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Engineering Economy for Economists

1. Abstract

The purpose of engineering economics is generally accepted to be helping engineers (and others) to make decisions regarding capital investment decisions. A less recognized but potentially fruitful purpose is to help economists better understand the workings of the economy by providing an engineering (as opposed to econometric) view of the underlying workings of the economy. This paper provides a review of some literature related to this topic and some thoughts on moving forward in this area.

2. Introduction

Engineering economy is inherently an interdisciplinary field, sitting, as the name implies, between engineering and some aspect of economics. One has only to look at the range of academic departments represented by contributors to *The Engineering Economist* to see the many fields with which engineering economy already relates.

As with other interdisciplinary fields, engineering economy has the promise of huge advancements and the risk of not having a well-defined "home base"—the risk of losing resources during hard times in competition with other academic departments/specialties within the same department. The primary "home base" that engineering economy has developed over the years is the proper application of time value of money concepts to capital investment decision-making. This topic, along with related topics of risk, option value, etc., are also covered in business and management schools, but engineering economy departments/sub-departments have held their ground owing to the importance of capital investments in the work of engineers.

Less studied in engineering economy has been the interface with the work of economists. Despite the use of the word "economy" in the title of the field, engineering economy has had little interface with the work of economists over the years. This paper attempts to extend that bridge.

Some previous work has been done looking for useful linkages between these fields. A paper[1] presented at the ASEE conference in 1996 addressed the topic of how microeconomic theory could be used to improve the work of capital investment decision-making. Boerger[2] developed in detail the application of economic theory to capital investment decision-making, focusing on the incorporation of the quality-engendering nature of capital investments into their valuation vis-à-vis their less-quality-engendering capital investment alternatives. That analysis also included a detailed application of that theory to investments in advanced automotive paint equipment. In 2002, Boerger[3] presented a framework for incorporating into the investment decision-making process the value of the improved flexibility of some advanced technologies in allowing firms to compete better with other firms (by applying economists work on game theory to the investment decision).

All of that previous work asked the question “How can microeconomic theory be used to improve capital investment decision-making?” This paper looks in the opposite direction: “How can engineering economists help the work of economists?” Economists are well-aware of the time-value-of-money and its importance to appropriate capital investments (though perhaps not to the degree of detail studied in the field of engineering economy). But it is the “engineering” side of engineering economy that seems to have the most potential here.

3. Economics vs. Engineering Economy

Before we can begin showing the potential for useful interaction in helping economists with their primary work, some definitions are needed to place the two fields relative to each other. If we are to understand the relative place of economics and engineering economy, textbook definitions will not be helpful. What we need is an understanding of the purpose of these two fields.

Economics, I suggest, is inherently concerned with public policy decision-making. While true that much of economics is concerned with understanding the decisions of and interactions between private economic actors, it does so with the ultimate end of understanding how we all can survive and prosper together in the face of 1) nature, which has no inherent interest in feeding us, and 2) other economic actors, who might just as well wish to feed themselves at our expense, if that be the easiest way to do it. Economics is the science of understanding these struggles—how they unfold without any societal intervention, but with the ultimate purpose of figuring out how to intervene in private interactions to ensure the welfare of society. If this public purpose were not the ultimate goal, all of the money government invests in collecting and analyzing economic data would be wasted.

Some might argue that economics shows those with market power (monopolists, oligopolists, monopsonists) how to use that power to maximize their wealth. While economics does present a model of how these actors should act if they are to maximize their wealth, it is really only done, I would argue, to understand how such entities operate, not to tell them how to operate. Clearly some of the economic models are useful in thinking through how businesses can succeed, as highlighted in some of the work reviewed earlier (along with many other authors applying economic theory to achieving business success). However, I suspect that monopolists don’t need economists to tell them that raising their prices (restricting their output below what a competitive market would produce) will increase their profits, and that is not the aim of economist’s work for the most part. Thus while economics may have some “prescriptive" aspects to it, it is primarily a “descriptive” field, insofar as private actors are concerned. Its “prescriptions” are primarily aimed at public policy.

In contrast, the field of engineering economy, as it has developed, has been primarily “prescriptive” of private actions. It asks how a firm should act if it is to maximize its profits (measured as “cash flows” or “returns”) or, at least, to rule out choices that would lead to lower returns. Engineering economy has not been concerned with how the economy as a whole operates or with the overall welfare of society (not that the field opposes these purposes, just that it doesn’t address them). Given these vastly differing goals, it is easy to see why there has not been much interaction between these fields.

4. Do Economists Need Any Help?

Economists are generally quite self-sufficient. As with practitioners in every field, they will solve their own problems with their own resources unless there is a good reason to call upon help. And economists are no different.

