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博 士 学 位 论 文

条件独立性检验及其在经济学中的应用

Conditional Independence Test and Its Applications in
Economics

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摘要

条件独立性作为概率论中的重要概念，不仅在经济金融建模中得到了广泛应用，而且还囊括了计量经济学和统计学中的一系列重要假设，如马尔科夫性质、格兰杰因果关系、随机缺失和外生性等，在参数估计、模型设定等计量理论以及数据处理、经济预测等实证应用方面扮演着重要角色。为此，研究条件独立性检验问题，有助于开发出计量经济学中相关假设的检验统计量，丰富和完善现有研究成果，从而为实证研究者提供更加合理可靠的理论工具。

大量经济金融理论和实际数据表明，变量之间大多呈现出非线性关系。常用的 t 和 F 统计量仅能捕获线性特征，故而不适用于非线性框架下的条件独立性检验问题。为了同时捕获经济金融变量之间的线性和多种非线性条件影响关系，部分文献借助非参数方法构造了条件独立性检验统计量。然而，这些统计量或者存在严重的维数灾问题，或者不具有统一的渐近分布，无法便捷有效地应用于实证研究中。考虑到现有文献的不足之处，本研究借助特征函数和非参数回归的优良性质，提出了具有更高收敛速度、更优有限样本性质、能够更加便捷地应用于识别变量之间影响关系的条件独立性检验统计量以及一系列派生统计量，并将理论研究成果应用到实际经济金融问题研究中。

首先，本文对条件密度函数做傅里叶变换，借助条件特征函数构造了条件独立性检验统计量。得益于特征函数、非参数回归的应用以及原假设仅依赖于条件变量的设定形式，该统计量的收敛速度快于 Su and Spingler (2013)^[1]、Su and White (2007^[2], 2008^[3], 2013^[4])、Huang (2010)^[5]、Bouezmarni and Taamouti (2012)^[6]、Bouezmarni et al. (2012)^[7]等绝大多数在非参数框架下构造的统计量，从而具有更高的检验功效，能够识别出收敛到原假设速度更快的局部备择假设。另外，与 Su and White (2012)^[8]统计量的渐近分布依赖于具体数据生成过程不同的是，本文统计量在 β 混合条件下渐近服从于标准正态分布。这也使得本文统计量同时适用于横截面和时间序列数据，相对于 Lin and Gozalo (1996)^[9]、Delgado and González-Manteiga (2001)^[10]以及 Su and Spingler (2013)^[11]仅适用于横截面数据而言，应用范围更加宽泛。

其次，与现有大多数文献(如 Su and White, 2007^[2])不同的是，本文采用相同带宽估计条件联合和条件边际特征函数，允许二者的非参数估计误差共同决定统计量的渐近性质。尽管这种处理方式增加了渐近分布的推导难度，但是在实际应用中避免了选择多个带宽的繁杂工作，并且显著改善了统计量的有限样

本性质，特别是水平性质。蒙特卡洛模拟结果表明本文统计量基于渐近分布即可得到合理的检验水平，无需采用耗时耗力的自举方法修正水平扭曲问题。

再次，通过对条件独立性检验统计量关于辅助参数求相应阶导数，本文首次构造了能够灵活地应用于考察变量之间具体条件相依形式的派生统计量，允许研究者在统一框架下识别变量的条件影响关系。特别地，若对其中一个辅助参数求一阶导数，可以构造遗漏变量和均值格兰杰因果检验统计量。相对于 Fan and Li (1996)^[11]、Lavergne and Vuong (2000)^[12]以及 Aït-Sahalia et al. (2001)^[13]等构造的遗漏变量检验统计量，本文统计量不仅具有更快的收敛速度和更优的有限样本性质，而且适用于横截面数据和时间序列数据。相对于 Granger (1969)^[14]的 F 统计量，本文统计量能够捕获线性和多种形式的非线性均值格兰杰因果关系，从而更适用于非线性框架下的均值格兰杰因果检验问题；另外，若对两个辅助参数分别求一阶偏导，可以构造条件不相关检验统计量；若对两个辅助参数分别求二阶偏导，则可构造条件异方差的非参数检验统计量。与 Hong (1997)^[15]、Hong and Shehadeh (1999)^[16]以及 Hsiao and Li (2001)^[17]等异方差检验统计量依赖于线性模型设定形式不同的是，本文将条件均值和条件方差模型均设定为非参数形式，避免了模型设定偏误对检验结果的影响。

最后，本文以中美产出与货币之间的格兰杰因果检验、货币超发对工业各行业经济增长的影响、股指和利率的马尔科夫性质检验以及外汇市场溢出效应检验为应用案例，阐明了理论研究成果的实际应用价值。这些实证研究一方面运用本文统计量揭示了 F 统计量和 Su and White (2007)^[2]等统计量无法捕获的非线性关系，突出了本文统计量的相对优势，为现有文献广泛采用非线性模型刻画经济金融变量之间关系提供了新的经验证据；另一方面也得出了一系列有益的研究结论，如我国产出货币之间存在双向非对称格兰杰因果关系、货币超发对不同行业经济增长的影响存在较大差异、股指和利率序列不具有马尔科夫性质以及外汇市场存在非线性溢出效应等等，能够为研究人员构建恰当模型、决策部门制定合理政策提供一定的参考依据。

关键词：条件独立性，特征函数，非参数回归，格兰杰因果检验，货币，产出

Abstract

Conditional independence is an important concept in probability theory and a widely used assumption in economic and financial modeling. It encompasses many important hypotheses in econometrics and statistics, such as Markov property, Granger causality, missing at random and exogeneity, and plays important roles in both econometric theories including parameter estimation as well as model specification and empirical applications such as data processing and economic forecasting. Therefore, studying on the test of conditional independence will contribute to develop new econometric tests about some related hypotheses, enrich and improve the existing literature and further provide more reasonable and reliable tools for empirical applications.

