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TITLE OF PROPOSED PROJECT **Standard Research Grant: Models and Causal Structure in Econometric Analysis**

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CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the Authorized Organizational Representative or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, lobbying activities (see below), responsible conduct of research, nondiscrimination, and flood hazard insurance (when applicable) as set forth in the NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG) (NSF 10-1). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

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In addition, if the applicant institution employs more than fifty persons, by electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

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The following certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

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The undersigned certifies, to the best of his or her knowledge and belief, that:
(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.
(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

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By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

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Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:
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(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF Grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

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The undersigned shall require that the language of this certification be included in any award documents for all subawards at all tiers.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME Susan E Lasley	Electronic Signature	Feb 1 2010 11:06AM

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
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* EAGER - EArly-concept Grants for Exploratory Research
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PROJECT SUMMARY

Intellectual Merit

Econometrics has been distinguished from simply statistics as applied to economics as being principally concerned with establishing causes or, what is frequently taken by economists to be the same thing, structural explanation. Economics has itself developed as a science of models. The proposed research is a systematic philosophical investigation of models and causal structure in econometrics, and is part of a larger project on the logic of econometric inference and its place in the explanatory practices of economics. While the philosophy of science has recently devoted much attention to models, when it comes to the case of economics, most of the attention has been paid to purely theoretical models. The proposed research aims to redress the balance by investigating models of data (measurement and statistical) and especially how they relate to theoretical models.

The intellectual merit of the proposed research rests in this: Econometrics is the core methodology of applied economics, yet its deepest foundations have rarely been examined. It is important to examine its methods philosophically – that is, at a higher level of generality – in order a) to better understand the key issues confronting econometrics, which may provide a framework in which students and professional economists can more clearly understand the conceptual structure in which econometric methods function as an aid to learning and more effective application; b) to better understand the relationship of different approaches within econometrics, raising the possibility that current internal disputes can be resolved better from a more detached perspective and so provide some guidance on how best to practice econometrics; c) to better understand the import for econometrics of the philosophical analysis of scientific inference generally, which may aid in improving those methods or relating them to methods of other sciences with the possibility of improving econometrics itself; and d) (the converse of this last point) to better understand the import of econometric methods for the problems of scientific inference generally, which may then provide a new resource to the philosophy of science, at present overwhelmingly informed by the problems of the natural sciences, and which may be of use in understanding (and possibly improving) the methods of other areas of science.

Broader Impact

The broader impact of the proposed research is itself implicit in its intellectual merits. Its broader impact falls in the category of a project that "will integrate research and education by advancing discovery and understanding while at the same time promoting teaching, training, and learning." A philosophical study – as described in the last paragraph – is an integrative study that aims to connect econometrics to the wider problems of science and, through that channel to the methods of other disciplines. The aim of the proposed study advances understanding both in the philosophy of science and in econometrics itself through a conceptual analysis that relates the workaday tools of econometrics to the broader, more abstract analysis of scientific inference. Such conceptual analysis is important in achieving pedagogically useful clarity of the basis, aims and success of a discipline – helpful to teaching, training, and learning. The aim is to better understand econometrics as it is practiced and to practice it better. Naturally, there is a much broader, though less direct impact: Professional economics is hugely influential in the design and conduct of public policy (witness recent political discussions and policy actions relative to the mortgage crisis and the debates over the stimulus aimed at meliorating the recession). That applied economists have an effective econometrics at hand and that they use econometrics effectively is essential to their giving good advice, soundly based in empirical evidence, for the conduct of economic policy.

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Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

PROJECT DESCRIPTION

1. Introduction: What is Econometrics?

The principal methods of empirical economics are referred to as *econometrics*. The proposed research focuses on the role of causal structure and models in sustaining econometric inference and analysis. This proposal covers a part of a larger project, which I conceive of as a systematic philosophical investigation of the logical foundations of econometrics and its place in the explanatory practices of economics.

Any investigation needs to begin by defining the field. In particular, is there a clear distinction between econometrics and the methods of statistics familiar in other fields? James Heckman, econometrician and winner of the Nobel Prize in Economic Science in 2000, relates econometrics to causal inference:

> *Most econometric theory* adapts methods originally developed in statistics. The major exception to this rule is the econometric analysis of the identification problem and the companion analyses of structural equations, causality, and economic policy evaluation. [Heckman 2000, p. 45, emphasis added.]
>
> . . .
>
> *The major contributions* of twentieth century econometrics to knowledge were the definition of causal parameters . . . the analysis of what is required to recover causal parameters from data . . . and clarification of the role of causal parameters in policy evaluation . . . [Heckman 2000, p. 45, abstract, emphasis added.]

Heckman's account of econometrics as a distinctively causal science is ahistorical – prescriptive of good practice perhaps, but not descriptive of the self-image of econometricians for most of the 20th century (see Hoover 2004, 2006). Yet, Heckman highlights areas in which the role of econometrics needs to be better understood. What it leaves out is the role of economic theory.

The philosopher Nancy Cartwright drew on econometrics to instruct physics on handling probabilities. Econometrics, she believed, provided a uniquely revealing application of statistics because, unlike, say, sociology, "economics is a discipline with a theory" (Cartwright 1989, p. 14). Economics is commonly divided between microeconomics and macroeconomics. For other purposes, however, it is divided between economic theory and empirical economics. In Ph.D courses (and even in undergraduate courses), micro- and macroeconomic *theory* usually constitute one required sequence and empirical tools, *statistics* and *econometrics*, another.

Economics has a reputation among social sciences as uniquely dominated by its theory. But the matter is more complicated than that. Eight-five percent of the articles in the September 2009 number of the *American Economic Review*, perhaps the premier journal in economics, involved empirical data, while only 15 percent were entirely theoretical. Economic theory is prestigious; yet, most articles in specialized field journals are empirical. Based on a JSTOR word search, I estimate that between the 1930s and 1950s between 30 and 40 percent of articles in economics involved econometrics, statistics, or empirical estimation (Hoover 2004). By 2000, the proportion had risen to about 70 percent. While these facts give the lie to the notion that economics, as actually practiced, is mainly an *a priori* theoretical discipline, there is, nonetheless, something special about the role of economic theory. Of the 85 percent of articles in the September 2009 *American Economic Review* that were empirical, almost all contained a section articulating an economic theory before entering on empirical investigation.

