The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

The Fallacy of Reversibility

Posted by Stuart Staniford on January 22, 2008 - 11:00am
Topic: Alternative energy
Tags: agriculture, biofuel, food prices, peak oil, relocalization [list all tags]

Why Peak Oil Actually Helps Industrial Agriculture

Claas (Caterpillar) Lexion 570 combine harvester in action. Image courtesy: Wikipedia.

A sizeable faction of the people who think peak oil is important, and happening soon enough to care about, think it has big implications for agriculture. And most of them agree on what those implications are: as a society, we are going to have to give up the big combine harvesters, the thunderous power of 275 horsepower tractors, and instead we will have to return to small-scale, hand-labor organic production. Rather than having 2-5% of the working population involved in agriculture, as in most western societies at present, most people will need to be involved in growing food. This is part of the agenda of the relocalization movement, which itself is a recent reincarnation of a long-standing movement for localism.

This argument has never really made sense to me, but my recent explorations of food prices and biofuels have sharpened up my conviction that the thinking behind this position is mistaken. In this piece, I'm going to first document that some influential peak-oilers do in fact believe this, then try to discuss what I think the reasoning is -- it's not usually made very explicit but it depends on something I'm calling the *Fallacy of Reversibility*. Finally, I'm going to lay out why I don't think things are going to go the way the proponents of relocalization expect, at least not any time soon.

Relocalization Quotes

The idea that "peak oil" was something that society was going to have to reckon with began amongst scientists with backgrounds in the oil industry - most famously Hubbert himself, and then elaborated by Colin Campbell, Jean Laherrere, Ken Deffeyes, and others.

These oil industry scientists - what I will call the **first wave** of peak oil thinkers and writers - were mainly interested in estimating when peak oil would be, and the likely supply side mitigations (or lack of them). The implications of peak oil for agriculture was not a major focus. However, a **second wave** of journalists, writers, and non-profits have been doing a lot to spread the word about peak oil - Richard Heinberg, James Kunstler, Julian Darley and the Post Carbon Institute, the staff of the Community Solution, and others have all written books, held conferences, and started non-profits to warn the world about the dangers of peak oil. Given that the world as a whole has been doing its best to stay in denial about peak oil these outreach efforts have been a valuable service -- certainly I have learned a lot from them. At the same time, these writers bought to the table an agenda about society in general, and agriculture in particular, that I believe lacks an empirical foundation.

Let me start with a quote from Jim Kunstler:

> We have to produce food differently. The ADM / Monsanto / Cargill model of industrial agribusiness is heading toward its Waterloo. As oil and gas deplete, we will be left with sterile soils and farming organized at an unworkable scale. Many lives will depend on our ability to fix this. Farming will soon return much closer to the center of American economic life. It will necessarily have to be done more locally, at a smaller-and-finer scale, and will require more human labor. The value-added activities associated with farming -- e.g. making products like cheese, wine, oils -- will also have to be done much more locally. This situation presents excellent business and vocational opportunities for America's young people (if they can unplug their Ipods long enough to pay attention.) It also presents huge problems in land-use reform. Not to mention the fact that the knowledge and skill for doing these things has to be painstakingly retrieved from the dumpster of history.

The Community Solution also believes that the current agricultural model cannot be sustained, though they are concerned about the ability to manage the transition:

> Reliance on large-scale agribusiness, driven by vast energy consumption, has resulted in an agricultural monoculture that is simply not sustainable. But where are the tens of millions of small farmers who will be necessary if we are to return to locally grown food crops? And what about all the food that is being used for feed, and now, for fuel?

The Post Carbon Institute is attempting to build model farms of the kind that they believe will be required post peak:

> Using science, proven tools, and evolving methodologies the Energy Farm Initiative seeks to demonstrate systems of agriculture that can sustain both farms and communities in the face of climate change and peak oil. This program weaves threads of

> the Relocalization vision into a fabric of local currency, local food and biofuel systems, revitalization of local industry, and community cooperation.
>
> Our aim is to build flexible systems that reduce dependence on high energy inputs and produce food and reliable renewable energy for local users. The steps in which this transition is manifest is the Local Energy Farm Initiative.

Another writer who has been very influential in getting the word out about peak oil is Richard Heinberg (including reportedly reaching former President Bill Clinton). I profiled Richard here. In December of last year, he wrote:

> The aim of substantially or entirely removing fossil fuels from agriculture is implicit in organic farming in all its various forms and permutations - including ecological agriculture, Biodynamics, Permaculture, Biointensive farming, and Natural Farming. All also have in common a prescription for the reduction or elimination of tillage, and the reduction or elimination of reliance on mechanized farm equipment. Nearly all of these systems rely on increased amounts of human labor, and on greater application of place-specific knowledge of soils, microorganisms, weather, water, and interactions between plants, animals, and humans...
>
> Because ecological organic farming methods are often dramatically more labor- and knowledge-intensive than industrial agriculture, their adoption will require an economic transformation of societies. The transition to a non-fossil-fuel food system will take time. Nearly every aspect of the process by which we feed ourselves must be redesigned. And, given the likelihood that global oil peak will occur soon, this transition must occur at a forced pace, backed by the full resources of national governments.

I have to say that I really don't like the sound of "at a forced pace, backed by the full resources of national governments". As JD, of Peak OIl Debunked, noted recently there is a history of attempts to forcibly reallocate land to urbanites: it's mainly been attempted by dictators, and the results have made the countries in question bywords of disaster (Cambodia and Zimbabwe are examples in recent decades).

The most thoughtful advocate of relocalization I know is Jason Bradford, who is quantitative enough to have investigated his own area, the rural Northern California county of Mendocino, and discovered that the county probably could not feed itself:

> Out of 2,246,400 acres of land in Mendocino County, 94,039 acres or 4.19 percent is considered prime agricultural soils (NRCS-USDA figures). Of that amount, much is unavailable and covered by roads, highways, cities, parks, and other land uses. While growth is very slow in Mendocino County, settlement patterns have tended to occur in areas dominated by prime soils. Only one third, or approximately 35,000 acres, of prime farmland remain available for agricultural use. Besides the unavailability of prime farmland, changes in hydrology as a result of agricultural and other human uses have affected the quality and use of prime farmland.
>
> The Caltrans EIR implies that in about a ca. 20 year span, Mendocino County went from 69,000 to 35,000 acres of prime farmland, down from and original endowment of

94,000 acres. This does seem like a remarkably high rate of loss, totaling 34,000 acres or about 1700 acres per year for 20 years. In either case, whether the real figure is closer to 69,000 or 35,000, both are far from the estimated need of ca. 95,000.

