Biofuels Policy and the Empirical Inputs to GTAP Models

Preliminary

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Major Question for this Talk

How good are the empirical estimates of market responses that are used in GTAP (and related) models of bio-fuels? What are the implications for policy analysis?

Some initial conclusions

- Some modeling framework is needed and GTAP provides one useful framework
- GTAP is (relatively) strong on equilibrium modeling, weak on empirical inputs
- Parameter estimates used in the GTAP bio-fuels models typically have a weak empirical basis.
- GTAP estimates of Yield Responses are higher than indicated by many research papers
- The treatment of "gains" from large reductions in food consumption is inappropriate
- The treatment of land elasticities should be improved

Major Conclusions

- Overall, there is no *single version* of the GTAP model that has a sufficiently strong scientific, empirical basis to serve as the basis for a policy decision as large in potential magnitude as the proposed biofuel mandates.
- A range of scientifically plausible GTAP results should be considered, together with the results of alternative (more empirically based) modeling approaches
- One of the emphasized GTAP models should consider the case of near-zero crop-yield price elasticities.
- Policy Makers have to take a stand on how to treat the social welfare loss from reduced food consumption.

Economics of Bio-fuel Carbon Policy

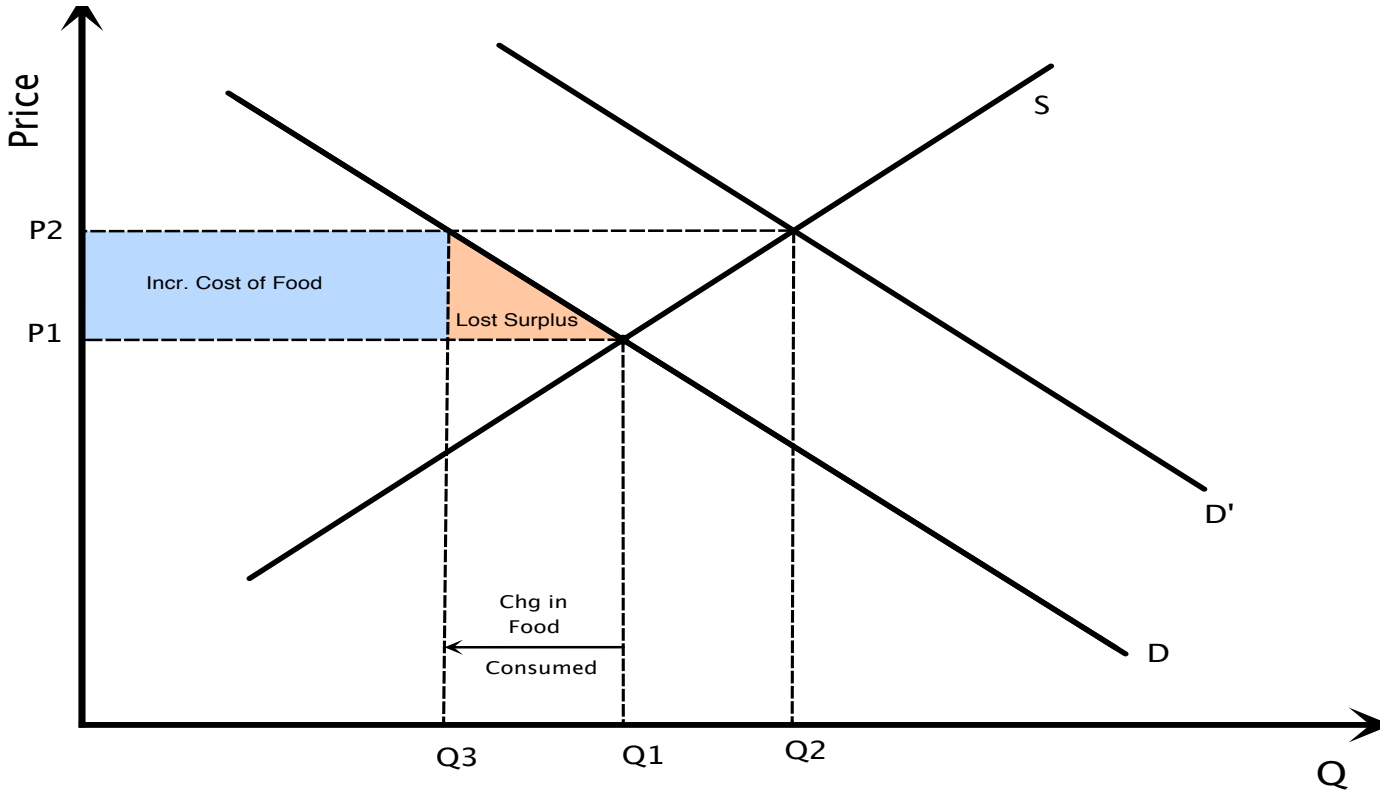
- Carbon gains from bio-fuels come from some combination of
  - Reduced Human Consumption of Crops
  - Increased Production of Crops via
    - YIELDS
    - LAND USE

All of these effects are *price-mediated* ("indirect") via the world market for food and fuels. To judge them, we have *no choice* but to consider "supply and demand" models of world food markets in equilibrium.

These models will be driven by [i] pure modeling choices and by [ii] **various assumed measures of the price responsiveness ("price elasticities") of food demand and supply**.

If the demand and supply elasticity estimates are bad, the output will be bad.

Figure: Bio-fuel Mandates Increase Demand for Crops



Crops used for bio-fuel: $Q2 - Q3$

Increased Production: $Q2 - Q1$

Relative Elasticities

Classic result from Intro to Microeconomics:

- The mandate raises price
- p goes up more as D and S are *less price elastic*
- How much of the mandate is provided by *more supply* vs. *less demand* is determined by the *relative price elasticities* of D and S (the relatively more elastic side accounts for more)
- The elasticity of crop supply is the sum of the price-elasticities of *yield* and *land use*.

