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On asymptotic normality in nonlinear regression¹

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Abstract

In this paper we reconsider the results in Wang (1995, 1996), who studies the conditions for asymptotic normality of L_1 - and (constrained) L_2 -norm regression estimators in the nonlinear regression model. Unfortunately, Wang fails to state necessary global conditions.

Key words: Asymptotic normality, nonlinear regression.

1 Nonlinear regression

We consider the nonlinear regression model

$$y_i = f(x_i, \vartheta) + e_i, \quad i = 1, \dots, N, \quad (1)$$

where $\vartheta \in R^m$ is a vector of unknown parameters and $\{e_i\}$ is an error process. An extensive literature investigates the asymptotic properties of M-estimators $\hat{\vartheta}_N$ of ϑ , minimizing the loss function

$$M_N(\vartheta) = \frac{1}{N} \sum_{i=1}^N \rho(y_i - f(x_i, \vartheta)), \quad (2)$$

for different choices of ρ -functions $\rho_p = |z|^p$, $p \geq 1$, (e.g., Berline, Liese and Vajda, 2000). Leading examples are L_1 ($p = 1$; e.g. Wang, 1995) and L_2 ($p = 2$; e.g. Wang, 1996) estimators.

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For independent and identically distributed (iid) processes, consistency and asymptotic normality conditions of model (1) have been studied for L_2 regression by Wu (1980). For the same model Oberhofer (1982) establishes consistency for L_1 regression and Jureckova and Prochazka (1994) derive conditions for consistency and asymptotic normality for the asymmetrically weighted L_1 (quantile) regression. The results of Wu and Oberhofer have been extended to dependent and/or heterogeneous processes in subsequent research (e.g., Prakasa Rao, 1984). A comprehensive treatment and annotated bibliography for M-estimation of model (1) is given by Liese and Vajda (2003, 2004).

In his main result stated in Theorem 2, Wang (1995) studies the asymptotic normality of the L_1 estimator of model (1). His main theorem is based on three assumptions: A1 concerns the errors e_i , in particular that e_1, \dots, e_N are iid, A2 and A3 concern the smoothness and boundedness of $\nabla f(x_i, \vartheta)$. The requirements of the latter two assumptions, however, are postulated in A2 only for ϑ in a neighborhood of the true value ϑ_0 , and in A3 for $\vartheta = \vartheta_0$.

The solely local nature of these assumptions is rather astounding, as even identifiability requires an assertion global in ϑ . An example for a suitable identification assumption would be: for every $\epsilon > 0$ there exists a positive δ_ϵ such that

$$\liminf_N \inf_{\|\vartheta - \vartheta_0\| \geq \epsilon} \frac{1}{N} \sum_{i=1}^N |f(x_i, \vartheta) - f(x_i, \vartheta_0)| > \delta_\epsilon. \quad (3)$$

Usually such an assertion is made when discussing consistency, e.g., Oberhofer (1982) for L_1 estimators and Wu (1980), who discusses the consistent directions of L_2 estimators. Then asymptotic normality is proved given consistency and rate of convergence of the estimator $\hat{\vartheta}_N$ minimizing $M_N(\vartheta)$ (e.g., Liese and Vajda, 2003, p. 458).

As a consequence, asymptotic normality cannot be established globally without consistency, where the latter is based on an assertion global in ϑ . It lies near at hand to ask, whether and where these considerations are reflected in the argumentation of Wang?

2 Asymptotic normality

Wang (1995) refers to Prakasa Rao (1987) and argues that the latter uses an analogous argumentation for the least squares (L_2) estimation of ϑ in (1). Unfortunately, Wang's adaption is incorrect, though this may be difficult to see at first sight. Indeed, Theorem 6.2.1 (p. 373) in Prakasa Rao (1987) holds only locally, i.e. for ϑ such that

$$\vartheta = \vartheta_0 + N^{-1/2}\phi, \quad (4)$$

where ϕ is contained in a neighborhood V of ϑ_0 and the local parameter $\hat{\phi}_N = N^{1/2}(\hat{\vartheta}_N - \vartheta)$ minimizes the loss function

$$M_N(\phi) = M_N(\vartheta_0 + N^{-1/2}\phi) - M_N(\vartheta_0). \quad (5)$$

But this is derestricted by Prakasa Rao (1987) in the remark after Theorem 6.2.5 (p. 377), and requires a (global) identifiability assumption such as (3) or assumption (C_1) in Prakasa Rao (1987, p. 372). The latter step, which is based on the work of Ivanov (1976), establishes a rate of convergence result and is missing in Wang's argumentation. In the last paragraph of p. 237, Wang (1995) merely mentions that V can be arbitrarily large. As V depends on N , however, this argument is ill-founded. V can be arbitrarily large, but independently from N . Hence, a correct proof requires the consistency of the estimator of ϑ and in addition its sufficiently fast convergence to ϑ_0 (e.g., Prakasa Rao, 1987, equations (6.2.28) and (6.2.29)).

Note that the same reasoning applies analogously to a more recent paper of Wang (1996), which considers the asymptotic normality of the L_2 estimator of the parameter vector in (1), subject to a set of nonlinear equality and inequality constraints. In Theorem 6, Wang (1996) shows that $N^{1/2}(\hat{\vartheta} - \vartheta_0)$ converges to a normal distribution if $N^{1/2}(\vartheta - \vartheta_0)$ is contained in a bounded set. Again, however, all assumptions employed are only local.

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