

## 4. Economic Growth and Diminishing Returns

Gail Tverberg - Energy Economics and Analysis Modeling

# Standard Definition of Economic Growth

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Amount of Goods and Services (= GDP) must be increasing

**Goods and Services = GDP**



Leonardo Sticks <http://www.rinusroelofs.nl/structure/davinci-sticks/gallery/gallery-01.html>

# How this economic growth is shared is important

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- ▶ Economic growth cannot benefit only the rich people
  - ▶ Or go only to growing government services
  - ▶ Or go only to bigger, nicer buildings for corporations
- ▶ If Peter Turchin in *Secular Cycles* is correct, for the economy to continue to function well, the “common worker” must also get more wages.
  - ▶ Common worker = farmer, worker in factory
  - ▶ Not just a few well-educated people
- ▶ This is a particular part of the economy that must grow

If we believe Turchin, to avoid collapse, a “stronger” condition must hold

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After tax income of common workers must be increasing

After-Tax Income of Common Workers



Leonardo Sticks <http://www.rinusroelofs.nl/structure/davinci-sticks/gallery/gallery-01.html>

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# If after-tax income of common workers is decreasing

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- ▶ Workers will have trouble paying for commitments
  - ▶ Food
  - ▶ Mortgages
  - ▶ Cost of raising children
  
- ▶ So those who want common jobs
  - ▶ Need jobs available
  - ▶ Need pay at least equal to what common workers have received previously
    - ▶ On after-inflation, after-tax basis

## Let's look at an example of what goes wrong

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- ▶ Based on problems noted by Peter Turchin in *Secular Cycles*

Suppose there is a plot of land that will provide work for 50 farmers

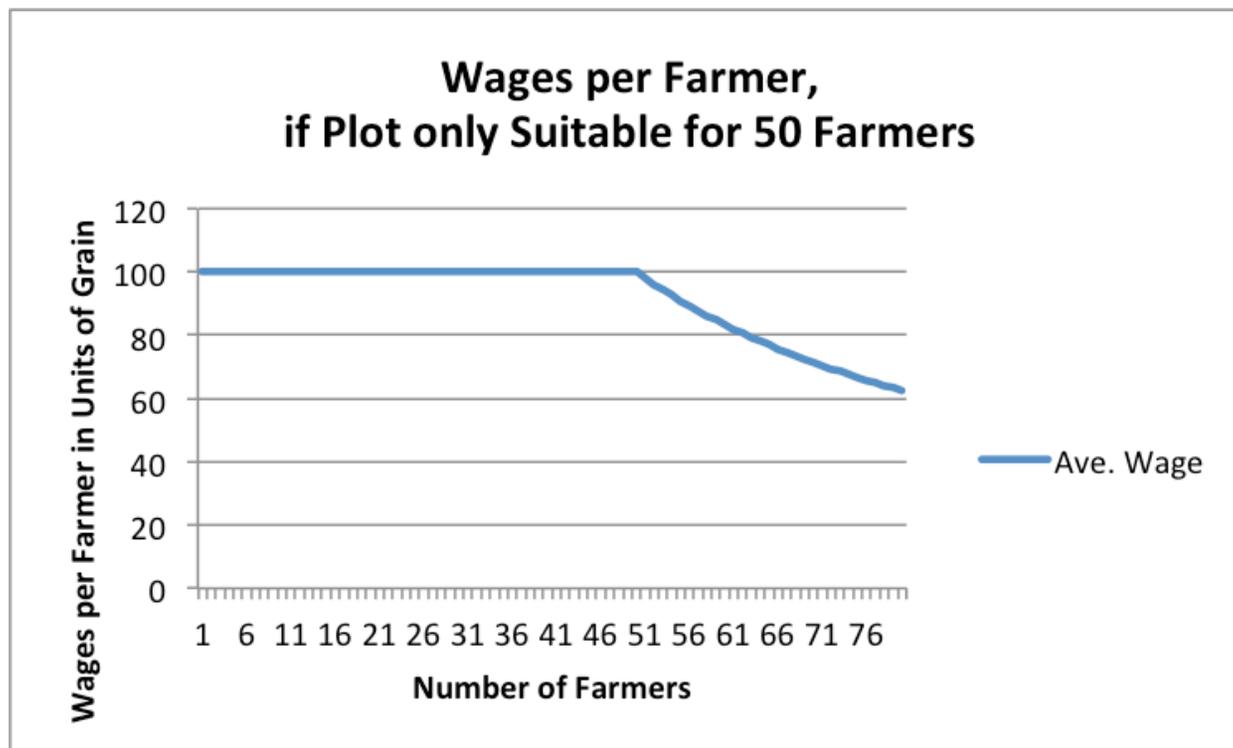
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- ▶ What happens when number of farmers rises above 50?
  - ▶ Suppose 60, 70 or 80 farmers share the land



# Land gets subdivided more ways

- ▶ Plots get smaller
- ▶ Each farmer grows less grain
- ▶ If paid in bushels of grain, wages drop



## Other ways farmer situation can be fixed

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- ▶ New farmers after 50 are only “helpers”
  - ▶ Get paid a lot less
- ▶ Or government sets up a program for older farmers to retire early, when problem of 51st farmer shows up
  - ▶ Cost of government program looks cheap, when only 1 extra farmer to pay for
  - ▶ Rapidly escalates, as more farmers need to be handled by government program
- ▶ Or maybe new “service” jobs that pay a lot less added

## Any of these situations results in falling after-tax income for the common worker

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- ▶ Result is clear based on bushels per worker
- ▶ Gets obscured if government hides the new problems with programs that will increase in size over time
  - ▶ Problem becomes hidden in future taxes
- ▶ If government programs are used to fix the problem
  - ▶ Taxes will rise in the future
  - ▶ Farmers will not think that they are poorer, but after taxes, they are poorer