To say anything about biofuel policy, have to the know the elasticities of demand, yield and land use.

Searchinger, et al, and Indirect Land Use

To the degree that the mandate is met (in market equilibrium) via increased land use, that may have very bad carbon consequences. (Some land worse than others.)

But note also:

Yield increases also have carbon implications (e.g. fertilizer use when the marginal productivity of fertilizer is low.)

Demand decreases (less food consumed) have large social welfare consequences.

GTAP Model

Greatly elaborates the S & D model of crops.

Many commodities, crops, inputs, fuel, countries, agricultural regions, etc. Interdependent supply and demand for each.

To compute the solution of the model have to know MANY demand elasticities, MANY input elasticities, etc.

Both *own* elasticities and all *cross* elasticities (e.g. effect of increased price of corn on wheat land use.)

Number of elasticities is partly controlled via "CET" functional form. Functional form itself determines many relationships (given that number of free parameters is much smaller than number of own and cross-price elasticities.)

BUT STILL: very, very many elasticities have to be empirically known.

GTAP Elasticities

Most presentations of GTAP style models focus more on [i] model framework and [ii] model results than on [iii] empirical inputs to the framework.

Contrast to Modern Micro-Empirical Modeling:

fewer parameters (simpler model, leaving out much detail and some equilibrium features) but paying much more attention to credible empirical estimates

How to Learn About Elasticities from Market Data

This topic is the gem of 20th century econometrics. Mostly ignored in the empirical work that forms the basis of GTAP results.

Central Insight: Market Data is created in a market equilibrium, but S & D curves are moving around over time and space.

Statistical estimates have to take this into account.

Most basic lesson: need an "exogenous' demand shifter" to trace out supply, an "exogenous supply shifter" to trace out demand.

Least Squares Estimates

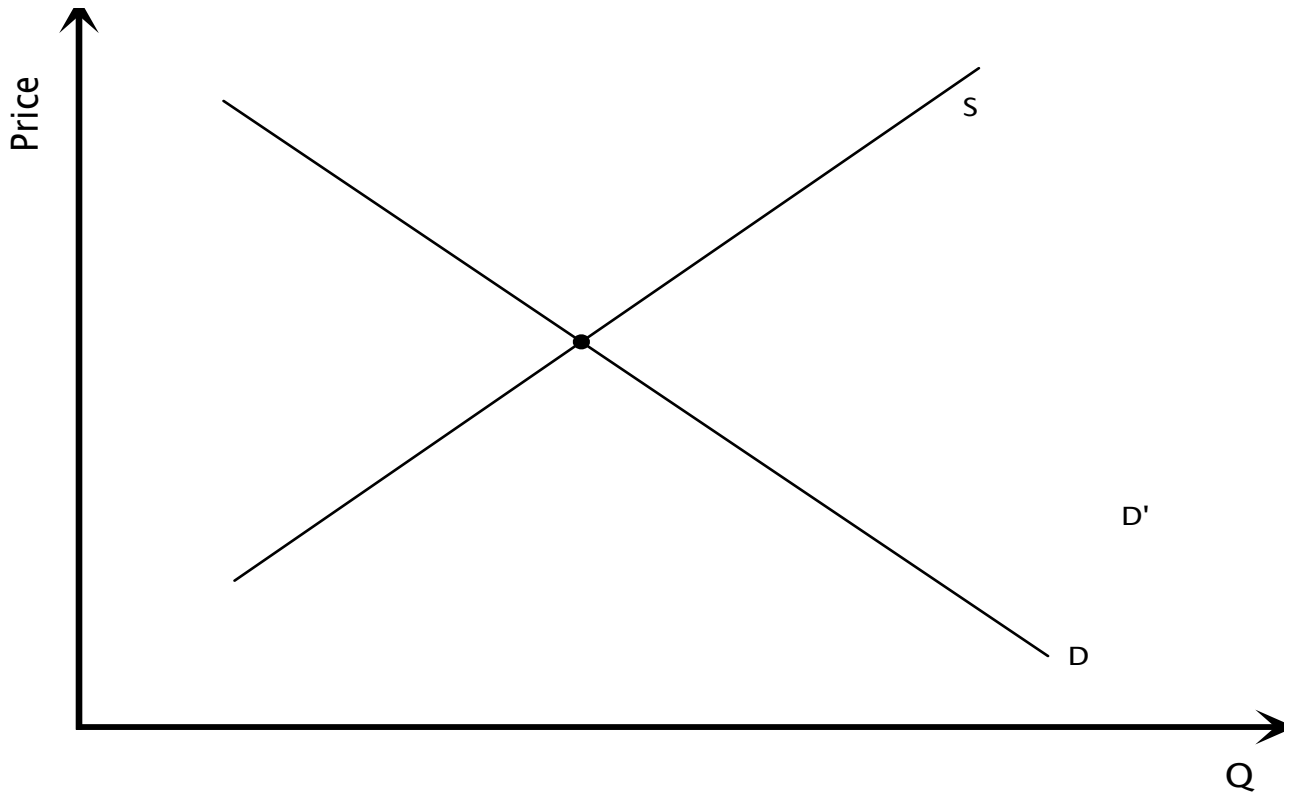
Some of the GTAP parameters are based on "least squares" regression estimates fit to market generated data; for example, yield regressed on price plus a time trend (to control for technological change.)

These estimates ignore the "simultaneity" problem that yield and price are determined together. Price is not an "exogenous variable," but an endogenous variable.

Co-movements of price and yield can reflect movements in other (confounding, unmeasured) factors that don't tell us about elasticities.

