ISSN: 1525-3066

Center for Policy Research
Working Paper No. 98

A MONTE CARLO STUDY FOR PURE AND PRETEST ESTIMATORS OF A PANEL DATA MODEL WITH SPATIALLY AUTOCORRELATED DISTURBANCES

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September 2007

$5.00

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Abstract

This paper examines the consequences of model misspecification using a panel data model with spatially autocorrelated disturbances. The performance of several maximum likelihood estimators assuming different specifications for this model are compared using Monte Carlo experiments. These include (i) MLE of a random effects model that ignore the spatial correlation; (ii) MLE described in Anselin (1988) which assumes that the individual effects are not spatially autocorrelated; (iii) MLE described in Kapoor, et al. (2006) which assumes that both the individual effects and the remainder error are governed by the same spatial autocorrelation; (iv) MLE described in Baltagi, et al. (2006) which allows the spatial correlation parameter for the individual effects to be different from that of the remainder error term. The latter model encompasses the other models and allows the researcher to test these specifications as restrictions on the general model using LM and LR tests. In fact, based on these tests, we suggest a pretest estimator which is shown to perform well in Monte Carlo experiments, ranking a close second to the true MLE in mean squared error performance.

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Michael Pfaffermayr gratefully acknowledges financial support from the Austrian Science foundation, grant Nr. P17028-G05. We would like to thank the editors and two anonymous referees for their helpful comments and suggestions.

JEL classification: C23; C12

Keywords: Panel data; Spatially autocorrelated residuals; Pretest estimator; Maximum-likelihood estimation

1 Introduction

The recent literature on spatial panel data models with error components adopts two alternative spatial autoregressive error processes. One specification assumes that only the remainder error term is spatially correlated but the individual effects are not (Anselin, 1988, Baltagi, Song, and Koh, 2003 and Anselin, Le Gallo and Jayet, 2005; we refer to this as the Anselin model). The other specification assumes that both the individual and remainder error components follow the same spatial error process (see Kapoor, Kelejian, and Prucha, 2006; we refer to this as the KKP model). In a companion paper, we introduced a generalized spatial panel data model which nests these two alternative processes in a more general model (see Baltagi, Egger, and Pfaffermayr, 2006).[1] The latter paper derived LM tests of the generalized model against its restricted alternatives and studied their size and power performance against LR-tests. This paper compares the performance of ML-estimates of these models under misspecification and suggests a pretest estimator based on the LM-tests derived by Baltagi, Egger, and Pfaffermayr (2006). We show that misspecified MLE can cause substantial loss in MSE where as the pretest estimator performs well, ranking a close second to the true MLE.

Section 2 derives the MLE for the various panel data models considered with first order spatial autocorrelation in the disturbances.[2] It also describes

[1]For an alternative spatial panel moving average process, see Fingelton (2006).

[2]While we focus on MLE in this paper, it is important to note that an alternative generalized moments estimator has been suggested by Kapoor, Kelejian and Prucha (2006) for the SAR panel model and Fingelton (2006) for the SMA panel model. The generalized moments estimator has the advantage that is computationally less demanding than MLE,

the algorithm to select the pretest estimator based on a sequence of LM tests derived in Baltagi et al. (2006). Section 3 gives the design of the Monte Carlo experiments and describes the results. These Monte Carlo experiments shed some light on the performance of say the Anselin MLE when the true specification is that of KKP, and vice versa. Also, it shows how robust is the MLE of the general spatial panel model to *overspecification*, i.e., if the true model is KKP or Anselin. Conversely, how the Anselin and KKP maximum likelihood estimates are affected by *underspecification* of the general model. Since the researcher does not know the true model, the Monte Carlo experiments show that the pretest estimator is a viable second best alternative to the true MLE in practice.

2 Maximum likelihood estimators of the alternative models

Baltagi, Egger, and Pfaffermayr (2006) considered the following generalized spatial error components model:

$$\begin{aligned} \mathbf{y} &= \mathbf{X}\boldsymbol{\beta} + \mathbf{u} \\ \mathbf{u} &= \mathbf{Z}_\mu \mathbf{u}_1 + \mathbf{u}_2 \\ \mathbf{u}_1 &= \rho_1 \mathbf{W}_N \mathbf{u}_1 + \boldsymbol{\mu} \\ \mathbf{u}_2 &= \rho_2 \mathbf{W} \mathbf{u}_2 + \boldsymbol{\nu}. \end{aligned} \quad (1)$$

This is a balanced panel, which consists of $n = NT$ observations, where N is the number of unique cross-sectional units, while T is the number of time

especially as N gets large.