## We call this condition “diminishing returns”

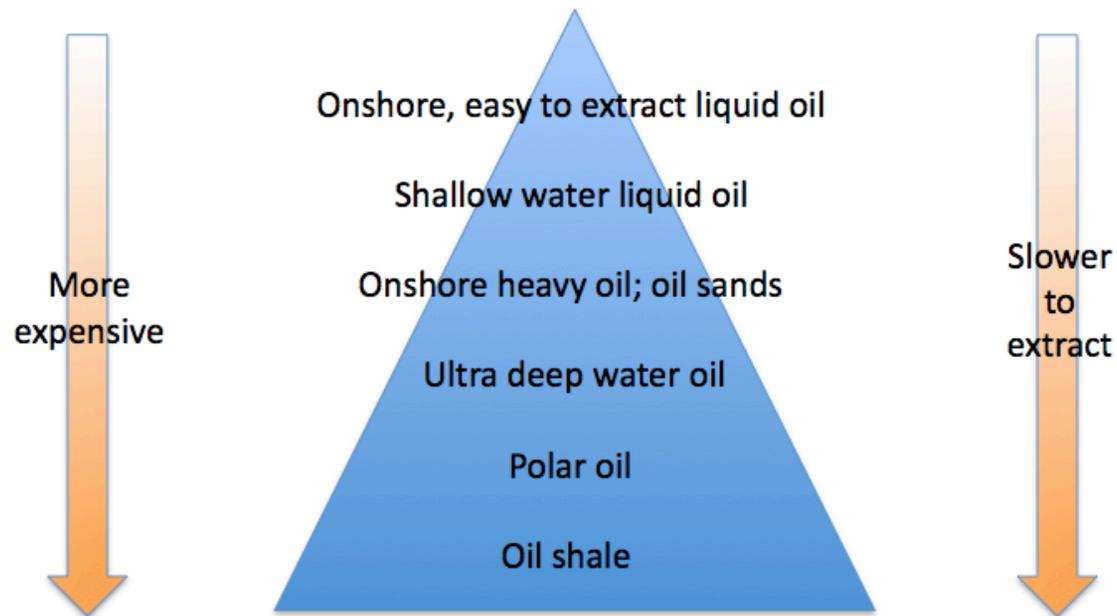
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- ▶ Added workers or other resources no longer provide the same benefit
  - ▶ Opposite of “becoming increasingly efficient”
- ▶ Very often, the effect becomes apparent very suddenly
  - ▶ Adding the 51<sup>st</sup> farmer, for example
- ▶ We will see on that the situation with oil supply is surprisingly similar to adding farmers, when there is no room for more farmers

We usually extract the “easiest to extract” oil first, and move on to more expensive oil

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## A huge amount of oil is available



## As you recall, oil is used almost everywhere

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### Food Uses

- ▶ Fertilizer transport
- ▶ Pesticides
- ▶ Herbicides
- ▶ Diesel for tractors
- ▶ Fast transport to market
- ▶ Diesel for irrigation
- ▶ Fuel for refrigeration
- ▶ Asphalt for roads

### Other Uses

- ▶ Medicines
- ▶ Plastics
- ▶ Gasoline
- ▶ Synthetic cloth
- ▶ Building materials
- ▶ Easier metal extraction and working
- ▶ Diesel for earth movers

## We have the same situation as with the farmers

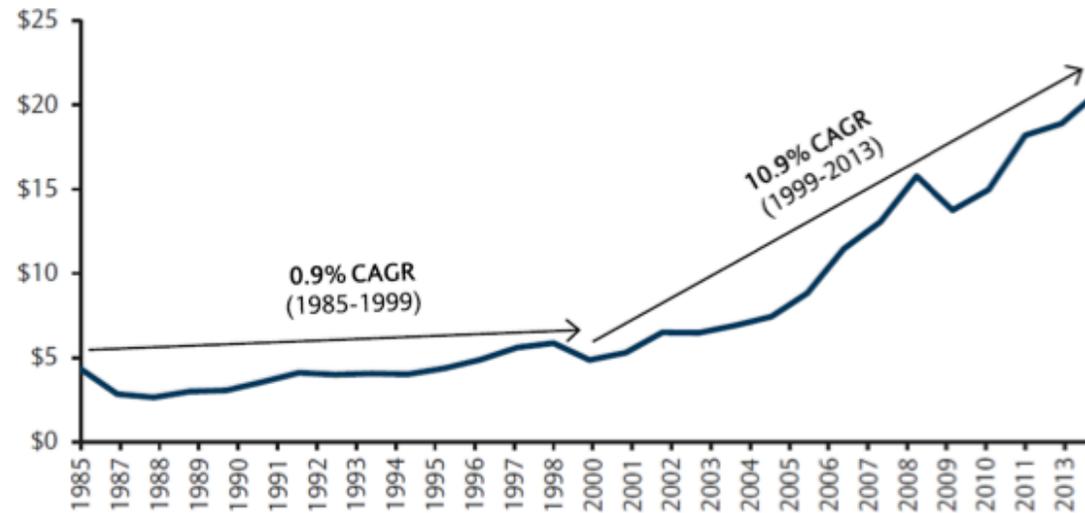
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- ▶ Initially, at the top of the triangle (earlier slide), it doesn't take many workers (or many other resources) to extract one barrel of oil
- ▶ In fact, the situation stays pretty much the same, for a long time
- ▶ It is only as we are forced to move from “conventional oil” to unconventional oil that a big upturn in costs takes place
  - ▶ Need more workers and more resources per barrel of oil

