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THE FUTURE OF ECONOMIC MODELLING

BY

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Abstract

One of the most common approaches to forecasting is that of the expert opinion, based on the informed judgement of experts acquainted with the phenomena (variable) in question. Typical of such an approach, the factors relevant to the variable are not considered in the context of an explicit framework. Rather, any factors relevant to the issue are weighted and evaluated subjectively by each expert. This same approach was used during the 25th annual Canadian Economics Association (CEA) meetings to predict the future of econometrics and economic modelling.

In this paper the relevance of this approach in analyzing the future of econometrics and economic modelling is examined. While the choice of the forecasting method is appropriate for the variable under question, the factors deemed relevant by the experts are not comprehensive. Furthermore, due to the absence of a panellist from the demand side (that is users of economic models), any future development in this area is largely ignored. An attempt is made in this study to incorporate the opinions of the demand side and the results show that what the demand side expects from economic models is not compatible with the future envisaged by the supply side (theoretical econometricians, mathematical economists etc.).

Resumé

Cette note analyse la prédiction faite au sujet de l'avenir des économétriques et modèles économique présentée a la 25^{ème} rencontre annuelle de l'Association Canadienne d'Economique (ACE).

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PREFACE

1. This paper discusses the future of econometrics and economic modelling as it pertains to applied research in business and government. It draws heavily on projections made by panel discussants on the future of econometrics (economic modelling) at the 25th annual meeting of the Canadian Economic Association (CEA) on June 4, 1991. In addition, the paper critically examines these projections and predicts the likely routes that economic modelling will take.

2. This type of exercise is ideal for a research organization such as ORAE, and in particular DSEA. Economic models have to be developed and modified continuously in DSEA to provide up-to-date econometric tools to meet diversified demands. Furthermore, any optimal allocation of personnel and computing resources require quality forecasts.

3. Decision makers as well as policy analysts in general also have to know which models will be available in the coming years and how flexible these models will be for analyzing policy scenarios in an always changing macro economy.

I. INTRODUCTION

4. In private or public business, long range forecasts are commonly employed to enhance the decision making process. Depending on the quality of the forecast, these decisions will help an organization to allocate resources to meet the likely scenarios of the future. Initially, analyzing the future of econometrics and economic modelling may sound like some theoretical exercise with little or no practical application. However, such activity is crucial to business and government agencies that rely on the policy recommendations derived from such models.

5. It should also be pointed out that some of these agencies may have a research unit that deals exclusively with the development of economic models. Thus, any systematic change in the trend of economic modelling has to be followed up and incorporated into each agency's analytical requirements.

6. In order to provide a cogent analysis of the subject, this paper will restrict the focus to a panel discussion held at the 25th Annual CEA meeting. The paper is divided as follows: In section II the forecasts of the panellists are summarized, in section III these forecasts are examined, and section IV concludes this study.

II. THE PANELLISTS' OUTLOOK

7. The CEA meeting devoted two sessions to the future direction of economic modelling. The discussants included such academic econometricians as J. Mckinnon, R. G. Bodkin and Peter Pauly. Apart from Bodkin, who

essentially summarized a chapter from his recently published book¹, the discussants were generally "thinking out loud" about future prospects of economic modelling based on their accumulated experience. Although there was a general consensus on the overall direction, each had specific viewpoints about certain aspects of economic modelling and/or econometrics.

THE MCKINNON-PAULY FORECAST.

8. The Mickinnon-Pauly predictions concentrated mainly on the growth of the micro-computer industry and its impact on future econometric practice. Particularly Mackinnon emphasized that the availability of cheap and powerful desk-top computing may help econometricians to develop computer intensive estimation procedures as well as large scale simulations. The latter is hoped to assist the modeller in generating the actual distribution of a variable and its associated hypothesis tests. The implications of this procedure are powerful. Social researchers will no longer be constrained by the availability of limited data to generate meaningful results.

9. Two examples of the most often used re-sampling methods discussed above are "Jackknife" and "Bootstrapping". Although these methods are relatively new in Economics and other Social Sciences, they were first developed around the 1950's along with Non-Parametric Statistics. Bootstrapping is a statistical procedure mainly used to estimate the actual distribution (Kurtosis etc.) from the actual data using iterative processes (Kotz-Johnson, 1982). Jackknife methods, on the other hand, are used to provide

¹ R.G. Bodkin, L.R. Klein and K. Marwah. **A History of Macroeconometric Model-Building.** 1991, (Aldersot: E. Elgar). From here on any references on Bodkin will be from ch. 17 pp 536-549. of this book.

approximations of both bias and standard deviation along with acceptable confidence limits (Kotz-Johnson, 1982)².

