ARB LCFS Expert Workgroup

Final Recommendations From The Elasticity Values Subgroup

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RECOMMENDATIONS FROM ELASTICITY SUBGROUP

Introduction

This paper aims to address recommendations about several elasticities parameters in the GTAP model used by the California Air Resources Board (CARB) to estimate land use emissions from biofuels as part of the Low Carbon Fuel Standard (LCFS) regulation. This document was produced as part of the effort of several other subgroups of the LCFS Expert Workgroup to assist CARB in refining and improving the land use and indirect effect analysis of transportation fuels.

The information and recommendation in this paper express the final findings of the "Elasticities Value Subgroup" after several months of research and discussions. As will be shown, the findings are not conclusive but express the better knowledge available found by subgroup members. We expect that continuous research may confirm or improve our recommendations in the future.

This document has three parts. The first part summarizes the recommendations from the LCFS Expert Elasticities Subgroup. The second part addresses the requests from CARB and other expert members from the October meeting. The third part provides detail of the investigation about the Elasticity with respect to area expansion.

Part I - Recommendations

1. "Must do as Part of Near Term Modeling" Recommendations

1.1 Elasticity with respect to area expansion

CARB should adopt the version of GTAP that varies the value of this parameter by region as documented in Tyner et al (2010).

Rationale

The initial CARB GTAP runs varied the ratio of new land yield to current land yield from 0.5 to 0.75. For each run the particular value of this parameter was fixed across all regions and all crops. No data-based analysis existed that could support any particular setting of this parameter. Since those initial runs, however, some evidence about what this ratio might be has emerged and Tyner et al have developed a data-based method to allow this ratio to vary across regions. Babcock and Carriquiry (2010) found no support for the hypothesis that the yield of newly converted land is less than the yield of existing soybean land in Brazil. UNICA (2009) calculates the ratio between yields in new and old cropland in Brazil as between 0.9 and 1.05. And new analysis of U.S. data conducted as part of this expert workgroup found that counties that expanded cultivated land in response to higher crop prices beginning in 2007 had, on average across crops, about the same yield as existing cropland. This empirical evidence strongly suggests that setting this parameter value at the upper limit of the current range of values (0.75) would dramatically underestimate crop yields on new land. The Tyner et al method uses a bio-process-based biogeochemistry model (the Terrestrial Ecosystem Model - TEM), which is well-documented and has been used in peer-reviewed studies about the patterns of land carbon dynamics across the globe considering multiple factors such as CO_2 fertilization, climate change and variability, land-use change, and ozone pollution. The Tyner et al approach results in yields on new land brought into production that are much closer to yields on existing land. Hence, the Tyner et al method is much more consistent with the (limited) empirical data than what was used in the initial CARB GTAP runs.

Other considerations

For sensitivity analysis, use as the central value the numbers in Tyner et al (2010) from TEM. We cannot recommend alternative values for use in a sensitivity analysis because there are no data that provides evidence that could suggest a range for this elasticity. The differences in the parameter at the AEZ level is a much better approach than a single number for all regions, which prevents us from recommending a common upper or lower level everywhere.

The time frame associated with this parameter is the long run. The estimates come from the TEM model, which compares net primary productivity (NPP) between new areas and current cropland areas. NPP in TEM is estimated using data from 1900 and 2000, which is consistent with a long run approach.

1.2 Yield elasticity with respect to price

Keep the central value of the yield elasticity with respect to price at 0.25 if only one value can be used for all crops and all countries. If this elasticity can be varied, then is should be increased for crops-country combinations that can be double-cropped and it should be decreased for combinations that cannot.

Rationale

Early studies that attempted to estimate the relationship between crop yields and price have relied on observations of annual changes in the price of fertilizer relative to the expected crop price to explain changes in national yields (Choi and Helmberger (1993); Houck and Gallagher (1976); and Menz and Pardey (1983). A more recent study by Huang and Khanna (2010) use both cross section and time series data to estimate the relationship between yields and price controlling for weather, trend, and the price of fertilizer. The overall conclusion of these studies is that the short-run response of yields to crop prices is quite inelastic. Houck and Gallagher (1976) found a relatively large response in some of their estimates, but Menz and Pardey's subsequent analysis demonstrated that the Houck and Gallagher estimates were not likely robust. Choi and Helmberger estimated that fertilizer demand increased with expected crop price, but they were not able to show a yield response to fertilizer use when a trend was included in their variable because fertilizer use and other technology use were highly collinear. They argue, however, that there must be a response of yield to increased fertilizer use, why else would farmers increase fertilizer applications when crop prices rise? Choi and Helmberger conclude by arguing for a positive but quite inelastic yield response to crop prices. Huang and Khanna estimated price-yield elasticities of 0.06, 0.15, and 0.43 for soybeans, corn, and wheat respectively. The overall conclusion that one can take from the literature is that the short-run (one year) response of U.S. yield to price is quite inelastic with an average value of somewhere between 0.05 and 0.2.

The long-run responsiveness of yield to price will be greater than the short-run response if there are lags in the adoption or development of new management practices or seed varieties. Hence, to the extent that existing studies provide reliable one-year estimates, they underestimate the long-run response of yields to price. There are sound theoretical reasons for believing that there are lags in the response to higher crop prices. Farmers have an incentive to adopt higher-yielding seed technologies and other management techniques with higher prices. Switching from one

seed variety or technology such as seed-planting populations, may require more than a single season to accomplish. And there are likely five to 15 year lags involved in developing new seed varieties and new management techniques that may be only profitable under high prices. However, it must be recognized that seed companies always have an incentive to develop higher-yielding varieties in a competitive environment. What is important for the long-run elasticity of yield to price is the additional incentive or ability to develop higher-yielding varieties because of current higher prices. Perhaps a reasonable increment to the short-run elasticity to account for long-run response is 0.05, which brings the average value between 0.1 and 0.25.

Finally, higher prices give farmers a greater incentive to double crop. For example, Babcock and Carriquiry demonstrated that the share of U.S. soybean production grown on double cropped acres has tracks the price of soybeans (see figure 17 of their report). Because higher prices induce additional production from the same land, it is as if yields had increased. Babcock and Carriquiry conclude that the incentive to double crop soybeans with corn and cotton in Brazil justifies use of a yield elasticity of 0.24 by itself. The smaller share of U.S. double cropped soybeans supports a smaller yield elasticity increment than 0.24. Thus, for countries that have the opportunity to double crop, such as the U.S., Brazil, Argentina, and some Asian rice-producing countries such as Thailand that can get multiple rice crops per year, and for crops that are subject to double cropping, such as U.S., Brazilian, and Argentine soybeans, corn and wheat, an additional increment should be given to the price-yield elasticity.

It is not clear if GTAP can assign different elasticities to different crops in different countries. If not then if the long-run price-yield elasticity not accounting for double cropping is set at 0.175, and if South America and the United States are the countries that contribute the most incremental commodity production in response to higher prices, then a mid-point value of 0.25 for the price-yield elasticity seems reasonable. If differentiation can occur by country, then setting the price-yield elasticity to 0.175 for countries with no double cropping, 0.25 for the U.S., and 0.3 for Brazil and Argentina will provide a more reasonable approximation to reality.

Other considerations

For sensitivity analysis, the central value of a single parameter setting should be 0.25. The lower bound on this elasticity should not be zero because of strong theoretical considerations (input use responds to crop price) and the reality of double cropping. But there is no empirical basis to choose either a lower limit or an upper limit for sensitivity analysis that applies to all countries together. If it is desirable to see what the results would be if all countries' yields are responsive to price and if all countries could double crop, then an upper limit of 0.35 could be used. If it desirable to see what the implications would be if yield response were quite low and if double cropping did not exist, then a value of 0.05 could be used

1.3. About Land Transformation Elasticity (CET elasticity)

Keep the same values used before, -0.2 as central value.

Rationale

The only country for which this elasticity has been calibrated is the United States. The calibration was done by Ahmed et al. (2008) based on transition probabilities matrix from Lubowski (2002) and Lubowski et al. (2006).

Other considerations

For sensitivity analysis, central value should be -0.2, lower bound -0.3 and upper bound -0.1
The central value for this elasticity (-0.2) is related to a five year response in the case of pasture, cropland and a revenue-share weighted average of the 3 land use categories. The lower response value (-0.1) is associated to responses expected at the 3 year time frame and the higher response value (-0.3) would be associated to 10 year time frame responses. From this, the central value seems to be associated to medium term and the upper value to a medium to long term response.