# Sudden shift in costs occurred in data of oil companies, beginning in 1999



## Costs are Rising



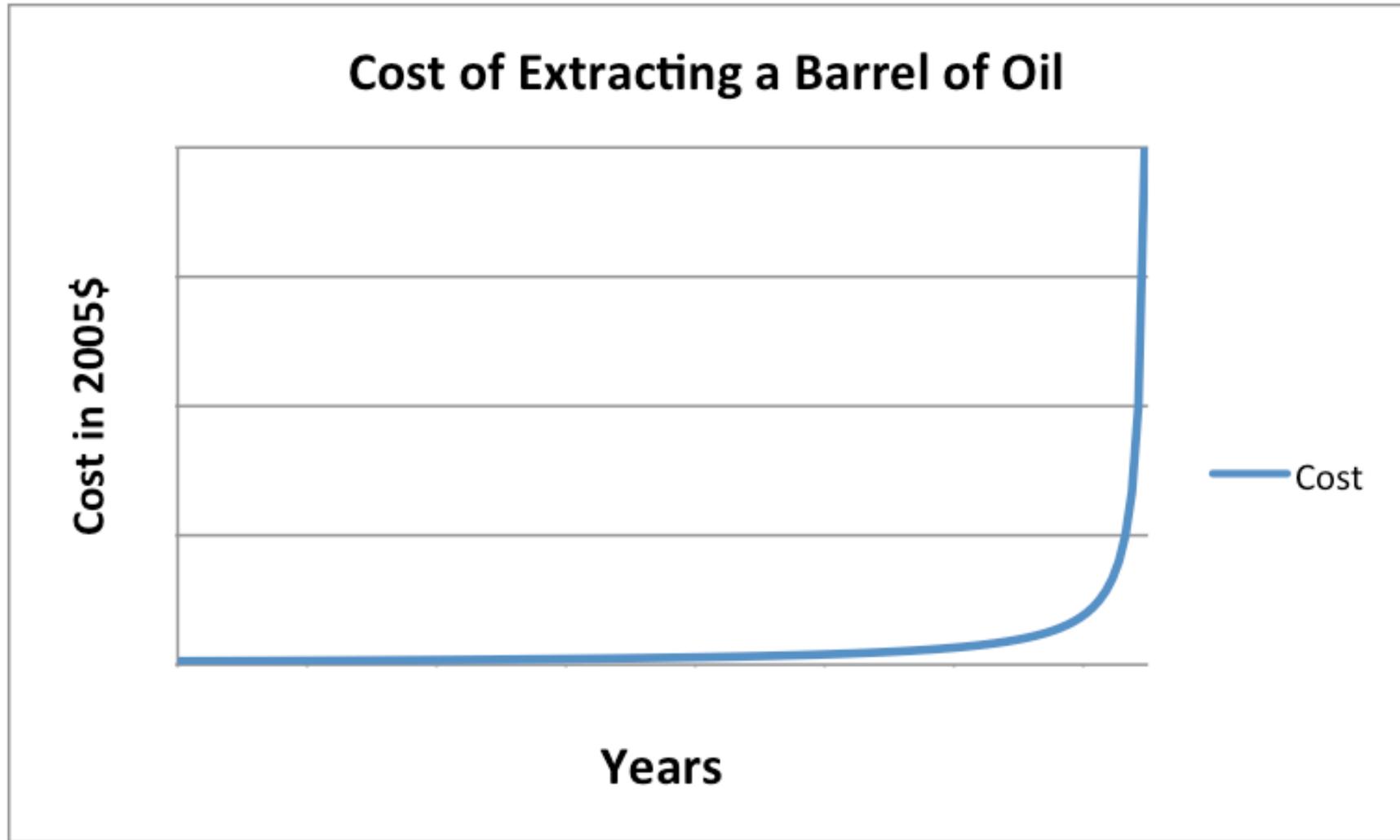
Source: IEA, Barclays Research

### E&P Capex per Barrel

Source: Barclays Capital

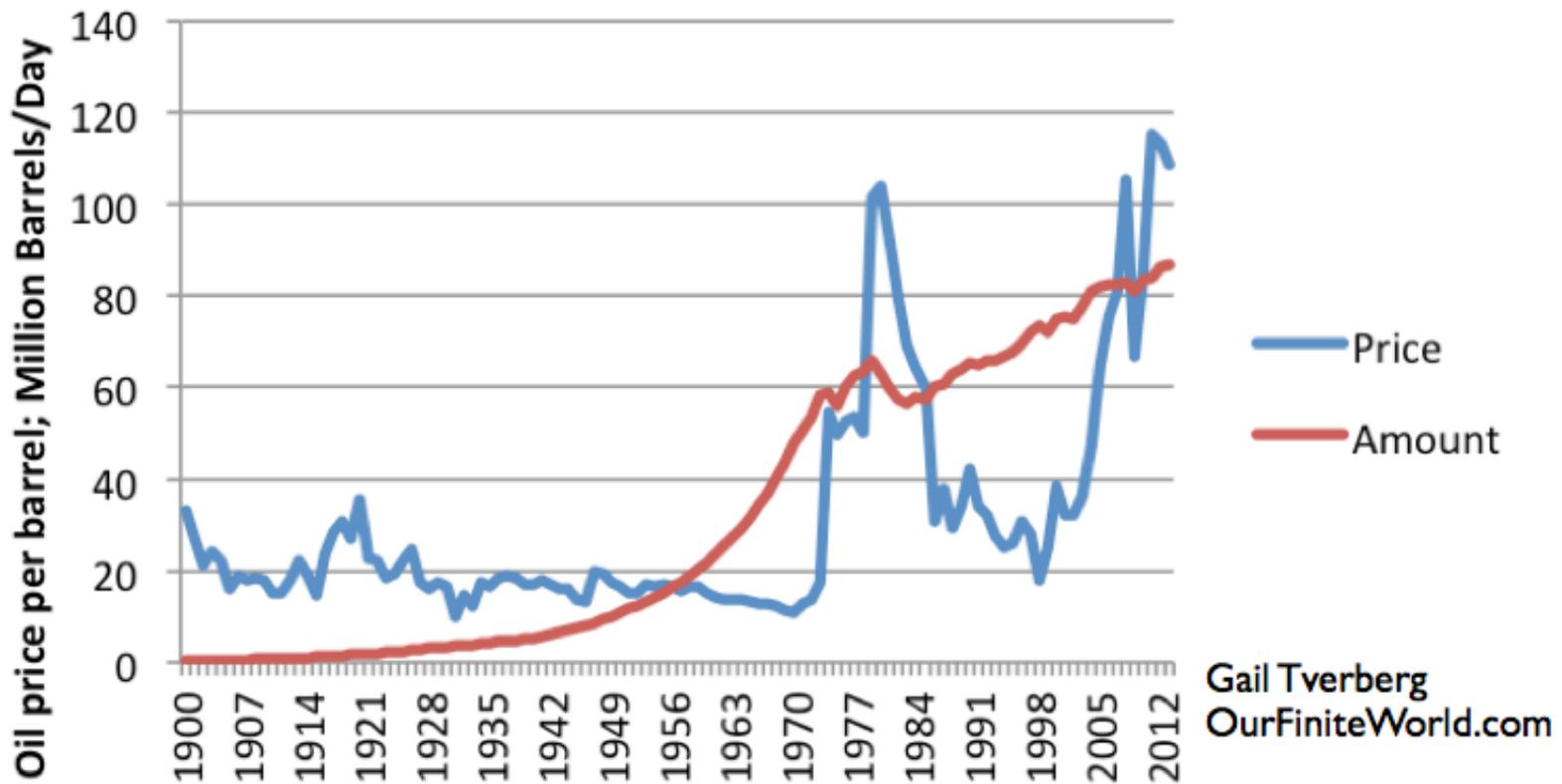
Source: Presentation by Steven Kopits at Columbia University, February 2014 <http://energypolicy.columbia.edu/events-calendar/global-oil-market-forecasting-main-approaches-key-drivers>

We usually see higher costs expressed as “higher cost per barrel of oil produced”