The tight connection of theory and empirics is reflected in the very origins of econometrics. The term gained widespread currency with the founding of the Econometric Society in 1933. The society defined econometrics as "economic theory in its relation to statistics and mathematics" and its object as the "unification of the theoretical-quantitative and the empirical-quantitative approach to economic problems" (cited by Frisch 1933, p. 1). "Econometrics" has come to refer mainly to the statistical apex of the economic theory-mathematics-statistics triangle, but it is a statistics that is conditioned by economic theory. The central problem, both historically, in the actual development of economics, and philosophically, in understanding the role of econometrics in economics, is found in the interplay of economic theory, mathematics, and statistics.

2. Background and Overview of the Project

While the history of econometrics has been documented elsewhere (Morgan 1990, Epstein 1987, Qin 1993, Klein 1987, Louçã 2007), the logical foundations of econometrics have been examined less systematically. The field of economics that treats general problems of explanation, inference, meaning, and conceptual schemes is referred to within economics as *methodology*. Methodology is not to be confused with the particular methods of econometrics or economic theory used by workaday economists. Indeed, it is often thought to be analogous to the philosophy of science (e.g., Caldwell 1994, Hands 2001). Most economic methodology, however, is a rather "in-house" affair in which economists, typically without searching reference to philosophical resources, engage in general reflections on their discipline. Indeed, the two most famous works of 20th century economic methodology, Lionel Robbin's *Nature and Significance of Economic Science* (1937) and Milton Friedman's (1953) "Essay on Positive Economics," are philosophically innocent. As a result, the continuing fame and importance of Friedman's essay among economists, in particular, has puzzled philosophers from the beginning. While methodologists sometimes display a nodding (and occasionally much deeper acquaintance) with philosophers, there is a tendency to view philosophy as a set of authoritative doctrines that can be borrowed when needed rather than as a practice that requires as much engagement as methodologists generally display towards economics itself.

These observations are not a criticism of economic methodology. My own extensive writings on the general problems of economics are methodological in exactly the sense in question. But the current project aims to take one step further back and to use the resources of the philosophy of science more fully to investigate the foundations of econometrics. Recent work in the philosophy of science, as well as in economic methodology, has taken a "naturalistic turn," privileging the practices of the fields under study and eschewing normative goals. I respect the intellectual impulse behind this naturalism – and its humility. A relevant philosophy of science must draw on a deep knowledge of the actual practices of the sciences studied. Nonetheless, I cannot rule out a prescriptive philosophy. I fully subscribe to what I have previously referred to as Rosenberg's "continuity thesis":

> If theory adjudicates the rules of science, then so does philosophy. In the absence of demarcation, philosophy is just very general, very abstract science and has the same kind of prescriptive force for the practice of science as any scientific theory. Because of its generality and abstractness it will have less detailed bearing on day-to-day science than, say, prescriptions about the calibration of pH meters, but it must have the same kind of bearing. [Rosenberg 1992, p. 11]

The main aim of the larger project is to understand in a very general way what makes econometrics work. If our philosophical inquiry also gives some guidance on how to make econometrics work more effectively, then so much the better. One dimension on which the project is important is captured in the possibility that it may inform a more effective econometrics.

I believe that I bring an uncommon perspective to this enterprise in that I am, and continue to be, a practicing monetary/macro-economist and applied econometrician as well as – at least by one of my departmental affiliations – a philosopher.

The ground to be covered in the project is not completely unexplored – the pathfinders and prospectors have been out – but the forests have not been cleared nor the ground tilled. Much of the methodological discussion about econometrics has taken place firmly within econometrics itself. For many years, there has been a battle of the schools between different general approaches (Pagan 1987; Hoover 1995b; Hartley, Hoover, and Salyer 1997, 1998). Within macroeconometrics, the London School of Economics approach (Hendry 1995; Mizon 1995; Faust and Whiteman 1995, 1997) and the related co-integrated vector autoregression approach (Juselius 1999, 2006; Hoover, Johansen, and Juselius 2008) have vied with dynamic structural modelers (Hansen and Sargent 1980), the vector autoregression approach (Sims 1980, Ingram 1995), the structural vector autoregression approach (Cooley and Leroy 1985; Leamer 1985; Sims 1986), and the calibration approach (Kydland and Prescott 1995). Related divisions exist in microeconometrics between structural modelers (Heckman 2000) and the natural experiments approach (Angrist and Kruger 2001). Systematic methodological accounts of econometrics are rare. Spanos's (1986, 1999) books are methodologically sophisticated econometrics textbooks. Magnus and Morgan's (1999) uses a highly focused experiment to address a range of econometric approaches. Darnell and Evans (1990) is one of the few explicitly methodological monographs on econometrics. It is more critical than constructive, focusing on competing schools. Lawson (1997), the product of a philosophical economist, and Cartwright (1989, 1999) bear on econometrics, but only in the context of larger and, in Cartwright's case, not completely economic interests.

Only two books are similar in spirit to the proposed project. Keuzenkamp (2000) is a philosophically informed investigation of econometrics. He advocates an information-theoretic approach, in which *simplicity* is the principal desideratum of econometrics, and he rejects realism. Stigum (2003) is the most systematic treatise on the philosophy of econometrics to date. Stigum's philosophical antecedents are firmly grounded in logical positivism. He advocates an axiomatic approach to the relationship of economic theory and econometrics that wavers somewhat between the syntactic and semantic views of theories. Like Keuzenkamp, Stigum is explicitly anti-realist.

My project is distinct from those of Keuzenkamp or Stigum. My earlier work has a decided causal realist flavor (Hoover 1991; 2001a, b; 2009). And in keeping with recent general work on scientific models (e.g, Morgan and Morrison 1999; Teller 2001; Geire 1999, 2006; and de Chadarevian *et al.*2004), I tend toward a "weaker" semantic view, in which the content of theories is found in families of related models, where "model" is not used in the sense current in formal logic, but instead refers to the kind of tools familiar to economists and econometricians such as the IS-LM model (Hicks 1937; De Vroey and Hoover 2004, the real-business-cycle model (Kydland and Prescott 1982; Hartley, Hoover, and Salyer 1997), or the neoclassical growth model (Solow 1956; Boianovsky and Hoover 2009) and to physicists such as the Ising model (Hughes 1999) or the rainbow model (Batterman 2001). This orientation raises a range of issues simply not contemplated in Keuzenkamp or Stigum's treatises (see section IV below).