ON COMPUTABLE GENERAL EQUILIBRIUM (CGE) MODELS.

10. Dr. Randy Wigle's analysis of the prospects of economic modelling was directed almost exclusively to CGE models. CGE models are essentially formulated as a system of equations based on the assumptions of Neo-classical economics. Some of these assumptions are:

- i. Labour and Capital supply are fixed and fully employed (i.e. if demand in some sector increases, labour and capital have to be given up somewhere in response to change in price.)
- ii. Relative price change affects or re-equilibrates the model.
- iii. The model solves a profit maximization problem subject to constraints:

$$Pr = P_i(A_i * L_i^\alpha * K_i^\beta) - f(w_i L_i, v_i K_i) \quad \text{I.1}$$

$$\text{subject to } (A_i * L_i^\alpha * K_i^\beta) \quad \text{I.2}$$

This is the standard microeconomic theory regarding profit maximization where,

-Pr is profit, P_i is the price level

$(A_i * L_i^\alpha * K_i^\beta)$ is a Cobb-Douglas Production function and $\alpha + \beta = 1$, and

$-f(w_i L_i, v_i K_i)$ is a Cost function associated with the production equation.

The cost function can be designed to accommodate additional variables such as tax on capital, imported goods, etc.

11. Although CGE models have been in use for the last few decades, they have failed to gain the popularity enjoyed by other economic models such as input-output or econometric models. According to Wigle, this may be due to

² A more formal definition and example is provided in the appendix.

the lack of adequate academic backing through research or teaching. In particular the whole applied general equilibrium field is treated as an independent research discipline with little or no economic application. Such misconceptions are of course untrue, since CGE models have been used extensively in policy oriented areas such as Taxation, Environmental Economics and Trade.³

12. However, in the coming decades, Wigle predicts a gradual acceptance of CGE models as a legitimate modelling tool by both theoretical and applied researchers alike. The availability of cheap computing facilities may also help develop robust estimation techniques as well as multi- dimensional modelling. Given the current popularity of issues such as international trade, tax and the environment, in the future CGE modelling may be the preferred alternative to other economic models.

MACROECONOMETRIC MODELLING.

13. The future direction of macro modelling was discussed by Peter Dungan and Ronald Bodkin. Persons who attended the panel discussion may recall that Bodkin's presentation was held in a separate session under a different topic. However, the contents of his speech are closely related to the futures sessions and hence will be reviewed alongside P. Dungan's presentation. As mentioned earlier, Bodkin's comments will also be complemented by material from his book.

³ Shoven and Whalley (1984) contains an excellent survey on CGE models and applications.

Present trend.

14. Although macro modelling is not as popular as it was during the 60's and 70's, it experienced a sort of "revival" in the 80's according to Bodkin. The reversal is partially explained by the availability of trained econometricians, computing facilities and the continued use of the models in Europe, Japan and some developing countries (Bodkin et. al., 1991). Furthermore the damaging critique by Lucas (1976) on macro models have been largely defused through new findings in expectation and macro modelling.

15. Both Bodkin and Dungan agree that the Lucas criticism was important in reminding practitioners about complacency in their estimation and restrictive assumptions. Like previous panellists, Bodkin and Dungan echoed the availability of cheap computing and its impact on modelling. This shows the considerable weight theoretical econometricians give to the growth of the computing industry in shaping the future of economic modelling.

Large vs. Small Scale Models.

16. Bodkin sees two extremes developing in terms of the size of future macro models (Bodkin et. al., 1991). The latest trend towards globalization, as seen in the proposed Europe '92 and a North American trade block, will require inter-country macro models to analyze different policy regimes. In fact in anticipation of the 1992 European merger, Emerson et. al (1988) used OECD's inter-country model to analyze the macroeconomic aspects of the union.

17. On the other extreme of large and complicated multi-sector, multi-country models, customized macro models containing 9 to 16 equations on specific sectors of an economy may also be common in the future. Such

models will be an indispensable analytical tool for small businesses that specialize in a specific product for a particular segment of the consumer market.

Forecast Errors.