A great quantity of economic and financial theories and real data indicate the nonlinear relationship among most of variables. Since t and F tests will miss many important nonlinear phenomena which generally exist in economic system, they are no longer applicable in nonlinear framework. To capture linear and various nonlinear relationships simultaneously, some literature tests conditional independence using nonparametric approach. However, these tests either suffer from severe curse of dimensionality problem, or do not have pivotal limiting distribution, and therefore could not be used in empirical studies conveniently. Considering the shortcomings of existing literature, this dissertation proposes a model-free test for conditional independence based on characteristic function and nonparametric regression approach and constructs a class of derivative tests gauge possible sources of conditional dependence. These tests have higher convergence rate and better finite sample performance than existing literature. Furthermore, this dissertation also applies these tests to study the relationships between economic and financial variables. Specifically, the contributions of this dissertation could be summarized as follows:

Firstly, by taking Fourier transformation of the conditional densities, this dissertation proposes a model-free test for conditional independence based on characteristic functions. Thanks to the use of nonparametric regression approach, conditional characteristic functions and the representation of the null hypothesis, which only relates to densities conditional on conditional variables, our test can detect a class of local alternatives that converge to the null hypothesis at a faster rate than most of the existing tests in the literature, such as Su and Spingler (2013), Su and White (2007, 2008, 2013), Huang (2010), Bouezmarni and Taamouti (2012), Bouezmarni et al. (2012). That is, our test is locally more powerful and could detect a class of local alternatives that con-

verge to the null hypothesis at a faster rate. Moreover, in contrast with Su and White's (2012) test, which is only pivotal for independence and martingale difference sequence observations, our test has a convenient asymptotic standard normal distribution under β mixing conditions. As a result, our test is applicable in both cross-sectional and time series contexts, and has extensive applications in comparison with Lin and Gozalo (1996), Delgado and González-Manteiga (2001) and Su and Spingler (2013), which is only applicable in cross-sectional data.

Secondly, unlike many nonparametric tests of conditional independence (e.g. Su and White, 2007), we use a single bandwidth rather than two different bandwidths in estimating both the conditional joint and marginal characteristic functions. As a result, nonparametric estimation errors of the conditional joint and marginal characteristic functions jointly affect the asymptotic distribution of our test statistic. Although this renders it more challenging to derive the asymptotic distribution of our test, it significantly improves the size performance of the proposed test in finite samples and avoids difficulties in choosing multi-bandwidths. Monte carlo simulation study shows that our tests have reasonable size using asymptotic critical values. It does not seem to be necessary to use bootstrap for our test, which is practically appealing because nonparametric bootstrap is very time consuming.

Thirdly, by differentiating our test statistic of conditional independence with respect to auxiliary parameters at the origin up to various orders, this dissertation firstly proposes a class of useful derivative tests to gauge possible sources of conditional dependence, which allow researchers to detect possible sources of rejection under a unified framework. Specifically, taking the first order partial derivative with respect to one auxiliary parameter, our test is a model-free test for omitted variables. This test is not only more powerful and has better finite sample performance than Fan and Li (1996), Lavergne and Vuong (2000), Aït-Sahalia et al. (2001), but also is applicable in both cross-sectional and time series contexts. Compared with Granger's (1969) F test, this test could capture linear and various nonlinear Granger causality in mean simultaneously, and therefore is more reliable in testing Granger causality in mean under the nonlinear framework. In addition, by taking the first order partial derivatives with respect to two auxiliary parameters, this test yields a nonparametric test of conditional uncorrelatedness, whereas taking the second order partial derivatives yields a nonparametric test of conditional heteroscedasticity. In contrast with Hong (1997), Hong and Shehadeh (1999), Hsiao and Li (2001), our test avoids misidentification problem by

setting nonparametric conditional mean and conditional variance models.

Finally, to show the significant value of our theoretical results, this dissertation applies the test statistic of conditional independence and the derivative tests to study relationships between various economic and financial variables, including nonlinear Granger causalities between China's output and money, the influence of money overhang to different sectors of industry, the Markov property of stock price index and interest rate, and the spillover effect in exchange rate market. On the one hand, our studies highlight the comparative advantages of our tests by documenting some nonlinear relationships which are ignored by the traditional Granger causality test and Su and White's (2007) test and provide justification on necessity of modeling the relationships of economic and financial variables via nonlinear models. On the other hand, we also obtain several interesting conclusions, such as the bidirectional asymmetric Granger causality relationships between China's money and output, the different effects of money overhang on various sectors of industry, the violation of Markov property of stock price index and interest rate as well as the existence of nonlinear spillover effect in exchange rate market. These conclusions may be helpful in building proper econometric models and provide valuable reference to decision makers in making reasonable economic policies.

Key Words: Conditional Independence, Characteristic Function, Nonparametric Regression, Granger Causality Test, Money, Output.

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