While I have written widely on economic methodology and particularly on econometric methodology, my previous work has been mainly critical and unsystematic (e.g., Hoover 1994a, 1995a, 2002, 2004, 2006; Hoover and Perez 1999, 2000, 2004). My larger project is a free-standing, *systematic* inquiry. I will not simply collect and freshen up previous work, though naturally the new study will be informed by all that I have learned in the earlier work. Particularly, I do not contemplate the republication of any significant existing work. Instead, I propose a foundational inquiry that will draw together various themes and threads from existing work, provide a constructive account that connects them, fill in gaps, and address topics that I have not previously studied. My aim is to understand the structure and logic of a scientific practice rather than as primarily an attempt to resolve doctrinal disputes.

3. Intellectual Merit and Broader Impact

The intellectual merit of the proposed research is implicit in the overview in the last section. More explicitly, however, it rest in this: Econometrics is the core methodology of applied economics, yet its deepest foundations have rarely been examined. It is important to examine its methods philosophically – that is, at a higher level of generality – in order a) to better understand the key issues confronting econometrics, which may provide a framework in which students and professional economists can more clearly understand the conceptual structure in which econometric methods function as an aid to learning and more effective application; b) to better understand the relationship of different approaches within econometrics, raising the possibility that current internal disputes can be resolved better from a more detached perspective and so provide some guidance on how best to practice econometrics; c) to better understand the import for econometrics of the philosophical analysis of scientific inference generally, which may aid in improving those methods or relating them to methods of other sciences with the possibility of improving econometrics itself; and d) (the converse of this last point) to better understand the import of econometric methods for the problems of scientific inference generally, which may then provide a new resource to the philosophy of science, at present overwhelmingly informed by the problems of the natural sciences, and which may be of use in understanding (and possibly improving) the methods of other areas of science.

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4. Framework for the Investigation

To give a more concrete idea of the nature of the proposed investigation, I offer in this section a discursive discussion of the issues that motivate the key parts of the project with indications of where I intend to start on the various issues. Some of these issues arise out of work that I have done over many years. I highlight some of that work in order to convey the significance of the issues and to illustrate my own capacity to contribute to a fruitful investigation of those underlying issues. Generally, I hope to convey that I have clear ideas of where to start the investigation. Yet the proposal is for new research, and it would be premature to indicate any strong conclusion – the research has yet to be done.

4.1 The Nature of Econometrics

Econometrics is not simply statistics applied to economic problems. While the foundations of the distinction were laid, as indicated previously, in the stress placed on the role of economic theory as a complement to statistics in the very beginnings of the Econometric Society, another important source was Haavelmo's seminal "Probability Approach in Econometrics" (1944), which addressed the fact that economists must generally engage in passive observation, rather than controlled experiments. Haavelmo developed a rich understanding of the role of probability models in providing foundations for a substitute for experimental controls (see Morgan 1990). Haavelmo's approach was taken up by the Cowles Commission in its foundational volumes (Koopmans 1950; Hood and Koopmans 1953).

Haavelmo and the Cowles Commission rejected the notion that economists could usefully quantify economic relationships as mere associations among data. The main issue was that a useful economics – useful either for prediction or for policy analysis – must be supported by a causal account. How do changing parameters or policy actions play out? Haavelmo saw the goal as mapping out autonomous or relatively invariant *structures* that would provide a guide for potential interventions in the economy and trace out their consequences (Aldrich 1989). The importance of counterfactuals to empirical economic analysis – later reemphasized with the so-called "Lucas critique" – was thus implicit in the roots of modern econometrics (Lucas 1976).

Although Simon (1953) contributed a famous paper on causality to a Cowles-Commission volume, the language of "structure" dominated the language of "cause." In part, this arose from taking theoretical economics as the starting point (Hoover 2004) and, in part, from the influence of logical positivism with its revival of Humean skepticism about powers and properties. In practice economics is a model-driven enterprise, and economists waver between different views of the relationship between theory and data. Because of the variety of models and the fact that models are clearly human artifacts, economists sometimes flirt with the idea that any structures in the data are simply human creations. On the other hand, despite the variety of models, economists typically insist that acceptable models must be compatible with general economic principles that are taken to be facts about the world whose workings may be discovered but are independent of the investigator. There is some doubt as to exactly what these principles are. Haavelmo takes a broader view in which the basic elements might be supply and demand relations; while more recent economists frequently demand that we get "beyond demand and supply curves" to the decision problems of individual economic agents (Sargent 1982). This more realist view is favorable to a structural or causal view of economic relations.

Models and causal structure come together in the key issue for the Cowles-Commission view of econometrics: the *identification problem*. This is essentially the problem, identified earlier by Frisch as the problem of "inverse inference," of working backward from observable data to economic structure. The classic example of the identification problem arises when quantities are determined jointly by supply and demand curves in each of which quantity depends on price – supply directly and demand inversely. Observations on two variables can pick out only one relationship between price and quantity; they cannot identify two independent relationships but only their joint solution. There are various ways in which such relations could be identified. The simplest occurs if, as well as depending on price, supply depends on some other variable and demand on yet another variable. But this is prior information. So, one question is where does such prior information come from?

The standard answer is that economic theory (or sometimes institutional knowledge or common sense) tells us. Yet that raises another question of just how precise economic theory is in providing such prior knowledge absent prior learning from empirical data. It is rare that only one structural model would be consistent with the fairly mild constraints of economic theory.

The standard solution to the identification problem reflects very limited ambition for empirical evidence. Statistical evidence is used only to estimate the strength of the connections between variables conditional on prior knowledge of their structure. Statistics are used for measurement primarily under the assumption that we already know pretty much what the structure being measured is like. They can also be used to test hypotheses, but only ones that are redundant relative to the maintained structural assumptions needed to secure identification.