18. Most often forecasts from macro models are presented without some sort of confidence intervals or probability limit around forecast values. Unfortunately one has to estimate the standard error of the forecast, which is an arduous task for large-scale macro models. The standard deviation of a forecast in macro modelling is a function of the system's parameter estimates, disturbance terms and the exogenous and lagged endogenous variables. The provision of forecast values along with a confidence limit should be a standard practice in the future for macro models. Bodkin's rationale for this prediction is that:

- a. such an exercise is conceptually possible, and macro models are unique in accommodating such estimations (Bodkin, et, al, 1991).
- b. given the availability of cheap computing resources, such a computer intensive exercise has a small (if any) marginal cost associated with it.

19. Bodkin also mentioned what he calls "experienced error", as opposed to expected error, that can be calculated from a comprehensive record dating from 1972 (quarterly data) on models and macro variables (McNees and Ries, 1983). By computing the absolute and mean square error of the forecast (from the actual value) one can have an alternative method of assessing a model's predictive power (Bodkin, et, al, 1991).

Application of Control Theory & Policy Simulation.

20. Once a macro model is operational, it is customary to experiment with the model using different policy targets and running several simulations. In the coming years, according to Bodkin, simulations will be designed with strict policy target values to assess how the model behaves "under pressure" (Bodkin, et, al, 1991). During such simulations if the model violates expected values or patterns (i.e. diverging when convergence is expected or providing negative numbers when above zero values are expected), we may have to re-specify an equation or block of equations. Based on recent application of control theory, the method shows some promise (Bodkin, et, al, 1991).

Specification of Lags and Expectations.

21. Both Dungan and Bodkin agree that significant progress has occurred in the application and specification of lags and they expect the trend to continue in the coming years. Furthermore, survey (panel) data about consumer opinion, preferences and expectations along with business expectations will complement the growing need to formulate expectation variables in macro models. Currently, rational expectation (RE) modelling is used frequently to formulate macroeconomic theory in theoretical research. Assuming it will have meaningful application to real-world phenomenon, it may be incorporated into macro models.

Monetary Aspects: Flow of Funds Models.

22. Macroeconometric models are associated with Keynesian economics. The fact that almost all macro models traditionally give the fiscal structure of the economy more weight lends to the credibility of the above assertion. Bodkin speculates that in coming years modellers will recognize the need to incorporate

the monetary sector by specifying a flow of funds sub model. The task, however, is not going to be as easy. Flow of funds accounts are not compiled as regularly and as accurately as national income accounts. Furthermore, the integration of flow of funds with both national income and input-output structure requires a meaningful and justifiable representation of dynamic inter-relationships within the model.

More Explanatory and Less Exogenous Relations.

23. Most often factors such as demographic changes and investment patterns are not explicitly defined in macro models. That is, such variables are treated as exogenous entities that have impacts on the economy or a sector without fully understanding their relationships to the dependent variables.

While such constraints are useful for explaining rudimentary economic relationships, they provide an inadequate analysis of the overall macro economy. Nevertheless, there is a growing trend in economics to explicitly define (endogenously) such relationships, and Bodkin hopes these tendencies will be facilitated by interdisciplinary work specifically in areas such as psychology, criminology and demography.

24. Particularly demographic variables may no longer be exogenously stated but will be explained by regressing variables such as birth rates, fertility rates, death rates as well as interprovincial or inter country immigration and emigration (Bodkin et al, 1991). The labour force composition and expected trend would also be explicitly defined and incorporated in a macro model, to further understand the labour supply.

25. Models that incorporate the latest research results from health economics and criminology will become valuable tools for analyzing the policy implications

of urban development, social security and medicare. Bodkin also emphasized that the medical sector is a multi million industry that warrants further study on its own. A sample survey of population jointly designed by social psychologists and economists will help explain:

- the spread of economic panic (in different countries, markets)
- group and imitative behaviour
- trends in fashion and preferences
- the controversial rational expectation and crowd behaviour or "contagion effects" (Bodkin, et al,1991).

26. One may also use information from engineering particularly to explain production functions. For example recent trends in the specification of a production relation include energy and material input alongside the standard variables of labour, capital and time. This will also help in a formal consideration of technological transfers or change.

III. CRITIQUE

27. The only blemish in this otherwise comprehensive and engaging discussion was the curious absence of a panellist representing an applied researcher from government or business. This seemingly minor omission unfortunately has enormous implications. Whatever is discovered in the academic world has to find its way into the applied realm.