"What do Statistical Demand Curves Show"

Working (1927)



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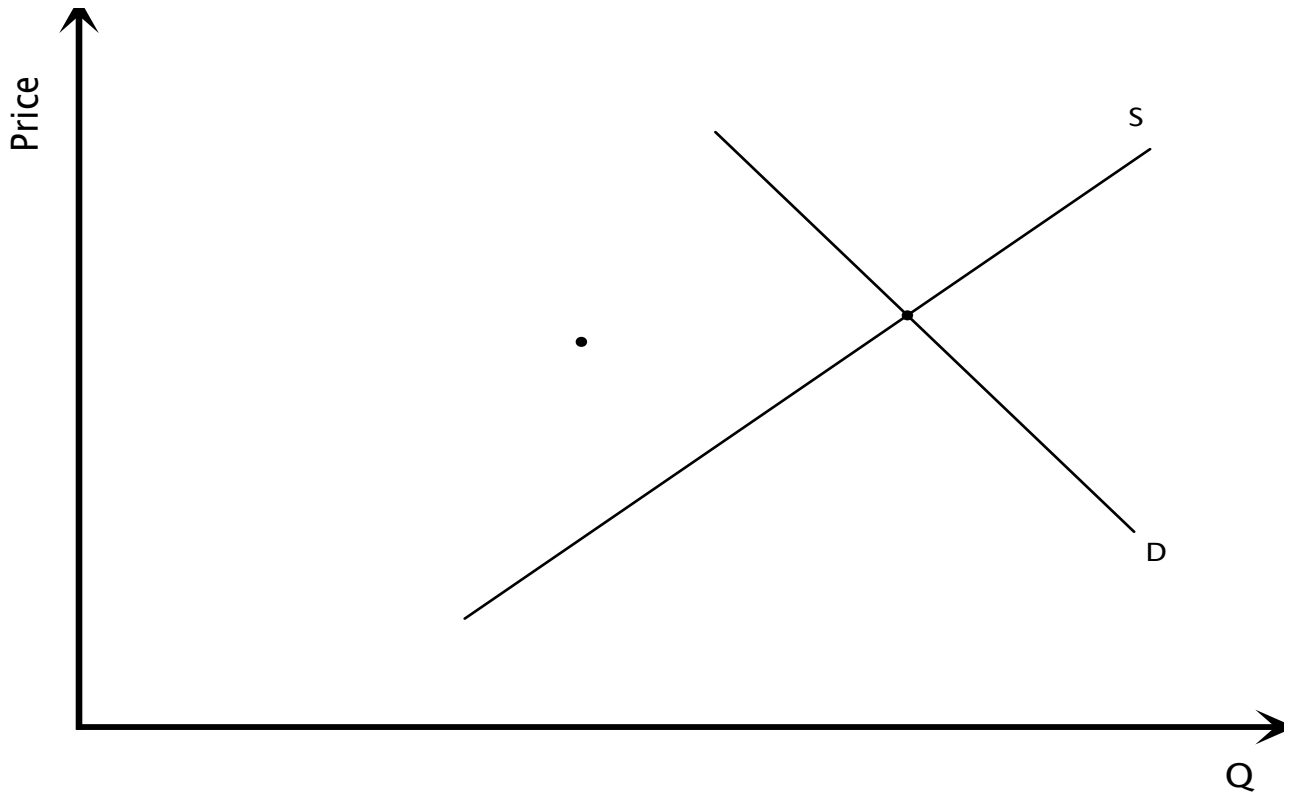

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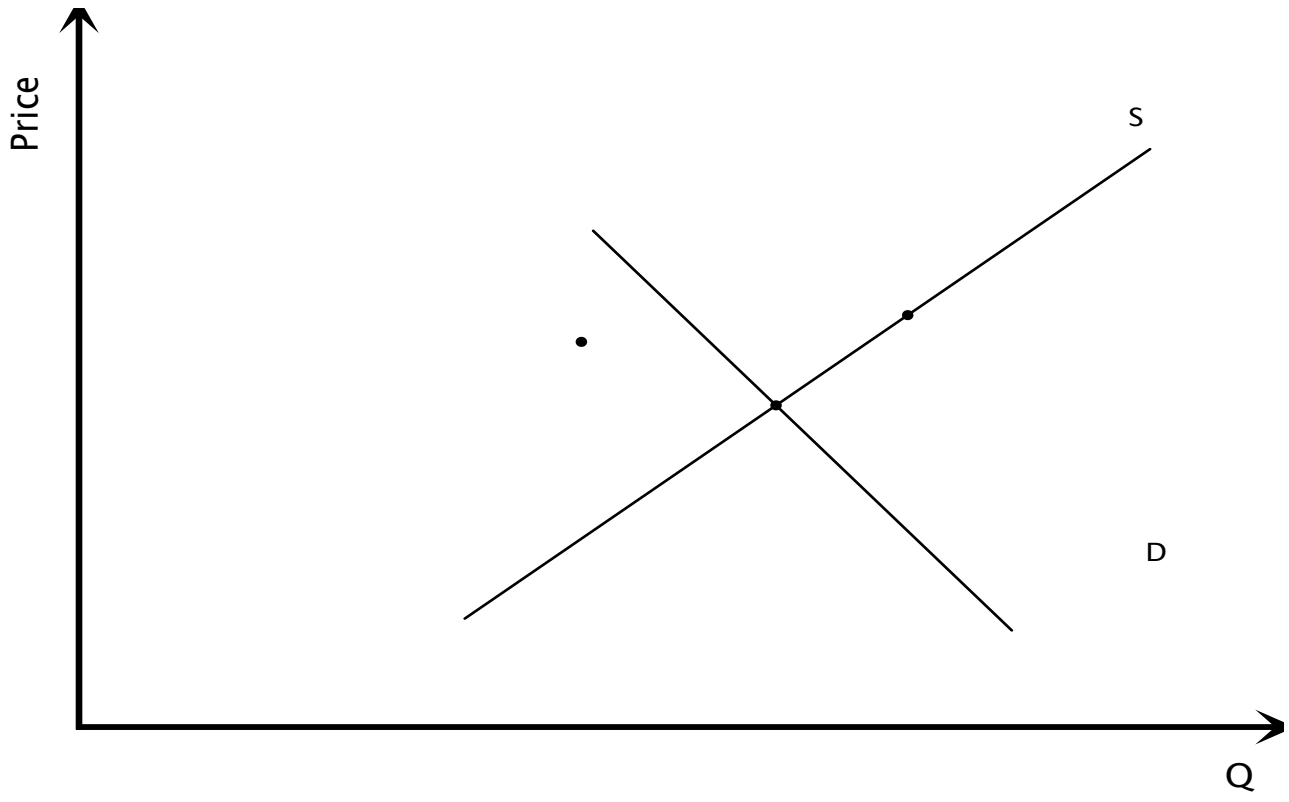