1.4. About the combination of elasticities used in different biofuel pathways

The version of GTAP used, the combination of parameters used and the number of scenarios run should be the same for all biofuel pathways. If, as was done in the past, the average result across the sensitivity runs is taken as the emission "score" of the biofuel pathway, then the average value of the parameter used across the scenarios should, at a minimum, equal the central value of the parameter.

Rationale

The purpose of running different scenarios is to show the sensitivity of model results to chosen parameters. The model used for each pathway should be the best model available for the exercise and it is the model's treatment of cross relationships between commodities and land cover types that should determine model results. The parameterization of the model should not depend on a particular biofuel being examined because then it is not the model that is driving results but rather the particular parameterization. For consistency and transparency of results, the same model and the same parameters should be used.

1.5 About a newer GTAP version

If possible, CARB should adopt the newest version of GTAP, used by Tyner et al. (2010).

Rationale

The new version of GTAP, used by Tyner et al. (2010) already considers all recommendations about elasticities listed before:
- yield elasticity with respect to price at 0.25;
- elasticity with respect to area expansion based on TEM as described in Tyner et al (2010);
- land transformation elasticity as -0.2

This new version of GTAP has also other improvements related to land use categories (added two new categories: the cropland-pasture and CRP land use types) and to the representation of byproducts.

2. Short Term Work/Research

Additional work is needed to calibrate GTAP predictions of land use change with the reality of land use changes that we have seen in response to a four year period of high crop returns in the United States and around the world. A four year time period approaches a medium-term response that should be reflected in GTAP results. What we have seen in the United States is a quite inelastic cropland response, almost no deforestation in response to higher crop prices, some movement out of CRP, which could be taken as a movement of pasture to crops, and a mixed response around the world. Are these responses consistent with what is being predicted by GTAP? If not, then how can we adjust the elasticities used by GTAP to make it more consistent with the observed changes in land use.

3. Long Run Recommendation

3.1 Parameterization of GTAP's CET Function

Develop a better method to increase flexibility in the function that determines own and cross price substitution elasticities across land cover types.

<u>Rationale</u>

The CET function in GTAP has but one parameter. This parameter, together with the baseline share of returns to land of different types, determine the own and cross price elasticities of land cover type. Babcock and Carriquiry demonstrated that this method leads to cross price elasticities that are not consistent with common sense and empirical estimates. For example, the cross price elasticity of forest land in the United States with respect to crop returns is an important factor in GTAP determining how much forest land is converted to cropland in response to biofuels-induced crop price increases. The value for this parameter in GTAP is -0.174: a 10% increase in crop returns decreases forest land by 1.74%. But this responsiveness is 35 times as great as the maximum response of forest land to crop returns over a 15 year time period using the response of forest land to changes in own forest returns as estimated by Lubowski (2002) and Lubowski,

Plantinga, and Stavins (2006). This suggests that GTAP's estimate of how much U.S. forest land is converted to cropland in response to increased crop prices is too large.

Adding more flexibility to the CET function to allow better calibration of the own and crop price elasticities is a longer run recommendation because there does not seem an easy and straightforward method of accomplishing this task. A possible approach is to use the same as Al-Riffai et al. (2010), where the CET function has two levels of substitution with two different elasticities of transformation. The upper level considers the substitution between forest land and total arable land, with country specific elasticities ranging from 0.1 to 0.13, and the lower level considers the substitution between pasture and cropland, which elasticities varies from 0.02 to 0.25. It allows a better calibration of CET elasticities to estimated own and cross price elasticities.

Part II - Answers to Requests from CARB and expert workgroup

At the October CARB Expert Workgroup Meeting some questions were raised that need to be be addressed by the elasticity subgroup. Here we tried to answer each one.

Issues that were raised:
1. Considerations on the range of elasticity values to use in sensitivity analyses
2. Should unmanaged land be added to the CET function model structure and if so, how?
3. Address/respond to issues raised in presentation by Steve Berry (yield response to price)
4. Look at issue of Armington trade elasticities in GTAP and the effect on LUC results. Compare to models like FAPRI which assume homogeneous goods and predict a much higher percentage of land conversion outside of the country where biofuel is produced (and its primary trading partners).
5. Discuss/determine which time frame is represented by various elasticity values – is the model consistently looking at a short, medium, or long run response
6. Discuss how the price yield elasticity may affect emissions due to higher use of inputs

Our answers are below.

1. Considerations on the range of elasticity values to use in sensitivity analyses

Yield elasticity with respect to price (crop yield elasticity)
For sensitivity analysis, the central value should be 0.25. The lower bound on this elasticity should not be zero because of strong theoretical considerations (input use responds to crop price) and the reality of double cropping. But there is other no empirical basis to choose either a lower limit or an upper limit for sensitivity analysis. Perhaps 0.05 and 0.35 if we want to see what the model will predict when yields are quite unresponsive to price and when yields and double cropping are quite responsive to price..

Elasticity with respect to area expansion.
For sensitivity analysis, use as the central value the numbers in Tyner et al (2010) from TEM. We cannot recommend alternative values for use in a sensitivity analysis because there is no evidence that if this elasticity is biased, it is biased in a systematic direction for all AEZ's. The differences in the parameter at the AEZ level is a much better approach than a single number for all regions, which prevents us from recommending a common upper or lower level everywhere. It is not clear how a sensitivity analysis to this parameter which changes across space could be accomplished. We suppose that the value of this parameter could be increased by, say, 15% for all AEZ's and then the model could run. But again, there is no rationale for believing that there

is a systematic bias in these parameters across all AEZ's. If there was, then the whole approach should be recalibrated to reflect this bias. There clearly could be a bias in the value for any particular AEZ, but the bias is just as likely to be positive as negative. Thus, we recommend that until a better method is developed for estimating the ratio of yields on new land to old land then no sensitivity analysis be conducted with respect to this elasticity.

Elasticity of land transformation

Central value: Keep the same as in current GTAP model (-0.2)

Alternative values: the same as used before (-0.1 and -0.3)

The main problem about this elasticity is the fact that the constant elasticity of transformation function used in GTAP assumes that all three land use types can be substituted under the same elasticity. This is not satisfactory because the direct and cross price elasticities derived from this parameter regarding forestland are too high compared to econometric estimates. It means that the better approach, suggested here as an improvement that CARB should seek at the long run, is to change the technological tree at GTAP to allow substitution between pastureland and cropland at a lower level, and at an upper level between forestland and the aggregate arable land. Besides that, the range used by GTAP (0.1 to 0.3) was estimated by Ahmed et al. (2008), based on the results from Lubowski et al. (2006). We are not aware of any other estimates, what make us believe that is better to keep using the values in GTAP.

2. Should unmanaged land be added to the CET function model structure and if so, how.

It is important to know that a share of the forest land in GTAP is unmanaged land, since the forest land area is a category built from the timberland area from Brent Sohngen model, as documented in Lee et al. (2005). In his model, forest land is a composite of common managed forest areas, natural forest land that is already being used to supply timber, and natural forest area that is accessible to supply timber. What is left out of the GTAP model could be classified as "unaccessible" natural forest area.[1]

To be able to increase the amount of forest area in GTAP from unmanaged or inaccessible area for CARB analysis, it is important: a) to understand what the forest land and unmanaged land categories in GTAP are representing and how they contribute to the total potential arable land in a region; b) understand how more land may affect the model.

About a):

[1] As example, the U.S. Forest Service (http://www.fia.fs.fed.us/) reports that the total forest area in U.S. is around 750 million acres (303.5 million ha), from which the total of unproductive unreserved private and public area is around 500 million acres (202,3 million ha), and the harvested annual area is 9.85 million acres (almost 4 million ha). The forestland area in GTAP amounts 337.8 million ha, even larger than the unproductive unreserved area declared by the U.S. Forest Service. In Brazil, the Brazilian Association of Planted Forest Producers (ABRAF) reported the area of commercial forests as 5.2 million ha in 2005 (http://www.abraflor.org.br/estatisticas.asp). The forestland in Brazil in the GTAP model is 157.6 million ha.

As it is not clear how much of the forestland category in GTAP is managed forest and how much is accessible but not explored natural forest, the first task should be to access the amount of natural forest already considered in the forestland category in GTAP. All the exercises carried by CARB at the moment were not able to convert considerable shares of the forestland category in any country in GTAP, which suggests that it will not make a noticeable difference to include more unaccessible forest areas in GTAP.