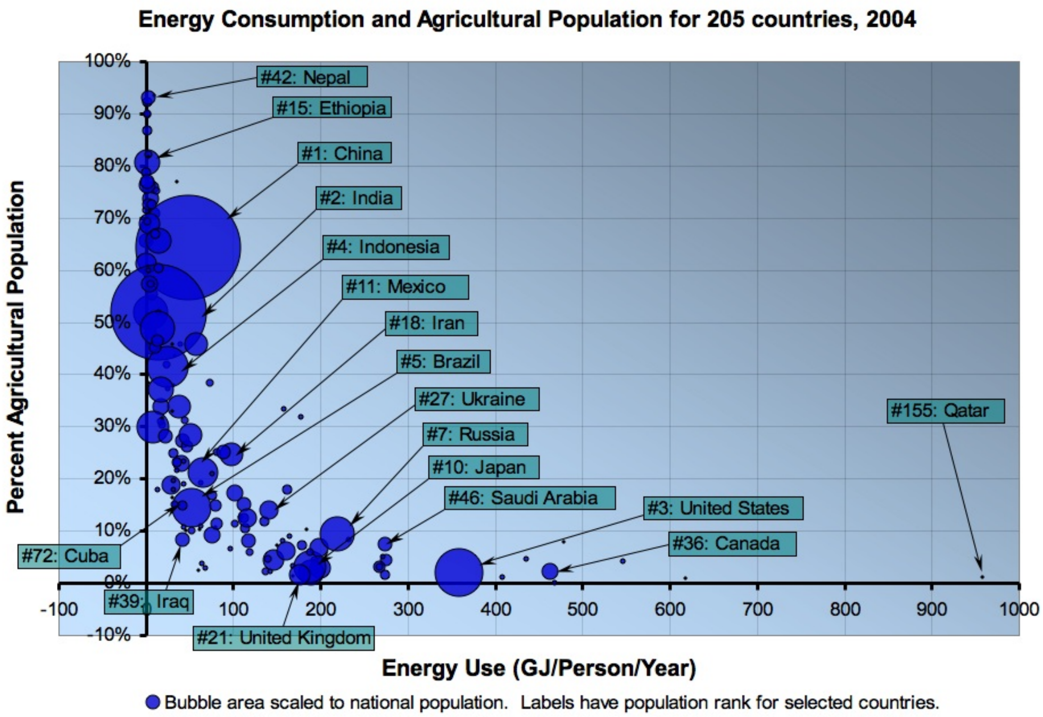
I think as Jason investigates further, he is going to find more reasons for pessimism about this path.

The Fallacy of Reversibility

So, the second wave peak oil writers see us as abandoning the combine harvester and returning to this kind of scene:

Raking hay by hand. Image courtesy: University of Minnesota.

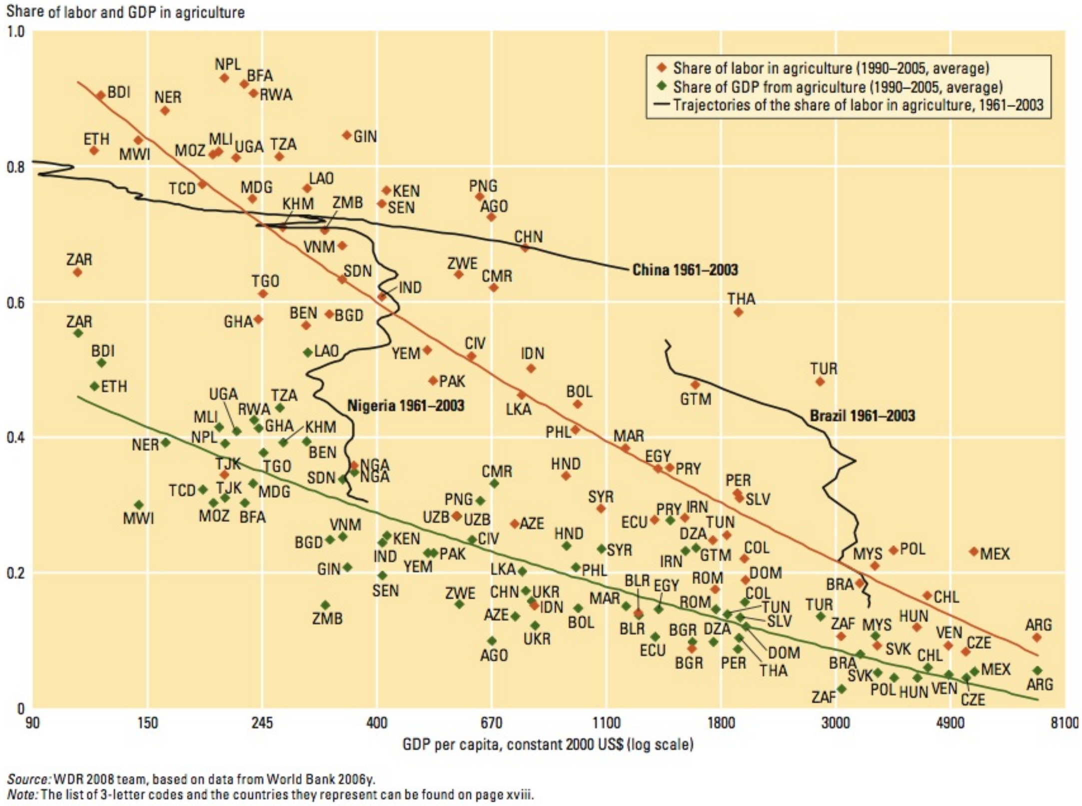
Let me try to summarize what I believe the underlying logic of their position is. What is certainly true is that pre-industrial societies generally use a lot less energy, and have a much larger share of their population involved in agriculture than industrialized societies do. Jason Bradford did a nice analysis a few weeks back, and I made this graph based on his analysis:



Industrial energy use per capita versus share of population used in agriculture. Source: [Does Less Energy Mean More Farmers]() based on data from the FAO and EIA.

Clearly, as countries have gone through the process of industrialization and development (roughly moving down the curve to the right), they have come to use more energy in general, and their agriculture has become far more mechanized and involves a smaller fraction of the population.

Another view of the same process can be seen in this World Bank graphic, which shows both the share of agriculture in the labor force and in gross domestic product, but this time plotted against GDP/capita:



Share of agriculture in labor force and GDP for a sample of countries. Source: Figure 1.2 of the World Bank's World Development Report 2008

This reminds us that countries that have far higher portions of the labor force in agriculture don't just use less energy, they are also far less wealthy. (Note that the scale in this graph is logarithmic and cuts off around Argentina - the full graph on a linear scale would have a sharply curved hyperbolic shape much like the energy versus agricultural population one from Jason's analysis).

So I think the argument of the relocalization advocates essentially is that, since we were using a lot less energy before we were industrialized, and our population was primarily agricultural then, and peak oil implies we will have less energy in the future, or at least less liquid fuel, then it must be the case that the agricultural population will grow again. In other words, having coming come down the curve in the graphs above from the top left to the lower right, our society will now start to retrace its steps back up the curve.