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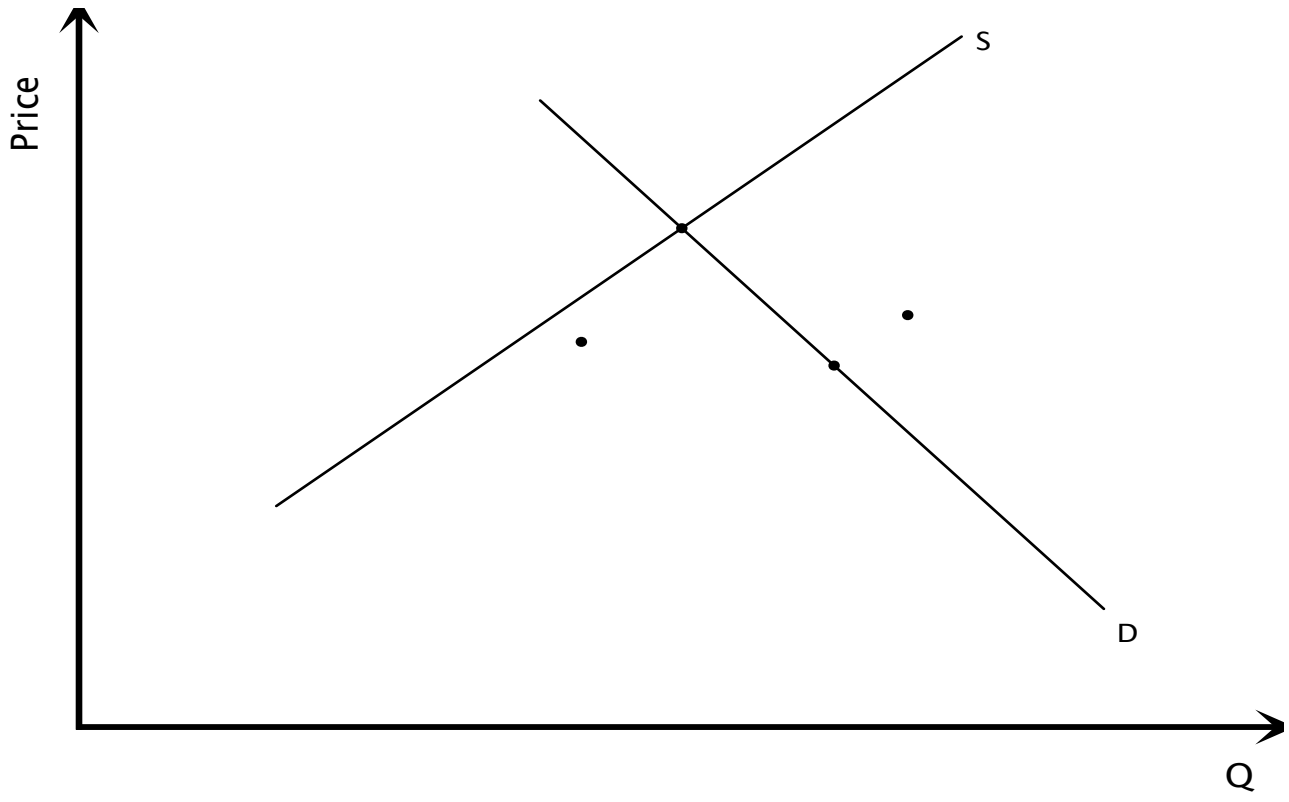

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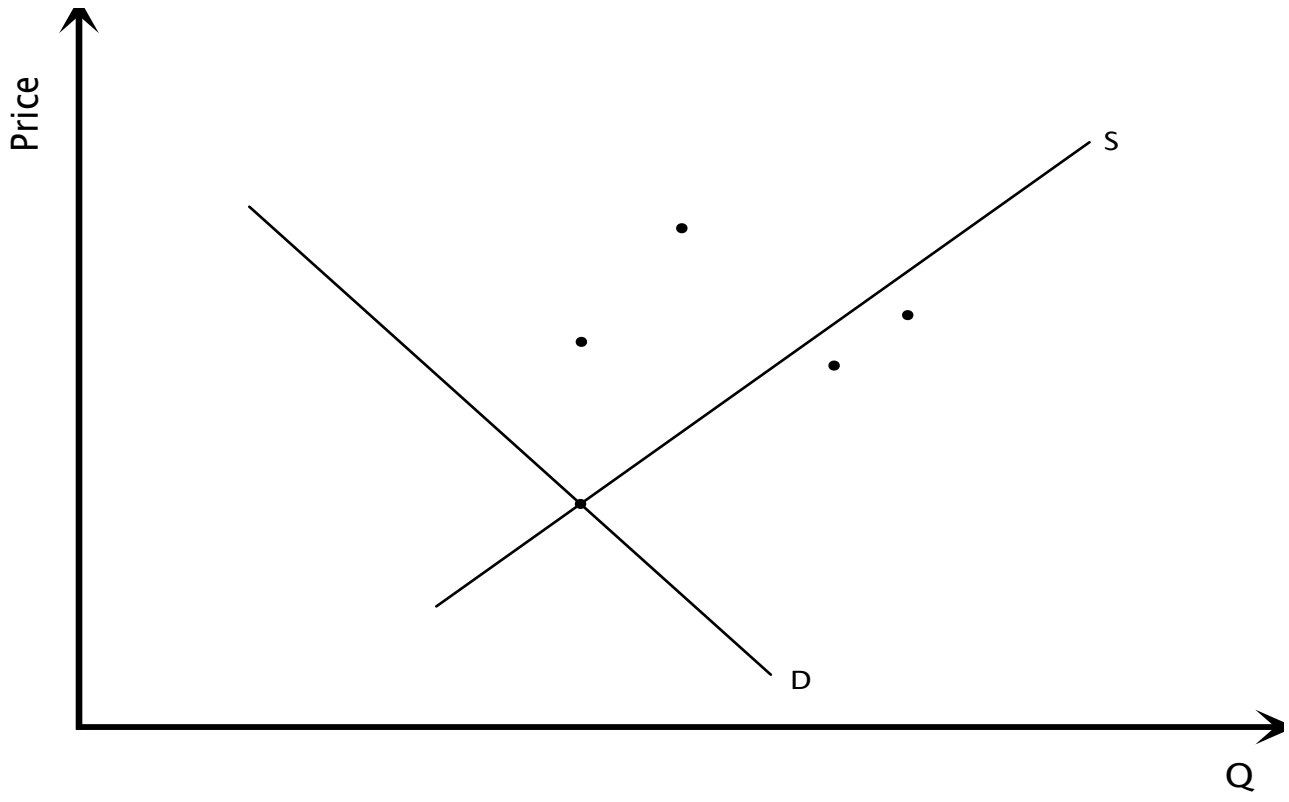

