity Payments

I obtained government payments data for programs other than CRP from the U.S. Agricultural Census available through NASS. County-level data is only available for census years (1992, 1997 and 2002). The census lists "total government payments," "payments from Conservation and Wetlands Reserve Programs," and "payments from all other farm programs." For the study period, CRP represents the vast majority of conservation-related payments; consequently, I assumed the government made all conservation payments through CRP only.[36] I assumed the

34 Lubowski, 2002.
35 *ibid.*
36 The 2002 Farm Bill emphasized "working lands" conservation programs (e.g., the Environmental Quality Improvement Program, or EQIP). Land enrolled in these programs can be cultivated and harvested to a greater extent than land retirement programs such as CRP. According to William McDow and David McNaught at Environmental Defense, "working lands" conservation programs now comprise about half of all federal conservation payments. However, for the study period 1991-2003, the assumption that CRP payments can be used as a proxy for *all* land enrolled in federal conservation programs remains valid.

“payments from all other farm programs” category is a reasonable estimate for the total amount of federal government dollars a county receives.

The U.S. Agricultural Census is conducted every five years and relies on self-reporting for data; in 2002, the Census achieved a response level of 88 percent. According to one agricultural economist at the Economic Research Service, Census data is prone to error. For example, the Census notoriously undercounts CRP payments because it does not treat whole-farm enrollments as farming operations. The Census also relies on farmers to accurately report federal payment information; in some cases, farmers may not distinguish federal conservation payments from state conservation payments. Nevertheless, the Census represents the best available county-level data for government payments. Other studies of agricultural land rents also used U.S. Agricultural Census data (Stavins & Jaffe [1990]; Barnard et al [1997]; Lubowski [2002]; Lubowski, Plantinga, & Stavins [2003]; Lubowski & Roberts [2003]).

<u>Government payments data: Conservation Reserve Program (CRP)</u>

I obtained CRP payment and enrollment data for 1991-1993 from the North Carolina office of the U.S. Farm Service Agency. I generated the *total* CRP acres in a given year by summing the number of newly enrolled CRP acres from all preceding years. This process relies on the assumption that none of land previously enrolled in CRP dropped out of the program; however, because CRP began in 1986, all land enrolled in CRP prior to 1991-1993 would have still been in the program during those years. County-level CRP payment data for 1991-1993 was not available, although the Farm Service Agency provided county-level *total* payments for 1986-1993. To construct county-level estimates of annual CRP payments for 1991-1993, I assumed per-acre payment rates were constant from 1986-1993 and divided total CRP payments for 1986-1993 by total enrolled acres for 1991, 1992, and 1993, respectively. I obtained CRP payment and enrollment data for 1995-2003 from the Environmental Working Group's Farm Subsidy Database.[37]

Land Capability Class (LCC) data

I obtained non-irrigated land capability class (LCC) data from Soil Survey Geographic (SSURGO) database which I received from the North Carolina branch of USDA's Natural Resource Conservation Service. For each county, the SSURGO database contains a wealth of soil information from dozens of sample sites. The LCC variable is "the broadest category of the land capability classification system. Class codes 1 through 8 are used to represent both irrigated and non-irrigated land capability classes. The ratings represent the dominant soil condition in a given sample site within each county.

- Class 1 soils have slight limitations that restrict their use.
- Class 2 soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.
- Class 3 soils have severe limitations that reduce the choice of plants or require special conservation practices, or both.
- Class 4 soils have very severe limitations that restrict the choice of plants or require very careful management, or both.
- Class 5 soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
- Class 6 soils have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
- Class 7 soils have very severe limitations that make them unsuited to cultivation and that restrict their use mainly to grazing, forestland, or wildlife.

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37 Available online at http://www.ewg.org/farm/region.php?fips=37000.

- Class 8 soils and miscellaneous areas have limitations that preclude their use for commercial plant production and limit their use to recreation, wildlife, or water supply or for esthetic purposes."[38]

To construct an overall LCC rating for each county, I used a weighted average of LCC ratings from all sample sites within a county based on the acreage of the sample site. Occasionally, sample site areas were missing; in these counties, I assumed all sample sites were of equal area and consequently used a simple mean to create the overall county LCC rating. Finally, I constructed a dummy variable to represent each county's LCC rating. I assigned a 0 to counties with average LCC ratings below four and a 1 to counties with average LCC ratings above four.

<u>Price data</u>

I estimated county-level prices for ten crops using a three-step process:

1. I obtained state-level market year average (MYA) price data from the NASS database.[39] The NASS database did not list prices for certain crops; in these cases, I used USDA's annual "Agricultural Prices" reports.[40]

2. To account for county-level price differences in North Carolina, I collected Posted County Price (PCP) data for 2001-2003 from the U.S. Farm Service Agency.[41] PCP data is available from 2001-2003, but only wheat, corn, sorghum, soybeans, oats, and barley are available. Although PCP data is published daily, I used the yearly average PCP; as a result, seasonal price differences are not captured in the county-level price data.

3. To estimate county PCPs for 1991-2001, I calculated a multiplier for each county using the ratio of PCP to state MYA prices for years in which both sets of data were available (2001-

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38 NRCS, 1997.
39 Available online at http://www.nass.usda.gov/QuickStats/.
40 Available online at http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1003.
41 Available online at https://indianocean.sc.egov.usda.gov/ACR/

2003). This county-level multiplier allows the estimation of historical PCP from the state-level MYA prices discussed in step 1, but rests on the assumption that the relationship between the PCP and MYA price in a given county is constant over time. An agricultural economist at the USDA Economic Research Service supported this assumption, however, and the extrapolated PCP data should identify counties in which prices tend to be higher or lower than the state MYA price.

Population-Interaction Zones for Agriculture (PIZA) data

I obtained PIZA data from ERS. The PIZA dataset classifies each county into five categories representing the extent to which urban activities affect the economic and social environment of agriculture. Strong interactions between urban-related population and farm production activities tend to "increase the value of farmland, change the production practices and enterprises of farm operators, and elevate the probability that farmland will be converted to urban-related uses."[42] The PIZA system groups land in each county into five categories; however, I recategorized that data into just two categories for simplicity purposes. "PIZA_LOW" represents the percentage of a county with zero or low urban-related population interaction, while "PIZA_HIGH" represents the percentage of a county with moderate, high, or very high urban-related population interaction.

[42] USDA ERS, 2005.