In fact, we have been seeing this problem with spiking oil prices since 1999

**World oil consumption vs price (2013\$)**

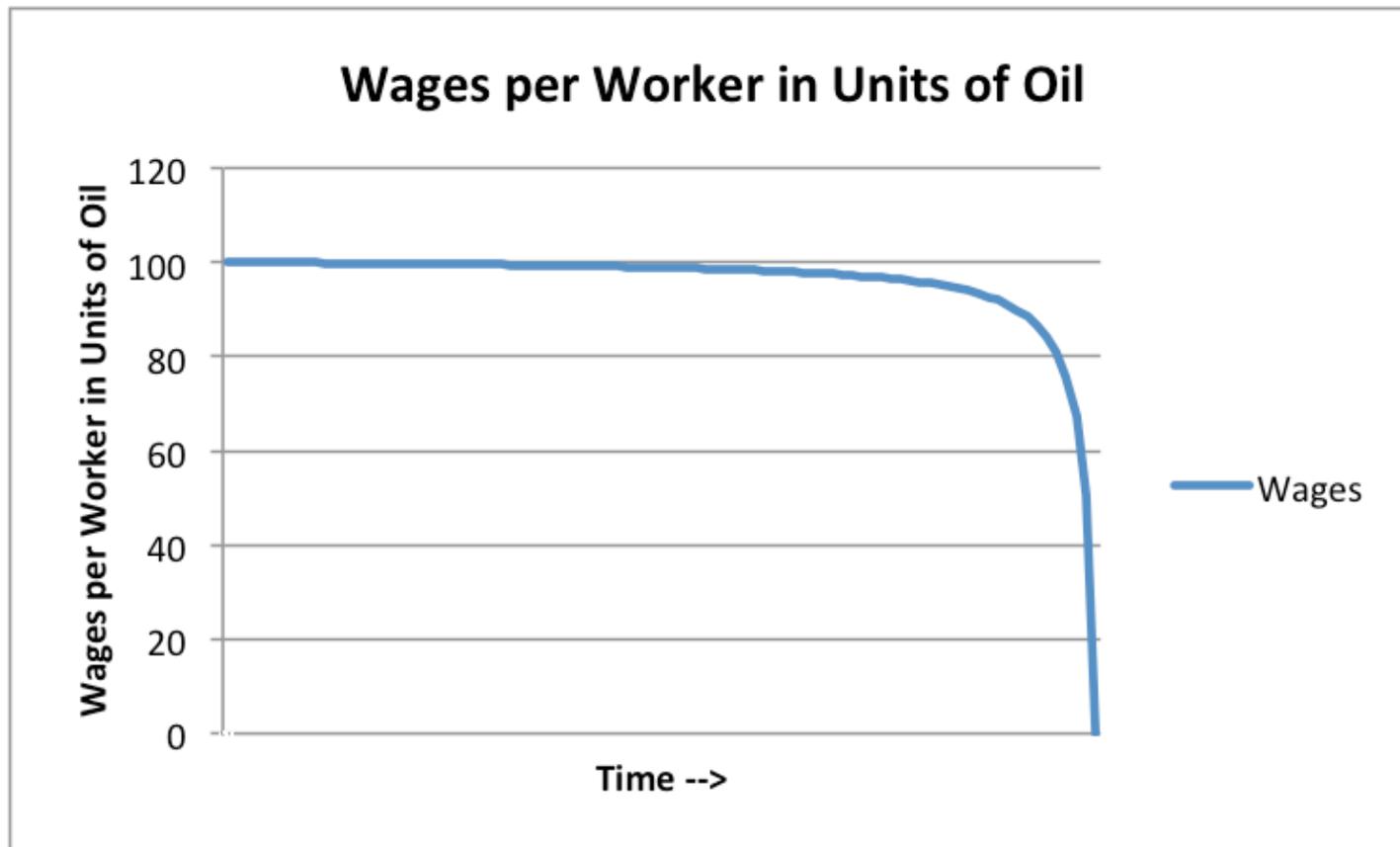


Based on data of Vaclav Smil and BP Statistical Review of World Energy 2014.

We could just as well flip Slide 15 chart over  
– wages per worker in terms of oil produced

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- ▶ Looks like the effect of adding too many farmers to field!



## We begin to have a conflict

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- ▶ On one side of the conflict:
- ▶ There is a need to pay all of the additional workers involved in oil extraction
- ▶ We also need to pay for all of the additional resources
  - ▶ Water and sand transported long distances, used for “fracking”
  - ▶ Special equipment to extract oil from deep under the sea

## On the other side of the conflict:

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- ▶ The value of the oil to society is determined by the goods and services it can produce
- ▶ The value of these services is determined by the energy content of the oil
  - ▶ How far the oil can make a car or truck travel
  - ▶ Or how much food agricultural machinery can produce with oil
- ▶ The oil is not becoming much more valuable on this basis
  - ▶ There are efficiency gains—through higher mileage vehicles—but these are small in comparison to increases in extraction cost

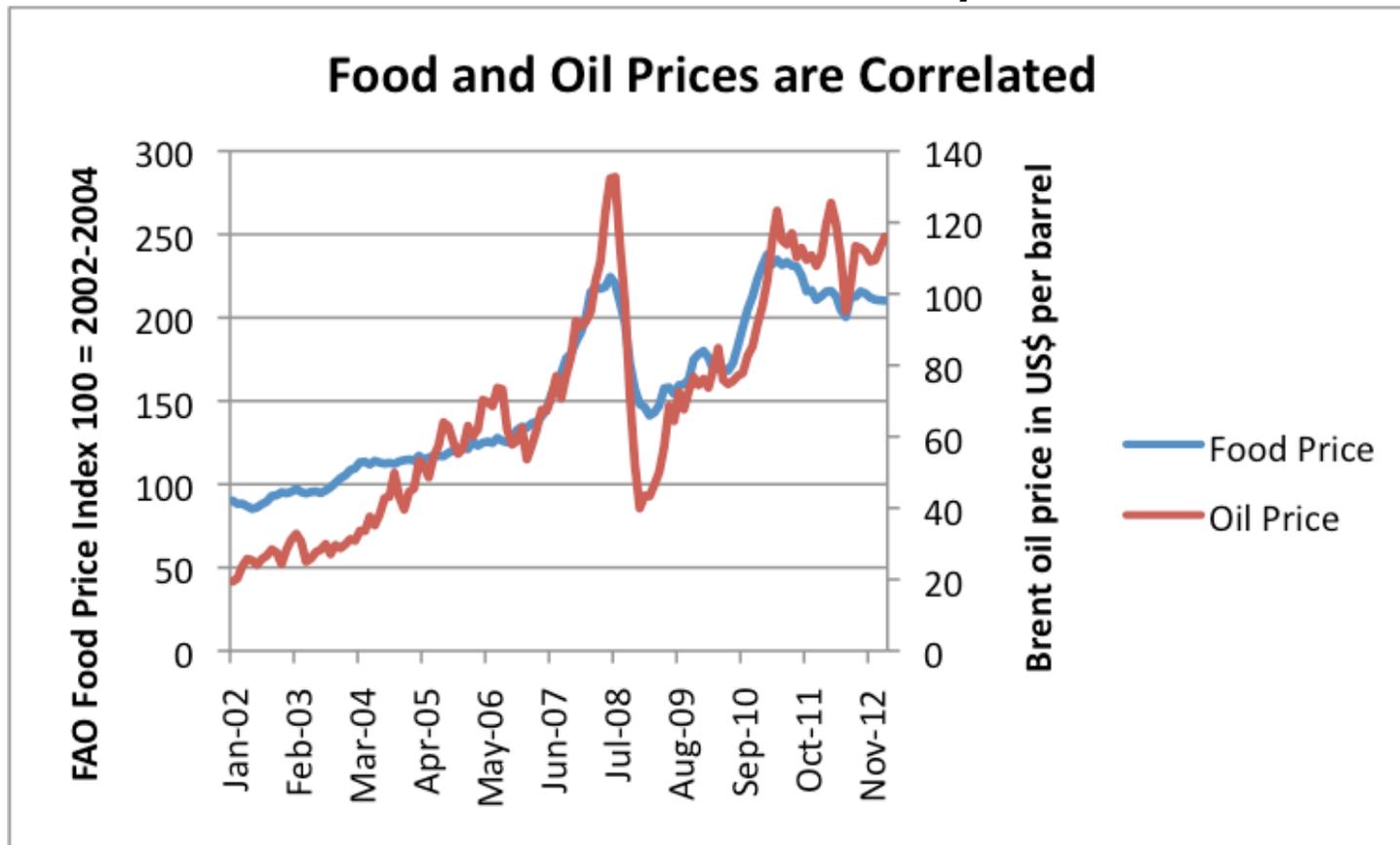
Result – it is very difficult for oil prices to rise as much as they need to