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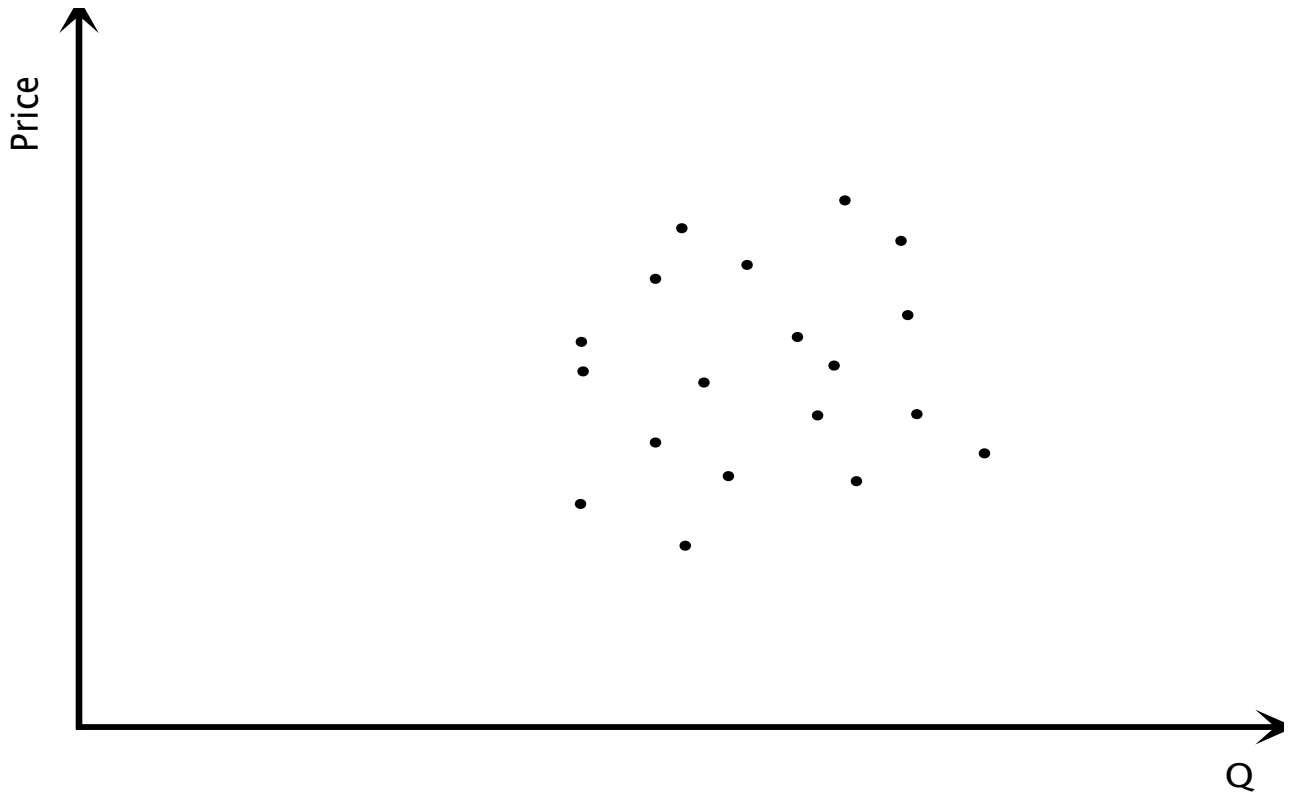


What does best-fit line through S & D data show? Nothing

Instrumental Variables

P. G. Wright (1928): to estimate production, need a variable that shifts demand on average, while not affecting supply.

An instrumental variable
for price in the supply equation is a demand shifter that

1. is not also a supply shifter (i.e. is "excludable" from supply),
2. is not correlated with the supply side unobservables (i.e. is "exogenous"), and
3. is correlated with price (because it is shifting demand and therefore equilibrium p.)

Example

Roberts and Schlenker (2010 NBER working paper) on crop S & D and bio-fuels.

- To learn S, need an exogenous demand-side shifter that is excluded from S.
- To learn D, need an exogenous supply-side shifter that is excluded from D.

Roberts and Schlenker:

- Weather shifts S and reveals supply
- Past weather shifts inventories, which are a (very close) substitute in demand for new crop production, so past weather shifts the demand for new crops and reveals current supply.

IV as "Natural Experiments"

One interpretation of instrumental variables (IV) is that we are looking for "natural experiments" as instruments. In this case, we want the natural experiment to mimic, as much as possible, the effect of greatly increased bio-fuels use.