It is important also to note that, when comparing GTAP data and official statistics, we may realize that the land cover classification is highly determined by interpretation of data. As example, an article at The Economist (http://www.economist.com/node/16886442) cited that FAO considers the potential arable land in Brazil as around 400 million ha, while the official data in the country considers 320 million ha. GTAP data shows that the total land available to agriculture in Brazil (adding forestry, cropland and livestock categories together) is around 389 million ha, already too high if compared to official Brazilian data, but close to FAO numbers. As GTAP numbers about cropland and pasture land in Brazil are fine compared with national and FAO statistics, it seems that the forestland category is the one we need to look carefully. That said, we can deduce that GTAP is already overestimating the potential agricultural land in Brazil given official country data (maybe due to consideration of accessible forest some areas not able to become arable land), or it is considering a very small amount of inaccessible forests given FAO data.

Adding to this discussion, it is possible to do a rough comparison of the GTAP unmanaged land area in AEZ 5 in Brazil and the official Brazilian data about Savannas in the country. The geographical distribution of Brazilian savannas is virtually inside the AEZ5 geographical distribution in GTAP, if we compare the GTAP AEZ maps and the country official maps about large ecosystems distribution. The official savanna area in Brazil in 2000 was 113,778 thousand ha, considering the natural area not converted to agriculture. The total amount of Brazilian unmanaged area in GTAP in AEZ5 is 57,750 thousand ha. Those numbers suggest that a big proportion of the Brazilian savanna was not mapped as unmanaged land, maybe due to interpretation of satellite data, classification of ecosystems, heterogeneity of vegetation on ground, etc. It means that, at least for AEZ5 in Brazil, a considerable share of the savanna area is available to conversion in GTAP, maybe as forest land or even as pasture land. It just illustrates that it is necessary first to better understand what is accounted in the GTAP unmanaged and forest land data at the country level before recommend to CARB to increase the area of "managed" forest.

So, we suggest that it is necessary first to do a detailed investigation about the land cover data in GTAP. It includes a careful comparison of the amount of potential agricultural land available in each GTAP region (pasture + cropland + forestland) with the local and world statistics about

potential arable land. In doing so, we can better identify the need to include unmanaged or accessible areas into the forest category in GTAP.

About b):
It is important to think how an increase in the area of forest land can affect GTAP results. It will increase the share of forest land in some AEZ, what will allow higher conversion of forests to cropland under a biofuels shock, since the constant elasticity of transformation (CET) function tends to convert more of that land category that is more available. But, the CET elasticity regarding forest land conversion is too high, which needs to be fixed in the long run changing the CET structure (see "3. Long run Recommendation"). The estimated value of such elasticity is smaller than 0.05 (Ahmed et al., 2008), but the central value used by GTAP is 0.2, since GTAP considers the substitution of the three land use types (forest, cropland and pasture) at same time. If someone increases the area of forest land in GTAP, it will contribute to a parameterization that already tends to convert more forest than the parameterization suggested by the literature.

3. Address/respond to issues raised in presentation by Steven Berry (yield response to price)

Steven Berry has advocated giving a higher weight to lower values of the yield elasticity with respect to price. Berry argues that the papers cited by Keeney and Hertel (2009) are flawed because they do not account for possible simultaneous equations bias. Berry also cites Roberts and Schlenker (2010) as using a better method (instrumental variables) to estimate agricultural supply and demand elasticities. He then argues that Roberts and Schlenker's results "argue against a large effect of prices on yields because: prices are highly serially correlated while yields are not and that prices are set in world markets but the cross-country spatial correlation of yields is low." (Berry 2010). But of course yields are not serially correlated: they mainly reflect weather which is not serially correlated. The effects of price on yield is likely much smaller than the effects of weather on yield for the types of crops being modeled by GTAP. Furthermore, it would be extremely unlikely that yields would be strongly correlated across countries because again, they mainly reflect weather, not prices. All Roberts and Schlenker were trying to do in this part of their analysis was to rule out strong simultaneity bias in their main econometric results which were to supply and demand elasticities. They were not trying to estimate the yield elasticity with respect to price. Given the dominant role that serially uncorrelated weather plays in determining crop yields, it would have been surprising if Roberts and Schlenker (2010) had found serially correlated yields or if they had found spatially correlated yields in countries that are separated by thousands of miles. The Roberts and Schlenker (2010) results provide no evidence that there is not a price-yield relationship, they just find evidence that any short-run price yield relationship is overwhelmed by variations in yields caused by weather. With respect to the Roberts and Schlenker findings that yields in the two largest producing countries for each crop are not correlated, it is important to note that China is one of the countries that is used in the comparison in three of the four crops (corn, wheat, and rice). The argument used by Roberts and

Schlenker is that if yields respond to price, then if prices rise, yields in the largest-producing countries should rise at the same time. If prices fall, then yields should fall. Thus yields should be correlated across countries over time. But a necessary condition for this to be true is that farmers in both countries face the same set of prices for incremental output in each country. But China's farmers have been largely isolated from world prices for most of the time period that Roberts and Schlenker use in their analysis. And given that China was used in three of the four crops means that a finding of no cross-country correlation provides no insight into the response of yields to expected price.

Turning to Berry's argument about simultaneous equations bias in the estimates cited by Keeney and Hertel (2009). Papers that regress realized yield on realized price are subject to simultaneous equations bias because weather affects realized yield, realized yield affects supply, and supply affects price. Furthermore, realized price also reflects movements in demand so a straight regression can give nonsensical results. However, Choi and Helberger (1993) estimate a yield-price relationship based on estimating the demand elasticity of fertilizer. Fertilizer demand is made a function of expected price. Furthermore, fertilizer rates are based on planned output rather than actual output, so a regression of fertilizer applications on expected price (or expected output) is not subject to the same criticism. The precision with which they estimate this relationship may be subject to criticism, but nobody believes that fertilizer demand is unresponsive to expected output price. Nor is there any disagreement that there is a zero average yield response to increased fertilizer rates. Combining these two must result in a positive relationship between yields and expected price. The trick, of course, is being able to precisely measure the relationship.

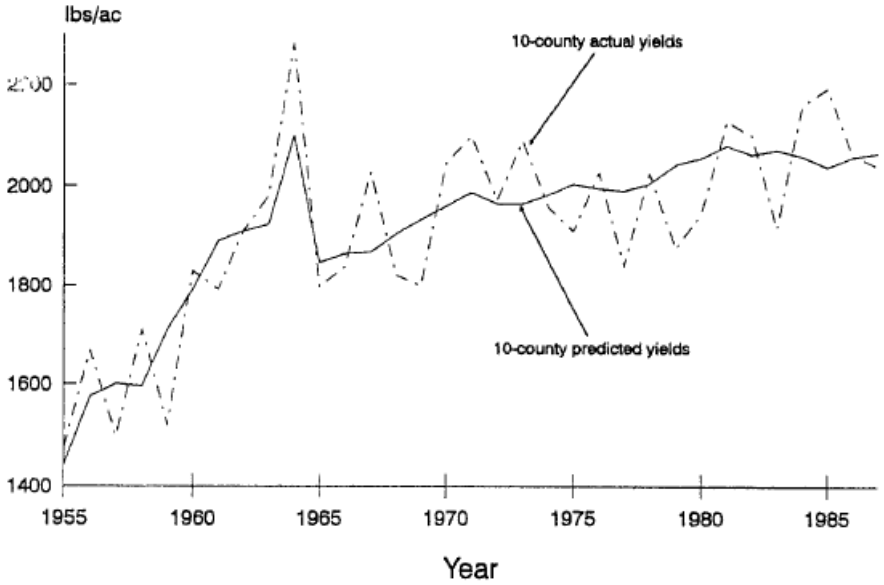
Berry also cites the paper by Huang and Khanna (2010) who correct for simultaneous equations bias and find a positive price-yield relationship. So while the early studies cited by Keeney and Hertel (2009) may be subject to simultaneous equations bias, the paper by Huang and Khanna (2010) is not.

Lastly, there are strong reasons supporting the idea that farmers have control over their average yields. They can choose to scout and control for pests or not. They can test their soils for fertility or not. They can choose to apply additional fertilizer or not. They have choice over which seed variety to choose. All of these decisions involve a tradeoff between cost and the value of higher average yield. The likelihood that the value of higher yield exceeds the cost depends on the level of output price. Thus more of these yield-increasing actions will be taken the higher is output price. The difficulty in measuring the relationship between price and yield is we do not have data measuring farmer actions: all we have is what happens to yield. And yields in any year are primarily driven by weather. Furthermore, it is difficult if not impossible to conduct a cross-section analysis because farmers in different regions face essentially the same price.