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- ▶ When oil prices rise, they tend to have an adverse impact on the rest of the economy
- ▶ Tends to lead to recession
- ▶ In the next few slides, we will look at how this happens

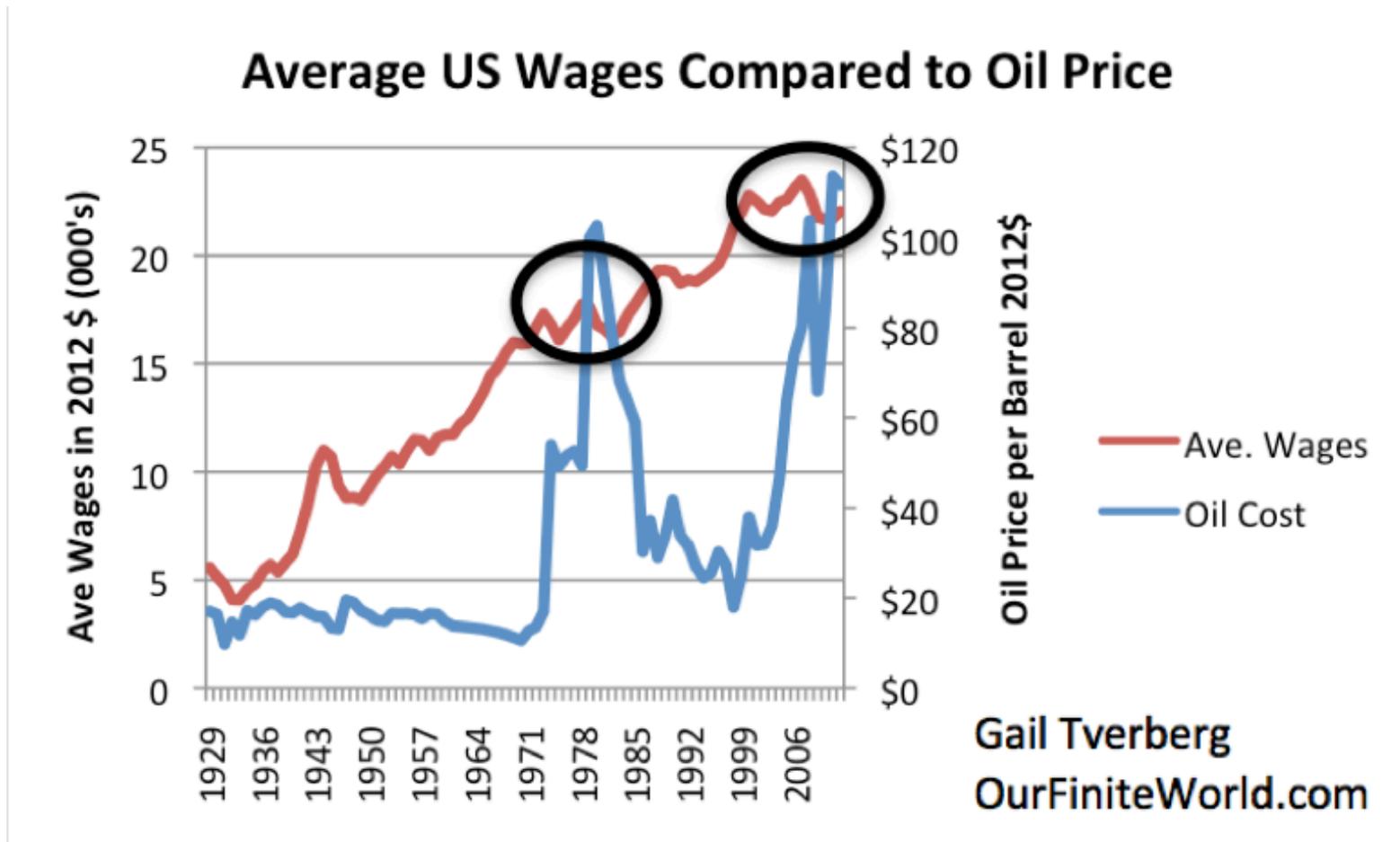
# Food prices tend to rise with oil prices

- ▶ Common workers are most adversely affected.



Based on data of Food and Agriculture Organization of the United Nations and US Energy Information Administration.