Exogenous Changes in D

Any serious empirical work

on the question of estimating production relationships has to begin with the question of how to deal with the problem of endogeneity. What is the exogenous change in D that traces out supply?

Or at least: what other method and set of assumptions justifies some other approach?

Other Possible Instruments

In a time-series or cross-section:

- Changes in Farm Policy? (Plantinga (1996) Plantinga (1996) uses changes in diary price supports in a land-use study, what about Euro CAP?
- Transportation costs? (Pfaff (1999) looks at cross-sectional variation in Brazil.)
- Changes in Tariffs / Trade?
- Changes in bio-fuel demand? (not yet)

Key points

1. Price, quantity, yield & land-use are jointly and *simultaneously* determined in equilibrium.
   - Therefore, correlations or traditional regression analysis of, e.g., price and yield reveal correlation, *but nothing about causation*.
   - Classic "instrumental variables" solutions to this problem say to study supply via plausibly *exogenous* changes in demand that can trace-out causal supply relationships.
2. Different empirical approaches will identify short vs. long-run elasticities. For bio-fuels, want the long-run elasticity.
3. Most recent studies ignore simultaneity and many focus only on short-run elasticities

GTAP: Yield Estimates

Most emphasis in written justification for 0.25 (Keeney-Hertel) is placed on US time series least-squares estimates, typically regressing annual yield on (expected) price and a time trend

Studies do not deal with simultaneity / endogeneity bias.

Possible Bias in Least Squares

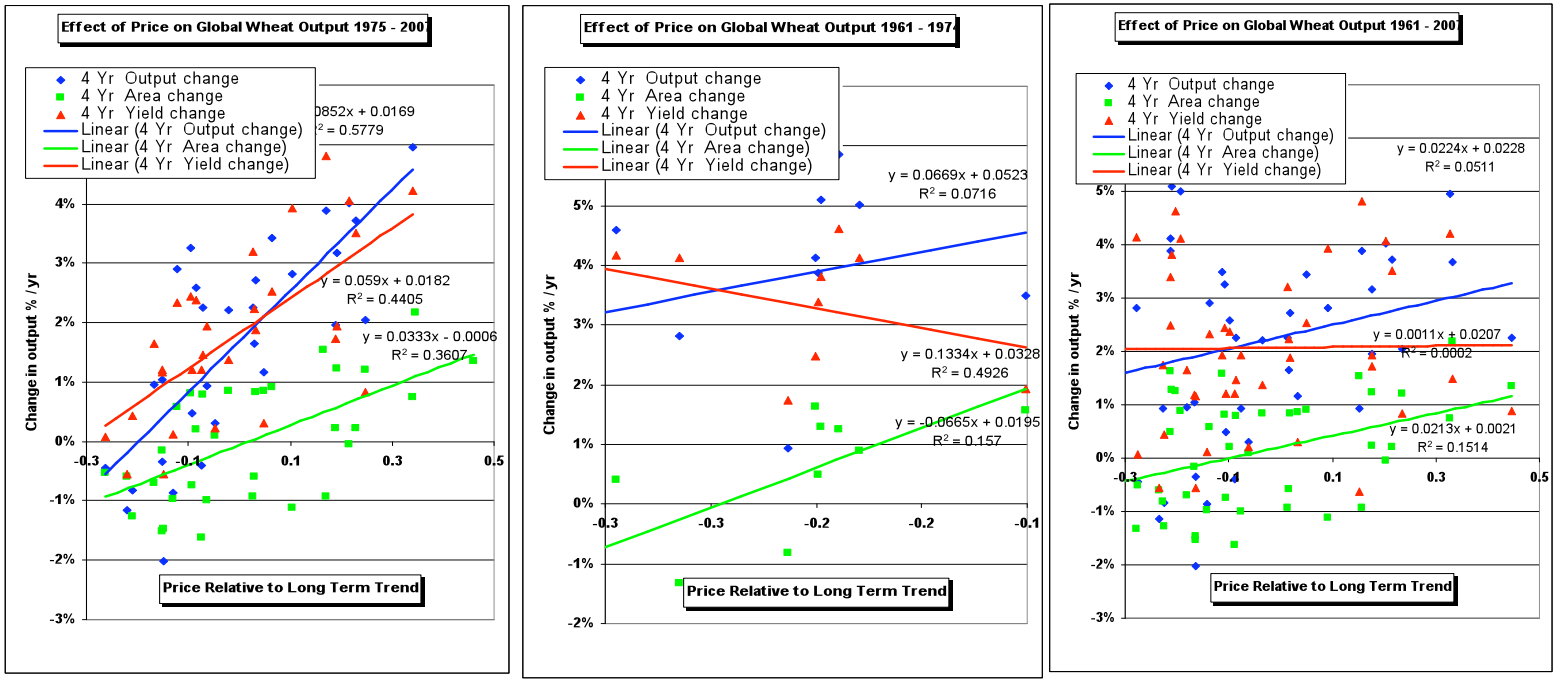
Classic simultaneity bias is that when current yields are exogenously good (good weather), current price is low, biasing the price coefficient to zero (or negative.)

However, studies use expected price (often futures prices at $t-1$) and the direction of the bias is not as obvious, especially if there is more than one unmeasured confounding factor.

Example: if D from China happens to grow when technology is improving faster than trend (and vice-versa), we will find a positive yield-price correlation that does not reflect causation from price to yield. Upward bias in OLS.