This implies that the process of industrialization and development is a reversible process. We in the developed world have evolved from low-energy high-agriculture societies into a high-energy low-agriculture society. So the thinking goes that we can/should/will reverse that process and go back to something like what we were 200 years ago (at least on these large macro-economic variables).

Now, coming from a background as a scientist, there are many reversible processes familiar in science (and indeed in everyday life), but there are also a lot of irreversible processes. Some examples of reversible processes - if you lift up a weight, you can set it back down again into the same position it was in before. If you blow up a balloon, then, up to a certain point, you can let the air out and get back more or less the uninflated balloon you had before you started. If you pump water from a lower reservoir to a higher reservoir, you can let it down again, and the lower reservoir will be in little different condition than if you hadn't bothered. If you freeze a liquid by cooling it, you can warm it up again and have the same liquid.

Here are some examples of irreversible processes. If you let grape juice ferment into wine, there's no way to get grape juice back. If you bake a cake in the oven, there's no way to turn it back into cake dough. If you ice and decorate the cake, but then accidentally drop it on the floor, there's no way to pick it up and have anything approaching the same cake as if you hadn't dropped it.

So when you industrialize a society, is that a reversible process? Can you take it on a backward path to a deindustrialized society that looks in the important ways like the society you had before the industrialization? As far as I can see, the "second wave" peak oil writers treat it as fairly obvious that this is both possible and desirable. It appears to me that it is neither possible or desirable, but at a minimum, someone arguing for it should seriously address the question. And it is this failure that I am calling the **Fallacy of Reversibility**. It is most pronounced in Kunstler, who in addition to believing we need a much higher level of involvement in agriculture also wants railways, canals, and sailing ships back, and is a strong proponent of nineteenth century urban forms.

I am going to christen this general faction of the peak oil community **reversalists**. This encompasses people advocating a return to earlier food growing or distribution practices (the local food movement), folks wanting to bring back the railways and tramcars, people believing that large scale corporations will all collapse, that the Internet will fail and we need to "make our own music and our own drama down the road. We're going to need playhouses and live performance halls. We're going to need violin and banjo players and playwrights and scenery-makers, and singers."

And before moving on, I stress that I'm not making an argument that our time is in all ways better than earlier times and that nostalgia for the past is entirely misplaced. Nor am I making an argument that peak oil does not pose a massive and important challenge to us. Instead, I'm making an argument that society is unlikely to reverse its trajectory of development, regardless of what we might like. Calls for it to do so are a distraction and get in the way of figuring out what we really need to be doing, and what the real options and dangers are.

Why it Won't Be So

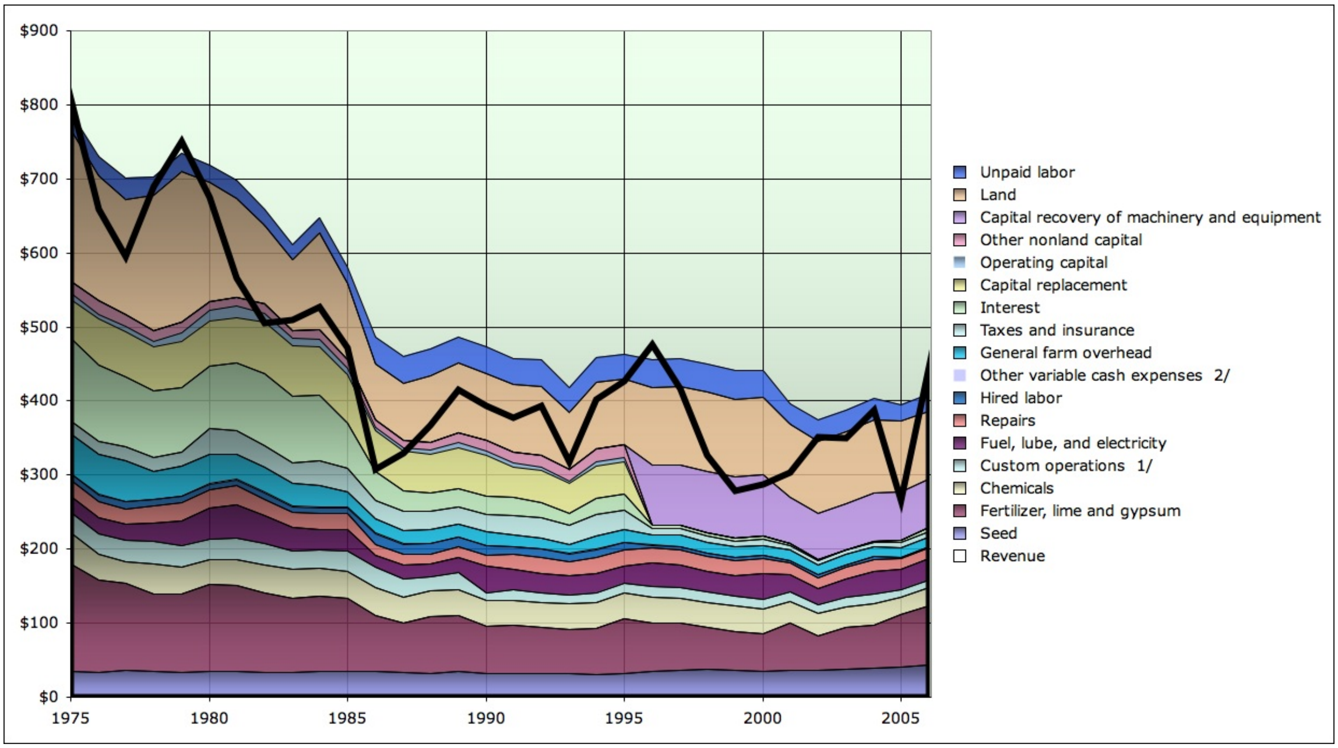
Although the reversalist approach to peak oil covers many dimensions of society, I'm going to confine my attention in this piece to the proposition that agriculture is likely to revert to eighteenth or nineteenth century approaches in the face of a slowly contracting oil supply. My central tool for looking at the question is going to be the factors going into the profitability of industrial agriculture. If it's the case that agriculture is going to revert to a manual low-energy process in the face of peak oil, then that should show up in the profitability data. Here are some natural predictions we might make:

- Industrial farming is less profitable at high oil prices than at low oil prices.
- Now that we are at, or close to, peak oil, industrial agriculture is beginning to show signs of strain, indicating it may break down in the future, allowing alternative approaches to take over.
- Industrial farmers use more labor in the face of high oil prices.
- Farms are starting to get smaller now that peak oil is nigh.
- In developing countries, where the farmers never unlocalized in the first place, the dynamics are changing to favor small subsistence farmers over larger mechanized operations.

As we shall see, the evidence doesn't provide any support for any of these propositions, and in fact it tends to provide at least some evidence for the opposite view: the industrial agricultural system appears to be strengthened by peak oil, and is likely to get stronger still in the near future. Rather than industrial farms losing money, land prices dropping, and desperate farmers loooking to throw in the towel and sell out to the hordes of neo-peasant reversalists, we find farm incomes rising, average farm sizes increasing, and no sign of greater use of labor in the production of the core arable crops in the US.