In a nutshell, the work of economists is as follows: Economists create theory of how actors behave in the economic marketplace, and those theories are formalized as models. For those models to have value they must be populated with parameters that approximate the true relationship between the variables of the model.

Do economists need help with theorizing? Not really (though we can all benefit from the creative insights of those around us). Do they need help with creating their models to implement those theories? Economists clearly have developed their own models to represent economic theory, but the determination of functional forms for the models has some potential for inquiry (see Heathfield and Wibe[4] for a concise summary of the functional forms often used by economists for production functions).

What about parameter estimates? Parameters are numbers representing the facts of the real world, which sound like the domain of engineers. But here again, economists have their own methods for obtaining parameters, with the primary method being statistical analysis—usually econometric analysis (regression analysis applied to answering economic questions). If econometrics provides adequate estimates of the models' functional forms and parameters, then there is little room for the work on non-economists in this domain.

Certainly the definition of "adequate" is important in answering that question. Some good parameter estimates are most certainly obtainable from statistical analysis. But the role of other methods in obtaining those parameters has been long recognized. Engineering analysis has been used to that end at least since the work of Leontief and his group of researchers at Harvard Univeristy in the late 1940s and early 1950s.

5. Leontief, Chenery and the Use of Engineering Analysis

In 1941 Leontief published the first edition of his classic work which presented his input-output model of the U.S. economy in the years 1919 and 1929, with the model expanded to 1939 with the second edition of that book in 1951[5]. This model for the first time provided a complete working model of the economy that could be used to explain how changes in one sector of the economy (e.g. growth in output or changes in productivity) would impact other sectors. To fit with the analysis technique he was using, Leontief used linear relationships between inputs and outputs ("production functions") in each industry.

Chenery, part of Leontief's Harvard Economic Research Project created in 1948 to extend the work of his earlier input-output efforts, took on the task of producing better empirical production functions using an engineering understanding of how inputs are transformed into outputs. For instance, in the 1953 book[6] edited by Leontief, Chenery presented process functions for gas transmission, evaporation, electrolysis and electrical transmission.

The kind of engineering production models developed by Chenery (and others—see for examples Swann 2002[7] and 2006[8]; see also Heathfield and Wibe[4] for another summary discussion of engineering approaches to the development of production functions) can often provide much more detail on the relationship between inputs and outputs than could be identified from statistical data. Additionally, because these models are usually based on ideal understandings of input/output relationships, these models can determine the best or "frontier" transformations, which are more useful to understanding where the economy is going than are statistical measures that incorporate the economy's embedded stock of technologies and capital equipment. Chenery does not propose that these engineering models are always necessarily best, but that in general a combination of engineering and statistical models will probably serve the economist's needs best.

6. Other Engineering Approaches to Applied Economics

There are approaches to illuminating the relationship between inputs and outputs even beyond standard statistical approaches and the kind of forward-looking analysis pioneered by Chenery. Swann (2006)[8] identifies ten approaches to the practice of applied economics, including "Engineering Economics," the Chenery-inspired kind of analysis just discussed:

- Applied Econometrics
- Experimental Economics
- Surveys and Questionaires
- Simulation
- Engineering Economics
- Economic History and History of Economic Thought
- Case Studies
- Interviews
- Common Sense and Intuition
- Metaphor

Some of the items in this list, like economic history, sit squarely within the field of economics. But others provide inspiration for avenues of inquiry for the engineering economist. For example, who better to prepare a case study of the technical transformation of inputs to outputs in a factory than someone with engineering skills. The same goes for interviews of people involved in those transformations and the design of surveys. While "Engineering Economics" (as that term has been used here) is useful to looking at the theoretical frontier of production, techniques like case studies are useful for understanding how those engineering relationships are modified by other parts of the production system. And such non-frontier-related questions can be useful in answering many public policy questions.

Even frontier-related analysis need not be restricted to Chenery-like engineering models. In addressing some economic public policy issues, one strategy may be to perform a case study of "best in class" production operations. Taking such a top-down approach to understanding a company/process on the frontier of productive efficiency may lead to different and, in some cases, better understanding of factors important to success than by starting with the physics of the process, as used by Chenery.

Thus, it seems that focusing solely on a Chenery-like approach to engineering input on economic problems may not provide the full scope of the potential work of engineering economists in helping to improve economic models. Starting with Swann's list of approaches seems like a useful place to start to think about the varied roles that an engineering economist might play.

7. Do Economists *Think* They Need Any Help?

Any program of collaboration between economists and engineering economists should recognize the extent to which collaboration is desired. Clearly the degree to which collaboration is desired will vary greatly, but Swann presents the case that applied economics is far too focused on the use of econometrics to the exclusion of the other methods listed above. He illustrates his conclusion about the status of alternative methods in applied economics by proposing that economists view econometrics as the "universal solvent" for use in applied economic investigations (the universal solvent, or "alkahest," was one of the three goals of alchemists in the middle ages, the others being the discovery of the elixir of life and the transmutation of base metals into gold). (Swann (2006)[8] 24) He explains in detail the problems with relying solely on econometrics for obtaining economic model parameters, leading to his presentation and discussion of the ten approaches listed above.

