Reduced-Form Model vs Structural Model

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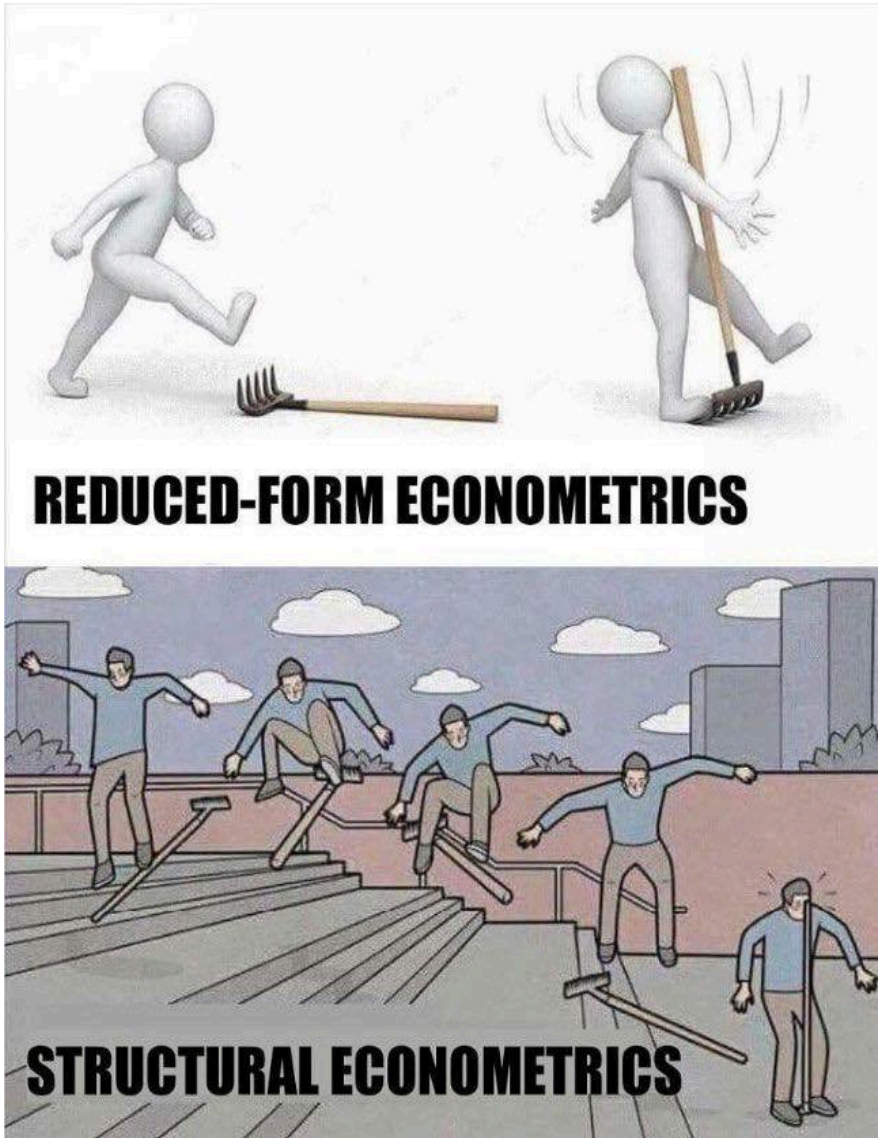


1 Introduction

When discussing the types of models in economics, there are two that will be focused on, **Reduced-Form model** and **Structural model**. Roughly speaking, reduced-form models evaluate the endogenous variables in terms of observable exogenous variables, while structural models are derived from theory and often include unobservable parameters that are helpful in describing the economic behavior or model operation as a deep level.

In the economics empirical research fields, there are two major factions in the academic community: **Reduced-Form Approach** and **Structural Approach**. The major differences between these two factions are their attitudes toward the role of economic theory in empirical research. Reduced-From Approach believe that empirical research should 'let data speak for itself'. They argue that economic theory models are determined by the scholars' will. The conclusion that the researcher's will is imposed on the data is only correct if the model itself is correct. Because the researchers cannot know what models are correct, their main research tools are simple: use various regression analyses.