Agricultural Profitability and Oil Prices

Most of my analysis is based on the data compiled by the [United States Department of Agriculture (USDA)]() on the average costs of growing various kinds of crops. This data is based on national surveys of farmers and represent an average for all farmers (some will be doing better than the average, some worse). Let's start with corn:

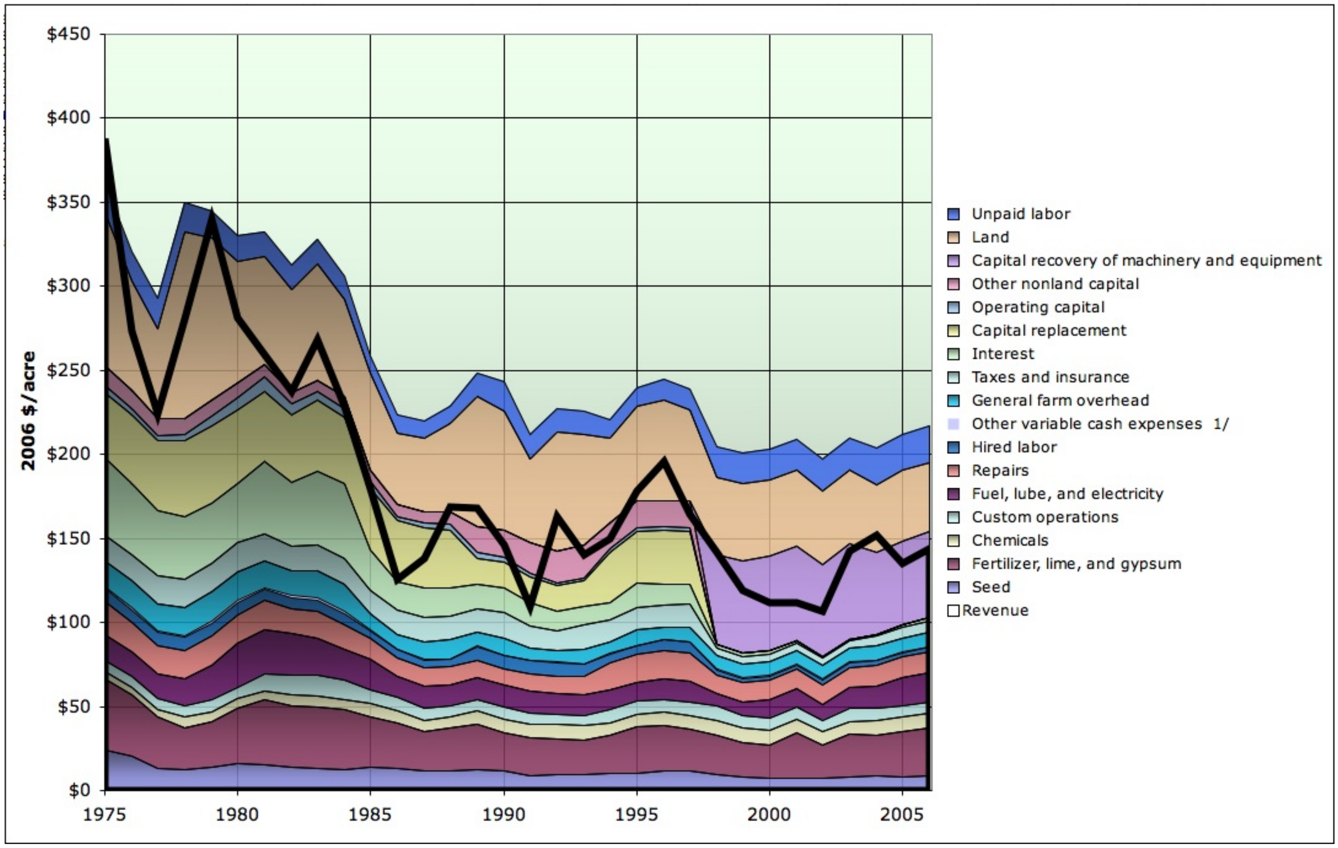


Average cost structure and revenue of US corn farmers, per acre, 1975-2006. Source: [USDA](). Costs have been adjusted to 2006 dollars via the [BLS]() CPI-U.

Here, the various colored bands are the different costs of producing corn, expressed in 2006 US dollars per acre of land planted in corn. The heavy black line is the revenue per acre of selling the corn. The big picture is that very little money is spent on labor (indeed, agriculture in the US is highly industrialized), that costs have been coming down over time, and that farming in recent decades has been an activity with modest and unpredictable profits (that graph represents a business I would not want to be in). The cost reduction per acre is particularly striking given that yields per acre have been improving steadily over this period - farmers have obviously gotten enormously more productive over time (all that machinery and those fancy chemicals really do work as advertised, it seems).

It's worth quickly noting that most of the spikes of better profitability come at times of high oil prices (1975, 1979, and 2006). We will explore this more systematically in a moment.

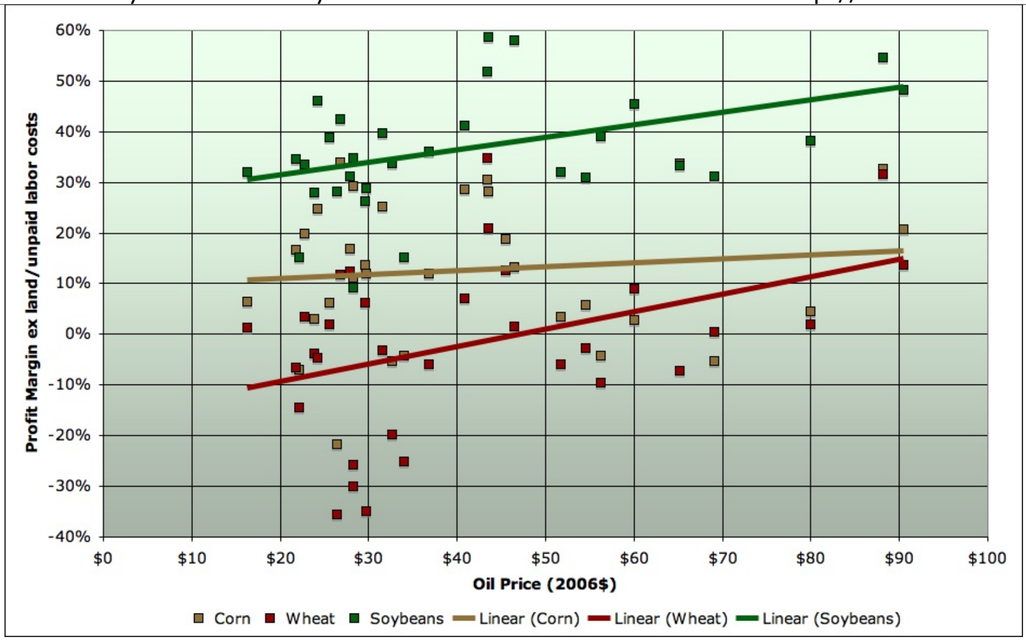
Here is the same thing for wheat:



Average cost structure and revenue of US wheat farmers, per acre, 1975-2006. Source: USDA. Costs have been adjusted to 2006 dollars via the BLS CPI-U.