Collaboration, of course, requires two parties, both of which want interaction, and if Swann is right collaboration may be difficult. But that need not stop engineering economists from thinking through a research and scholastic program that would begin to develop a storehouse of information useful to solving economics-related public policy problems. And there surely will be some avenues for immediate interaction with the work of economists.

8. Examples for Helping to Think Through an Engineering Economic Research Agenda

The work of Chenery was targeted toward building better models of the American economy and its industries. That is an important task for improving overall economic public policy decision-making, but only one among many in which an engineering understanding can help with economists' prescriptions for how society can encourage welfare for its members. Following are a few examples to stimulate thinking.

Example 1: The Retention of Manufacturing in Developed Countries

American has clearly lost a large amount of its manufacturing base over time. This change has caused concern among many people for a variety of reasons, including the dislocations to American workers and the retention of an appropriate industrial base for national security reasons, among others.

A research agenda related to this topic for engineering economists might be to help economists understand the equilibrium for manufacturing activity in the U.S. One path to that end would be the development of case studies for product lines that have gone overseas (case studies in the sense of a Harvard Business Review case study, for example, where the goal is mainly just to describe the situation and the results, not to come to any final conclusions). Another approach might be case studies of manufacturers that seem to have overcome those challenges and perhaps even thrived. Again, these could be purely scientific descriptions based on interviews, plant visits, observations from outside the company, etc. Such purely descriptive information could be taken further to analyze some of the key factors in how the success was achieved.

Such case studies would surely discover many factors related to success or failure, many of which would be only tangentially related to the engineering/technical aspects of the process. For best results an interdisciplinary team would work on such studies, though a fact of life is that working on complex problems will probably always have everyone stretching their disciplinary boundaries. The point is to ensure that engineers, especially ones with skills and inclination for studying economic questions, are able to capture features of these enterprises that may otherwise be too far outside the domain of an economist to capture and include in her/his model.

Example 2: The Role of Product Innovation and Product Quality in Business Competitiveness

We know intuitively that product innovation and quality are important to competitiveness, but exactly how it works is important to understanding the future welfare of society and what government can do to encourage it. Engineering economists can help improve economic models by helping to quantify changes in product quality that may mask the true nature of economic growth. They can also study the role of quality in the value of products to consumers, thus improving the demand functions used by economists. The whole area of product differentiation and quality is one that has caused difficulties for economists and for which an engineering-based approach is ideally suited. This work could perhaps, again, begin with case studies to get a feel for how the area can be best approached.

Example 3: The Future of Small Business

How do small businesses come to be created and survive when large businesses have such significant advantages? Are small businesses doomed to fail? Must they expect lower wages and returns to capital, or are there ways to take advantage of some inherent economic advantages of small business?

Engineering economists can help economists understand these public policy questions by going into these firms and understanding the challenges they face, by immersing themselves in the challenges, identifying key variables that may affect competitiveness and publishing those findings.

9. Why Engineering Economy Programs?

Many of the case studies and detailed investigations just described are being done under various academic banners already, to one degree or another. So a reasonable question is why engineering economy should take on this project when it already has its own niche.

There really is no overriding reason why any investigation need be done under one academic department or another. Some of the Chenery-like work has been and will be done by economists learning about the physics of pipe flow and the flow of electricity through transmission lines. And there is nothing wrong with that. But many other improvements to economic models (and consequent economic prescriptions for the economy) will not occur because of a lack of skills or interest or due to the absence of an organized project with a mission of incorporating that improved information into those models.

In addition to economists doing some engineering analysis, many engineers already do economic analysis. Machine design is not only a technical undertaking but also an economic one. Manufacturing and industrial engineers goal is the improved economy of manufacturing processes. And many of these engineers would be useful to an engineering economic enterprise of interface with the public policy-related problems of economists.

But to achieve the best interaction between engineering and economics, use of a field on the border between the two seems likely to be best, and engineering economy is an established field in such a position. Engineering economy need not give up its concentration on investment decision-making. In fact, the kinds of detailed analysis and case studies envisioned could serve to improve the understanding of how investments are made and how they should best be made. Whether that broader program should be called “engineering economics” instead of “engineering economy” is a question to ponder, but whatever it is called, it seems clear that some such enterprise on the border between engineering and economics, taking on the task of serving as a think tank and repository of engineering-related economic information useful to the public policy problems of economics, would be worthwhile.

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