The Networking of Resource Production

Posted by aeldric on September 22, 2010 - 10:40am in The Oil Drum: Australia/New Zealand
Topic: Supply/Production
Tags: collapse dynamics, economic collapse, globalised economy, peak, peak everything [list all tags]

Lately I have been grappling with a question: I keep hearing that once "non-conventional oil" is accounted for, we have trillions of barrels of oil. Counting coal-seam methane we have gas for centuries. Based on recent claims we probably have enough coal to build a bridge to the moon and enough iron to run a 20-line railway to Mars and back.

Of course this does not consider production rates – but given these forecasts, should we really worry about production rates? Given the technologies at hand, what would cause the production rate of a resource to peak? In a world of networked resource dependencies, what would be the consequences?

All resources can be found in any required quantity if there is enough energy input available. For example:
- Most elements are present in seawater. Want gold? You can extract it by the ton from sea water.
- Oil can be synthesised from any organic compound.

So why shouldn't production rates increase pretty much indefinitely?

This question led me into a tangled series of questions about the modes of failure of networked resource production. How does failure occur and how is imminent failure signalled?

I have three conclusions:
1. There is a theoretical limit to how long a networked resource system can continue to function.
2. This limit is reached with little warning.
3. Even after the limit is approached and the squeeze on networked resources starts, the nature of the problem is not apparent to the resource producers, who are likely to say "there is still plenty of our resource available - we just need more inputs and better price signals"

All three conclusions are surprising. Why should there be a theoretical limit? Why would the warning signs be hidden? Why would the problem be difficult to diagnose even after the first impacts are felt?

But before I get to this, I should answer the question "What is a network of produced resources?"

Networked Resources

The process of extracting resources from the ground has become more complicated. During the Iron Age the production of iron required some bog-iron ore, a hot fire, and a lot of muscle. Now the production of iron requires an immense list of reagents, catalysts, fuels, and processes. If any of these inputs is absent, production stops.

In modern times, the production of resources is an interlinked chain of mutual dependencies.

But resources aren't just networked because of these interconnected dependencies - in some cases, when a resource is in short supply, one resource will even be used as a substitute for another. For example when oil is in short supply organically-sourced substitutions (such as alcohol) are possible.

So sometimes one resource will substitute for another.

If we assume a technical ability to synthesize, extract and substitute, is Peak Production of any given resource even a theoretical possibility? I'd like to come back to that question. For a start, we should look at what to look for when/if we start to bump into a global resource constraint. Oil is an obvious candidate for this examination.

Local Peak Vs World Peak – Different Signatures.

In many parts of the world we have seen oil fields display a peak in production. Although it is a gross simplification, I am going to say that early in the history of oil field depletion this peak appeared to take the form of a Bell Curve – a gradual ramp up of production, a peak in production, and a gradual ramp down.

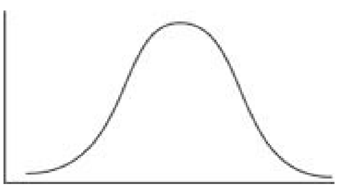

Fig. 1. Bell Curve.

Phoenix observed recently that this relative symmetry was as much a product of economics as it was of geology. If low-cost oil is available from a field in the next county, there is no incentive to invest money in a declining field to squeeze out a few extra high-priced barrels of oil. It makes economic sense to simply let the field run down slowly.

More recently the shape of a depleting field has shown a distinct skew, with a sharp peak, decline, and then a "fat tail".

Why? Because if oil is in short supply, then the price of oil tends to rise. At higher prices it becomes economic to use sophisticated drilling and production techniques to push the production of a field higher, past where it would normally have peaked. This extracts more oil and gets the oil out faster, but as a consequence, when the field declines it declines suddenly. The decline is arrested (though at a lower production level) by "Enhanced Oil Recovery" (EOR) techniques. These techniques cannot push a field's production levels back to peak levels, they simply create a fat tail.

In summary: In an open, global market, the shape of a production graph will depend on the degree of constraint of the resource. When constraint is present, the price goes up. As the price point grows higher the production peak is pushed higher and the decline is sudden, followed by a fat tail.

Technical Limits.

Given the advances of technology, is Peak Production of any given resource even a theoretical possibility? We have advances in substitution, synthesis and extraction. Do these advances have limits?

Substitution

Given that one resource can often be substituted for another – why isn't it done more often?

Simple. We always select the most efficient usage that we know of. In general, the substitutes are less efficient. You can build an Electric Car, thus substituting Lithium and electricity for petrol. However, what you have is a car that is more expensive and doesn't go as far on a "full tank". So substituting lithium/electricity for petrol works, but offers less utility. If it offered more utility, we would all be driving electric cars!