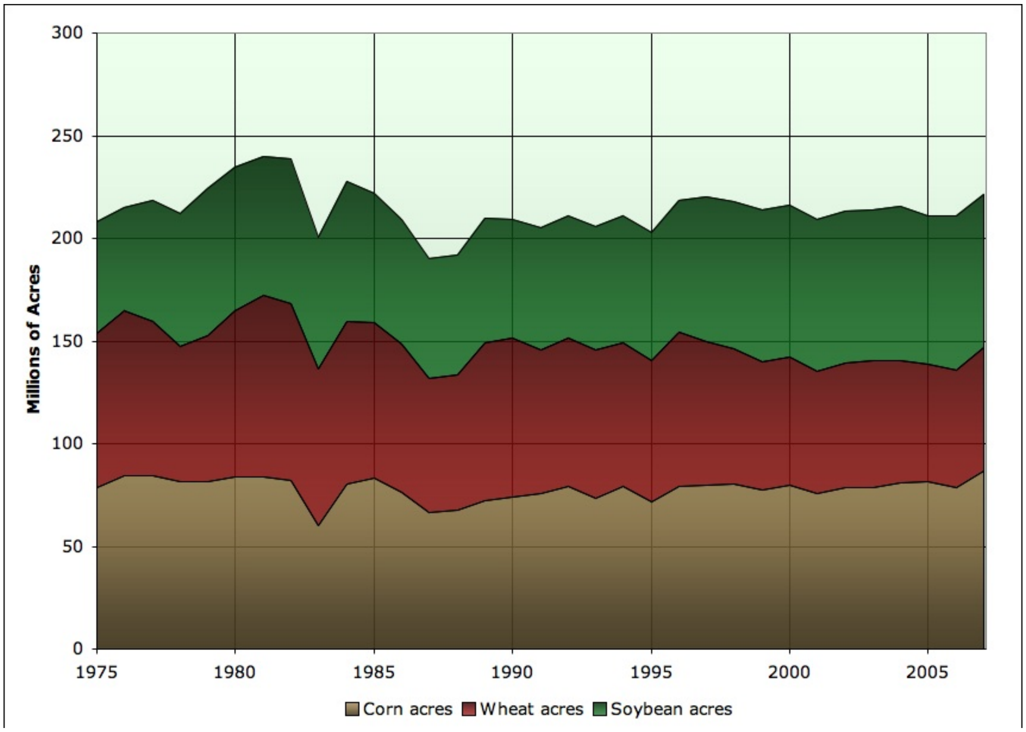
The story is similar, except that both costs and revenues per acre are lower, and profitability is even worse.

To look at the relationship between profitability and oil prices for the sectors as a whole, I took the profit margin (revenues - costs)/revenues, but excluded land and unpaid labor from the costs. The reason for excluding land is that I would expect land prices to mainly reflect the profits being made on the land, so including them in costs is confounding understanding the profitability of the sector (obviously, an individual farm has to worry about the land costs, but the land is only worth anything because people are farming it, so it's a confounding effect at at sector level). I excluded unpaid labor as owner's compensation which I consider more a form of profit than a cost. For that definition of profit margin, for the three main arable field crops, we get this graph:



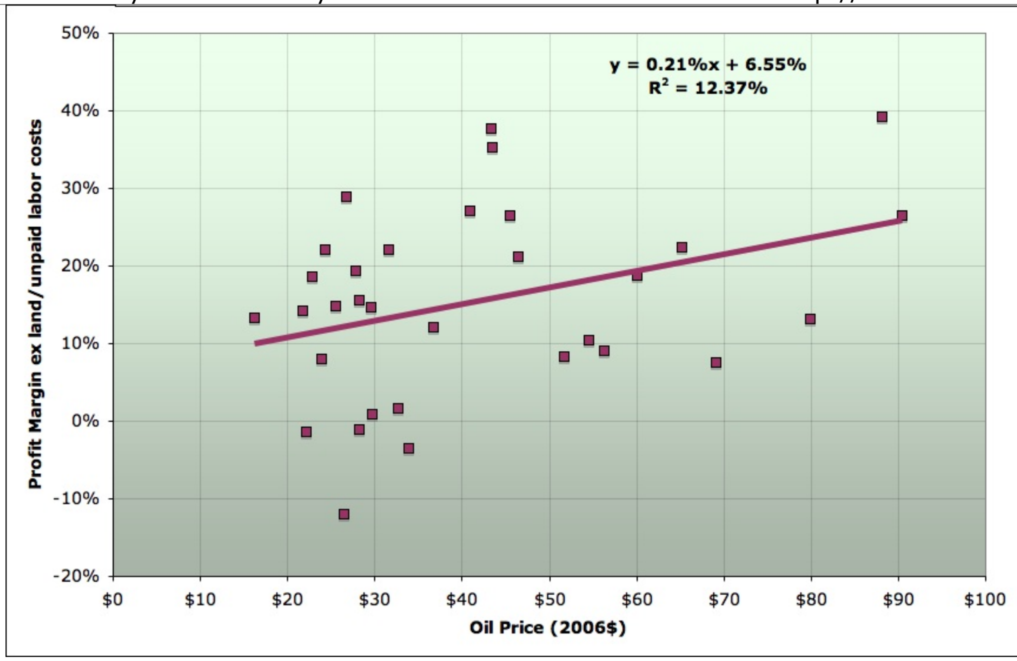
Average profit margin for US farmers on three main field crops, versus oil prices. Profit margin is computed without the land rent or unpaid labor cost components, 1975-2006. Source: [USDA](#) and author's calculations for profit margin, [BP](#) for oil prices in 2006 dollars.

There is a very weak upward slope to all three lines (ie in the direction of better profits at higher oil prices). In an effort to reduce the noise, I produced a weighted average according to the planted acreage of the three crops:



Acreage of three main field crops in the United States, 1975-2007. Source: [USDA](#).

and thus got this graph:



Average profit margin for US farmers on acreage weighted average of three main field crops, versus oil prices. Profit margin is computed without the land rent or unpaid labor cost components, 1975-2006. Source: USDA and author's calculations for profit margin, BP for oil prices in 2006 dollars

The relationship is somewhat stronger - profits are a little likelier to be higher when oil is expensive, but oil prices explain only about 12% of the variance in profit margins. The relationship is just barely statistically significant (p = 4.9%), but I wouldn't set too much store in it, given that the regression is not controlled for any other factors that might be explanatory.