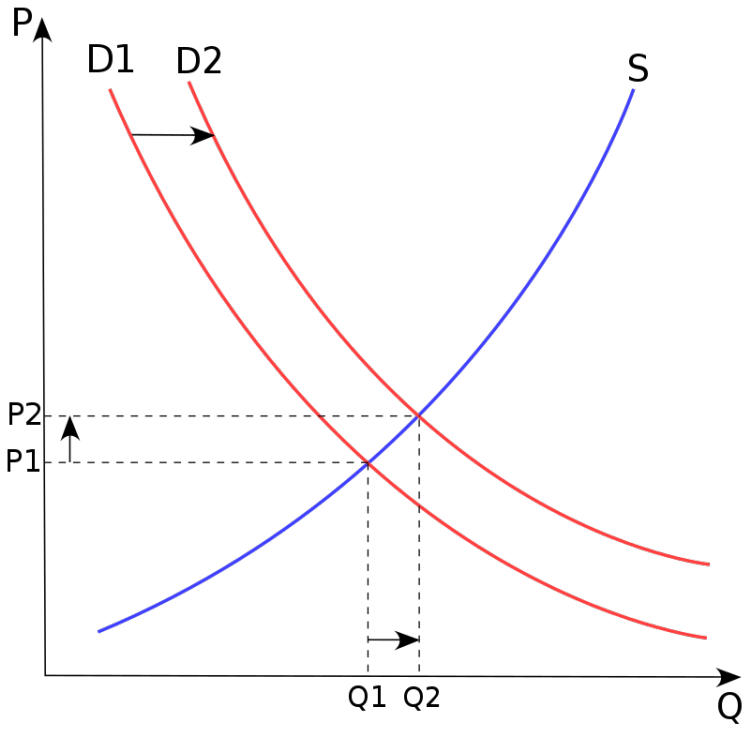
By contrast, Structural Approach believes that data cannot fully reveal its generating process. They believe that if the goal of economic research is the data generating process, then the data generation structure can only be understood with the application of the researcher's model, even if the researcher's models may be wrong. And sometimes a structural model is also called a generative model.

2 Endogenous & Exogenous Variables

The emphasis of endogenous and exogenous variables is necessary for understanding the definition. In a given economics model, an exogenous variable is one whose value is determined outside the model and is imposed on the model, and an exogenous change is a deviation in exogenous variables. While an endogenous variable is a variable whose value

is determined by the model. An endogenous change is a change in the endogenous variable corresponding to the exogenous change that has been imposed on that model.

For example, suppose we have a supply-demand curve. In this model, an increase in consumer's income is not included in, which is an exogenous change in demand that can result in the movement in the equilibrium price and state, which are endogenous variables indeed. Although the exogenous variable, income is unobservable and outside in this model, it still has an impact on the model as exogenous change.



3 Reduced-From & Structural Model

A reduced form is a functional relationship for which the inputs are exogenous variables (this includes unobservables, i.e., structural errors)and the outputs are endogenous variables. In statistics and econometrics particularly, the reduced form of a system of equation is the result of solving the system for the endogenous variables. This can express the endogenous

variables as functions of the exogenous variables.

In structural econometric models, economic theory is used to develop mathematical statements about how a set of observable "endogenous" variables, y, are related to another set of observable "explanatory" variables, x. Economic theory also may relate the y variables to a set of unobservable variables, ξ. These theoretical relations usually are in the form of equalities: $y = g(x, \xi, \Theta)$, where $g(\ .)$ is a function and Θ a set of unknown parameters or functions. While, in econometrics, the equations of a structural form model are estimated in their theoretically given form. Intuitively, you may wonder whether can we derive the reduced form from structural model directly by solving the equations? The answer is yes, an alternative approach to model estimation is to first solve the theoretical equations for the endogenous variables to obtain reduced form equation, and then to estimate the reduced form equations. But we can't do this every time, sometimes there is not explict expression for reduced-form by solving structural model.

4 Example

Suppose $\mathbf{Y}$ is the vector of variables to be explained (endogenous) by a economic model and $\mathbf{X}$ be the vector of explanatory (exogenous) variables. Additionally, let ϵ be the vector of error terms. The general expression of the reduced form is

$$\mathbf{Y} = g(\mathbf{X}, \epsilon)$$

where g is the function that shows the relationship between $\mathbf{X}$ and $\mathbf{Y}$, possibly from vectors to vectors in the case of a multiple-equation model. The structural form is given by:

$$f(\mathbf{Y}, \mathbf{X}, \epsilon) = 0$$

Now let's come back to the supply and demand model. If we assume that demand is determined not by price, but also by an exogenous variable, (such as income, but we are not sure), we can consider the structural supply and demand model:

$$\text{Supply} : Q = a_S + b_S P + u_S$$

$$\text{Demand} : Q = a_D + b_D P + cZ + u_D$$

where u_S, u_D are random error terms. Just as what we say above, we can get reduced form by solving equations for endogenous variable, here is Q and P.

$$Q = \pi_{10} + \pi_{11} Z + e_Q$$

$$P = \pi_{20} + \pi_{21} Z + e_P$$

Where the parameters π_{ij} depend on the parameters a_i, b_i, c of the structural model, and where the reduced form error e_i each depend on the structural parameters and on both structural errors. It is noticeable that both endogenous variables depend on the exogenous variable Z.