So substitution is less efficient. However, in a pinch we can still do it..... right? I want to come back to that question, because that is at the crux of the problem. The question is: Surely, in a pinch, we can accept the less efficient substitution? The answer turns out to be... theoretically,.... errrr..... no. I want to come back to the reason, but first let us look at other technological promises.

Improved Extraction Techniques

How about improvements in our ability to synthesize and extract? I mentioned earlier that you can get just about any element from sea water. Why don't we? Again it comes down to efficiency.

As a rule of thumb, when the quality of the ore drops, the amount of energy required to extract the resource rises:

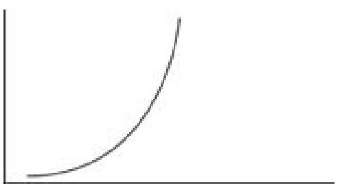

Fig. 2. Energy Consumed as Quality of Extractable Resource Drops

Unfortunately. All over the world Mining companies are reporting declining ore quality.

This is fine; we can go on forever - as long as we have endless energy. But to produce that energy we need more resources. And to extract the resources we need more energy – which requires more resources, which requires more..... And now we begin to see the problem.

Very similar issues exist for synthesis. As an example - In theory, oil can be synthesized from almost any organic material. So why don't we? Because it is inefficient. Unless the starting point is relatively close to oil, the energy consumed in synthesis approaches the energy provided by the oil. The Energy Return On Energy Invested is low – or even negative.

In Summary: The key concept here is that most elements and compounds can be produced in essentially unlimited quantities if we ignore dependencies. So "peak production of X" is not dependent on remaining resources of X. The extraction rate depends on the dependencies associated with production of X. These might include energy, nitric acid, security of workers, acceptable disposal of wastes, etc. The dependencies will in turn have dependencies with limits.

Resources are dependent on other resources. When we run into a limit in the dependencies on one or more resources these will, in turn, limit one or more others, which will impact others, etc.

Signalling the end in a Networked Resource System.

When we talk about production of resources, "Easy Oil" isn't the only thing we are reaching the end of.

We are digging deeper for coal, extracting minerals from ores that have lower concentrations, creating more environmental damage for the same produced quantity, consuming more energy to achieve the same produced quantity, etc.

The inputs required are increasing for any given quantity of produced resource. Consequently there is less left over after the net gain is calculated. Ultimately, if more resources are used in production, less wealth is left over for us to share amongst ourselves.

Our standard of living depends on the margin between resources produced and resources consumed in the production process:

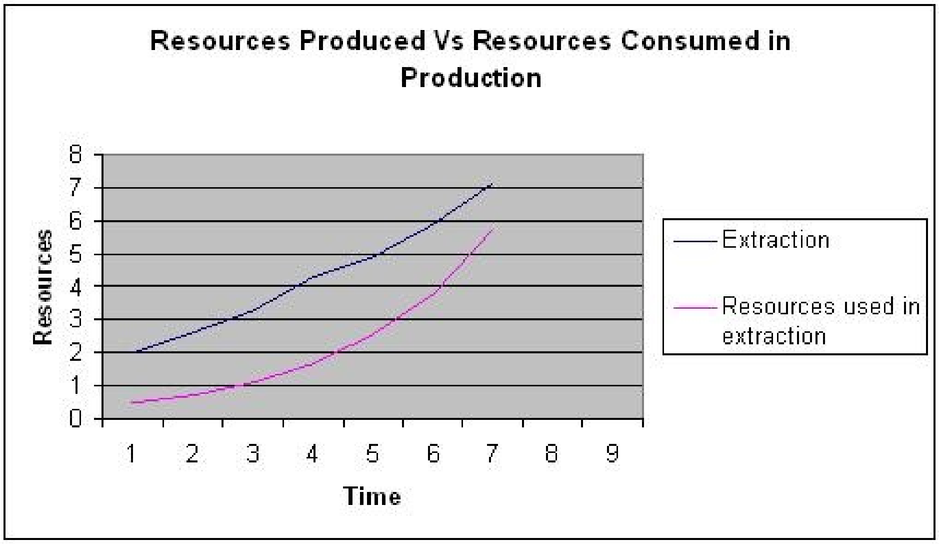

Fig. 3. Our Prosperity is found in the gap between the pink line and the blue line.

We live in the margin. If you think that wealth can somehow be decoupled from resource availability, consider what the stock market would do if all resource companies announced that available resources are in permanent decline. The entity that we refer to as "The Economy" is simply a way of expressing the degree of available resources. It is worth examining that concept further.