Instability in Yield-Price Correlations Over Time

Trends in yield and area vs. price before and after 1974, and whole data series 1961-2007



Yield-Price Correlations in Lynwood-Lywood, Pinkney and Cockerill (2009) Data

US Time Series / Least Squares Corn Yield Elasticities: Comparison of Keeney-Hertel 2009 Parameter Reports to Authors' Comments

Paper	Time Period	KH Reported Elasticity	Authors' Report / Comments
Houck and Gallagher	1951-1971	0.24-0.76	same
Menz and Pardey	1951-1971	0.61	same, replication of Houck Gallagher
Menz and Pardey	1972-1980	*	statistically insignificant and treated as zero given additional agronomic and econometric evidence on fertilizer
Choi and Helmberber	1964-1988	0.27	0.27 is "upper bound" that includes effect of both technology and price; estimate with control for technology is *negative*; overall conclusion is that "yields are found to be quite insensitive to price."
Kaufmann and Snell	1969-1987	*	input (not yield) elasticity; range of 0.0002 to 0.65; elasticity is 0.02 "at the sample mean"

* Not Reported in KH 2009

More Evidence on Yields

- Keeney-Hertel (KH) summarize farm-level studies as typically finding no price effects on yields
- KH and others, however, emphasize variation in fertilizer use (correlation with price, variation over space and time). Why increase fertilizer if no yield effect?
- But then why difficulty in relating yield to price?

Two Rationalizations of Results

1. KH: Management Heterogeneity
   - KH: while individual farms typically show no yield-price effect, perhaps when price rises better farmers take over
   - ... interesting, speculative, perhaps stronger in US than elsewhere
2. Low *Marginal* Productivity of Inputs: Menz-Pardey, Some Agronomics
   - Idea is that the marginal return to fertilizer is rapidly decreasing near the optimal or usual level of use.

Figure: Cerrato-Blackmer Fits to Yield Experiments

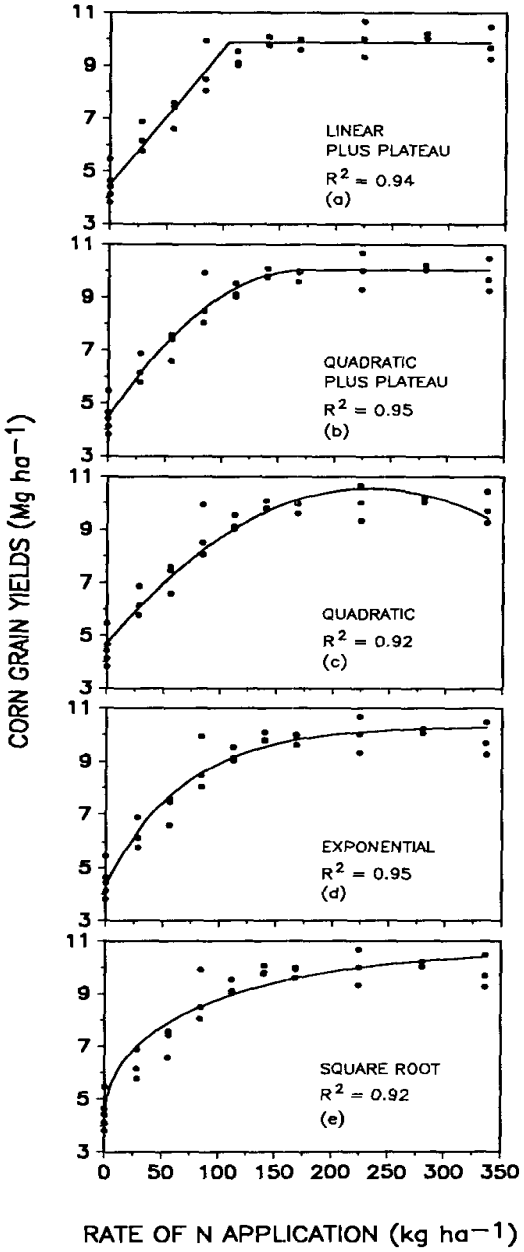


Fig. 1. Example of how each of the five models fits the response data for one site-year (Site 5 in 1986).

Modern Econometrics Evidence on Yields

Roberts and Schlenker (NBER 2010) argue against any large effect of prices on yield because

- Prices are highly serially correlated while yields are not, and
- Prices are set in a world market for crops, but the cross-country spatial correlation of yields is low.

Huang and Khanna (2010) use a cross-section time-series panel-data of counties from 1977-2007. They use "modern" econometric methods, applying a fairly standard instrumental-variables panel data method (are the instruments convincing?) Finding: "the coefficients on crop prices can be translated into a yield elasticity of 0.15, 0.06, and 0.43 for corn, soybeans, and wheat, respectively."

Some Conclusions on Yield

Overall the tradition empirical literature on yields is very weak and uses methods that are contrary to classic econometric principles. The recent "modern" literature is small.

Any CGE / GTAP results that show large gains from yield increases are inconsistent with at least a very large fraction of the empirical literature. including some very recent work.

- Substantial weight should be put on a GTAP run that assumes zero net yield growth.
- There is some intellectual argument for higher yield elasticities, and some weight might also be put on GTAP runs that assume moderate yield gains.

Land Use Elasticities

(my analysis is less far along here)

- Same concerns about endogeneity of price and land use apply here.
- GTAP models based on US results. Other regions have very different land-use rules, capital markets, agronomic features, etc.
- GTAP predictions ought to be compared to actual historical record (Gibbs)
- Hard enough to get an empirical estimate of "aggregate land elasticity," very hard to get all the cross-land use elasticities (use of land for wheat with respect to price of corn.
- CET production function has to impose many of these cross-price effects via functional form governed by a few parameters.
- Other kinds of empirical studies could use richer empirical specifications (Lubowski, Plantinga, et al: flexible logits, etc.) How different are the implications for exogenous increases in price?

Unmanaged Forest

Unmanaged forest is missing from model because of a lack of observed land-rent. Gibbs (2010) says this is a large fraction of world land and is of particular carbon interest.

Again, other kinds of empirical models (not fully world general equilibrium) can handle land use choice without observed rents for forest. At the least, need a comparison of GTAP to these studies.

show Gibbs slides about here

Long vs. Short Run Elasticities

Particularly for land-use elasticities, looking for long-run effect of an expected long-run change in price that comes from a long-run increase in bio-fuels.