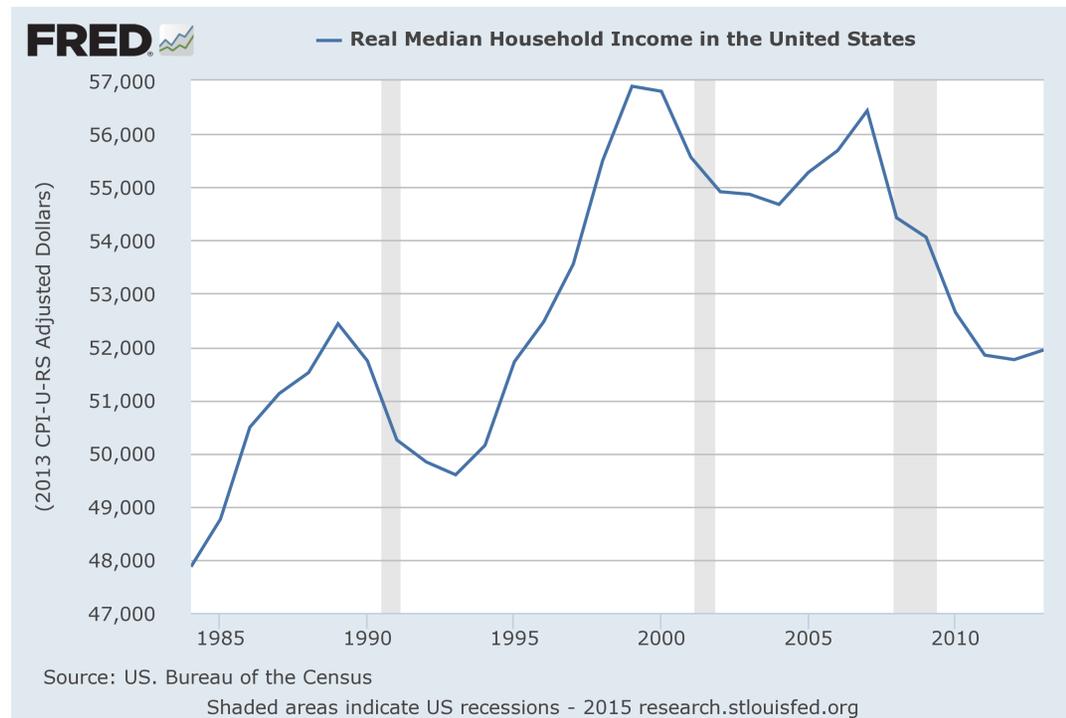
# Wages don't rise as oil prices rise



Average wages in 2012\$ compared to Brent oil price, also in 2012\$. Average wages reflect wages adjusted using CPI-Urban, divided by total population.

# In fact, US median wages have fallen since 2000, as oil prices rose

- ▶ Common workers are doing less well, both because of rising food prices and falling wages
- ▶ 1993-1999 period had low oil price (\$26), rising median wages



## The spike in oil prices in 2005 – 2008 led to the 2007 – 2009 recession

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- ▶ Impact greatest in countries that used the largest percentages of oil in their energy mix
- ▶ Recession = Contraction of the economy
- ▶ Economist James Hamilton showed that 10 out of 11 US recessions since World War II were associated with oil price spikes
- ▶ I wrote, “Oil Supply Limits and the Continuing Financial Crisis,” published in the journal *Energy*

## In 2007-2009: Workers needed to buy food, and also fuel to get to work

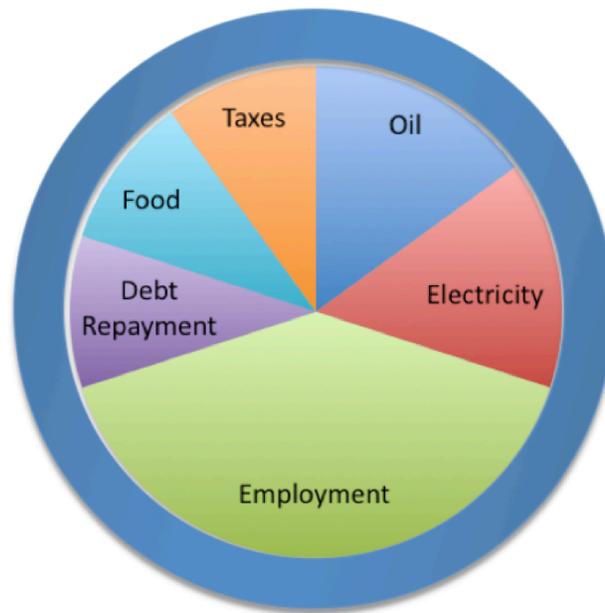
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- ▶ Workers cut back on things that weren't necessities
  - ▶ Examples: Restaurant meals, contributions, vacation trips
- ▶ Workers in these industries lost their jobs
  - ▶ Often could not pay their home loans
  - ▶ Banks got into financial difficulty
- ▶ Home building industry adversely affected
  - ▶ Fewer new homes built
  - ▶ Workers lost jobs in home building industry
- ▶ Recession = negative economic growth followed

# Liebig's Law of the Minimum

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- ▶ Agricultural yield is proportional to the amount of the most limiting nutrient
- ▶ Chemical reactions – output limited by the reagent with smallest quantity



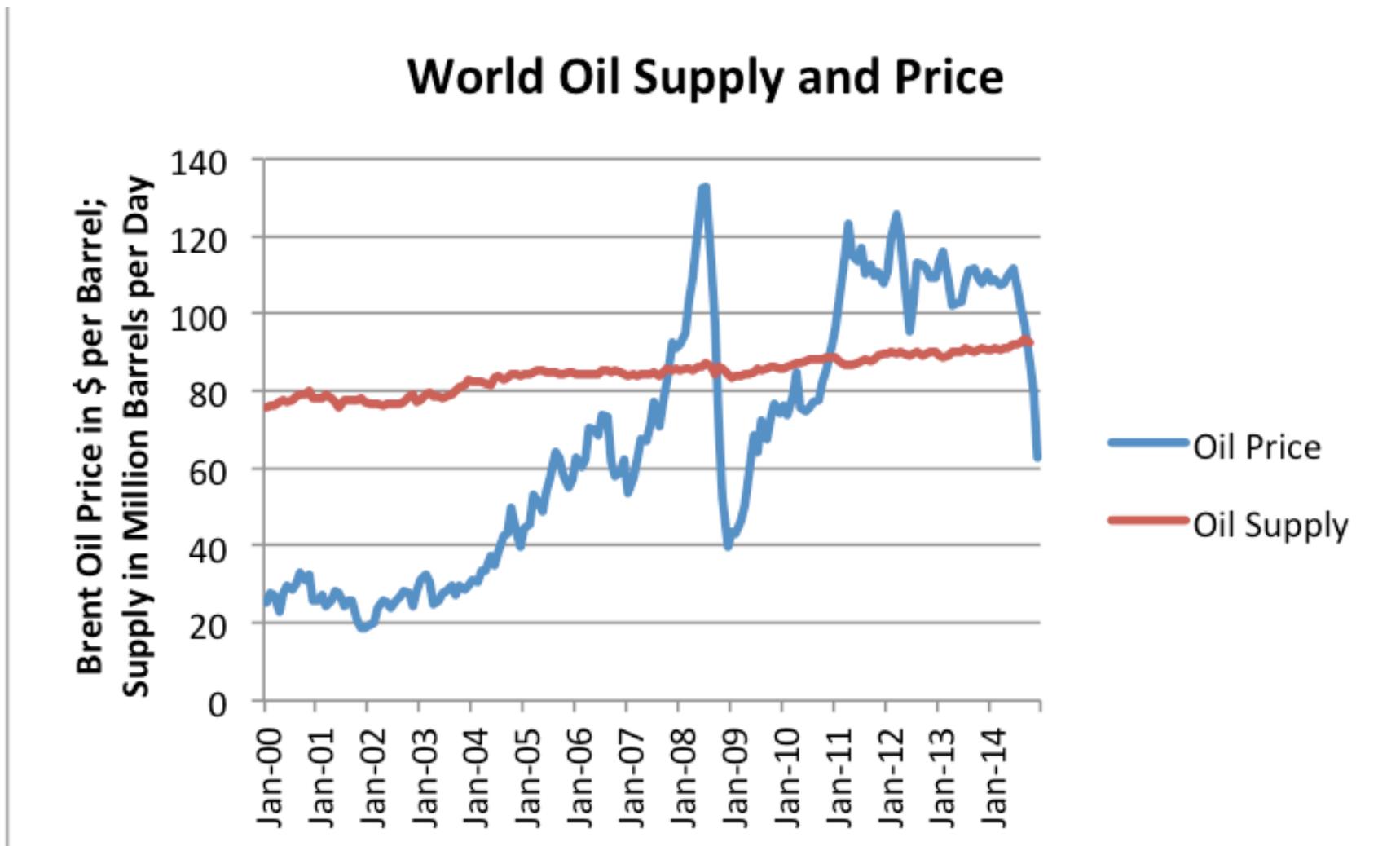
- ▶ Recession seems to be similar-limited oil shrinks economy