Various economists have found the weak empiricism of the standard solution to the identification problem to be problematic. Two polar strategies for short-circuiting the issue gained some traction. One strategy, exemplified by work on vector autoregressions (VARs), gives up on prior identification altogether and tries to work only with so-called *reduced forms* – essentially giving up on causal structure in favor of correlation (Liu 1960; Sims 1980). It was quickly pointed out that VARs were unsuitable for counterfactual analysis (Cooley and LeRoy 1985). The effect of a supply shock (e.g., weather on crops) cannot be analyzed unless we can identify a supply curve; the effect of a policy action cannot be analyzed unless we can distinguish the policy rule from the structures policy is meant to influence. The profession quickly accepted this criticism (Sims 1982, 1986). So, called *structural* VARs differ in detail from the models that the original VARs were meant to replace, but the fundamental weakness of the standard approach to identification remains.

The second strategy is exemplified by *calibrated models* (Kydland and Prescott 1982, Hartley, Salyer, and Hoover 1997, 1998). Calibration gives up on estimation altogether. The "best established" theory is supposed not only to provide the causal structure of models, it is also supposed to tell us the strength of the connections, to provide parameter values. Sometimes parameter values are said to be implied by accounting identities or facts that are independent of particular structures or sometimes by estimation in other contexts. Calibration raises a raft of questions, including how can estimation in other contexts supply parameter values when estimation is rejected in the principal context. More basically, calibration is a kind of *apriorism*. In resting on the "best established" economic theory, calibration begs the question. How can any theory become best established if it the models in which it is exhibited are based only on the best established theory? Rarely, if ever, is economic theory restrictive enough to pick out a single model. Calibration provides no way to test or to adjudicate the competing claims of alternative models.

While these two polar strategies continue to have adherents, most economists occupy the muddled middle ground. Models are estimated with strongly maintained (and often highly simplified) identification assumptions and typically with equally strongly maintained stochastic assumptions about the behavior of the error terms (i.e., of departures from the maintained model). The consistency of data with the maintained stochastic assumptions is typically testable and very frequently strongly rejected. One too common strategy is simply to soldier on ignoring the contradiction. A second is to try to repair the statistical properties through data transformations. Unfortunately, such transformations are not innocuous and often undermine the identification assumptions themselves (Hendry 1995; Spanos 1995; Hoover 1988; Hoover, Johansen, and Juselius 2009)

Two additional approaches aim to resolve some of the problems with this muddled middle ground. The so-called LSE (London School of Economics) approach associated with David Hendry and various colleagues focuses on stochastic specification (Mizon 1995). Its main elements are that it starts with very general specifications and works through a series of encompassing tests in which alternative models are compared for their information content while checking consistency with the assumption that errors should be well-behaved stochastically at each stage. This general-to-specific search strategy seeks to find the informationally richest model or model class consistent with the data. The rhetoric of the LSE approach emphasizes the general-to-specific element, but the most fundamental element, I claim, is the notion of *encompassing*, which is a methodology for adjudicating between competing models. The general-to-specific approach on this view should be seen principally as a method for systematically executing encompassing tests. The LSE approach typically makes only weak prior assumptions, and therefore is regarded as theoretically thin by many economists.

A second, quite different approach, which has a limited following among economists, is the graphic-theoretic or Bayes-net methods of causal inference (Spirtes, Glymour, Scheines 2001; Pearl 2000; Swanson and Granger 1997). The strategy is to ask what restrictions causal structures would place on the independence relations among economic data. Independence relations indicated statistically in the data limit the admissible class of causal structures. Although they are rarely treated together, graph-theoretic causal search and the LSE approach bear a family resemblance. Models are adjudicated in both approaches through nesting them in more general models. (Hoover, Demiralp, and Perez 2009 is a perhaps unique attempt to combine the techniques in an applied study.)

4.2 A Pragmatic Approach to Empirical Economics

Models and the Piecemeal Strategy for Securing Economic Knowledge

My general approach is perhaps best described as pragmatic in Peirce's sense (Hoover 1994b). It rejects foundationalism and the rationalism implicit in appeals to *a priori* theory in econometrics. The issue is instead what we believe and what we doubt at the moment. The object of scientific investigation is to resolve doubts. In the process, new doubts may arise – even doubts about what we previously took to be beyond doubt. Thus, provisional indubitability is consistent with a through-going fallibilism.

This approach is broadly compatible with perspectival realism (e.g., Giere 1999, 2006; Teller 2001). Models provide perspectives that are limited, incomplete, and not suitable for all purposes but which nonetheless capture something that is about the structure of the world. If we disagree, it is with the idea that models at best approximate the true. Truth may be – as it is for Peirce – a regulatory ideal towards which we hope models will converge. But as such, it is not a standard against which we may claim that models are approximations, because it is not a standard that we could ever know that we had to hand, even if we in fact did. Rather than approximations, models should be viewed as instruments that, when successfully employed, can be used to tell the truth (in a workaday sense of the word) – from a perspective, with a purpose, to a degree of scope and precision.

The econometric approach to identification provides a valuable insight in highlighting the role of maintained assumptions. But these are not *a priori* truths from timeless and unrevisable theory. They are simply the points that we do not find doubtful at the moment. To the degree that we do not doubt this assumptions, a theoretical model can act as a measuring instrument (Cartwright 1989; Boumans 2005, 2007). However, when there is doubt about maintained assumptions or bases for competition between models, the problem shifts to adjudication. While the standard approach to identification provides limited resources for adjudication, as it provides no basis for questioning maintained assumptions, the encompassing strategy of the LSE approach puts adjudication at its heart. Any pair of models that can be compared involve some shared presuppositions that are currently unchallenged and have implications that may conflict. The encompassing principle nests the models into a larger model in which, depending on parameter values, one of the root models could dominate the other, both could fail to find support, or elements of each could contribute to the more general model. The competition is restricted to a class of models (e.g., to linear models, nonlinear models, acyclical causal models, or cyclical causal models). No model class is perfectly general, so adjudication is not final – the strategy is both piecemeal and competitive.

The LSE's development of the encompassing approach is mainly concerned with statistical specification of data models, but it provides useful exemplars of adjudication between competing models. The problem is to understand the principles of adjudication in a philosophically general way that will, at the same time, clarify the basis for the methods and provide general lessons for adjudication among models in other contexts. As already noted, something analogous to encompassing is implicit in graph-theoretic search algorithms at the level of causal models. This analogy stands in need of more careful elaboration; and, in general, we should recognize that models are related in hierarchies in which models at different levels make different prior (that is not actually doubted) presuppositions. For example, a stereotypical econometric inference involves data models, causal models, and theoretical models. Data models, to take one instance, can rest on presuppositions that are neutral between the competing claims of different causal models in that they do not build in causal presuppositions.

