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Energy Return on (Energy) Invested (EROI), Oil Prices, and Energy Transitions

Posted by David Murphy on June 15, 2012 - 7:51am
Topic: Supply/Production
Tags: energy policy, energy prices, eroi [list all tags]

This is a guest post by Matthew Kuperus Heun (Calvin College) and Martin de Wit (Stellenbosch University & de Wit Sustainable Options) based on their recent paper in Energy Policy.

The Oil Drum Editors' Preface

The following analysis provides an interesting view on the relationship between EROI (Energy Return on Energy Invested) and market prices, but the strong inverse correlation that the authors emphasize may be an artifact of the underlying Cleveland (2005) EROI statistics that they use. Cleveland's indirect energy intensity approach, based on calculating EROI from $/BTU and adjusting for energy quality using price indices, will plausibly result in lower EROI during periods of oil price spikes because of higher prices of inputs that do not correspond with higher energy inputs, and will, therefore, overstate changes in EROI that are unrelated to "energy quality."

Because this post is excerpted, we suggest that readers refer to the full paper in Energy Policy for details of the analysis not mentioned below.

Introduction

The economical and sustainable provision of energy to run modern economies and meet human development goals is one of the Grand Challenges facing the world today. There is increasing evidence that the physical scarcity of fossil fuels is a serious possibility to reckon with. An important question to ask is whether price signals of physical scarcity will be sufficient to cause transitions to alternative fuel sources.

One proposed physical indicator of energy supply scarcity is energy return on (energy) invested (EROI). Little work has been done so far to model, test, and understand the relationship between oil prices and EROI over time. This post (based on our recent paper) investigates whether declining EROI is associated with increasing oil price and speculates on the implications of these results on oil policy. The questions addressed are:

- "How is EROI related to energy prices?"
- "What implications do EROI trends over time have for economic and energy policy?"
- "What is required to ensure a smooth transition away from oil toward substitutes?"

We propose a physically based model of the interaction between physical scarcity and market prices, with a focus on the behaviour of EROI and oil prices over time.

Model Development

We developed a model of the relationship between EROI and energy prices of the form

$$P_{E,t} = \frac{m_t c_{E,prod,t}}{1 - \frac{1}{EROI}}$$

Eqn. 14

where $c_{E,prod,t}$ is the cost of producing a unit of energy in time t (in $/GJ), m_t is the markup (ratio of price to cost), and EROI is the gross energy output to energy input. This equation is a form of the "net energy cliff" for prices, wherein we acknowledge that making a profit requires a higher price when energy production declines for the same input "effort." Carey King and Charles Hall obtained a similar result recently (King, C.W., Hall, C.A.S., 2011. Relating financial and energy return on investment. *Sustainability* 3 (10), pp. 1810–1832).

Historical Trends

Figure 1 presents data on EROI, oil price, production cost and mark-up in an easily comparable way. Divisia-corrected EROI for the U.S. remained approximately constant from the mid- 1950s to early 1970s, declined rapidly in the 1970s and increased again in the mid-1990s. The available data indicates that EROI for the world (Gagnon et al., 2009) and the U.S. (Cleveland, 2005) are falling at the present time. The present rate of technology improvement appears to be insufficient to put oil production EROI on a positive slope with respect to time. Time series data for oil prices are available from many sources. We used inflation-adjusted data for the average U.S. oil price ($/barrel) for the period 1946–2010 as based on historical free market (stripper) prices of Illinois Crude. Producer prices for U.S. domestic oil are available from the U.S. Energy Information Agency (EIA, 2010) and show a peak in the early 1980s and a continuous rise from the early 2000s onwards.

Dividing the U.S. oil price by the U.S. producer prices provides an estimate of the oil price mark-up ratio. Over much of the period for which data are available, the mark-up ratio has been relatively constant, except for the spike in the 1970s and the recent decline since 1990. It does not appear that oil producers in the U.S. are (currently) in a position to charge a premium for ever-scarcer oil. In fact, just the opposite appears to be happening: the mark-up ratio has been trending downward over the last two decades.