But certainly, there is no evidence for the idea that farms are **less** profitable at high oil prices - that inference is completely unsupported by the data since 1975.

The analysis does not include 2007, since the cost data are not available yet, but it is likely that 2007 had high profit margins (since crop prices were very high), and certainly it had fairly high oil prices. I will argue below that this is a harbinger of the game-changing role of biofuels, which will tend in the future to make industrial farming more profitable as oil prices rise.

Labor Usage in Arable Crop Production

Let's turn for a moment to the use of labor in the farm system. If it was the case that peak oil was promoting a return to a more local, less industrialized, style of agriculture, we might expect to see usage of labor correlated with oil prices - when oil prices are high, farmers are differentially likely to prefer to do things manually and use less expensive fuel to get the job done. So I looked at the total labor input (both paid and unpaid) into the crop versus oil prices:

Average labor expended per acre by US farmers of corn, wheat, and soybeans, versus oil prices 1975-2006. Both are converted to 2006$. Source: [USDA](#).

What we see is that wheat and soybeans show essentially no meaningful relationship between oil prices and the amount of labor per acre that farmers use. They use the same low amount regardless. Corn farmers actually spend **less** on labor when oil prices are high, for reasons that are unclear - however the relationship is quite strong (r^2 of 43%) and very statistically significant (p = 0.005%).

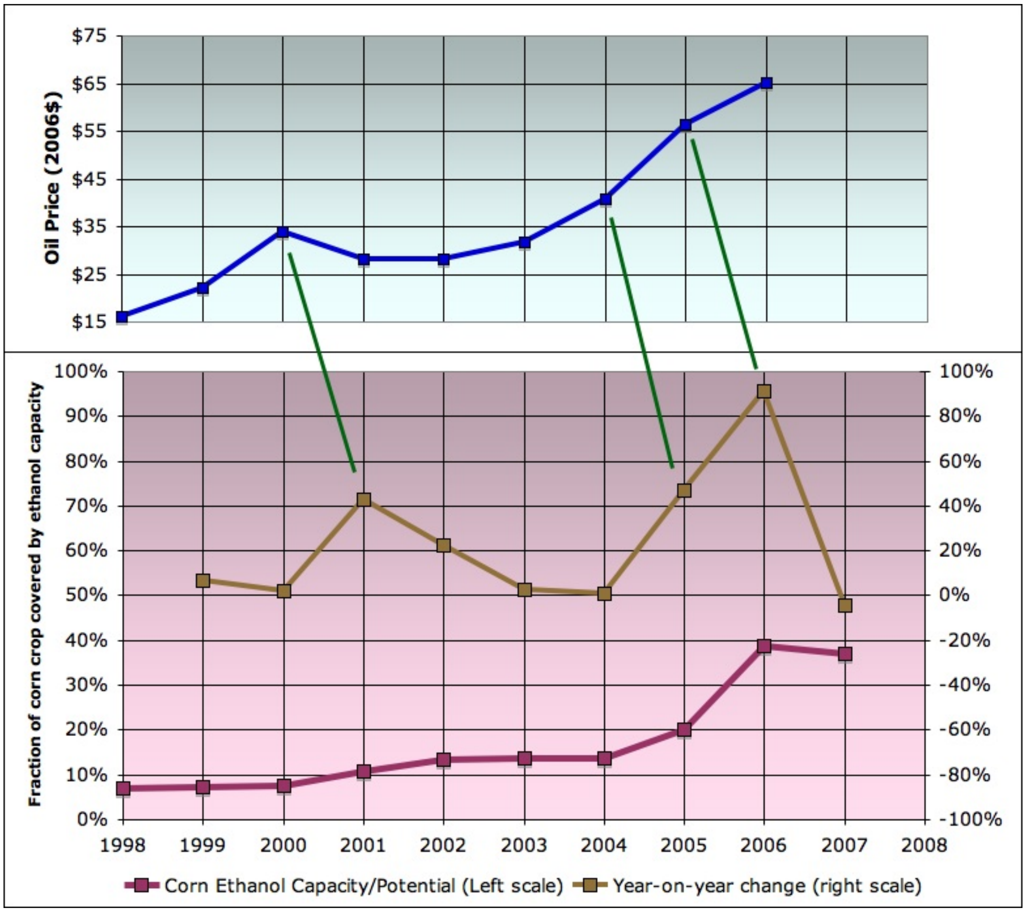
So again, there is no evidence in the data for the reversalist idea that farmers might need more labor when oil prices get high on account of peak oil.

Biofuels and the Future of Industrial Agriculture

A possible objection to my argument thus far is that, although we may be at or near peak oil, nonetheless we haven't seen anything yet in terms of how high oil prices could go - $100/barrel is nothing, and when we see $200/barrel or $300/barrel, then the situation will change, industrial agriculture will fall apart, and the reversalist future (which is really the past) will start to play out.

Now, I certainly would not discount the possibility that oil could get to $200/barrel. With an income elasticity near 1, we would expect to see oil usage expand by a few percent a year due to global economic growth if prices were constant. Since supply has not been increasing at all for the last couple of years, higher prices have been required to balance supply and demand. Since elasticity of oil demand is more like 0.05, it takes several tens of percent of price increases each year to balance the missing single percentage point increases in supply that aren't occuring. That's how we got to $100 oil. If supply continues to be flat, it's quite possible oil will get to $200 in a few years time. On the other hand, if the credit-collapse recession in the US turns severe, as it certainly could, oil prices could fall a lot instead. If we do manage to get a boost in supply from the 2008 megaprojects, that will moderate prices also, at least for a time.