That farmers have control over their yields was revealed by Foster and Babcock (1993) who found that flue-cured tobacco farmers dropped their yields by 12% in one year in response to a change in the marginal value of yield caused by a policy change. Yield growth following the policy change was 1/8th as large as before the change. Figure 2 from Foster and Babcock is reproduced below. The policy change first took effect with the 1965 crop. The dashed line is the average actual yield across 10 counties. The solid line is the average yield after controlling for weather. As can be seen, both the yield level and the subsequent growth rate in yields shows that tobacco farmers had a strong and measureable control over their yields.

In summary then, Berry is correct that studies purporting to find a strong relationship between yield and price may be subject to simultaneous equation bias. But the Roberts and Schlenker (2010) study that he cites as providing no evidence of a relationship between yield in price used a method that has very low power; that is, the probability that Roberts and Schlenker (2010) could have found a price-yield relationship if in fact it exists is extremely low. Furthermore, Berry cites Huang and Khanna (2010) as not being subject to simultaneity bias and these authors actually find a positive price-yield relationship. And lastly, there are strong reasons for believing that such a relationship exists, and if the change in incentives is strong enough, then it can be found in the data, as demonstrated by Foster and Babcock (1993).

Figure 2. Predicted and Average North Carolina Tobacco Yields



Note: Predicted yields were calculated at the mean values of the rainfall variables.

4. Look at issue of Armington trade elasticities in GTAP and the effect on LUC results.
Compare to models like FAPRI which assume homogeneous goods and predict a much higher percentage of land conversion outside of the country where biofuel is produced (and its primary trading partners).

Armington Trade elasticities
Recommendation: keep the original GTAP values.
Rational: Sensitivity analysis in the first version of CARB document has shown an impact of a minus 2% change in carbon intensity when moving from the lower to the upper bound of such elasticity (plus or minus one standard deviation). The Armington trade elasticities were estimated by Hertel et al. (2004). The literature is quite sparse on this parameter. Based on trade data from US, corn exports trends have changed little in the recent expansion of biofuels and the 2008 food price crisis, suggesting that world markets in agricultural commodities are not as flexible as assumed in partial equilibrium models as FAPRI, which considers agricultural commodities as homogeneous goods. This rigidity in export markets is somewhat of a puzzle because world prices for the major agricultural commodities are quite integrated. But if corn and other crops are homogeneous goods, we should have expected a larger supply response outside the United States and a resulting drop in imports because of the higher prices in recent years. That we have not seen such a response can be explained by either a lower supply response in the rest of the world than is assumed by FAPRI or that the Armington trade elasticities assumed in GTAP are appropriate. Given that GTAP is the model chosen by CARB for analysis of biofuels, we recommend that to maintain the use of the Armington trade elasticities in GTAP. A scenario that greatly increases these elasticities could be run to determine how sensitive results are to the underlying assumption that agricultural commodities are not homogeneous goods in the long run.

5. Discuss/determine which time frame is represented by various elasticity values – is the model consistently looking at a short, medium, or long run response

We believe that GTAP parameters should reflect medium to long run responses, since the calculation of a carbon coefficient need to reflect such time frame. Although it is not easy to determine the exact time frame for some parameters, evidence exists to believe that much of the elasticities discussed here are reflecting medium to long run responses.

<u>Crop yield elasticity</u>: We should be using a long-run elasticity and our recommendation is based on long-run considerations.

<u>Elasticity with respect to area expansion</u>: the estimates come from the TEM model, which compares net primary productivity (NPP) between new areas and current cropland areas. NPP in TEM is estimated using data from 1900 and 2000, what is consistent with a long run approach.

Elasticity of land transformation: Ahmed et al. (2008) describe this elasticity as being estimated based on transition probabilities matrix from Lubowski (2002) and Lubowski et al. (2006), based on plot level data from USDA (2000), which tracks the amount of land of each quality in each use at each point in time, and ultimately an elasticity estimate that is more appropriate for a longer time frame. The central value for this elasticity (-0.2) is related to a five year response in the case of pasture, cropland and a revenue-share weighted average of the 3 land use categories. The lower response value (-0.1) is associated to responses expected at the 3 year time frame and the higher response value (-0.3) would be associated to 10 year time frame responses. From this, the central value seems to be associated to medium term and the upper value to a medium to long term response. However, for forest land the appropriate elasticity value would be lower than 0.05 even under a 100 year time frame. It means that, although -0.1 is not appropriate for a medium-long term analysis in the case of cropland and pastureland, it is already too high for forestland. Unless the model can be improved in the future by separating the CET nests of forestland from the one for pasture and cropland, it is more appropriate to keep using the range -0.1 to -0.3.

6. Discuss how the price yield elasticity may affect emissions due to higher use of inputs

CARB has shown some concern about the price yield elasticity inducing higher use of fertilizers or other process that could increase emissions. The price yield elasticity is a parameter which affects the substitutability among land and other inputs. Actually, the technology representation of crop production in GTAP does not allow substitution between land and fertilizers. Figure 1 in Keeney and Hertel (2009), reproduced below, shows the possibility of substitution among inputs and factors in crop production in GTAP. The price yield elasticity affects the σ_{VA} elasticity. Fertilizers are part of "Purchased inputs" in this figure. So, higher substitution possibilities among land and other inputs induced by the price yield elasticity does not increase the use and emissions from fertilizers. However, it may increase the use of energy inputs, which include fossil fuels, since land can be substituted for the Capital-Energy bundle.

To be able to assess how the price yield elasticity increase emissions through a higher use of the capital-energy composite when substituting land, it is necessary to run a biofuel scenario in the GTAP model with and without the price yield elasticity and calculate how much more energy is being used in the feedstock production for biofuels. In this way, we will not double count emissions from life cycle analysis. GTAP is able to report CO_2 emissions from energy use in each sector (coefficients CO2DF and CO2IF under headers CODF and COIF, respectively, in the view base and updated core data in GTAP). We have performed such exercise for the Corn Ethanol scenario A in the document "Proposed Regulation to Implement the Low Carbon Fuel Standard – Volume I" (table IV-10 page IV-31). This scenario assumes the price yield elasticity as 0.4. Below we show the results.

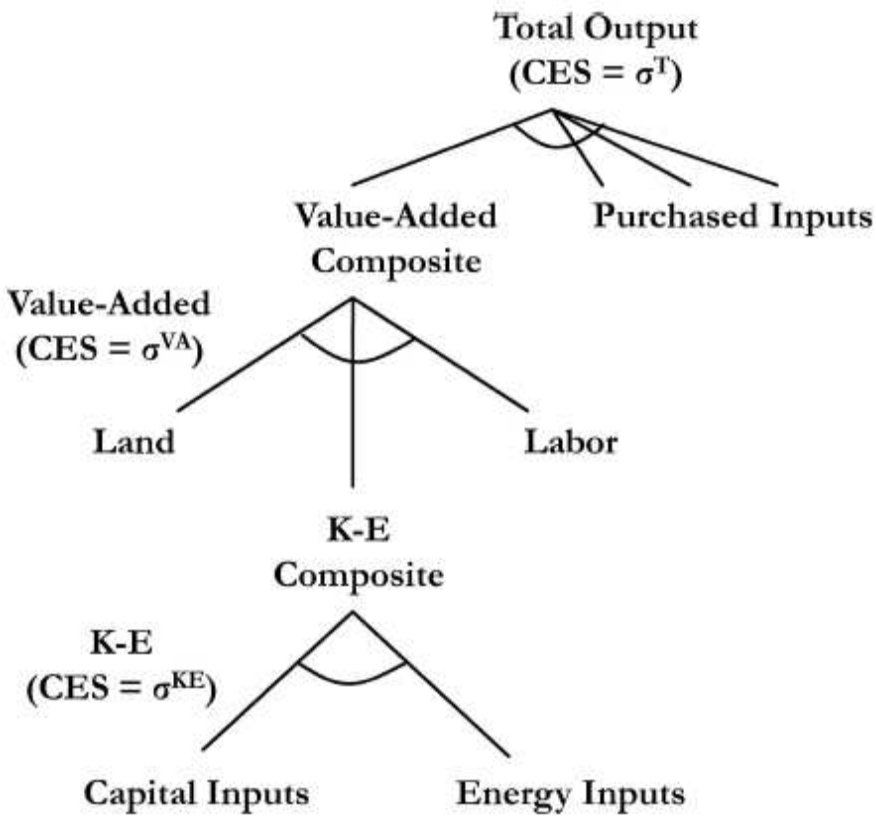


Figure 1. Nested CES production function for crop output

From: Keeney and Hertel (2009)

