ON THE RELATIONSHIP BETWEEN ENERGY, WORK, POWER AND ECONOMIC GROWTH

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ABSTRACT

There are strong empirical arguments for the so-called `Hubbert thesis', namely that global petroleum output is now approaching its peak. Recent (2004-2005) sharp increases in oil prices, which show no signs of being a temporary `spike', make the Hubbert theory increasingly plausible. This event would have obvious implications for prices and economic activities directly dependent on oil products, especially petrochemicals and transportation. While the Hubbert arguments are not (yet) universally accepted by oil geologists or by the oil industry – at least in public – they cannot be dismissed lightly. One reason, among several, is that economic incentives facing powerful economic interests strongly favor continuing indefinitely on the `business as usual path'. For instance, the stock market valuations of major oil companies, such as Shell, BP and Exxon are directly dependant on proven reserves. This fact, alone, makes the public pronouncements of the established petroleum interests suspect. Another reason for skepticism is the obvious competition for influence among members of the OPEC cartel. Finally, among the economic incentives for refusing to acknowledge the reality – perhaps the only one that restrains the largest producers, and the OPEC cartel from price gouging – is the fear that, if oil prices were to rise too high (and remain high), the industrial countries might get serious about reducing consumption through taxation or regulation such as extended CAFÉ standards. An even scarier scenario for the oil exporters is the prospect – however dim – of rapid development of viable technological energy alternatives.

This paper suggests another, perhaps even more potent, reason for concern. The standard neoclassical theory taught in the economic departments of major universities and accepted by most of the economists who advise governments (and business leaders) attributes economic output (GDP) and economic growth to only two so-called `factors of production' namely capital and labor, which are also assumed to be substitutable for each other. The reasons for this are primarily historical. Natural resources or `gifts of nature' were originally attributed to `land' which later in the 19th century was absorbed into the larger category `capital'. Whatever the reason, standard economic theory does not treat energy *per se* as a factor of production. Energy is treated, instead, as an intermediate product of labor and capital. The arguments for and against this odd notion are not central to the current situation. What is central is that, if energy is *not* a primary input to the economy, it follows that the availability of energy, and the price of energy, are not critical to economic activity or economic growth. For instance, if expenditures for energy are only a small percentage – say 4% – of the total GDP, it seems to follow (from the neoclassical theory) that raising the price of energy by even a factor of two would only reduce the GDP (if at all) by a negligible amount. The established theory assumes that growth is mostly attributable to technological improvement, which is assumed to be exogenous and automatic.

This paper argues, to the contrary, that while `raw' energy inputs (as raw materials and sunlight) are not drivers of economic output, energy converted into `*useful work*' in the physical sense, is indeed a factor of production, along with traditional capital and labor. Useful work can be thought of as the product of raw energy (exergy) inputs, such as biomass and fossil fuels, multiplied by the efficiency of conversion into useful forms, such as electric power and useful heat. Of course, adding a third factor of production undermines the substitutability assumption in the neoclassical theory. However, on

reflection, it seems obvious that capital, human labor and useful work are both substitutes and complements.

The qualitative argument for introducing useful work as a factor is that economic growth has always been a positive feedback cycle, in which lower costs lead to lower prices (of goods and services) which generates increased demand and – through economies of scale, R&D and learning from experience, lower costs again. Evidently the costs of useful work as produced by so-called `prime movers' – such as the steam engine – has fallen by orders of magnitude since the industrial revolution began. These declining costs have caused lower costs of iron and steel, engineering products, structures, and so on. More convincing, perhaps, is the fact that when the new three-factor approach is introduced quantitatively, it is possible to explain historical growth of the US economy since 1900 with a remarkably high degree of accuracy – allowing for some recent contributions from information technology – without the uncomfortable and unrealistic assumption that technological progress is introduced from outside the system like `manna from heaven'.

Apart from the above theoretical arguments, the key implication of the new theory is that continued US economic growth – widely acknowledged to be the `locomotive of global growth, at least for the immediate future – depends upon continually increasing inputs of useful work (as defined above). In the past, the costs of useful work declined in part because of the discovery of cheap sources of energy (such as Persian Gulf oil) and partly because of improved extraction and recovery technology. However, these sources of lower costs appear to be nearly exhausted. The second source of declining costs has been from increasing efficiency (and scale) of energy conversion technologies, notably internal combustion engines and electric power generation. However, future increases in primary conversion efficiency show every indication of being slower and more costly than in the past. Moreover, the obvious technological alternatives to fossil-fuels (including nuclear power) do not show any promise of declining costs.

Where can we look for the gains in conversion efficiency that will (hopefully) drive future economic growth? The obvious candidate is energy policy. The paper concludes with a few personal comments on this topic.