28. Unless there is a solid bridge connecting theoreticians from academia with researchers from business and government, none of the wondrous discoveries projected earlier will be utilized. In this section each projection from the panellists will be examined from the perspective of applied economists and

the existing demand for economic modelling, in government and business agencies.

LARGE SCALE SIMULATIONS.

29. Large scale simulations to approximate the actual distribution of a set of observations have interesting implications to applied research. The only limiting factor here is the time constraint the researcher has, and the availability of extensive literature on the subject in applied journals (refereed or not). If the researcher has limited time to produce results, he or she has to resort to old but proven methods (this is regardless of fast computing resources). Fortunately the literature on methods such as Bootstrapping and Jackknife is vast thanks mainly to applied journals in mathematics and statistics. Thus the prospect of large scale simulations to approximate actual distribution looks bright.

30. The same cannot be said for new estimation techniques. The most time consuming aspect of applied research in the social sciences is the collection of "quality" data that approximates the theoretical depiction of the social or economic relationship under question. Therefore, there is not much time for the researcher to choose from the myriad of estimation techniques that promise more efficient and less biased variable estimators.

31. The choice of estimation techniques, then, should be embedded ultimately within the design of research, which is itself determined by the theoretical, practical and philosophical content of the research problem. In addition, much to the dismay of the researcher, most of these estimators are assessed through a Monte Carlo simulation and are not explicitly tested with real world data. It has been customary, and if the trend continues the researcher will continue to use simple estimation procedures (such as OLS)

when faced with the above dilemma, echoing an East African proverb "The devil you know is better than an angel you do not know!".

AVAILABILITY OF COMPUTATIONAL RESOURCES.

32. It is usually seen as a miracle of marked proportion when a number of economists agree on any one subject. But that was what the audience witnessed at the "Future of econometrics and economic modelling" panel discussion. The item that brought this unusual consensus among the panellists was the availability of cheap computing resources for economic modelling.

33. The availability of cheap computing resources implies, among other things the proliferation of software packages to satisfy divergent needs. Popular econometrics packages like SHAZAM will amalgamate "user friendly" formats with the latest and highly sophisticated estimation methods. Unfortunately ease and comfort of accessible computation has its cost: complacency and abuse.

34. Although most software reference manuals contain a short description of available estimation subroutines, they are not adequate (i.e. they usually refer the user to a text of a journal). This results in the researcher inadvertently using the wrong estimation or lag structure. The implication is obvious.

35. With the proliferation of powerful desk-top computers, it is not entirely impossible that at least some senior managers may want to join in the analytical game. Consequently a simple customized macro model, as Bodkin described earlier, with easy "menu-driven" format will soon be available for anyone. With a simple stroke of a key he or she can produce "estimates" of popular economic indicators (albeit with dubious meanings) such as productivity, induced

multiplier and GDP share, without giving much attention to the caveats embedded in the model.

36. Abuses such as these are not presented for arguments sake; they have already occurred. After all if the procedures outlined by the Cowles Commission and by econometricians like Haavelmo were taken seriously, the Lucas critique would not have been necessary.

CGE MODELS

37. The popularity of environmental economics and international trade may bring CGE models into the spotlight. However, their integration into the mainstream of economic modelling may not be realized in the coming decades. As Wigle pointed out, the academic circle has been very slow to accept this field as a legitimate area of research. In most universities students are introduced to CGE models during graduate work and particularly if one is studying or specializing in applied micro-economics.

38. Furthermore, even if CGE models receive instant recognition in academia, there is going to be a considerable time lag before applied researchers begin to use them as alternative modelling tools. One possible way of reducing the lag time is by introducing the model to researchers directly. This can be achieved by diverting resources to current and actual economic problems and presenting the results in applied journals.

THE PROSPECTS FOR MACRO MODELS.

39. Relatively speaking, the Bodkin-Dungan projections on the future of economic modelling implicitly incorporates the needs of applied researchers. This is not surprising, however, since the majority of research on macro

modelling is done by and for government and business policy advisers (this has been true since the late seventies, thanks mainly to the Lucas critique). One can also see that Bodkin's (and to some extent Dungan's) projections seem to be more of what ought to be done in the future than what is likely to happen.

40. Given the embarrassing criticisms macro modellers received in the last decade (regarding their careless specifications), the need to emphasize prudence is well taken. Already some progress in this direction is under way through a more rigorous specification of lags and expectations.