An Illustration: Models and Causation

The general points here can be illustrated with a concrete example that has the advantage of showing how lessons from econometrics may be generalized to broader contexts. The example involves Reichenbach's (1956, p. 157) *principle of the common cause*: "If an improbable coincidence has occurred, there must exist a common cause." A typical gloss runs: If *A* and *B* are probabilistically dependent, then either one causes the other or they have a common cause. The principle of the common cause is closely related to the causal Markov condition, which is employed extensively in the graph-theoretic search algorithms (Spirtes *et al.* 2001, Pearl 2000). Elliot Sober (1994, 2001) has criticized the principle with a counterexample: bread prices in England rise on trend; sea levels in Venice rise on trend; bread prices and sea levels are, therefore, correlated; yet *ex hypothesi* they are not causally connected and, therefore, do not have a common cause. Cartwright (2007, ch. 6) and Reiss (2007) take Sober's counterexample as evidence against graph-theoretic (Bayes-net) causal search algorithms.

I argue that Sober's counterexample fails because he has failed to recognize the hierarchy of models and the different presuppositions involved in causal inference (see Hoover 2003). Reichenbach's principle requires judgments of probabilities. Probabilities are obtained through a probability model that interprets observable data (frequencies) as probabilities. These probabilities are then fed into causal models. Sober wrongly assumes common correlation statistics translate directly to probabilities. But this is true only for data that are well modeled as stationary – that is, as having time-invariant probability distributions (e.g., with constant means and variances). But his counterexample is much better modeled as a nonstationary process in which probability distributions are time dependent. *Prima facie* evidence for this is just that stationary processes cannot trend as he supposes. But more formally, it is that a stationary and nonstationary process can be nested in a single data model, and given the data in this thought experiment, the nonstationary model could encompass the stationary model with a very high likelihood. One thing to notice is that the adjudication among the statistical models does not presuppose the truth or falsehood of probabilistic dependence and so, contrary to Sober does not beg any causal questions (Sober 2001).

Recognizing the distinct role of data models and causal models defuses Sober's counterexample, because a high correlation judged on ordinary correlation statistics – as a matter of mathematical fact – does not imply probabilistic dependence in a nonstationary process. In a stationary process the distribution of the correlation statistic is strongly peaked and its variance falls as more observations accumulate so that it converges on the true population value of a dependence parameter. With two probabilistically independent random walks (nonstationary processes), as more observations accumulate the correlation statistic converges to a uniform distribution on the –1 to +1 interval – that is, we are bound to find many examples of high correlation even though there is no probabilistic dependence between the variables. The nonstationary model of bread prices and sea levels gives us no reason to begin invoking the principle of the common cause with respect to the causal model, because no "improbable coincidence" has occurred, only the quite probable coincidence that should be expected in such a process.

Graph-theoretic algorithms appear to be vulnerable to criticism based on Sober's counterexample, because they typically elide the step from facts about frequencies to the probability distribution by estimating frequencies and inferring causal order in a single procedure, which, as they are typically programmed, presuppose stationary data. The appearance, however, is misleading, based on the false impression that the linkage runs directly from data to causal model without the intermediate stage of a data model. In fact, the data-modeling step is implicit. The data-modeling steps and the probabilistic inferential steps are separable, and can easily be separated; so Sober's counterexample does not touch them in principle.

The general point is not about stationary and nonstationary processes. Rather it is that if we need probabilities for causal inference, we must adjudicate among alternative probability models in a data-modeling stage. There are types of probability models. The stages are distinguished by the fact that causal presuppositions are not made at the data-modeling stage. At each stage, adjudication among models can proceed using encompassing principles.

The example provides a hint about the relationship between the LSE general-to-specific approach to specification search and the graph-theoretic approach to causal modeling. They are, in fact, most at home at different stages of the modeling process: the general-to-specific modeling is directed toward an adequate statistical characterization of the data – i.e., to a probability model of the data. Graph-theoretical causal search must start with such a probability model and addresses the level of causal modeling. The two approaches are complementary, not antagonistic.

In any case, this is merely an illustration of the relations between models at different stages and strategies for adjudication that I propose to examine in more detail in the proposed research.

4.3 Models and Counterfactuals

Key Issues in Counterfactual Analysis in Econometrics

The previous example concentrated on inference (on "hunting causes" in Cartwright's 2007 parlance). As we have already seen, however, causal analysis was important in the development of econometrics because economists sought to conduct counterfactual policy analysis (Cartwright's "using causes"). Another essential element of the proposed research is to understand the relationships among models, causation, and counterfactuals in econometrics.

Much of recent philosophical analysis of counterfactuals and of counterfactual accounts of causation is based in Lewis's (1973, 1979, 2001) "possible worlds" analysis. The notion of possible worlds is a vapory one – at least for the purposes of a philosophy of science in close connection to scientific practice. The metric for closeness of possible world's is particularly vague. In contrast, economic models define possible worlds substantially more precisely: each parameterization is a clear alternative possibility, and counterfactual experiments are defined by changing parameters with reference to ones asserted to exist in reality.

This schematic account of counterfactual analysis raises a number of issues that need to be addressed in the proposed research. First, models are representations of pieces of reality, not of the whole. Thus, we need to consider how models are situated in the background of unanalyzed or less fully represented aspects of economic reality. This is a question that Simon (1996) addressed in his analysis of *near decomposability.*

Second, as suggested earlier, models form hierarchies from data models to causal models to theoretical models (which interpret and explain the existence of particular causal structures). Some of the confusion in counterfactual analysis in economics comes from failing to recognize that counterfactuals play different roles at each level. Data models do not support counterfactual inference. Causal models support counterfactual inference, but their scope is ambiguous and they may or may not be robust in the sense of being projectible into the situations that most interest us. Theory models do support counterfactual inference, but their utility depends on how convincingly they can be linked to causal models that are more easily studied in the data. Competing theory models are the least easy to adjudicate.

Third, Lewis's analysis of causation presupposes prior universal laws that underwrite counterfactual judgments. Like Woodward (2003, p. 16 and ch. 6), I believe that this gets things backwards. Laws (or in economics, theoretical models) are abstractions from causal knowledge. In keeping with the piecemeal pragmatism advocated above, we have better resources for knowing causal connections in the world than we have for knowing universal laws. And causal structure is the key to the support of counterfactual analysis.