Global CO_2 Emissions from energy use by agricultural sectors in GTAP, in Mt of C (Price yield elasticity = 0.4)

	CrGrains	**OthGrains**	**Oilseeds**	**Sugarcane**	**Livestock**	**Forestry**	Total
Baseline	24.26	32.92	13.39	5.3	85.32	27.22	188.41
Scenario A With PYE*	26.03	32.63	13.46	5.3	85.43	27.39	190.24
Scenario A Without PYE	25.89	32.53	13.45	5.3	85.42	27.43	190.02
Absolute Change from Baseline with PYE	1.77	-0.29	0.07	0	0.11	0.17	1.83
Absolute Change from baseline without PYE	1.63	-0.39	0.06	0	0.1	0.21	1.61
Diference between Scenario A with and without PYE	0.14	0.1	0.01	0	0.01	-0.04	0.22

*PYE: Price-yield elasticity

The table shows that the amount of emissions from energy use in agricultural production is slightly higher when the price-yield elasticity is active. In the corn ethanol scenario A crop grains increase emissions from energy use by 1.63 Mt of C in the world when the price yield elasticity is not considered in the model, and by 1.77 Mt of C when the price yield elasticity is in place. It

means an increase of 0.14 Mt of C due to the consideration of the price yield elasticity of 0.4. Considering all the agricultural emissions from higher energy use due to land substitution in the corn ethanol scenario, the extra emissions due to the activation of the price yield elasticity is 0.22 Mt of C. Although not negligible, it seems GTAP produces a small substitution between land and the capital-energy composite. If we convert this number to Mg of CO_2 and add it to the emissions from land use changes the LUC carbon intensity does not change.

We performed the same exercise in the Sugarcane ethanol scenario A. We observed that the ethanol shock generate more emissions (0.3 Mt of C) from energy use in agriculture than the baseline scenario. However, the model didn't produce any difference in global energy use emissions in agricultural sectors between the scenarios with and without the price yield elasticity. The smaller value for this elasticity in that scenario (0.25) compared with the corn ethanol one as also the smaller shock (2 billion gallons) help to explain the virtually no difference in emissions due to higher substitution between land and the capital-energy composite.
We decide to perform one more simulation with the corn ethanol scenario, changing the price yield elasticity in the scenario A from 0.4 to 0.25. Results are shown in the table below.

Global CO_2 Emissions from energy use by agricultural sectors in GTAP, in Mt of C (Price yield elasticity = 0.25)

	CrGrains	**OthGrains**	**Oilseeds**	**Sugarcane**	**Livestock**	**Forestry**	Total
Baseline	24.26	32.92	13.39	5.3	85.32	27.22	188.41
Scenario A With PYE*	25.94	32.57	13.45	5.3	85.43	27.42	190.11
Scenario A Without PYE	25.89	32.53	13.45	5.3	85.42	27.43	190.02
Absolute Change from Baseline with PYE	1.68	-0.35	0.06	0	0.11	0.2	1.7
Absolute Change from baseline without PYE	1.63	-0.39	0.06	0	0.1	0.21	1.61
Diference between Scenario A with and without PYE	0.05	0.04	0	0	0.01	-0.01	0.09

*PYE: Price-yield elasticity

With the price elasticity of 0.25 the increase in Carbon emissions from energy use in agriculture due to this elasticity is 0.09 Mt of C. Again, if we convert this number to Mg of CO_2 and add it to the emissions from land use changes the LUC carbon intensity does not change.
Considering that, we believe that the price yield elasticity is not able to increase emissions from inputs substituting land in a way that will change the LUC carbon intensity.

This is not to say, however, that yield increases due to a higher price will not increase emissions through purchased inputs, such as fertilizer. It is just that GTAP cannot be used to account for these additional emissions. Without a good understanding of exactly which management practices and input decisions are used to increase yields, it is not possible to estimate the extent, if any, that emissions will increase as yields increase.

Part III – Detailed Investigation about the Elasticity with Respect to Area Expansion

1. Literature Review

One important GTAP model parameter used in the California LCFS calculation by CARB is the "elasticity of crop yields with respect to area expansion". It expresses the yields that will be realized from newly converted lands relative to yields on acreage previously devoted to that crop. In page IV-20 of the Staff Report, it is asserted that: "…because almost all of the land that is well-suited to crop production has already been converted to agricultural uses, yields on newly converted lands are almost always lower than corresponding yields on existing crop lands."

It can be true in the United States and the European Union, however, in many other parts of the world, as in Latin America, there is considerable potential well-suited agricultural area for crop expansion. Some studies have shown this potential in terms of land available to agriculture or biomass production, as Chou et al. (1977), Edmonds and Reilly (1985) and Bot et al. (2000). Such research suggests that the elasticity of crop yields with respect to area expansion is *potentially larger* in those regions with *larger land availability*.

More importantly, the GTAP model is highly sensitive to the value of this elasticity since the indirect land use change carbon intensity can vary more than 75% when this elasticity is changed from 0.25 to 0.75. We note that CARB staff chose values ranging from 0.5 to 0.75 (except one scenario for sugarcane ethanol in which 0.8 was used for Brazil) to be used in the GTAP model runs though there is no explanation to the basis of such decision. In fact, from a microeconomic perspective, we would hardly expect investments in new areas if the yield of the new crop would be half of the traditional area, as assumed with an elasticity of 0.5 proposed by CARB staff.

We intend here to investigate the literature for possible estimates or evidences about the CARB assumption about this parameter. We notice that this was not something the literature has cared about, and the references about it are, in the majority, working papers or research reports not yet published in peer review journals.

Babcock and Carriquiry (2010) have investigated the validity of the assumption made by CARB about land converted to cropland being less productive than traditional cropland areas. They build an econometric model to test the hypothesis of decreasing yields in soybean production in Brazil related to expansion of soybean area and agricultural land. They conclude that the hypothesis that the yield of newly converted land is less than the yield of new soybean land in Brazil can not be confirmed, and so there is not enough evidence to conclude that land expansion has affected yield growth in that country.

Al-Riffai et al. (2010) have investigated the environmental impact of the EU biofuels mandate using IFPRI general equilibrium Mirage model, a model built in part based on GTAP. They

followed the GTAP and CARB assumptions that marginal land productivity in all regions is half the existing average productivity, but did not present any rationality about such assumption. Curiously, they increase this ratio to 75% for Brazil.

Tyner et al. (2009) have estimated the land use changes and carbon emissions related to a US corn ethanol program using the GTAP model. They have improved the GTAP model to better represent byproducts from ethanol production and have assumed that the ratio of average and marginal productivities (the elasticity of crop yields with respect to area expansion) is equal to 0.66. This value is higher than the 0.5 value assumed by CARB. The same number is used by Hertel et al. (2010), who affirms that there is no strong evidence about such value, and such lack of evidence is a lacuna that needs do be investigated by the scientific community.

Tyner et al. (2010), keeping the investigation about impacts of a US corn ethanol program, have improved the GTAP model in several ways. The most important change has to do with the ratio of marginal and average productivities, what CARB has denominated as elasticity of crop yield with respect to area expansion. As they explain, it measures the productivity of new cropland versus the productivity of existing cropland. They come up with a set of regional values for this parameter, at the AEZ level, which is obtained from a bio-process-based biogeochemistry model, known as the Terrestrial Ecosystem Model (TEM) (Zhuang et al., 2003)[2]. TEM is well-documented and has been used to examine patterns of land carbon dynamics across the globe including how they are influenced by multiple factors such as CO_2 fertilization, climate change and variability, land-use change, and ozone pollution.[3] So, the elasticity of crop yield with respect to area expansion in the Tyner et al (2009) improved version of GTAP vary across the world and among AEZs. They found that this approach reduces the impacts on land use changes, since the land conversion factors in several AEZs are higher than the single conversion factor of 0.66 used in earlier work. The conversion factors from the TEM model are shown in table A2. In this table zero means no land is available and 1 shows that the marginal and average productivities are equal. Table A2 indicates that the US land conversion factors range from 0.51 to 1, depending on the AEZ. Table A2 shows that the Brazil land conversion factors range from 0.89 to 1, and most of them are around 0.9. This means that previous estimates were underestimating the marginal productivity of land in regions as Brazil.

[2] TEM is a process-based ecosystem model that uses spatially referenced information on climate, elevation, soils, vegetation and water availability to estimate monthly vegetation and soil carbon and nitrogen fluxes and pool sizes at the 0.5 by 0.5 degree of latitude and longitude.

[3] TEM has been also applied in combination with an economic model in some peer reviewed integrated analysis of biofuels inpacts on the global emissions. See for example Melillo et al. (2009).