It seems that the reduced form of an econometric model is one that has been rearranged algebraically so that all endogenous variables are on the left side of equations and only predetermined variables(like exogenous variables) are on the right side. So are they just different in format or expression? Or we just need a reduced form that is more easy and clear rather than a structural model? Actually no.

The following phrase represents the underlying rationale of structural modeling, that measurement cannot be done without some kind of theory.

Structural equations are then equations that come from an underlying economic (or

physical, or legal) model. Structural estimation is precisely estimation which uses these equations to identify parameters of interest, and inform counter-factual. Without economic modeling, labor and other applied economists differ little from sociologists who are adept as using STATA.

— Deniel S. Hamermesh

5 Lucas Critique

It is named after Robert Lucas for his work on macroeconomic policy-making and evaluation. This critique argues that it is wrong to forecast the effects of a change in economic policy entirely relying on the observed historical data. If the policymakers rely too much on the relationship observed in previous data and experiences without considering potential changes in economic behavior, then their expected outcomes may not be realized.

Lucas summarized his critique that *Given that the structure of an econometric model consists of optimal decision rules of economic agents and that optimal decision rules vary systematically with changes in the structure of series relevant to the decision-maker, it follows that any change in policy will systematically alter the structure of econometric models.*

An important conclusion is that if we just use the observable data to construct the model, without considering the agent's response and reaction. The result is likely to be wrong. If we want to predict the effect of a policy experiment, we should model the "deep parameters" which we called primitive parameters, rather than just the historical observable data. The so-called primitive parameters(relating to agent preference, technology or other factors) are supposed to reflect the individual behavior. If the structural model includes the primitive parameters, it can be used to predict the agent behavior responding to the policy change and forecast the potential result. That is the main idea of this Critique standard.

So go back to the reduced-form and structural model. In most cases, if using observable data to construct a reduced-form model, without consideration of primitive parameters in a

more deep level, the result is not reliable to make a prediction. While structural can adapt this problem better.

6 Summary

It seems that the structural model can always overwhelm the reduced-form model. But in practice, the structural model still encounters many obstacles. And reduced-form still has a wide application.

The reduced-form model has many advantages. Firstly, it is intuitive and can show the causal relationship within a certain set of variables clearly. Secondly, in reduced-form, we always treat the behavior of agents as a black box so we don't need to impose complex assumptions. So we can get an easy and understandable model. But as we mention in the last section, this characteristic of reduced-form also is a shortcoming, which let it can not reveal the underlying true causal mechanism in specific economic problems. So if the goal of the study is to identify an exact mechanism of interaction and causality, a structural model may be a better choice.

A significant difference between structural approach and reduced-form is that we no longer care a certain set of causal relationships, and no longer treat the interaction and decision process as a black box, but try to open the black box and establish a model of the entire process and deep parameters. There are many benefits to do that. First, the structural model can reveal the mechanism of the true causal relationship. Secondly, the prediction result can satisfy the Lucas Critique and is more reliable. Thirdly, a more important application is that we can conduct counterfactual analysis in a structural model.

However, there is no a perfect model and we need to pay for the benefits of the structural model. The greatest challenge in the development of the structural model is that the estimation of parameter becomes increasingly difficult as the complexity of the model increase. What's more, we need to impose more assumption when modeling structure.

References

[1]James J. Heckman(2008) Econometric Causality. Discussion paper series.

[2]Hanmin. F(2007) The American economic education system and its enlightenment to China.

[3] Phil Haile(2015) Lecture Note:Intro to Econ 556 A Perspective on Empirical Economics

[4] Ashley M. Funk (2011) Structural and Reduced-Form Models: An Evaluation of Current Modeling Criteria in Econometric Methods

[5] Peter C. Reiss & Frank A. Wolak (2007)Structural econometric modeling: rationales and examples from industrial organization