But, fourth, unlike Woodward who seeks to define the causal relationship with reference to token counterfactual manipulations, I argue that the causal relationship is a structural one, which is not defined by manipulations or interventions, but in fact map out the implications of manipulations for observations. While I would turn Woodward's relationship between manipulation and cause on its head, my view still supports the idea that manipulations or interventions can be an excellent tool for learning about casual structure – just not for defining it. In particular, Woodward's emphasis on manipulability leads him to a *modularity* requirement – namely, that each cause be independently manipulable with respect to other causes.

An Illustration: Models and Causation

A requirement of modularity is problematic for econometric analysis and econometric analysis suggests that it is not essential. An example, illustrates some of the issues. A typical model of the connection of monetary policy to prices depends on a money supply rule in which a policy parameter λ governs the growth rate of (log) money (m_t), which is also hit by a random shock (ε_t) outside of anyone' control,

$$m_t = \lambda + m_{t-1} + \varepsilon_t \quad .$$

and (log) prices depend on money according to

$$p_t = m_t + \alpha\lambda - \delta + v_t \quad ,$$

where v_t is a random shock. (Subscripts index time, and δ and α are parameters.) This model is the solution to a more complex theoretical model. The parameter λ shows up in the price equation because in the more complex model, agents incorporate an understanding of the policy rule into their expectations of the future path of money. Notice Two points: First, the relationship is *nonmodular*: an intervention that alters m may do so by altering λ, yet that necessarily alters p, but only in part because of the change in m; it also alters the *relationship* between p and m in that the parameters of the price equation change. Yet, in sense that can be made precise, it is evident that m causes p despite the nonmodularity (Hoover 2001a, ch. 3). Second, ordinary econometric estimation cannot identify the parameters of the price equation separately but can only estimate their combination $\alpha\lambda - \delta$. Thus, any attempt systematically to control p using m – which must change λ – necessarily alters the functional form of the price equation (i.e., alters $\alpha\lambda - \delta$) as well. This is an example of econometric non-invariance stigmatized as the "Lucas critique" (Lucas 1976). The key point is that unless we can separately identify the parameters in $\alpha\lambda - \delta$, then legitimate counterfactuals are not possible. Lucas argued that large-scale macroeconometric models traded in unidentified parameters that, in effect, left the causal structure hidden and, therefore, that they were useless for policy analysis. This is closely related to the objections lodged against vector autoregressions above, since the money-supply rule, together with the price equation with $\alpha\lambda - \delta$ treated as a single coefficient constitute a vector autoregression (i.e., a reduced form of a structural dynamic system). Vector autoregressions suffer from the Lucas critique and do not support counterfactual analysis.

Econometrics provides examples of non-modular, yet clearly causal, models, suggesting that causal order should not presuppose modularity. But the lessons also run from philosophy to econometrics. One response to the Lucas critique is to restrict the analysis of policy analysis to "shocks" – that is, to unsystematic changes in the error terms (ε_t and ν_t) and tracing out their effects. These are, in fact, perfectly well-defined counterfactuals and can be evaluated accurately within the structural vector autoregression, because they present a way of altering m without altering λ. And they may reveal some information about causal structure. But they are, what Cartwright (2007, ch. ??) refers to as "impostor counterfactuals" – the counterfactual question that they legitimately answer is not the counterfactual question that we wish to answer. The central question about monetary policy is, what is the effect of a change in a systematic policy? Raising λ implies a systematic increase in the growth rate of money; but a shock to ε_t is the equivalent of the policymaker rolling the dice. It is a serious practical problem that the answers to these impostor counterfactuals have actually been used to guide policy. An important part of the problem in this case arises from a failure on the part of econometricians to distinguish the data model – of which the vector autoregression is a good candidate – from the causal model (see Demiralp and Hoover 2003; Demiralp, Hoover, and Perez 2008; Hoover, Demiralp, and Perez 2009). An important element of the proposed research is to understand and clarify the interrelationships among the levels of models that support different sorts of counterfactual analysis.

5. Summary: Principal Research Problems

The goal of the current proposal is to investigate the philosophical foundations of econometrics with respect to two of its most salient features: first, that economics is a science of models and, second, that econometrics is distinguished from statistics (implicitly or explicitly) in its object of isolating causal structure. There are four main issues to be addressed:

1. The manner in which economic reality can be represented even quantitatively and causally using models that view it from different perspectives and make different claims in point of scope, focus, and precision. My starting point is the notion that, despite vast differences, such perspectives might often be compatible in a manner similar to Giere's perspectival realism.

2. Econometric modeling, estimation, and policy analysis apparently presuppose a hierarchy of models, roughly data (probability) models → causal models → theoretical models (and perhaps more complicated than such a simple schema implies). The architecture of the models and their interrelationships will be explored.

3. While admitting that models with different perspectives may be compatible (issue 1), nonetheless the process of adjudicating models with genuinely competing claims is central to econometric logic. When are claims genuinely in conflict? What should decide between them? Here, the encompassing principle, which has been developed at the level of data models, will be the starting point. What is its logic? And how does it generalize to other levels of modeling?

4. The fundamental use of econometric models is for policy analysis – counterfactual inference. The central issue here is to develop the mutual illumination that philosophical analysis of counterfactuals and econometric analysis of policy can provide each other.

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Rosenberg, Alexander. (1992) *Economics: Mathematical Politics or Science of Diminishing Returns?* Chicago: Chicago University Press.

Sargent, Thomas J. (1982) "Beyond Demand and Supply Curves in Macroeconomics," *American Economic Review* 72(2), 382-389.

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Simon, Herbert A. (1996) *The Sciences of the Artificial*, 3 rd ed. Cambridge, MA: MIT Press.

Sims, Christopher A. (1980). "Macroeconomics and Reality," *Econometrica* 48(1), 1-48.

Sims, Christopher A. (1986) "Are Forecasting Models Usable for Policy Analysis?" *Federal Reserve Bank of Minneapolis Quarterly Review* 10(1), 2-15.

Sober, Elliot. (1994) "The Principle of the Common Cause," in *From a Biological Point of View.* Cambridge: Cambridge University Press, pp. 158-74.

