The Valley of Death for New Energy Technologies

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In policy discussions about transitions between different energy technologies, one often hears of a "valley of death" between the invention or R&D phase and commercial implementation. The notion is that while substantial resources appear to be available to finance basic research and develop new technologies, available funds drop precipitously once the basic research has been completed. Many promising technologies then perish in a "valley of death" before displacing the incumbent technologies as the dominant source of commercial energy supply.

The academic literature offers explanations for the valley of death phenomenon as it pertains to the energy industries. However, few attempts have been made to develop a formal economic model that could account for the phenomenon. Many authors point to differences in information between developers of new technology and potential financiers that may make it difficult to convince the latter to invest in the new unproven technology. Others have suggested that government support of basic R&D might, paradoxically, contribute to the outcome. It may alleviate the need to ensure new technology meets market needs and thus make it difficult to demonstrate that it does. Extensive government support for basic research may also lead to an overhang of early stage projects and reduce the probability that any one of them will become commercially successful. Nevertheless, there is strong support for subsidizing basic research mostly on the grounds that there are large positive externalities that are hard to capture in market returns.

Our paper adds to the literature on the valley of death phenomenon in several ways. First, we use a simple endogenous growth model that incorporates displacement of fossil energy technologies by non-fossil alternatives. This allows us to model the gradual displacement of one energy technology by another. In addition, since energy technology both has a strong influence on, and is also strongly influenced by, economic growth, it is important to examine the issue in the context of a growing economy.

Second, we allow for progress in the fossil fuel technologies as well as the alternatives. Most of the existing literature on the valley of death phenomenon implicitly assumes that only new energy technologies can be improved upon. The fact that tremendous technological change has occurred in fossil fuel technologies has meant that non-fossil alternatives have to compete against a moving target.

Third, unlike most of literature on the valley of death phenomenon, we assume that learning-by-doing in addition to explicit R&D contributes to the accumulation of knowledge about alternative technologies. While this assumption is commonplace in papers focusing on technological change, the literature on the valley of death phenomenon has tended to assume that R&D alone drives down costs.

Fourth, consistent with the previous literature, we associate the early stage of the process of displacing old energy technologies with new ones as consisting largely of R&D expenditure. However, we associate the "commercialization phase" with the need to build physical capital to supply energy services. The model can thus explain why the valley of death phenomenon appears to apply more to the energy industry than to other industries that are also characterized by high levels of R&D and competitions to displace one technology by another. The energy industry, unlike many other industries, requires substantial capital investment beyond the R&D phase in order to commercialize the new technologies.

Our main conclusion is that, along the efficient path for the economy, the full long-run costs of the non-fossil alternative energy supply (including a competitive rate of return on capital) are not covered until some time after fossil fuels are abandoned. Even so, substantial investment in the non-fossil alternative is required long before that time. In particular, substantial investment in new energy technologies is required before fossil fuels are abandoned in order to ensure uninterrupted supply of energy services.

Since the cost of fossil fuel using capital is sunk, that capital will continue to be used so long as the energy price covers merely its short-run operating costs. Thus, from the time investment in fossil fuel using capital ceases until the time fossil fuels are abandoned, the operating cost of fossil fuel production sets the energy price. Furthermore, when the switch occurs, the price of energy just matches the operating costs of renewable energy production. Prior to that time, the energy price cannot cover renewable energy production operating costs, let alone provide a competitive rate of return to the capital employed.

While the paper demonstrates the main conclusion holds in very general terms, we also solve the model numerically in order to judge the quantitative significance of the main result. Because the model is stylized, it is difficult to use real world data to set reasonable parameter values. Nevertheless, we used a range of data sources and previous studies to choose parameter values consistent with observations from the world economy for 2008. In the resulting numerical solution, even though investment in the alternative technology is positive from the beginning (2008), it is almost 88 years before the energy price covers the full cost of energy supply using the new technology. There is also a period of more than 5 years immediately after the transition in energy sources when the alternative technology alone supplies energy services but the energy price is so low that no investment in more capacity to supply that energy output is justified. With regard to fossil fuels, the numerical results imply that slightly over 80% of the initial stock of fossil fuel resources are exploited. While fossil fuels are abandoned after about 82 years, investment in capital to supply energy services from fossil fuels ceases after about 76 years. Investment in technology to control fossil fuel cost increases ceases after slightly more than 79.5 years.

The optimal transition path in the model can be seen as a "valley of death" in the sense that new technologies will find it difficult to compete to supply energy services. Investments to deploy the new technology are required before they are profitable. Early on in the transition, it is efficient to make them largely because they help to reduce costs and prepare for future energy supply. As emphasized by previous authors, however, many of these benefits may not be appropriable and thus the efficient path may not be supported as a competitive equilibrium. Nevertheless, in the model presented, any subsidies to renewable energy in the initial phase ought not extend to subsidizing energy production on a commercial scale.