periods. The $(n \times 1)$ vector $\mathbf{y}$ denotes the dependent variable, $\mathbf{X}$ is an $(n \times K)$ matrix of non-stochastic exogenous variables. $\boldsymbol{\beta}$ is the corresponding $K \times 1$ parameter vector. $\mathbf{Z}_\mu = \boldsymbol{\iota}_T \otimes \mathbf{I}_N$ denotes the design matrix for the $(N \times 1)$ vector of random individual effects $\mathbf{u}_1$. $\boldsymbol{\iota}_T$ is a $(T \times 1)$ vector of ones and $\mathbf{I}_N$ is an identity matrix of dimension N. The vector of individual effects $\boldsymbol{\mu}$ is assumed to be $i.i.d.N(0, \sigma_\mu^2 \mathbf{I}_N)$, while the $(n \times 1)$ vector of remainder disturbances $\boldsymbol{\nu}$ is assumed to be $i.i.d.N(0, \sigma_\nu^2 \mathbf{I}_n)$. Furthermore, the elements of $\boldsymbol{\mu}$ and $\boldsymbol{\nu}$ are assumed to be independent of each other. Both $\mathbf{u}_1$ and $\mathbf{u}_2$ are spatially correlated involving the same spatial weight matrix $\mathbf{W}_N$ for each time period, but with different spatial autocorrelation parameters ρ_1 and ρ_2, respectively. $\mathbf{W}_N$ exhibits zero diagonal elements, the remaining entries are usually assumed to decline with distance. The eigenvalues of $\mathbf{W}_N$ are bounded and smaller than 1 in absolute value (see Kelejian and Prucha, 2005). The latter assumption holds for the row normalized $\mathbf{W}_N$. It also holds for the maximum-row normalized spatial weights matrices. This assumption also implies that all row and column sums of $\mathbf{W}_N$ are uniformly bounded in absolute value. In addition, we assume that $|\rho_r| < 1$ for $r = 1, 2$. The data are ordered such that $i = 1, ..., N$ is the fast index and $t = 1, ..., T$ is the slow one. The spatial weights matrix for the panel is then given by $\mathbf{W} = \mathbf{I}_T \otimes \mathbf{W}_N$, which is block diagonal and of dimension $(n \times n)$.

This model encompasses both the KKP model, which assumes that $\rho_1 = \rho_2$, and the Anselin model, which maintains that $\rho_1 = 0$. The familiar random effects (RE) panel data model without any spatial correlation is represented by $\rho_1 = \rho_2 = 0$ (see Baltagi, 2005).

In order to derive the $(n \times n)$ variance-covariance of the generalized model, we define $\mathbf{A} = (\mathbf{I}_N - \rho_1 \mathbf{W}_N)$ and $\mathbf{B} = (\mathbf{I}_N - \rho_2 \mathbf{W}_N)$. This allows us to write

$$\begin{aligned} \mathbf{u}_1 &= \mathbf{A}^{-1}\boldsymbol{\mu} \sim N(0, \sigma_\mu^2(\mathbf{A}'\mathbf{A})^{-1}) && (2) \\ \mathbf{u}_2 &= (\mathbf{I}_T \otimes \mathbf{B}^{-1})\boldsymbol{\nu} \sim N(0, \sigma_\nu^2(\mathbf{I}_T \otimes (\mathbf{B}'\mathbf{B})^{-1})). && (3) \end{aligned}$$

and

$$\begin{aligned} \boldsymbol{\Omega}_u &= E(\mathbf{u}\mathbf{u}') = E[(\mathbf{Z}_\mu \mathbf{u}_1 + \mathbf{u}_2)(\mathbf{Z}_\mu \mathbf{u}_1 + \mathbf{u}_2)'] && (4) \\ &= \overline{\mathbf{J}}_T \otimes [T\sigma_\mu^2(\mathbf{A}'\mathbf{A})^{-1} + \sigma_\nu^2(\mathbf{B}'\mathbf{B})^{-1}] + \sigma_\nu^2(\mathbf{E}_T \otimes (\mathbf{B}'\mathbf{B})^{-1}) = \sigma_\nu^2 \boldsymbol{\Sigma}_u. \end{aligned}$$

This uses the fact that $E[\mathbf{u}_1\mathbf{u}_2'] = \mathbf{0}$ since $\boldsymbol{\mu}$ and $\boldsymbol{\nu}$ are independent by assumption. Note that $\mathbf{Z}_\mu \mathbf{Z}_\mu' = \mathbf{J}_T \otimes \mathbf{I}_N$ where $\mathbf{J}_T$ denotes a $(T \times T)$ matrix of ones. We define $\mathbf{E}_T = \mathbf{I}_T - \overline{\mathbf{J}}_T$, where $\overline{\mathbf{J}}_T = \mathbf{J}_T/T$ is the averaging matrix over T. The inverse of $\boldsymbol{\Omega}_u$ can then be obtained from the inverse of smaller dimension $(N \times N)$ matrices as follows:

