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# A Second Look at the Induced Innovation Hypothesis

by

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## 1. Introduction

The "induced innovation hypothesis," first formulated and developed by Professors Yujiro Hayami and Vernon Ruttan, is a theoretically very appealing and empirically very powerful hypothesis. Simply put, it implies that innovations in technology occur in response to (and in the direction of) perceived factor scarcities or more generally changed economic conditions. Induced innovation therefore always connotes causality. Viewed in this way, technological change is endogenous rather than exogenous, as is commonly assumed. Induced innovation also suggests that whatever technological change that takes place is likely to be biased, that is, at constant relative prices, the optimal factor proportions will not necessarily remain the same after the technological change.

Innovations

However, innovations in technology, which imply the discovery and invention of new production possibilities that have not existed before, must be carefully distinguished from new adoptions of already existing but heretofore unused technology. New adoptions can also come about in response to actual or perceived factor scarcities or changed economic

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conditions. For example, as labor becomes more scarce, mechanization may become more widely adopted, but the mechanization technology itself may have already been in existence for a long time, and may even have been used extensively elsewhere, perhaps in a different country. If only actual market data for a single country are available, it is difficult to distinguish between a shift of the production possibilities frontier (innovation) and a movement along the frontier (adoption). In addition, there may also be innovations that are not induced, that is, innovations that do not have a predisposed direction. All of this makes the rigorous empirical verification of the "induced innovation hypothesis" extremely difficult, if not impossible.

2. A Single Producer

We may further analyze the situation by considering the process of innovation under the assumption that there is only a single producer. The producer is induced to allocate efforts for innovation. For example, labor may have become or is expected to become much more expensive relative to capital, and resources are thus allocated to seek labor saving innovations. However, the efforts do not necessarily result in innovations, the latter being partially random and generally unpredictable outcomes. Moreover, innovations, once discovered, are not necessarily implemented, depending on not only the relative prices of the outputs and inputs but also the expected benefits relative to the costs of implementing the innovations at the prices prevailing or expected to prevail at that particular time. For example, an energy-saving innovation the efforts for which were induced by the change in

expectations of energy prices in the seventies may not be implemented today because of the currently prevailing low prices of energy. However, such an innovation, if directly observed, would in itself constitute a verification of the induced innovation hypothesis. Unfortunately, an unimplemented innovation is never reflected in the data on the actual operations of the producer.

Thus, the market data alone cannot throw light on the question of whether there has been an induced innovation or not. If ten years later, the price of energy rises again, and the innovation is finally implemented, then the quantity of energy used will be observed to decline with the rising relative price of energy and at a rate that is faster than previous similar increases in the relative price of energy. However, this does not constitute a proof of the "induced innovation hypothesis" because it does not involve a new innovation, but merely the adoption of an existing, albeit heretofore unused, innovation. The observed relationship between the observed decline in energy use and the prevailing prices provides evidence for the effect of changes in relative prices on adoption but not for induced innovation.

The conclusion of this line of argument is that the observed relationship (or lack thereof) between factor use and relative factor prices (or scarcities) over time in itself is neither necessary nor sufficient to verify or refute the "induced innovation hypothesis" in the absence of additional assumptions.

3. Many Producers

With many producers, the difficulties of verification are compounded because not every producer will decide to adopt a given innovation because of producer-specific but possibly unobservable characteristics and conditions and even if every producer decides to adopt, they may not all adopt at the same time. Rather, they may adopt in a time-distributed pattern. Thus, as the innovation diffuses throughout the population of producers, the observed aggregate factor-use is going to continue to change on the strength of a previous innovation even though there is no current innovation. This is going to vitiate any inference on induced innovation drawn on the basis of the aggregate data.

## 4.Other Verifiability Issues

In addition to the separation of the effect of innovation from the effect of adoption, there are a number of additional issues that concern the empirical verifiability of the "induced innovation hypothesis". They include: (1) the confounding of the effects of economies of scale and innovation, and the biases in the scale effects with the biases of technological change; (2) the effects of aggregation and of diffusion; (3) the effects of quantity rationing with fixed prices; (4) the confounding of the degree of complementarity of inputs and the bias of technological change; and (5) use of an appropriately general functional form.

## 5.Conclusion

Given all of these complications, what can be done? The situation is not hopeless. One can use (1) pooled international and cross-sectional data to distinguish between innovations and adoption of existing innovations; (2) engineering data or experimental data so that the unimplemented innovations can also be taken into account; (3) functional form assumptions to attempt to disentangle scale and technological change effects.1

It is useful to realize that the "induced innovation hypothesis" is more a hypothesis on the allocation of research and development efforts than actual adoption. Of course, if there is no innovation, there cannot be adoption. But innovation itself does not necessarily lead to adoption. Thus, the actual production choices adopted may not reveal information about innovations that have not been implemented. This is the crux of the problem of the empirical verification of the "induced innovation hypothesis".

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1A further complicated factor is that innovation may in some instances consists of making a given scale possible. In other words, innovation is embodied in scale. In that case, even scale effects should be attributed to innovation.