41. The amalgamation of new research findings in social psychology and other disciplines into economic modelling is not an unlikely prospect in the future. In fact, government and business agencies usually have a more conducive environment for inter-disciplinary study than academic institutions. Demographic characteristics, for example, are receiving a lot of attention in the retail business community. Targeting a specific segment of the population and designing a product accordingly is now a multi-million dollar industry. At the same time a multitude of research in the area of consumer behaviour by psychologists is illuminating some curious facts about preferences and expectations.⁴

42. Bodkin's predictions regarding the development and subsequent integration of the flow of funds sector into macro models is highly unlikely. First, as Bodkin has pointed out, there is limited data on the financial sector. Second, it requires a substantial amount of resources both in capital and labour to perform adequate research in refining the existing data. Third, an appropriate integration of the flow of funds sector with input-output and macro

⁴ The Herrnstein and Prelec (1991) study provides an alternative theory of individual (consumer) choice by incorporating findings from experimental psychologists.

models may require restrictive assumptions and a-priori specifications that, undoubtedly, will be damaging in the long run.

43. It should be noted that there are a number of consulting agencies in the private (e.g. Informetrica) and public sectors that are large enough to devote a substantial amount of their resources to the development of newer estimation techniques. Thus to some extent the prediction of the panellists may be realized in such agencies. Unfortunately many agencies do not have this luxury. In most business and government departments, economic models are updated primarily to satisfy the organization's output requirements. For example, if senior staff requires information on how the GST is affecting their product, the model will be modified to incorporate tax effects. Only after such immediate concerns are dealt with, will the researcher turn his or her attention to the improvement of the overall modelling strategy.

WHAT IS MISSING.

44. Although some of the panellists mentioned time series (TS) models in passing, none gave these models the importance they deserve. Beginning with the seminal work of Box and Jenkins (1970) on Autoregressive and Moving average models, TS models have become the fastest growing discipline in econometrics and statistics. While the specifications of TS models essentially describe variables as a function of their past values, the short-term forecasting ability of the models have been a welcome and cost-effective solution to business forecasters. The popularity of these models have been such that currently a number of new journals are providing a forum for rapid transformation of time series theory into practical use.

45. There is also a growing trend in the business community to combine TS models with macro models to enhance both predictive and expository power.

TS models are also proving to be the most adaptive. Like other statistical models TS models are constrained by the identification and extrapolation of existing or established patterns. A combination of several of these models has been proven to furnish the most accurate forecasts.

46. Given these factors, the future of economic modelling will probably be led by TS research and development. Looking at the current topics in TS, we should expect the subjective and judgemental factors of the modeller to incorporate as much information as possible from other models and disciplines to reduce the uncertainty inherent in modelling.

ECONOMIC MODELLING IN DSEA

47. Given the future directions of economic modelling discussed above and the existing demand for economic analysis in DSEA in the near future, the relevant question becomes, where should DSEA concentrate its analytical resources in the coming years?

48. Currently for projects that require impact analysis on the national and regional economies, an I-O model is desirable. To this end, an "in-house" I-O model is being developed and is being used to study various acquisition options. Based on available literature and past experiences, such impact models require improvements first in the area of long-term analysis, (that is when the impact of a project is believed to extend into the future) and second in the restrictive assumption of availability of abundant factor supply.

49. The first issue can be solved by building a dynamic I-O model. But such an undertaking is extremely time consuming and may require additional resources. An alternative is to use a customized macroeconometric model, as discussed earlier, to analyze the I-O simulation results further by assessing their

impact on major macroeconomic variables. There is relatively little time and resources invested in this case and costs substantially less to maintain.

50. The problem associated with the restrictive assumption of abundant supply may also be solved at least partially by using a macroeconomic model. A CGE model can also be a useful alternative. However, the assumptions embedded in CGE models are, as discussed earlier, as restrictive as an I-O model and the cost associated with building such a model is extremely high.

51. Until recently, Statistics Canada (SC) produced a closed version of an I-O model, to determine the induced or multiplier effect of an impact generated by households expenditure. However, this requires the estimation of the marginal propensity to consume (MPC) which a static I-O model is not equipped to handle. Due to this and other related problems SC has stopped marketing the closed version of the model.⁵ If DSEA builds a small scale macroeconomic model, induced effects can be easily incorporated into an impact analysis.