Table A2. Regional land conversion factors obtained from NPP data for a generic C4 crop[1]

AEZ[2]\Region[3]	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19
1	0.00	0.00	0.91	0.00	0.00	0.00	0.93	1.00	0.95	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.68	0.61	1.00
2	0.00	0.00	0.92	0.00	0.00	0.00	0.89	1.00	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	1.00	1.00
3	0.00	0.00	0.93	0.00	0.00	0.00	0.86	1.00	0.90	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.89	0.74
4	0.00	1.00	0.89	0.00	0.00	1.00	0.93	1.00	0.88	0.00	0.88	0.89	1.00	0.00	0.00	0.00	0.86	0.92	0.92
5	0.00	0.00	0.93	0.00	0.00	0.90	0.98	0.88	0.90	0.00	0.90	0.91	0.98	0.00	0.00	0.00	0.00	1.00	0.96
6	0.00	0.00	0.91	0.00	0.00	0.88	0.98	0.97	0.85	0.00	0.88	0.95	0.78	0.00	0.00	0.00	0.00	1.00	0.88
7	0.73	0.00	0.00	0.89	0.00	0.80	0.90	0.59	1.00	1.00	0.00	0.00	0.43	1.00	0.98	0.00	0.46	0.80	0.65
8	0.71	0.90	0.00	0.91	0.00	1.00	0.71	0.72	0.90	1.00	0.00	0.00	0.60	0.84	0.84	0.00	0.71	0.79	0.86
9	1.00	1.00	0.00	0.85	1.00	0.98	0.88	1.00	0.91	1.00	0.00	0.00	1.00	0.94	0.82	0.00	0.77	0.84	0.93
10	0.93	0.96	0.88	0.88	0.96	0.84	1.00	0.89	1.00	0.93	0.00	1.00	0.92	0.89	0.89	0.87	0.98	0.88	0.92
11	0.96	0.83	1.00	1.00	0.94	0.95	0.90	1.00	0.87	0.84	0.00	1.00	0.79	0.89	1.00	0.00	0.00	0.77	0.96
12	0.89	0.86	0.91	0.00	0.95	0.92	0.90	1.00	0.84	0.00	0.00	1.00	1.00	0.00	0.89	0.00	0.00	1.00	0.98
13	0.92	1.00	0.00	0.55	0.00	1.00	1.00	0.00	1.00	1.00	0.00	0.00	1.00	0.63	0.97	0.00	0.00	0.00	0.00
14	0.51	0.89	0.00	0.80	0.00	0.92	1.00	0.00	1.00	1.00	0.00	0.00	1.00	0.90	1.00	0.95	0.00	0.00	0.00
15	0.71	0.90	0.00	0.83	1.00	1.00	1.00	0.00	0.64	1.00	0.00	1.00	1.00	0.90	1.00	0.87	0.00	0.00	1.00
16	1.00	0.89	0.00	1.00	0.00	1.00	1.00	0.00	0.92	0.00	0.00	1.00	1.00	0.85	1.00	1.00	0.00	0.00	1.00
17	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1 In this table zero means no land is available and 1 means that the marginal and average productivities are equal.
2 Rows are AEZs from AEZ1 to AEZ18.
3 Columns are regions and regions are listed in Appendix B.

Source: Tyner et al. (2010). Regions and AEZ correspondence are described in the paper.

Besides the use of the TEM model to calculate the elasticity of crop yields with respect to area expansion, the only other attempt to estimate this parameter was documented in a letter from the Brazilian Sugarcane Industry Association (UNICA, 2009) addressed to CARB regarding its impressions and recommendation about the LCFS. In this letter, UNICA affirms that empirical data in Brazil suggests that crop yield elasticity with respect to area expansion should be around 0.9-0.95. To calculate this number they have separated new and traditional areas in Brazil according to the growth in planted area for crops in the time horizon from 2001 to 2007, based on microregional data, and compared the yields between these two types of area.

2. New Estimates of the Productivity of New Land vs Old Land in the United States

One of the crucial assumptions for the calculation of the LUC carbon intensity of biofuels is the so-called elasticity of crop yields with respect to area expansion. This elasticity attempts to capture differences in yields from newly converted lands and established areas of the same crop. The basic premise of CARB is that "all of the land that is well-suited to crop production has already been converted to agricultural uses, yields on newly converted lands are almost always lower than corresponding yields on existing cropland." For the CARB analysis, this input for the GTAP model was selected in the range of 0.5 to 0.75. Sensitivity analysis indicates that a change from 0.5 to 0.75 results in a 38% reduction in LUC intensity.

Figure 1 shows that since 2006, the prices of corn, soybeans, and wheat have risen dramatically. In response to stronger prices, aggregate crop acreage has increased in the United States. NASS reports acreage of principle crops. The average acreage over the 2004 to 2006 time period was 2.95 million acres lower than the average over 2007 to 2009 time period. Thus the 60 to 80%

increase in prices has led to about a 1% increase in acreage. Over the same two time periods, average corn ethanol production increased by more than 5 billion gallons.

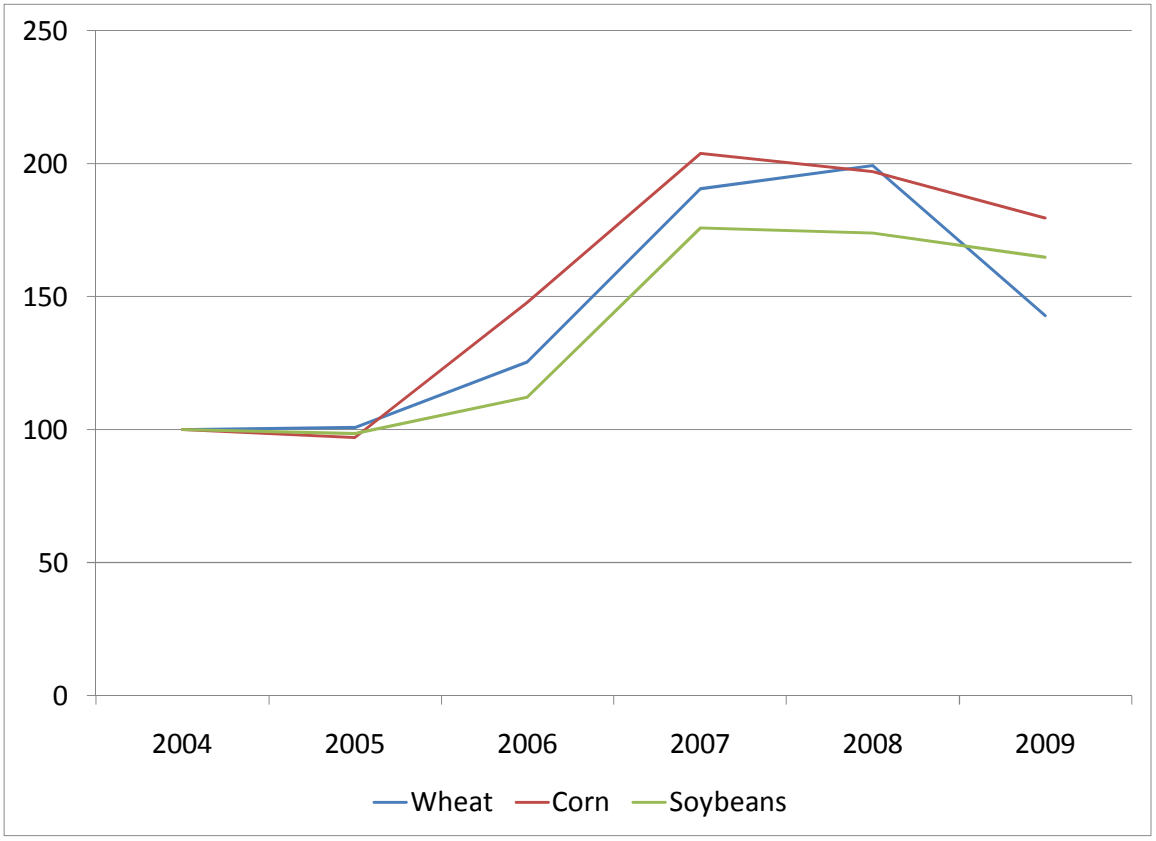


Figure 1. Index of Prices Received by U.S. Farmers for Corn, Soybeans, and Wheat (2004 = 100).

Figure 2 shows crop acreage of the top 15 (in terms of acreage) U.S. crops. From 2006 to 2009, crop acreage of these 15 crops increased by about 5 million acres. As shown, acreage is dominated by corn, soybeans and wheat, all of which showed an increase.