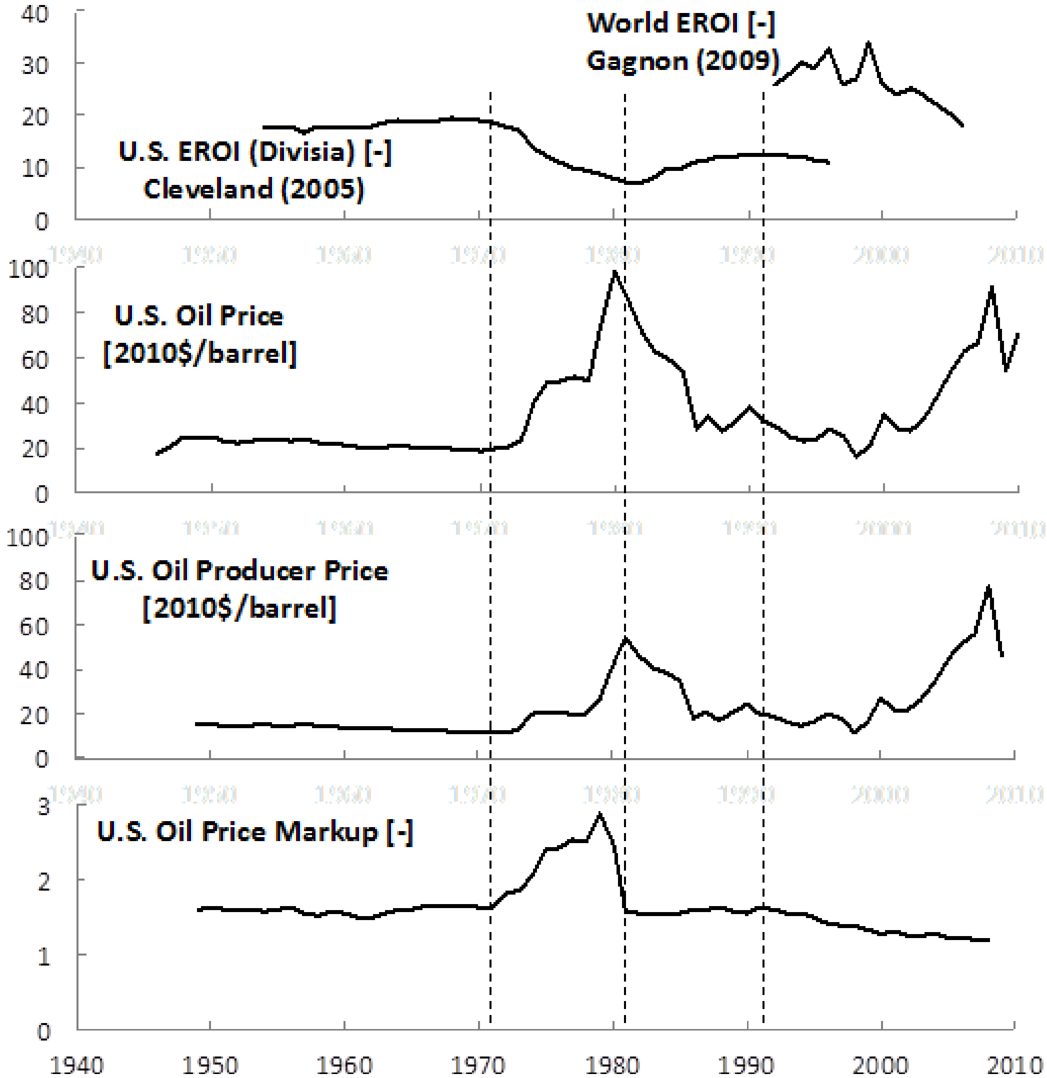

Figure 1: Summary of U.S. time-series data

EROI-Price Correlation

To assess the relationship between EROI and production costs ($c_{E,prod,t}$), we plotted producer prices vs. EROI for the years 1954–1996. We found good inverse correlation. The graph below shows several empirical models that were evaluated statistically.