Sober, Elliot. (2001) 'Venetian Sea Levels, British Bread Prices, and the Principle of the Common Cause," *British Journal for the Philosophy of Science*, 52(2), pp. 331-46.

Solow, Robert M. (1956) "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics* 70(1), 65-94.

Spanos, Aris. (1986) *Statistical Foundations of Econometric Modelling*. Cambridge: Cambridge University Press.

Spanos, Aris. (1995) "On Theory Testing in Econometrics: Modeling with Nonexperimental Data," *Journal of Econometrics* 67(1), 189-226.

Spanos, Aris. (1999) *Probability Theory and Statistical Inference : Econometric Modeling with Observational Data*. Cambridge: Cambridge University Press.

Spirtes, Peter, Clark Glymour, and Richard Scheines. (2001) *Causation, Prediction, and Search,* 2nd edition. Cambridge, MA: MIT.

Stigum, Bernt P. (2003) *Econometrics and the Philosophy of Economics: Theory-Data Confrontations in Economics.* Princeton: Princeton University Press.

Swanson, Norman R. and Clive W.J. Granger. (1997) "Impulse Response Functions Based on a Causal Approach to Residual Orthogonalization in Vector Autoregressions," *Journal of the American Statistical Association* 92(437), 357-367.

Teller, Paul. (2001) "Twilight of the Perfect Model Model", *Erkenntnis* 55(3), 393–415.

Woodward, James. (2003) *Making Things Happen: A Theory of Causal Explanation.* Oxford: Oxford University Press.

BIOGRAPHICAL SKETCH: KEVIN HOOVER

I. Professional Preparation

Oxford University, Oxford, England:

Nuffield College:	D.Phil	1985	Economics
Balliol College	M.A.	1983	Politics and Economics
	B.A. (1st Class Honours)	1979	Politics and Economics
College of William and Mary, Williamsburg, VA	A.B. (High Honors)	1977	Philosophy

II. Appointments

2006-present *Duke University*:
- 2006-present: Professor of Economics
- 2006-present: Professor of Philosophy

1985-present Department of Economics, *University of California*, Davis:
- 2006-present: Professor Emeritus.
- 1999-2006: Chair (sabbatical leave 2004-05)
- 1995-2006: Professor
- 1993-94: Acting Chair
- 1991-95: Associate Professor
- 1985-91: Assistant Professor

1983-85 Lecturer in Economics, *Lady Margaret Hall*, *Oxford University*

1981-84 Heyworth Prize Research Fellow, *Nuffield College*, *Oxford University*

1979-81 Research Associate, *Federal Reserve Bank of San Francisco*

III. Publications

i. Most Closely Related to the Project (in chronological order)

Hoover, Kevin D. (2001) *Causality in Macroeconomics.* Cambridge: Cambridge University, Press.

Hoover, Kevin D. (2002) "Econometrics and Reality," in Uskali Mäki (ed.) *Fact and Fiction in Economics: Models, Realism, and Social Construction.* Cambridge: Cambridge University Press. http://econ.duke.edu/~kdh9/Source%20Materials/Research/EconometricsandReality.pdf

Hoover, Kevin D. (2003) "Nonstationary Time Series, Cointegration,and the Principle of the Common Cause," *British Journal for the Philosophy of Science*, 2003. http://econ.duke.edu/~kdh9/Source%20Materials/Research/6.%20Nonstationary%20Time%20Series%20and%20Common%20Cause.pdf

Demiralp, Selva, Kevin D. Hoover, and Stephen J. Perez (2008) "A Bootstrap Method for Identifying and Evaluating a Structural Vector Autoregression," *Oxford Economic Papers* 70(4), 2008, 509-533. http://econ.duke.edu/~kdh9/Source%20Materials/Research/CausalBootstrap.pdf

Hoover, Kevin D. (2010) "Probability and Structure in Econometric Models," in *The Proceedings of the 13th International Congress of Logic, Methodology and Philosophy of Science*. London: King's College Publications, forthcoming. http://econ.duke.edu/~kdh9/Source%20Materials/Research/Probability%20and%20Structure%2019%20September%202007.pdf

ii. Other Significant Publications (in chronological order)

Hoover, Kevin D. and Stephen J. Perez. (1999) "Data Mining Reconsidered: Encompassing and the General-to-Specific Approach to Specification Search," *Econometrics Journal* 2(2), 167-191. http://econ.duke.edu/~kdh9/Source%20Materials/Research/3.%20Data%20Mining%20Reconsidered.pdf

Hoover, Kevin D. and Stephen J. Perez. (2000) "Three Attitudes Towards Data Mining," *Journal of Economic Methodology* 7(2), 195-210. http://econ.duke.edu/~kdh9/Source%20 Materials/Research/Three%20Attitudes.pdf

Hoover, Kevin D. (2001) *The Methodology of Empirical Macroeconomics.* Cambridge: Cambridge University Press.

Hoover, Kevin D., Johansen, and Juselius (2008) "Allowing the Data to Speak Freely: The Macroeconometrics of the Cointegrated Vector Autoregression," *American Economic Review*, forthcoming May. http://econ.duke.edu/~kdh9/Source%20Materials/Research/The%20CVAR%20 Approach%20with%20abstract.pdf

Hoover, Kevin D. (2010) "Idealizing Reduction: The Microfoundations of Macroeconomics," *Erkenntnis*, forthcoming.

IV. Synergistic Activities

1) Developed an algorithm with co-author Steven J. Perez for automatic specification search in econometrics that was the starting point (by their own explicit acknowledgment) for David Hendry's and Hans-Martin Krolzig's commercially available econometric search program *PcGets*.

2) Developed a unique data-based approach to teaching undergraduate macroeconomics, which after having used for many years is being turned into a textbook: http://econ.duke.edu/~kdh9/Macro_Text_Webs/Second%20Draft/linkpage.html

V. Collaborators & Other Affiliations Collaborators and Co-editors (since January 2006)

Mauro Boianovsky, Department of Economics; University of Brazilia, Brazil
Selva Demiralp, Department of Economics, Koç University, Instanbul, Turkey
Søren Johansen, Department of Economics, University of Copenhagen, Denmark
Katarina Juselius, Department of Economics, University of Copenhagen, Denmark
Stephen J. Perez, Department of Economics, California State University, Sacramento
Mark V. Siegler, Department of Economics, California State University, Sacramento.