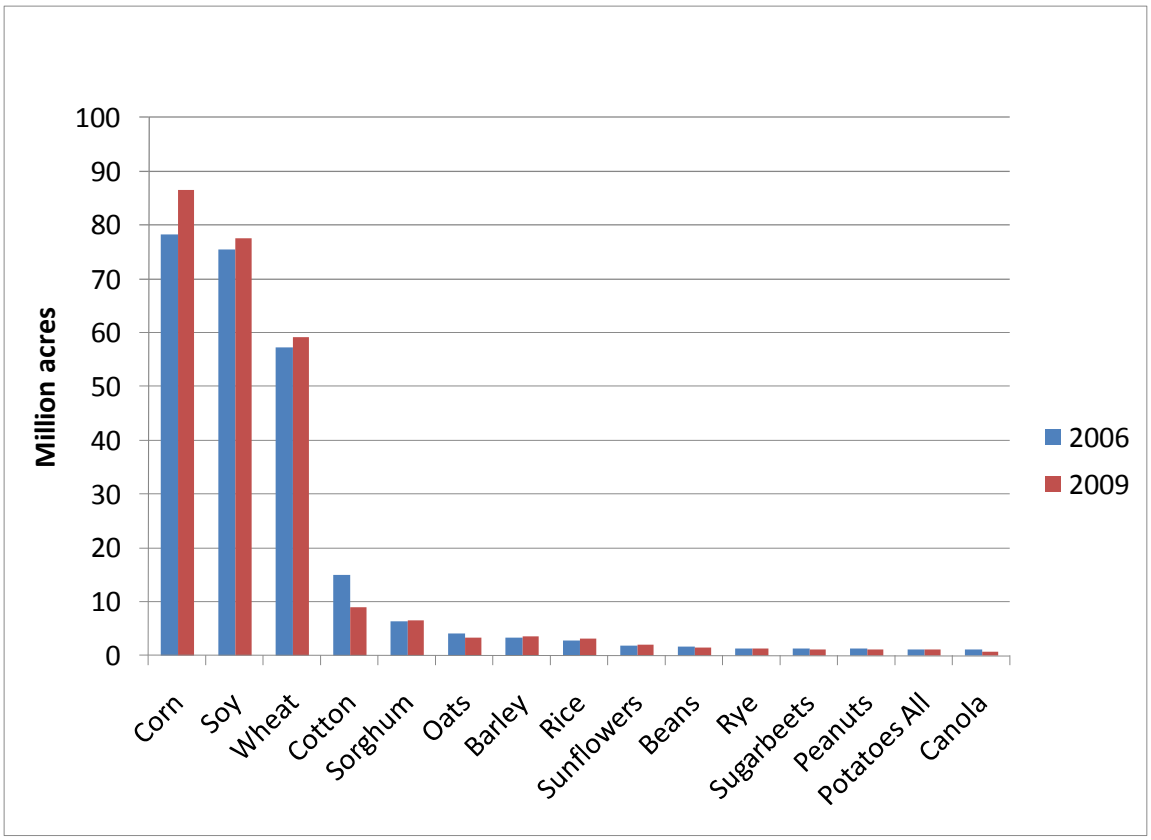


Figure 2. U.S. Crop acreage in 2006 and 2009

Figure 3 shows the change in acreage for states that showed the most change from 2006 to 2009. Perhaps not surprisingly, large agricultural states show the most change in acreage. The acreage decreases in North Dakota, Illinois and Indiana are likely due to adverse planting season weather that prevented farmers from entering their fields. Figure 4 presents the same data but on a percentage basis.

The data demonstrate that U.S. crop acreage expanded due to higher crop prices. This expansion should give some insight into whether crop yields in areas that expanded are higher or lower than crop yields in regions that were already being planted before the large increase in crop prices.

One method for determining the extent to which crop yields in expansion regions are lower than in regions that were previously planted would be to overlay the location of expansion regions on a soil and climate map and to determine any inherent difference in productivity. Due to limitations in time, resources, and expertise on our sub-group, an alternative method was devised.

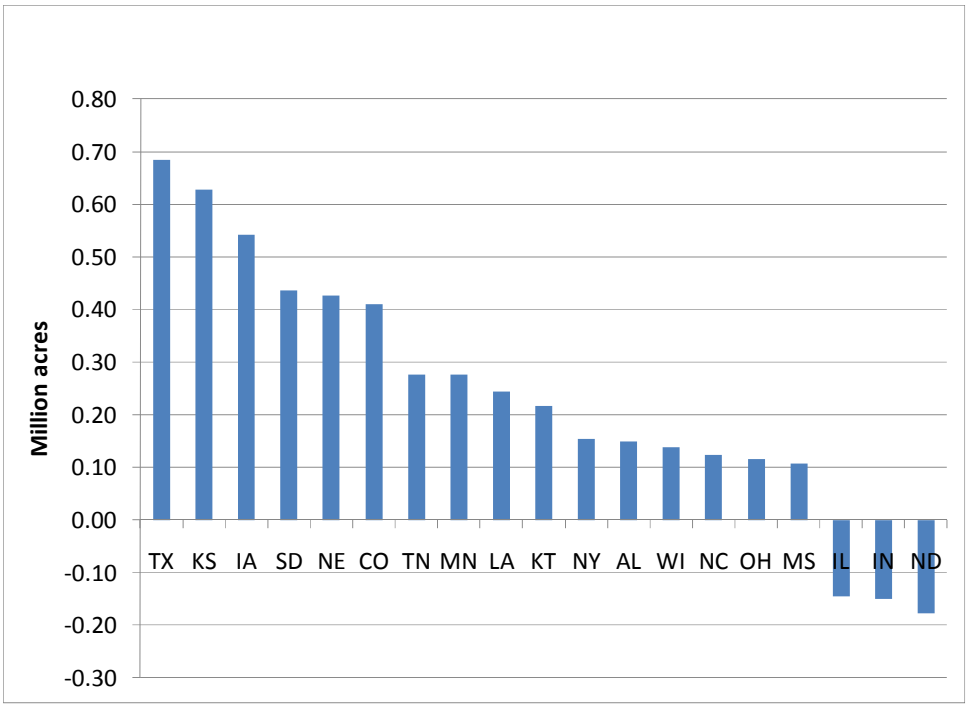


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Figure 3. State Level Change in Crop Acreage of 15 Top U.S. Crops

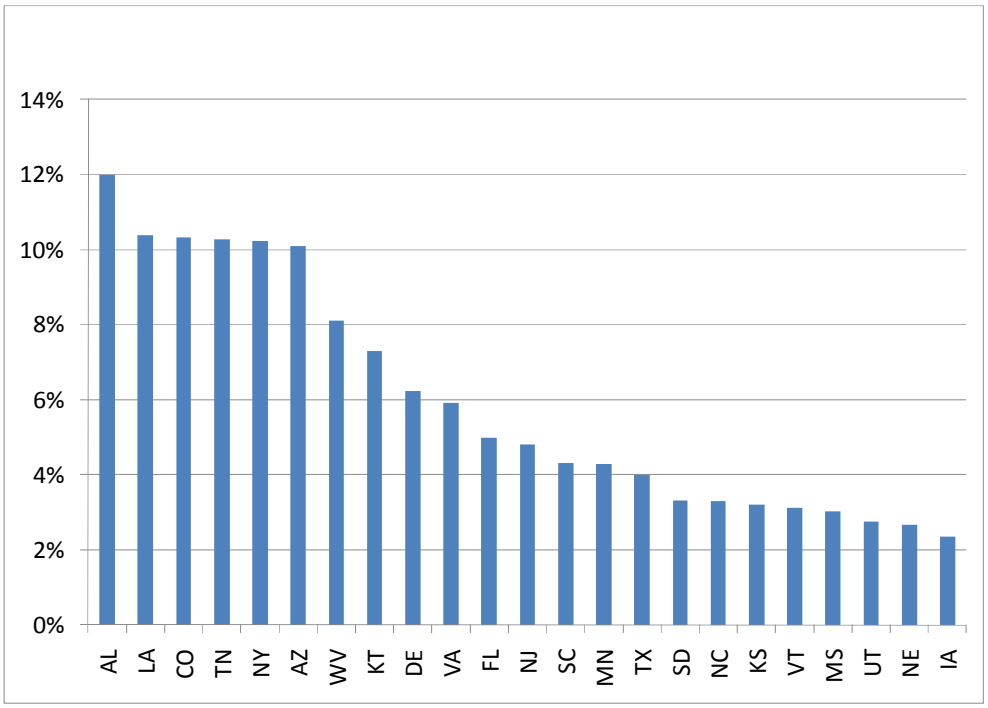


Figure 4. Percentage Change in Acreage of 15 Top Crops

A good metric of productivity of an area that is crop specific is the average crop yield in a region. If all areas that expanded crop acreage have lower average yields than areas that were previously planted, then we can say that land on which crop expansion occurred is less productive. Thus all one needs to do is to find the areas that expanded, estimate average crop yields in those regions, and compare the yield on expansion areas to the average yield that would have occurred had the expansion not taken place. This is a fairly straightforward exercise and we use NASS county data to make the calculations.