Production Land Model.

Let us assume that there is a resource "A". A is consumed at a rate that increases by 5% each year. Why? Many reasons: Because our population is increasing, because global GDP is increasing, because Chinese kids want Happy Toys with their Happy Meals. For a myriad of reasons, demand for most resources goes up each year, and so production goes up.

So let us say that this year we produce 10 units of resource A, and we consume 1 unit of other resources to produce A.

Increasing at 5% per year, production of A will double every 14 years. Will consumption of the input resources double every 14 years? On the one hand you might say "No" because we will get more efficient at producing A.

However, on the other hand, after 14 years we might find that A is harder to get. In order to double the production, we might need to go from a 3% pure ore to a 2% pure ore, thus requiring us to process 50% more material – so inputs required for production might go up by 50% per unit of produced ore or (based on Fig 2 above) even more!! Consequently, for this example, a doubling of production would lead to a three-fold increase in inputs.

Let us build a model:

For the sake of a simple model, let us say that all resources will grow at 5% per year. As a consequence of the reduced quality of the resources, inputs required to support this accelerating production rate will grow at 10% per year.

Let us assume that infinite substitution is possible - if oil becomes less available, then we will use more lithium, etc.

Here is a first-order model of "Production Land" -

Resource A is produced at 10 units per year and production consumes 1 unit of resources per year.
Resource B is produced at 20 units per year and production consumes 1 unit of resources per year.
Resource C is produced at 30 units per year and production consumes 2 units of resources per year.

Total Production is 60 units increasing at 5% per year.
Total consumption is 4 units, increasing at 10% per year.

At 5% growth, production doubles every 14 years.

After 42 years production has doubled 3 times to 480, and consumption of inputs is at 256, leaving 224 units of extracted resources for people to consume. Looking at the graph below, we can see that at 42 years things look fine. However the system will not survive the next double. For production to reach 960, consumption of inputs must reach 1,024 – more resources will be used in extraction than actually result from the extraction process. Oops.

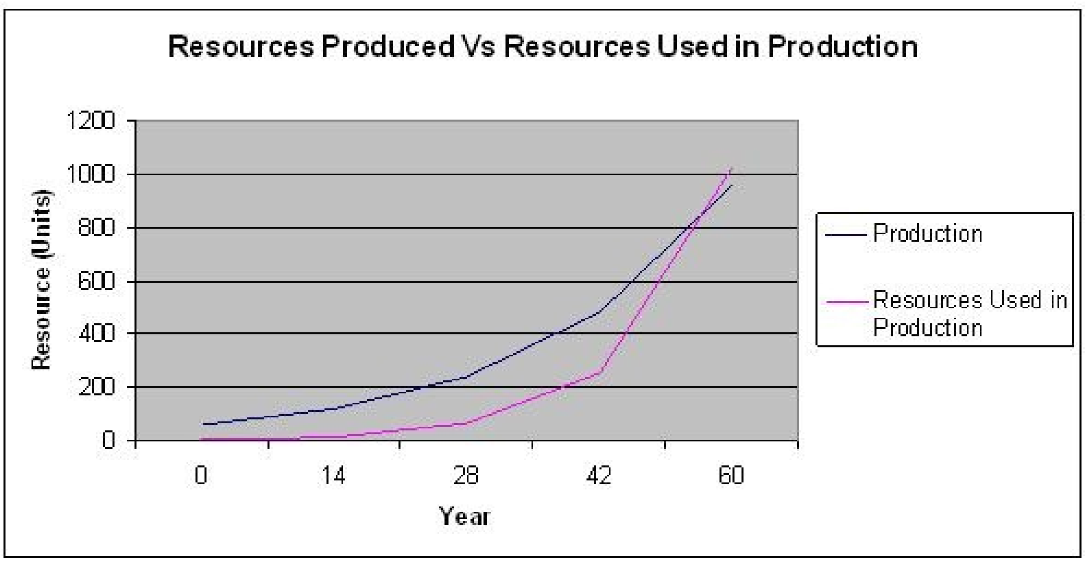

Figure 4. "Production land" model. Resources Produced Vs Resources Consumed.

Note that for the first 42 years thing seem to be fine in this model. In the 5 years from around 43 years to 48 years the model goes through a sudden contraction – the squeeze has a sudden onset. At the 48 year point it is likely that the margin has been squeezed so far that society can no longer run in a BAU fashion going forward.

HOWEVER it gets worse. Initially, the people in Production Land may not have any visibility of the true nature of the problem. Resources don't really come in fungible "Units" - so money gets used as a proxy.