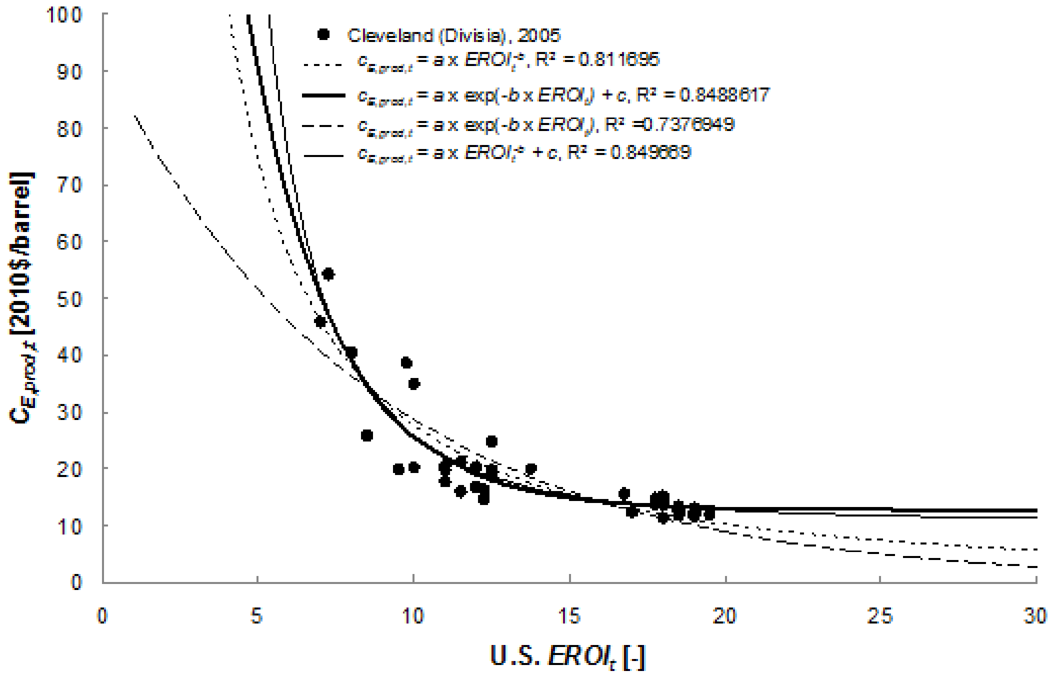

Figure 2: Correlation between producer prices ($c_{E,prod,t}$) and Divisia-corrected EROI (Cleveland, 2005) for U.S. domestic oil production for the years 1954–1996.

EROI Extrapolation

Based on the Cleveland EROI data, we can extrapolate EROI forward through time. This is, necessarily, difficult to do, thus our approach is to bound the future EROI prediction with a linear and an exponential decay function as shown in the following graph.

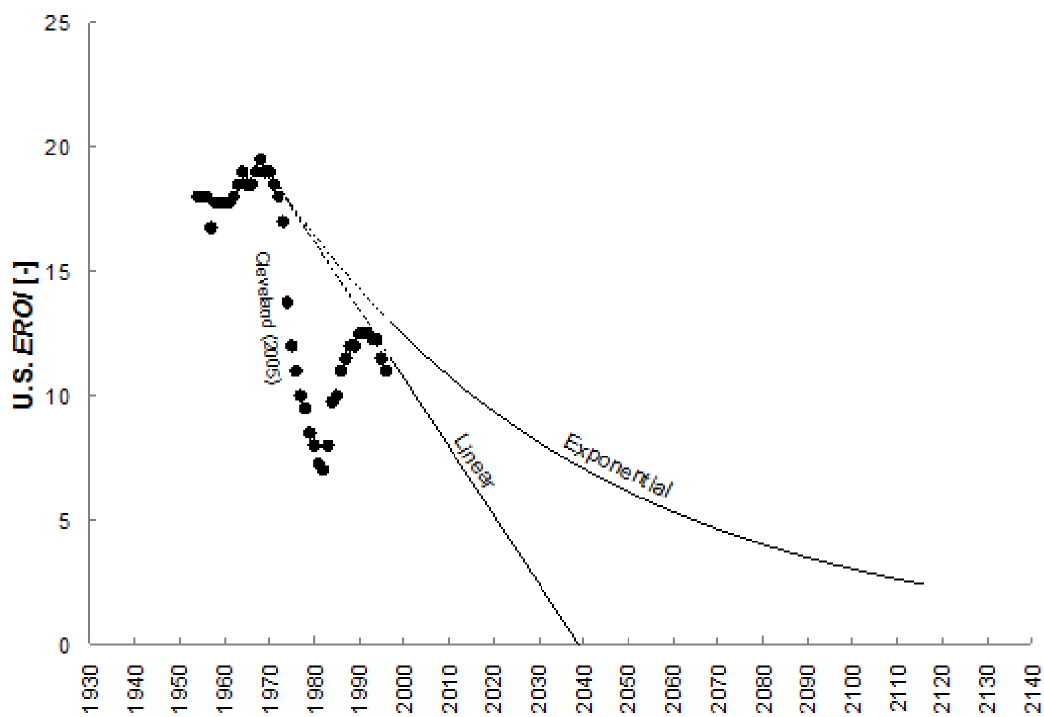

Figure 3: Linear and exponential EROI decline scenarios.