3. Data and Methods

Data of yield and planted area for each county was obtained from the National Agricultural Statistics Services (NASS) from 2000 to 2008 for the top 15 principal crops, which account for approximately 80% of total planted area for principal crops in the United States. The 15 crops are corn, soybeans, wheat, cotton, sorghum, oats, barley, rice, sunflower, beans dry edible, rye, sugar beets, peanuts for nuts, potatoes, and canola.[4] 2009 data for wheat has not yet been released by NASS so we only use the 2007 to 2008 time period to measure acreage expansion.

The first step is to measure crop yields for each county. To minimize the effects of weather variations, trend yields for each county were estimated for each crop and county. These trends were then used to estimate what yield would be in 2009. This 2009 trend for each crop is used to measure the crop-specific productivity of each county.[5]

The second step is to identify those counties where expansion occurred. This was accomplished by comparing average planted acreage of the 15 crops in 2007 and 2008, and comparing this acreage to average planted acreage in the period 2005 to 2006. If planted acreage in the latter period was higher, then the county is designated as an expansion county. Figures 1 and 2 show the change in acreage on both an acreage basis and a percentage change basis.

[4] Alfalfa is actually in the top 16 crops, but county level data for alfalfa is not available.

[5] Ideally more time would be spent collecting data from further back and to ensuring that all estimated trend yields give good estimates of productivity differences. But time and resource constraints being what they are, such an effort could not be done. Thus the county productivity measures reflect average growing conditions from 2000 to 2008 in each county and trend yields may be affected by yield outliers that occur either early or late in the sample period.

Figure 1 Percentage Change in Total Planted Acreage

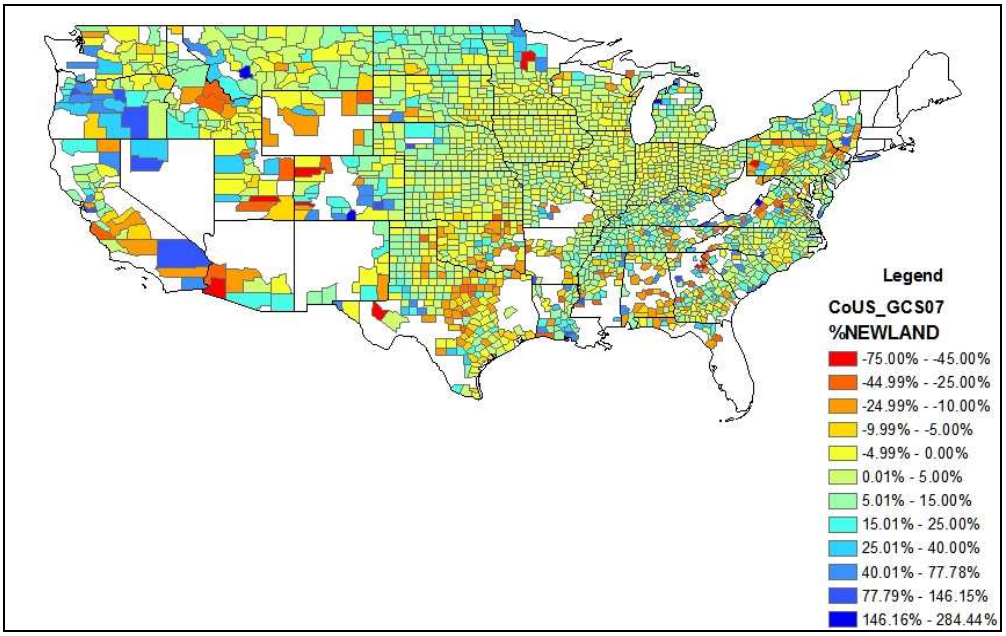
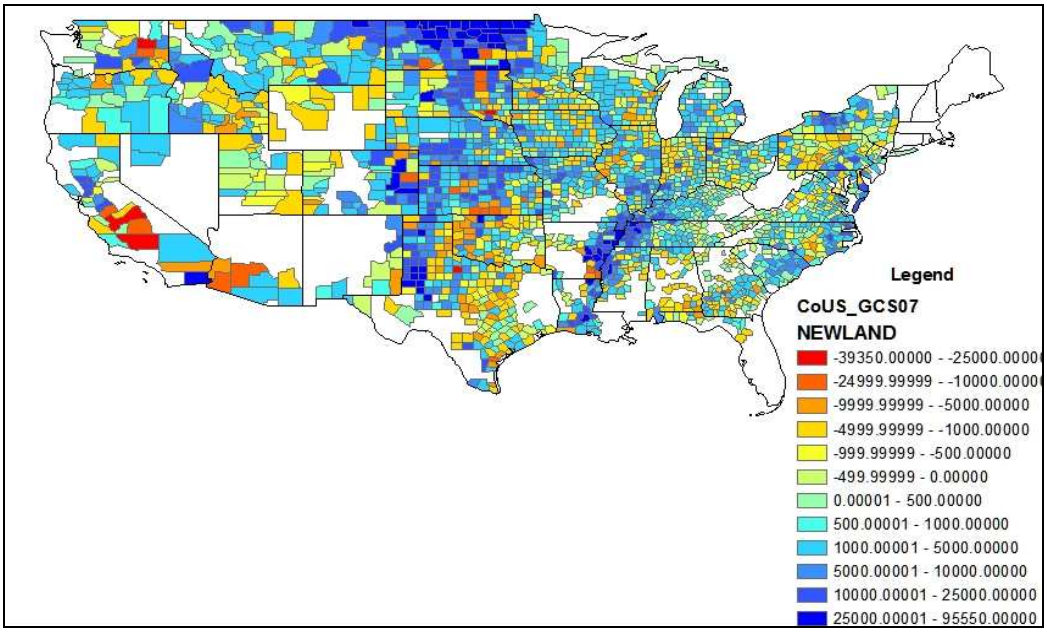


Figure 2 Change in Total Planted Acreage



Not all crops in expansion counties increased their acreage levels. We want to measure crop-specific productivity only for those crops that actually increased acreage in the expansion

counties. Thus the next step was to identify those crops that increased acreage in each expansion county.

For those crops that increased in acreage in expansion counties, the 2009 trend yield for the county is taken as the yield that occurred on the expanded acreage. This may overstate the productivity of the land that was newly planted to the crop within a county, but this is as fine a geographic resolution that we will be able to obtain using county data.

The average yield for a crop across all expansion counties was estimated by weighting the 2009 trend yield for the crop in each county by the change in crop acreage in the county.

The average yield that would have occurred without expansion was estimated by weighting each 2009 county trend yield for the crop by the average planted acreage across 2005 and 2006. This measures what U.S. average yield would be in 2009 had acreage not changed.

The ratio of the average yield across all expansion counties to the average yield that would have occurred without expansion is an estimate of the elasticity of crop yields with respect to area expansion. The results are shown in Table 1.

Table 1. Results

Commodity	No Expansion Yield	Yield in Expansion Counties	Ratio
Wheat (bu)	40.5	49.8	1.23
Potatoes (cwt)	426.9	519.8	1.22
Peanuts (lbs)	3244.8	3622.6	1.12
Barley (bu)	60.3	63.4	1.05
Canola (lbs)	1537.3	1567.3	1.02
Rice (pounds)	7141.3	7014.0	0.98
Cotton (lbs)	914.3	886.4	0.97
Corn (bu)	158.7	151.4	0.95
Rye (bu)	19.3	18.0	0.93
Beans (lbs)	1726.7	1584.4	0.92
Sugarbeets (tons)	26.8	24.0	0.90
Sorghum(bu)	70.8	60.8	0.86
Oats (bu)	62.3	52.6	0.84
Soybeans (bu)	43.5	35.7	0.82

As shown, the results vary quite a bit across crops. On aggregate measure would be to weight the ratios by 2009 planted acreage. The resulting weighted average is 0.98.

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