Graduate Advisors and Postdoctoral Sponsors

Ph.D supervisor and committee

Charles Goodhart, Financial Markets Group, London School of Economics, England
Peter M. Oppenheimer, Christ Church, University of Oxford, England
Peter Sinclair, Department of Economics, University of Birmingham, England
No postdoctoral sponsors

Thesis Advisor and Postgraduate-Scholar Sponsor

Advised on the doctoral research as chair or committee member for 22 students; served as postdoctoral sponsor to 0 scholars. ***Thesis advisor*** **1)** Ryan Brady, United States Naval Academy, **2)** Derek Hung Chat Chen, World Bank, Washington, D.C., **3)** Selva Demiralp, Koç University, Instanbul, Turkey, **4)** Pedro Garcia Duarte, University of Sao Paolo, Brazil, **5)** Clinton Greene, University of Missouri, St. Louis, **6)** Kirk Elwood, James Madison University, **7)** Charles Haase, current affiliation unknown, **8)** James Hartley, Mount Holyoke College**, 9)** Christopher Kavalec, California Energy Commission, **10)** Kailash Khandke, Furman University, **11)** Sharmila Kumari King, University of the Pacific, **12)** Andres Luco, not yet placed; **13)** Ronald McNamara, Midwest Independent Transmission System Operator, Inc. **14)** Stephen Perez, California State University, Sacramento, **14)** Piyachart Phiromswad, Sasin Graduate Institute of Business Administration, Chulalongkorn University, **14)** Matthew Rafferty, Quinnipiac University, **17)** Mark Siegler California State Unversity, Sacramento, **18)** Derek Stimel, Menlo College, **19)** Kristin Van Gaasbeck, California State Unversity, Sacramento, **20)** Shiu-Tang Wang, current affiliation unknown, **21)** James Woods, Portland State University, **22)** Xiaonian Xu, China Europe International Business School 2

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
Duke University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Kevin D Hoover

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Kevin D Hoover - PI	0.00	1.49	2.00	[redacted]	$
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	1.49	2.00	[redacted]	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				[redacted]	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)					
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)					
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				[redacted]	
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				0	
H. TOTAL DIRECT COSTS (A THROUGH G)				[redacted]	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 56.0000, [redacted]					
TOTAL INDIRECT COSTS (F&A)				[redacted]	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)					
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ [redacted]	$
M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $					

PI/PD NAME
Kevin D Hoover

ORG. REP. NAME*
Susan Lasley

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION **Duke University**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Kevin D Hoover**				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Kevin D Hoover - none**	0.00	1.49	0.00	[redacted]	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	1.49	0.00	[redacted]	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				[redacted]	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)					
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)					
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				[redacted]	
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**0**	
H. TOTAL DIRECT COSTS (A THROUGH G)				[redacted]	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 56.0000, [redacted])**					
TOTAL INDIRECT COSTS (F&A)				[redacted]	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)					
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ [redacted]	$
M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $					

PI/PD NAME **Kevin D Hoover**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Susan Lasley**	Date Checked	Date Of Rate Sheet	Initials - ORG

2 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION	FOR NSF USE ONLY		
Duke University	PROPOSAL NO.	DURATION (months)	
		Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR	AWARD NO.		
Kevin D Hoover			

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Kevin D Hoover - PI	0.00	2.98	2.00	[redacted]	$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	2.98	2.00	[redacted]	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				[redacted]	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)					
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)					
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				[redacted]	
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				0	
H. TOTAL DIRECT COSTS (A THROUGH G)				[redacted]	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				[redacted]	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)					
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ [redacted]	$

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME	FOR NSF USE ONLY		
Kevin D Hoover	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*	Date Checked	Date Of Rate Sheet	Initials - ORG
Susan Lasley			

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

BUDGET JUSTIFICATION

Personnel

Kevin Hoover, Principal Investigator (2 Summer Months in 2010 plus one course buyout in each academic year 2010-11 and 2011-12): Professor Hoover will serve as Principal Investigator and will be responsible for conducting all research necessary to complete this project.

Fringe Benefits

The federal fringe benefit rate for exempt personnel is 24% for FY 10/11 and 24.2% for FY 11/12.

Travel

Travel funds are requested for the PI to attend two meetings annually - one national, one international. The budgeted amounts reflect the differences in costs of each type of travel. Travel to international conferences is particularly justified because the density of researchers interested in the philosophy of economics, economic methodology, and related areas is far higher in Europe than in the United States, which is reflected in a richer infrastructure for hosting relevant conferences. For example, the London School of Economics, the University of Amsterdam, Erasmus University, Rotterdam, Tilburg University, and the University of Helsinki all have groups in economic methodology or philosophy of science with a demonstrated interest in the problems of economics. No similarly focused programs exist in the United States, although some groups devoted to philosophy of science more broadly are open to economics as a target science.

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Kevin Hoover

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Standard Research Grant:Models and Causal Structure in Econometric Analysis

Source of Support: National Science Foundation
Total Award Amount: $ 236,411 Total Award Period Covered: 07/01/10 - 06/30/12
Location of Project: Duke University
Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 1.49 Sumr: 2.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

 USE ADDITIONAL SHEETS AS NECESSARY

FACILITIES, EQUIPMENT & OTHER RESOURCES

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. USE additional pages as necessary.

Laboratory: The project will be housed at Duke University in the Departments of Economics and Philosophy, which are located on the central and east campuses respectively. In addition, Duke provides outstanding infrastructure in the campus libraries and campus-wide technology

Clinical:

Animal:

Computer: Computer needs for this project are basic: Hoover's personal desktop computer, commonly available office software (Windows, Excel, Internet Explorer, etc.), and specialized econometric software (E-views, PcGive, etc.) already installed. The project will be supported by computer

Office: The Departments of Economics and Philosophy each provide a faculty office for Hoover. No other space is needed to support the research in this grant.

Other:

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate identifying the location and pertinent capabilities of each.

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual arrangements with other organizations.

FACILITIES, EQUIPMENT & OTHER RESOURCES

Continuation Page:

LABORATORY FACILITIES (continued):

services.

COMPUTER FACILITIES (continued):

services provided within the Duke Economics Department.