In 2007-2009, high cost of oil extraction=>  
high oil prices => recession

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- ▶ Could high cost of oil extraction also lead (indirectly) to low oil prices?

Back in 2008, there was a sharp drop in oil prices; seeing another sharp drop now



## How falling inflation-adjusted wages of common worker can lead to low oil prices

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- ▶ Common workers buy mostly goods, few services
- ▶ Large number of common workers means these workers buy a significant share of food, oil for commuting, and basic household goods
  - ▶ Not true for less basic goods and services
- ▶ If inflation adjusted wages of common workers are falling
  - ▶ Common workers have to cut back somewhere
    - ▶ Cut back on goods made from commodities
    - ▶ Leads to lower commodity prices

## Commodity prices tend to be variable to begin with

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- ▶ Lack of affordability by common workers may be a big part of today's low oil and metal prices
- ▶ Effect is different from non-commodity prices
  - ▶ Also different from effect when diminishing returns is less of a problem for oil
- ▶ Economists have missed this point
  - ▶ Assume that prices will rise to cover the cost of oil extraction
- ▶ If prices don't cover the cost of oil extraction, we have a big problem!

## Another way oil prices can fall has to do with borrowing ability of workers

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- ▶ Workers can't to take out additional loans for cars and homes
  - ▶ Workers with falling after-tax incomes especially affected
- ▶ We will talk more about this later

We talked about diminishing returns with oil. Situation with coal is similar.

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- ▶ Cost of coal extraction gradually rises
- ▶ One example – Within a single mine
  - ▶ Owner extracts the easy to extract coal first
  - ▶ Later extracts from narrow, deep coal seams
  - ▶ Each worker extracts less coal
  - ▶ Eventually so little coal produced by each worker that the mine must be closed
    - ▶ Owner cannot afford to pay the workers, plus the owners' other expenses, at the market price for coal

## Situation with coal is similar to oil (continued)

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- ▶ Another example—early coal mines are the “best” ones
  - ▶ Closest to users
  - ▶ Best quality coal
  - ▶ As these are depleted, new mines are farther away and have poorer quality coal
    - ▶ More miners must be added, to produce the same quantity of coal
    - ▶ Production per miner drops
    - ▶ If miner paid in coal, his wages would drop
  - ▶ Can society as a whole afford to maintain coal miners’ wages, even though they are not producing as much coal, on average?
    - ▶ Would require coal price to rise, and others to pay the higher cost

# Non-Energy Diminishing Returns

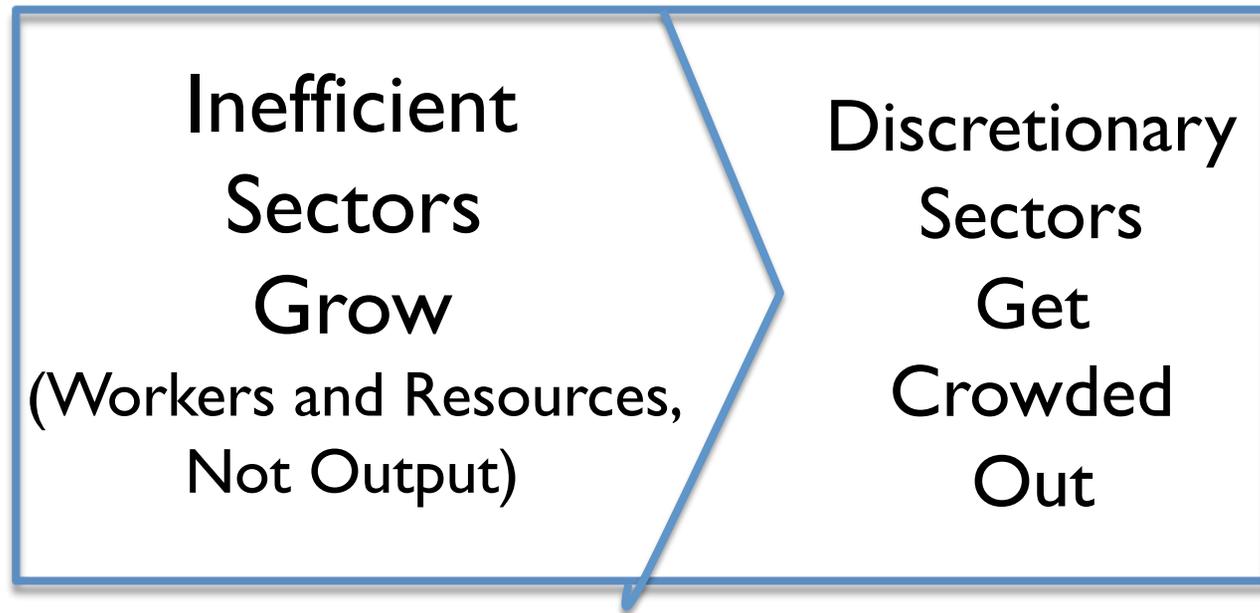
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- ▶ Many other parts of the economy are affected by diminishing returns, including
  - ▶ Extraction of metals
    - ▶ Ores containing lower percentages of metals
  - ▶ Water supply
    - ▶ Need to use desalination, or bring oil by pipeline from a distance
  - ▶ Pollution – and attempts to mitigate pollution
    - ▶ Workarounds for carbon dioxide and other pollutants are expensive
  - ▶ Cost of medical care
    - ▶ Increased specialization, more expensive procedures
    - ▶ Little change in outcomes
  - ▶ Advanced education – more and more needed, for all jobs