The linear EROI decay line is expected to lead to a faster ramp-up of prices compared to the gradual exponential EROI decay line.

Oil Price Predictions

Using the best model of producer cost vs. EROI and the linear and exponential decay scenarios for the evolution of EROI with time, we can make predictions of oil prices into the future (beyond 1996, the extent of the Cleveland (2005) data).

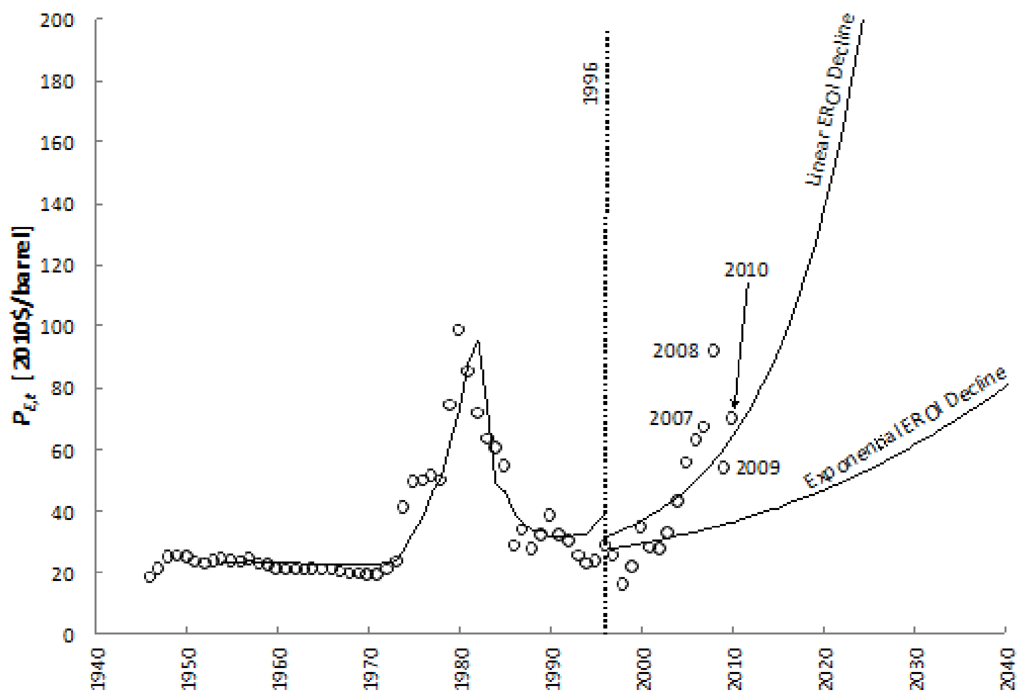

Figure 17: U.S. oil price projections as a function of time

At this point, all indications are that prices are trending above the curve for linear EROI decline: the 2011 average oil price for Illinois crude is $87.48 (see History of Illinois Basin Crude Oil Prices). For 2012, we are already notably higher in the range $95-110. A possible explanation is that a Fear Premium is being paid for geo-political risk on Iran or elsewhere.

Conclusion

One cannot take a smooth transition from oil to other forms of energy for granted. Our paper highlights four factors indicating that a smooth transition away from oil is unlikely: insufficient oil-sector technological development to overcome depletion, declining mark-up, a non-linear relationship between EROI and production costs, and the non-linear relationship between EROI and oil price. In fact, with EROI values tending downward below 10, the risk of significant increases in oil prices, all other factors constant, is very high.

Significant transitions in energy technologies are not fast. Fouquet, in a study of previous energy transitions, indicates that, historically, the time-scale for diffusion to dominance for a new energy technology is on the order of three decades for the fastest transitions.

Several policy implications, most notably to diversify away from oil toward alternative energy sources and to prepare for depletion-induced oil price shocks, lead to the conclusion that some form of management and support will be required to achieve a smooth transition away from oil.

The Dutch example on energy transition management provides some experience, but more research is needed to understand how policy makers can better influence energy transitions.

For additional details, see Energy return on (energy) invested (EROI), oil prices, and energy transitions.