Annual time-series studies, at best, get short-run effects, likely to greatly understate long-run change in land use.

In the ag literature: Nerlove (1956) model of slow adjustment to long-run equilibrium. Many "modern" improvements, e.g. Eckstein (1985)

Long-run studies of cross-sectional land-use may be better than time-series (Stavins & Jaffe (1990) Pfaff (1999), etc.)

Long-run vs. Short-run and Choice of Data

Cross-Sectional Data

(or a combination of cross-section and time-series) may be best for the study of long-run land use. Time-series models at least have to take account of slow adjustment.

CET Land Functions

Not clear (to me) how the non-CET land-use studies directly map into CET elasticities – fit to be similar "in the middle" of the data?

The CET function, calibrated to an emipirical study, will still behave differently than the empirical estimated function, particularly for a large policy experiment that is away from the middle of the data.

Open question: how restrictive is the CET function?

Conclusions about the GTAP Land Model

- The empirical basis of GTAP land-use model is not well established.
- The US experience may not be general
- The lack of unmanaged forest in the model is troubling
- The CET function may be restrictive in important ways (more research)

- The GTAP model land results should be [i] compared to the historical record and [ii] supplemented with more empirically based studies that predict the land-use effects of exogenous changes in prices.

Demand Reduction as Source of Carbon Gain

Roberts and Schenkler (2010) estimate that aggregate demand for calories from potential biofuel stocks is quite low, but nonetheless predict that demand reduction would provide about 1/3 of the biofuel stock. (Because supply is also fairly inelastic.)

In RS (2010): Demand reduction $\Rightarrow$ \$155 billion in lost consumer surplus worldwide.

Social welfare loss would likely be *worse* if we highly weight reduced food consumption by the world's poorest consumers. (These are likely the relatively most elastic and the most harmed by a reduction.)

GTAP (and other CGE) results are similar in terms of demand reduction.

show JRC tables of predicted demand reduction here

Reduction in Food to Reduce Carbon?

What is the proper attitude of policy-makers toward reduced carbon emissions via reduced food consumption?

Would one support a direct tax on food to fight global warming?

Economists would ask:

- What is the total social welfare impact of the policy? Need to take a stand on the dollar welfare gain from avoided climate change and on distributional impacts of both food prices and warming.
- Alternatively, what is the *most socially efficient* policy to achieve each given level of avoided climate change. Here, need to have models of alternative policies.

Removing the Consumption Effect

Another alternative is to somehow "remove" the consumption effect from the model so that it is not counted. Hertel, et al (2010, Bioscience) do a version of this and it greatly increases implied land use.

However, have to remember that in the actual policy the reduced food consumption will not actually be offset, so there is an implicitly offsetting social valuation of the actually-to-be-lost consumption and the actually-to-be-gained reduction in carbon.

Open Question: Quality of the Demand Parameters in GTAP.

There are many of these and once again

- Simultaneity is a problem
- CET functions will impose some results
- Regionally, elasticities are likely to be quite different

Perfectly Inelastic Demand or Perfectly Elastic Supply?

There are some claims that [i] biofuel mandates will not increase food prices or that [ii] increased food prices will not reduce consumption.

Note: RS (2010) find substantial demand reductions from policy *even though* they also find biofuels account for only 1/3 of the "great price run-up." These are compatible findings.

Note that if claims of benign food consumption effects are correct, then *current GTAP (and other) results are completely wrong.*

Also note that if prices do not increase, then price-induced yield effects cannot happen.

Conclusions about Demand Reduction

- Policy-makers have to take a stand on the social welfare effects of demand reduction and
  1. Explicitly compare to social welfare cost of climate change, or
  2. Explicitly consider the social welfare efficiency of alternate policies, or
  3. Somehow appropriately "remove" the demand reduction effect from the analysis (which implies a particular social welfare stance.)

The empirical basis of the demand parameters is largely yet to be explored. Somewhat similar aggregate demand reduction result to RS (2010) is reassuring, but more detailed consumption results are more difficult to compare to literature.

Major Conclusions, again

- Overall, there is no *single version* of the GTAP model that has a sufficiently strong scientific, empirical basis to serve as the basis for a policy decision as large in potential magnitude as the proposed biofuel mandates.
- A range of scientifically plausible GTAP results should be considered, together with the results of alternative (more empirically based) modeling approaches
- One of the emphasized GTAP models should consider the case of near-zero crop-yield price elasticities.
- Policy Makers have to take a stand on how to treat the social welfare loss from reduced food consumption.

Using Multiple Models

Problem of setting Carbon Policy is similar to problem of Fed Reserve in setting monetary policy. Huge potential positive and negative effects of policy and equilibrium models are necessary. However, the existing models are controversial, imperfect and (while sophisticated) have a weak empirical basis. (E.g. macro-models did not predict the crash.)

The Fed has a "Fed Model" but they do not necessarily do what it says. Regional Feds have alternative models, etc., plus the Board makes use of all possible empirical information, including data that is "outside of" the official model.

Outside of an *immediate* crises, the Fed tries to take small incremental steps and measure the results.

Analog to Finance Research

Should financial economists have advised clients to bet $100,000,000s, leveraged 100-1, on the basis of the "latest research"?

Research is good, research is imperfect, models are good, models are imperfect. Many sources should be consulted and the more obvious imperfections in the research the more cautious policy-makers should be.

At the least . . .

In addition to the current GTAP runs, policy-makers should place some large emphasis on a model that mimics much empirical research in assuming that there are not significant price-yield gains and that "corrects for" the cost of reductions in consumption of food.

And, the plausibility of GTAP predictions should be compared to those of empirical projects that focus less on equilibrium computation and more on empirical justifications.

Example:

if predictions contrast with RS (2010), then why? Is the extra detail of GTAP really helping, or it is false complication?

Example:

Do the land-use predictions of GTAP accord with historical experience? Do we know why not?