## All of the diminishing returns act together

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- ▶ Make it harder and harder to produce goods cheaply
- ▶ More and more workers needed for increasingly inefficient sectors
- ▶ Makes it hard to produce as much goods in total

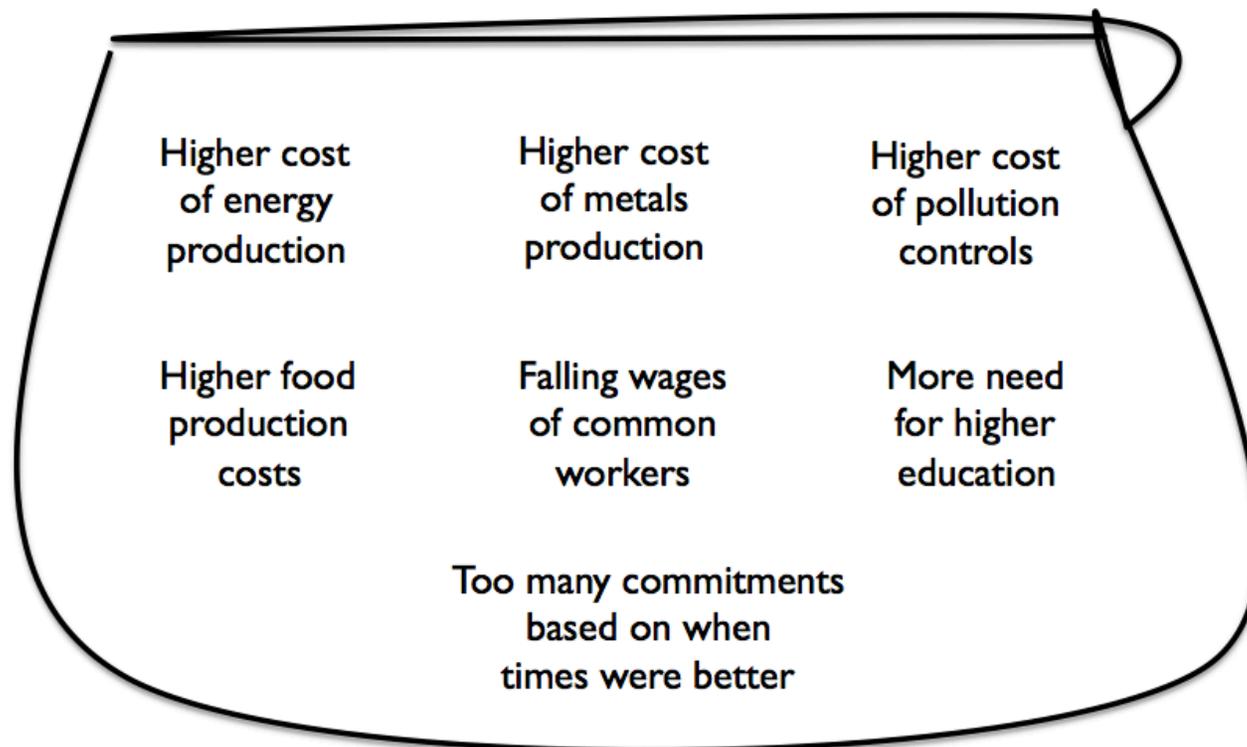


# Another way of viewing the diminishing returns acting together

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- ▶ Workers can no longer afford all of the costs required

## Financial Failure Basket



Gail Tverberg [OurFiniteWorld.com](http://OurFiniteWorld.com)

## How do we produce economic growth, then?

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- ▶ We have talked about how to produce decline using diminishing returns
- ▶ Now we want the opposite

Answer: We need to produce the goods the common worker needs more cheaply

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- ▶ In some sense, this is the opposite of diminishing returns
- ▶ Instead of goods becoming ever-more expensive to produce, they become ever cheaper-to-produce
- ▶ We can do this by adding increasing amounts of cheap energy
  - ▶ Human energy is expensive; other energy is cheaper
  - ▶ Coal and hydroelectricity tend to be the cheapest supplemental sources
  - ▶ Some people talk about “leveraging” human energy with other energy

# Leverage

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**Leverage increases the power of Person**

<http://www.svtuition.org/2011/08/impact-of-leverage-on-risk-and-return.html>

# Some ways of leveraging human energy with supplemental energy

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- ▶ Adding machines to do part of the work
  - ▶ Sewing machines
  - ▶ Machines used in manufacturing
  - ▶ Computers to aid help human workers do job better
- ▶ Additional education for workers
  - ▶ Education requires energy use as well
  - ▶ If very little supplemental energy, everyone need to be farmers
  - ▶ Adding energy use allows farmers to produce more, so that others can spend time as teachers and students
- ▶ Adding roads and better transportation
  - ▶ Less food spoilage; easier to get goods to market

# To increasingly leverage human energy

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- ▶ We need to add more and more energy to human energy
- ▶ This energy needs to be inexpensive
  - ▶ We already saw the adverse impact expensive energy had on the economy
- ▶ One reason energy must be cheap is the limited funds people have for buying energy products
  - ▶ If energy costs \$1 per unit and workers have \$100, they can buy 100 units.
  - ▶ If energy costs \$10 per unit, the same \$100 will buy 10 units
  - ▶ If energy costs \$100 per unit, the same \$100 will buy only 1 unit

## If the economy is to grow, need to make more affordable goods

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- ▶ Wages of common worker must buy more and more
- ▶ In theory, increased efficiency can help
  - ▶ But this requires building new cars, trucks, electrical generating stations
  - ▶ Requires large amounts of energy use
  - ▶ Reaches thermodynamic limits
- ▶ We get back to needing more and more cheap energy to supplement human energy

# Cheap-to-extract oil provides a subsidy to society that leads to economic growth

- ▶ This subsidy to society is lost, as the cost of extraction rises