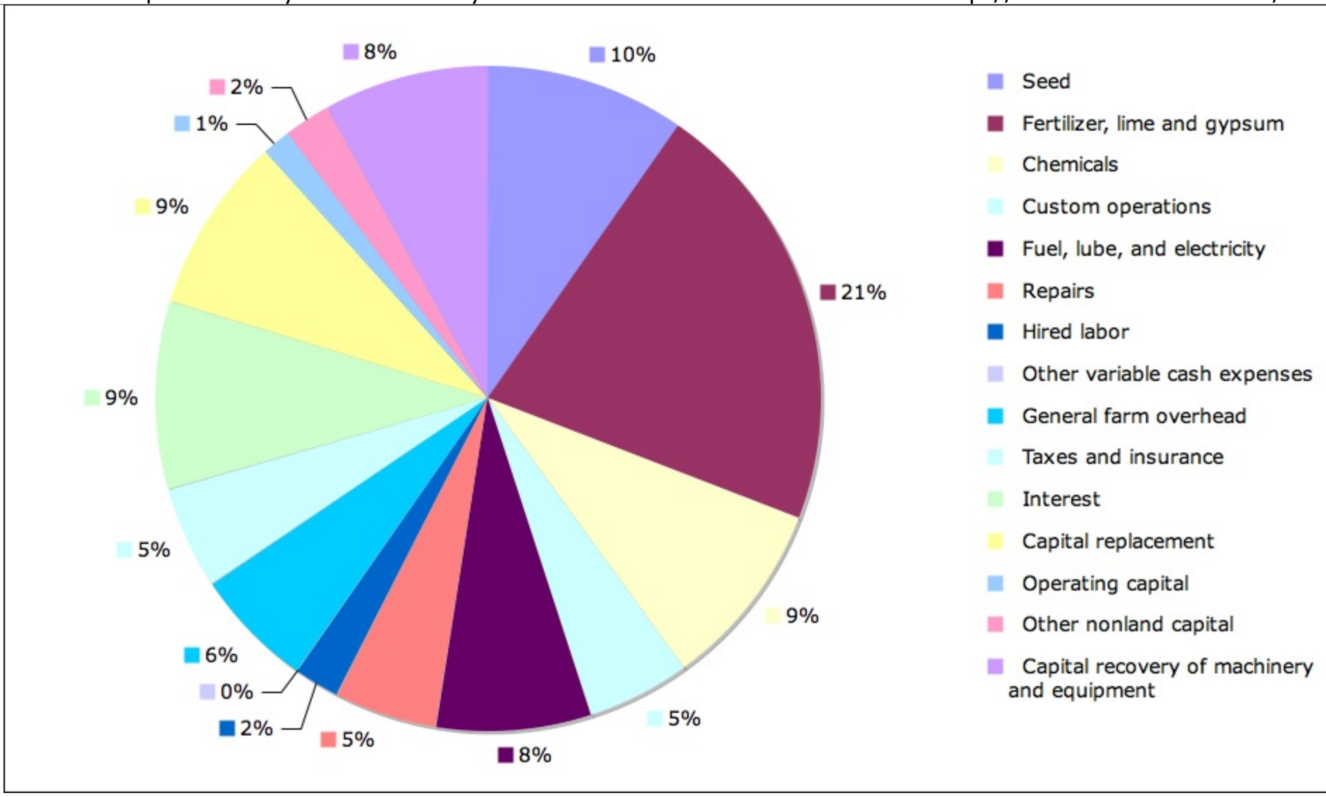
But what I would argue is that if oil gets to $200/barrel, industrial agriculture is likely to do very well. I pointed out in Fermenting the Food Supply that corn-ethanol has been profitable even without subsidies at times in the last few years, and that whenever oil prices go up sharply, there is a huge spurt in the growth of the biofuel industry. This creates an arbitrage between food prices and fuel prices, and mean that the former must go up whenever the latter go up (since the biofuel industry can very easily use most of the global food supply without adding more than a modest fraction to the fuel supply). This next graphic summarized the key point:



Bottom panel: capacity of ethanol plants at year end, in production and under construction, as a percentage of total ethanol potential of the entire US corn crop in that year (left scale), together with year on year change in that percentage (right scale). Top panel: oil prices (annual average in $2006). Sources: USDA National Agricultural Statistics Service for corn production, National Corn Growers Association for conversion efficiencies, and Renewable Fuels Association for ethanol plant capacities. Oil prices are sourced from BP.

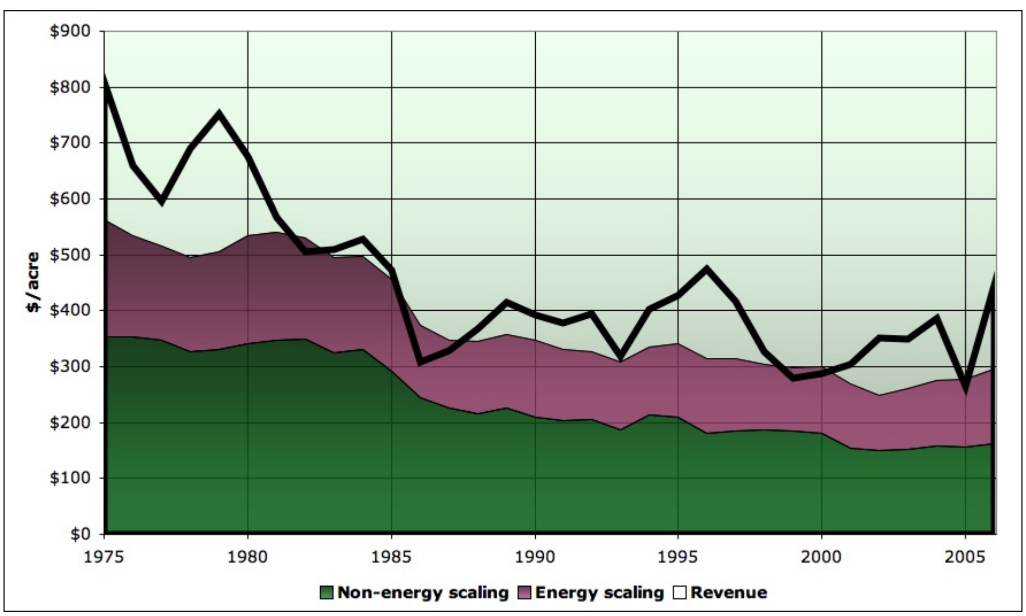
> I suggested earlier that the growth rate has a lot to do with oil prices, and I've made that more explicit in the graph above with the green lines. When oil prices spike up, a year or so later we have a new burst of ethanol capacity under construction (which then comes on stream 1-2 years after that).

This has had a lot to do with the high crop prices of the last two years. Thus, if we get $200 oil, I confidently expect a new burst of growth in crop prices and for farm revenues to go up a lot. If we look at the average costs over the last thirty years:



Average cost structure and revenue of US corn farmers, per acre, 1975-2006. Source: USDA.