As a consequence, when we enter the squeeze phase, the people who produce each resource will be convinced that "there is still plenty of our resource available - we just need more inputs". (How often have we heard that there are trillions of barrels of oil still to be extracted from shale, etc?)

From their perspective, they are right – steadily improving production techniques have allowed production to ramp up steadily. Even though the quality of the resource is declining, they see no real consequence beyond a requirement for more inputs and more planning.

However, as we approach the crunch, the inputs are becoming expensive and consequently the price of the resource goes up (as we have seen in virtually every significant resource). Since resources are typically inputs for other resources, this problem spreads quickly.

From the producer's viewpoint, the problem is not a shortage of resources; it is expensive inputs and a failure of the market to price their resource "correctly".

Unfortunately, customers are not able to pay at the "correct" price point because the increased price of everything else - including staples such as food and energy - has depleted their cash reserves. In fact society in general is likely to show a lack of liquidity after a series of "price shocks" associated with food and energy resources.

So the problem will not present itself as a lack of resources, it will present itself as a lack of money. The Production Land Society will see that they have a lack of liquidity. The Government of Production Land will create extra liquidity. (Why does this sound familiar?) But this will not fix the problem, since money is a proxy for the problem, not the problem.

If the question is "How is the imminent collapse of a networked resource base signalled?", then I would have to say that the answer is "Ambiguously".

Conclusions

The question that I promised to answer is this: "If we assume a technical ability to synthesize, extract and substitute, is Peak Production of any given resource even a theoretical possibility?"

I think we can now see that the answer is "Yes". Because of the increasing cost of extraction of resources of a steadily reducing quality, and the reduced utility of substitution there is an **absolute theoretical limit** to how far these processes can be pushed.

An additional piece of information came to light: We will have few warnings as we approach that limit. And the warnings will look like .... errr .... what we are seeing right now.

Some conclusions that this argument seems to be pushing us towards:
1. Production of any given resource is supported by a network of dependencies. These dependencies are, in turn supported by a network of further dependencies. In an environment of unconstrained availability of resources, this is not a problem. However, in an environment in which multiple resources may be approaching their economic production limit, a cascading failure can be initiated. There will be few clear, unambiguous warning signs, because our tendency to use substitutable resources with networked dependencies can easily obfuscate the nature of the problem.
2. Production Peaks may be delayed by substitution and improved extraction, but the network of dependencies that result mean that peaks may come all at once - "Peak Everything".
3. World-wide constraints are a new phenomenon. The symmetric Hubbert curve was an anomaly caused by the globalization of the resource at a time when resources were relatively unconstrained. In a globalized, resource-constrained economy the production curve is not symmetrical; the curve is higher, skewed, with a sudden drop, and then levelling out into a fat tail.

The resultant decline in resource production will be driven, more than anything else, by any constraints that may occur in energy production.

What warning signs will we see?

1. We should be looking for increasing substitution of resources – where the replacement resource offers LESS utility than the resource that it is replacing. For example, we are starting to see electric cars. These cars are more expensive, but have less range and carrying capacity than the petrol-driven cars they replace.
2. Society becomes conscious of limitations, and starts initiatives such as a drive to limit pollution and conserve/reuse/recycle resources. We have seen this since the late 1970s
3. Inputs to resource extraction go up in price. This leads to the extracted resource going up in price. Since this resource is likely to be an input to other resources, we expect to see widespread inflation in the price of numerous interconnected resources. Which seems to be happening. I live in Australia, so this is good – the run-up in prices for steel and coal has led to massive windfalls for the Australian economy.
4. Remembering that society is funded by the excess - the difference between resources extracted and the resources consumed in the extraction process - Initially the impact of a decline in available resources would force an improvement in society's efficiency. We have certainly seen many instances of that – ranging from improved energy efficiency to the introduction of computer-related efficiencies.
5. When improved efficiencies are no longer enough to cover the squeeze, the increase in resource price will flow onto an increase in commodity price. Until recently our society has succeeded in negating this by outsourcing commodity production to areas with cheap labour.
6. When cheap labour can no longer compensate for rising resource costs, the price of commodities will start to creep up. This seems to be occurring now.

Can we avoid this?

I believe that I have demonstrated that the claims of endless oil (and other resources) are not lies (as far as those making the claims are concerned), but are also not realizable. Taken in isolation we have endless quantities of any given resource - viewed as a system, we don't have what we thought we had.

If nothing changes, a squeeze is seemingly inevitable.

Obviously there are ways we can avoid this squeeze. The simplest way is to increase the amount of energy available, without increasing the resources consumed to produce it. With unlimited energy all things are possible.

I open the forum to other suggestions/criticisms/alternative theories.