52. The use of Bootstrapping, Jackknife and Time Series techniques will probably be the most extensively used methods in DSEA since the quality and quantity of data continues to be the main concern of applied work, and the methods mentioned above are expected to improve data quality extensively. For example, DSEA was recently tasked to determine the break-even point between the cost of a video-teleconferencing system and the savings in Travel Duty (TD) costs which will accrue by using the system. One of the main problems encountered in that study was the availability of reliable data from

⁵ For detailed discussion on Statistics Canada's decision to suspend the closed version of the I-O model consult the following article: "Statistics Canada's Input-Output Model: General Description, Critical Analysis of Partially Closed Version and Alternative Solutions." Ottawa: Statistics Canada, Input-Output Division, June, 1991.

headquarters on personnel travel costs. The Bootstrapping technique would be useful here since one can generate a stochastic break-even point by re-sampling from existing data. A stochastic break-even point can then be used to present a confidence interval with each break-even point calculated. Updating time series data for use in a macroeconometric model or any other database can be done (at least for the short-term) with univariate time series model extrapolation techniques.

53. The above models and techniques are assumed to be needed by DSEA in the near future, at least based on the analytical demands of the last two years. Policy directions in DND and in most government departments in Canada are shifting towards fiscal responsibility and infrastructure rationalization and other cost cutting measures which will undoubtedly be the main topics in the coming decade. Such a shift in direction will affect both the availability of resources for building complicated models and the demand for models that estimate regional and national impacts.

54. Post closure (military bases) studies and other resource allocation problems may also command a portion of the analytical work in the future. What options are available to the Canadian defence industrial base (DIB) with the recent reduction in hostilities? As argued particularly in the press, is there a substantial peace dividend likely in Canadian macro economy? What are the impacts of defence expenditure reductions on imports, exports and overall international trade? These and other similar questions may have to be addressed in the coming years if DND is to follow an informed policy goal. Most of the questions posed above require some sort of econometric or multi-variate time series models as well as reliable data to produce meaningful answers. Maintaining sophisticated models such as these with a limited budget and resources will be a major undertaking in DSEA and other government

agencies. Possibly some of the most creative solutions will come from researchers in the non-academic sectors.

IV. CONCLUSIONS

55. The future direction of economic modelling has important implications to any one associated with economic analysis. The panel discussion at the 25th CEA meeting is a good starting point for initiating discussions. A more thorough understanding of the current situation in regards to the future implications of economic modelling or econometrics can be obtained through a survey of a number of business and government agencies. Such occasional visits to private and public institutions is not only beneficial for research but also for teaching and training.

56. An interesting example of this is presented in the September, 1991 issue of the Journal of Economic Literature. In assessing the current state of graduate education in economics (the study is based on U. S. institutions only), the authors surveyed business and government employers of economists to comment on the training of the new recruits. The responses include among others:

- a. New recruits are well trained in technical areas such as theory and quantitative methods, but were unable to conduct independent research.
- b. The recruits knowledge of economic institutions were minimal.
- c. The recruits required training in real world situations and data (Hansen, 1991).

57. Of course one has to read the whole article before commenting on Hansen's findings, but the need to bridge the gap between educational

institutions and business and government is crucial for applied research and even to economics as a discipline.

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**APPENDIX A
TO THE FUTURE OF
ECONOMIC MODELLING
DATED NOVEMBER, 1991**

APPENDIX

A. BOOTSTRAPPING

As mentioned earlier bootstrapping is a useful tool of analyzing or mimicking the actual distribution of a set of observations. More specifically one can estimate the mean, the variance and higher moments of probability distribution. Efron (1979) gives an interesting review on the subject.

Suppose a researcher has a set of observations B such that $B = (b_1, b_2, \dots, b_{20})$ and some information about the standard deviation σ^B is required. The bootstrapping procedure begins by randomly drawing observations from B using a random number generator. These new sets of observations will have been picked independently and with replacement from B . Once this is done the desired variable, σ^B will be estimated. We repeat the above procedures for a total of T times (say 1000). This should give us enough points to plot a reasonable distribution.

B. JACKKNIFE

The Jackknife procedure is essentially the same as bootstrapping with the exception that an observation is randomly deleted from the sample, for each simulation computed. Using the same data set B , the jackknife procedure will begin by taking an observation from the sample and calculating the desired variable from the remaining 19 observations. Like the bootstrapping method, the above procedures are repeated a large number of times.

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