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The NCSTAR model as an alternative to the GWR model

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Abstract

This paper compares the GWR model, usually used to integrate and examine the spatial heterogeneity of a relationship, and the NCSTAR model. The former will give a vector of local parameter estimates for each observation of the data set, according to its nearest neighbors in space. However, it supposes that all variables enter linearly the model. To correct this failure, a NCSTAR model is proposed. It can be seen as a linear model which coefficients are given by the outputs of an ANN model. These outputs can be related not only to geographical variables but also to social, financial or economic variables (according the nature of the relationship under study) via a nonlinear function which functional form has not to be specified. Moreover, the confidence intervals for the NCSTAR estimates can be computed.

Keywords: Neural network models; Spatial heterogeneity; Statistical inference

1. Introduction

Spatial econometrics deals with spatial dependence and spatial heterogeneity, respectively defined, according to [1], as the lack of independence between observations and the lack of stability over space of the relationship under study.

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Both reflect the importance of distance in spatial economics. To model spatial heterogeneity, [2] introduces the method of spatial expansion. In addition to the base regressors which are the ones of an ordinary regression, the model contains variables which are the product of these base regressors with the matrix of geographical coordinates. Another possibility is to use the GWR model introduced by [3] and named geographically weighted regression by [4]. It is a non-parametric locally linear model which uses distance weighted sub-samples of the data, in which greatest weights are assigned to nearest geographical observations, to give estimates for each point in space. Thought valid inferences using traditional least-squares method cannot be drawn from these estimates as they are all based on the same dataset with different weights and they are all conditional to a single decay parameter, the simplicity of the model is still attractive. It has been used to estimate houses prices [5,6], the effects of municipal and regional attributes on employment growth [7], regional industrialization [8] and more frequently to analyze spatial stationarity [9,10]. The Neuro-Coefficient Smooth Transition Auto Regressive (NCSTAR) model developed by [11], in the time-series context, can be seen as a linear model, the coefficients of which are given by the outputs of a single hidden feedforward network. [12–14] among others, give the theoretic background of the universal approximator property of such artificial neural network (ANN) model. It has been used by [15] in modelling exchange rates. The paper is organized as follows: section 2 briefly presents the GWR model, section 3 describes the NCSTAR model, section 4 is devoted to one application, and a conclusion follows in section 5.

2. The GWR model

It can be written as follows:

$$W_i^{1/2} y = W_i^{1/2} \widetilde{X} \beta_i + W_i^{1/2} e\,, \tag{1}$$

where y is a $n \times 1$ vector of dependent variable, $\widetilde{X} = [1, X]$ is a $n \times (p+1)$ matrix of explanatory variables, β_i is a $(p+1) \times 1$ vector of parameters and W_i is a $n \times n$ diagonal matrix of spatial weights. The latter are associated with i, a point in space, and $i = 1, \ldots, n$. The model assumes that the errors e are independently and normally distributed with zero mean and constant variance. Before estimating (1), one needs to choose a function for the spatial weight matrix. It is composed by a vector of distance and a decay parameter, because for a particular point i, nearest observations matter more than furthest ones. Brunsdon et al. [4] suggest to use an exponential function which is of the form:

$$W_i = \sqrt{\exp(-d_i/\theta)}\,, \tag{2}$$

with d_i, the vector of distance between observation i and all other observations and θ the decay parameter. The tri-cube function proposed by [17] is defined as:

$$W_i = (1 - (d_i/q_i)^3)^3 I(d_i < q_i)\,, \tag{3}$$