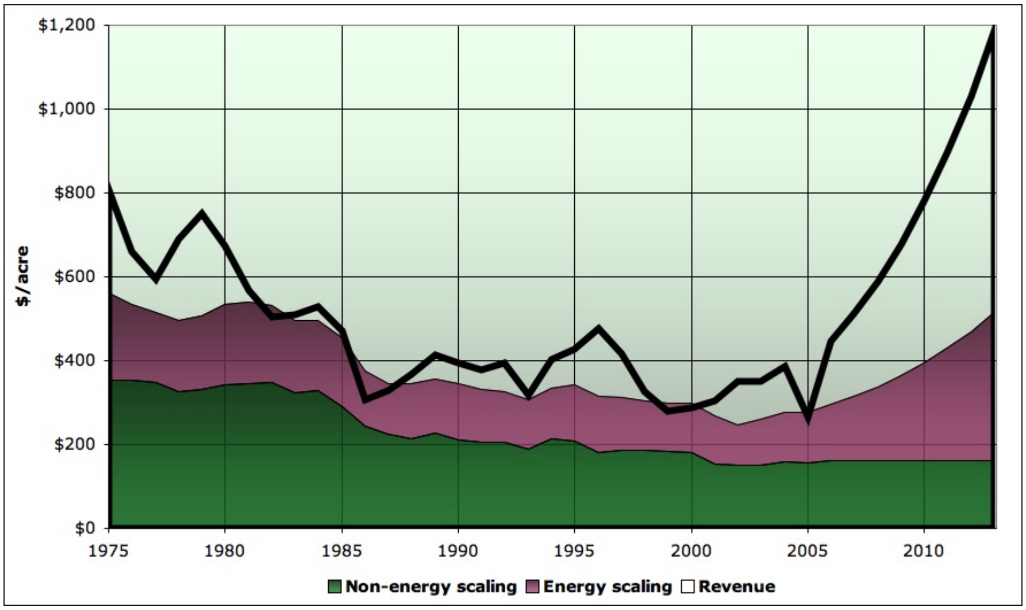
we can see that some costs are of a kind that scale with energy prices. The "fuel" component is certainly that way, but fertilizer is almost entirely made from natural gas and will tend to go up in periods of high energy prices. And, for safety, I've also included chemicals, most of which have petroleum or natural gas as the feedstock (though I imagine most of the value is added in manufacturing, rather than in the raw fossil fuel input). However, the rest of the farm costs don't have a direct relationship to energy costs (the various forms of labor, cost of capital, etc). So with this decomposition, the history of corn farm costs and profits looks as follows:



Revenue of corn farmers, together with cost structure decomposed into hypothesized energy price scaling and energy price independent components . Costs exclude the land rent or unpaid labor cost components, 1975-2006. Source: USDA.

As you can see, the non-energy components have not increased much at all since 2002, but the energy-related portions have been increasing sharply. All costs were high in the 1970s and early 1980s (when not only were energy costs high but interest rates were extremely high too, so that capital costs were very great).

So going forward, I expect to see significant increases in food prices and farm profitability (with a significant caveat for the possibility of a credit-induced severe recession). The following hypothetical scenario for what happens to the corn curve if both energy and corn prices increase by 15%/year in real terms, while other farm costs (eg labor, cost of capital) stay flat in real terms. As you can see - industrial farmers do very well in that case:

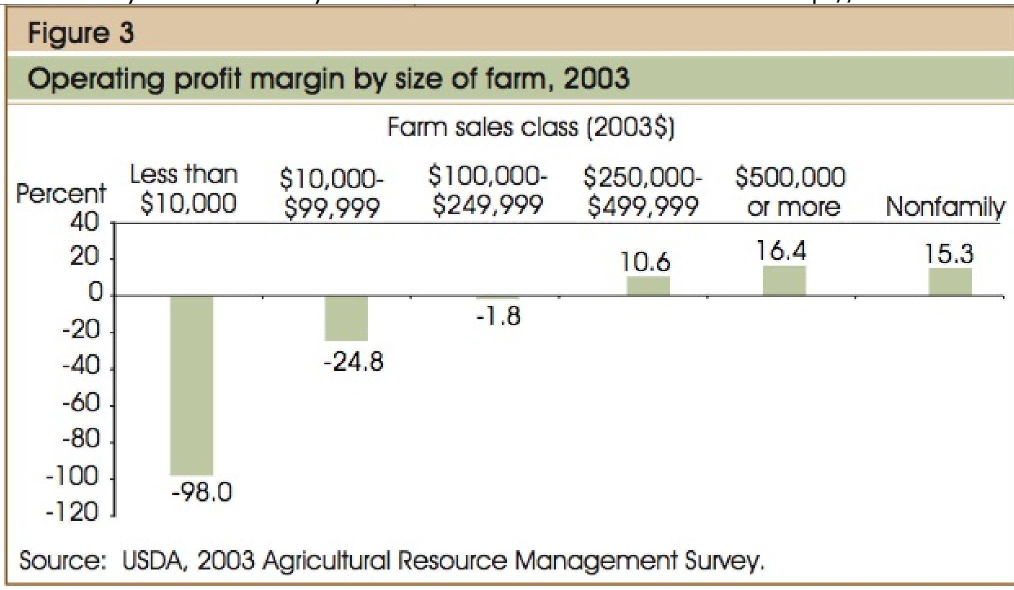


Revenue of corn farmers, together with cost structure decomposed into hypothesized energy price scaling and energy price independent components . Costs exclude the land rent or unpaid labor cost components. Actuals for 1975-2006, and ***scenario (not forecast)*** *for 2007-2013 based on 15% annual increases in energy-scaling costs and corn prices, with flat other costs. Source: USDA.*

Clearly, farmers making money like that will not be selling out to hordes of the urban poor trying to go back to the land, nor will they need to employ them. Instead, the farmers will simply outbid the urban poor for the energy required to operate the farms (and in the US, the farm sector only uses 2.2% of all petroleum in the country).

Farm Size Trends

Farms in the US have been getting steadily bigger for a long time. The reasons are very simple: there are substantial economies of scale in industrial farming - it's desirable to keep the expensive machinery and administrative labor working at maximum capacity, which means spreading it out over as much land as possible. That leads to this kind of graph:



Operating profit as a function of farm size in the US, 2003. Source: USDA.

Small farms lose money at a great rate, and only large operations make a profit. This is a recipe for larger farms as the small ones sell out to their wealthier neighbors. As the share of energy in the cost structure grows, this graph may moderate a little (since fertilizer and fuel usage are likely directly proportional to acreage). However, there is nothing in high energy costs that will make it reverse - it will still be beneficial to spread the non-energy costs over more acreage. Thus although the trend of increasing farm size may slow, there is nothing to put it into reverse.

And in the developing world, another important factor comes into play. As we discussed last week, over half of all households in rural areas in developing countries are net food importers, even though the vast majority are involved in agriculture somehow. Thus, rising food prices will place tremendous stress on very poor households that grow some food, but not enough to live on. They may be forced to sell their land to larger landholders that produce a surplus. Thus, we may see the exact opposite of what the relocalization movement might predict - farm sizes in developing countries may increase in the face of peak oil.

In Conclusion

I've argued in this piece that industrial agriculture is likely to be stronger and more profitable when oil prices are high, not weaker. So the reversalist future of local food production on smaller farms with higher labor input will not come to pass as a result of peak oil. The industrial agricultural sector owns most of the land, and will be in an excellent position to increase their land holdings as remaining subsistence farmers fail or consolidate in the face of high food prices. Industrial farmers will have no reason to sell out to improverished urban dwellers. Thus the industrialization of the land is not a reversible process any time soon - it is a fallacy to think so. The reversalists are expressing wishful thinking and nostalgia for the past, not a reasoned analysis of how the future is likely to play out. And urbanites worried about their future should not be looking to buy or rent a smallholding as a solution to their problems - industrial farmers are extremely efficient, and there is no way to compete with them except by becoming one.

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