$$\begin{aligned} \boldsymbol{\Omega}_u^{-1} &= \overline{\mathbf{J}}_T \otimes [T\sigma_\mu^2(\mathbf{A}'\mathbf{A})^{-1} + \sigma_\nu^2(\mathbf{B}'\mathbf{B})^{-1}]^{-1} + \frac{1}{\sigma_\nu^2}(\mathbf{E}_T \otimes (\mathbf{B}'\mathbf{B})) && (5) \\ &= \frac{1}{\sigma_\nu^2}\left[\overline{\mathbf{J}}_T \otimes [\tfrac{T\sigma_\mu^2}{\sigma_\nu^2}(\mathbf{A}'\mathbf{A})^{-1} + (\mathbf{B}'\mathbf{B})^{-1}]^{-1} + (\mathbf{E}_T \otimes (\mathbf{B}'\mathbf{B}))\right] = \frac{1}{\sigma_\nu^2}\boldsymbol{\Sigma}_u^{-1} \end{aligned}$$

Furthermore, $\det[\boldsymbol{\Omega}_u] = \det[T\sigma_\mu^2(\mathbf{A}'\mathbf{A})^{-1} + \sigma_\nu^2(\mathbf{B}'\mathbf{B})^{-1}]\det[\sigma_\nu^2(\mathbf{B}'\mathbf{B})^{-1}]^{T-1}$. Assuming normality of the disturbances the log likelihood function of the unrestricted model is given by

$$\begin{aligned} L(\boldsymbol{\beta}, \sigma_\nu^2, \sigma_\mu^2, \rho_1, \rho_2) &= -\frac{NT}{2}\ln 2\pi - \frac{1}{2}\ln\det[T\sigma_\mu^2(\mathbf{A}'\mathbf{A})^{-1} + \sigma_\nu^2(\mathbf{B}'\mathbf{B})^{-1}] \\ &\quad -\frac{T-1}{2}\ln\det(\sigma_\nu^2(\mathbf{B}'\mathbf{B})^{-\mathbf{1}}) - \frac{1}{2}\mathbf{u}'\boldsymbol{\Omega}_u^{-1}\mathbf{u}, && (6) \end{aligned}$$

where $\mathbf{u} = \mathbf{y} - \mathbf{X}\boldsymbol{\beta}$. For the special case of $\rho_1 = 0$, this implies that $\mathbf{A} = \mathbf{I}_N$ and the restricted log likelihood function reduces to the one considered by

Anselin (1988, p.154):

$$
\begin{aligned}
L_{\mathrm{A}}(\boldsymbol{\beta}, \sigma_\nu^2, \sigma_\mu^2, \rho_2) &= -\tfrac{NT}{2} \ln 2\pi\sigma_\nu^2 - \tfrac{1}{2} \ln \det [T\sigma_\mu^2 \mathbf{I}_N + \sigma_\nu^2(\mathbf{B}'\mathbf{B})^{-1}]^{-1} \qquad (7) \\
&\quad + \tfrac{T-1}{2} \ln \det(\mathbf{B}'\mathbf{B}) - \tfrac{1}{2}\mathbf{u}'\boldsymbol{\Omega}_{u,\mathrm{A}}^{-1}\mathbf{u} \\
\boldsymbol{\Omega}_{u,\mathrm{A}}^{-1} &= \tfrac{1}{\sigma_\nu^2}\left[\overline{\mathbf{J}}_T \otimes \left(\tfrac{T\sigma_\mu^2}{\sigma_\nu^2}\mathbf{I}_N + (\mathbf{B}'\mathbf{B})^{-1}\right)^{-1}\right] + \tfrac{1}{\sigma_\nu^2}\left[\mathbf{E}_T \otimes (\mathbf{B}'\mathbf{B})\right].
\end{aligned}
$$

For the alternative case with $\rho_1 = \rho_2 = \rho \neq 0$, $\mathbf{A} = \mathbf{B}$ and we obtain the log likelihood representation of the KKP estimator:

$$
\begin{aligned}
L_{\mathrm{KKP}}(\boldsymbol{\beta}, \sigma_\nu^2, \sigma_\mu^2, \rho) &= -\tfrac{NT}{2} \ln 2\pi\sigma_\nu^2 - \tfrac{N}{2} \ln(\frac{\sigma_1^2}{\sigma_\nu^2}) + \tfrac{T}{2} \ln \det(\mathbf{B}'\mathbf{B}) - \tfrac{1}{2}\mathbf{u}'\boldsymbol{\Omega}_{u,\mathrm{KKP}}^{-1}\mathbf{u} \\
\boldsymbol{\Omega}_{u,\mathrm{KKP}}^{-1} &= \tfrac{1}{T\sigma_\mu^2+\sigma_\nu^2}[\overline{\mathbf{J}}_T \otimes (\mathbf{B}'\mathbf{B})] + \tfrac{1}{\sigma_\nu^2}[\mathbf{E}_T \otimes (\mathbf{B}'\mathbf{B})]. \qquad (8)
\end{aligned}
$$

Finally, with $\rho_1 = \rho_2 = 0$, the log likelihood reduces to the one representing the familiar RE model without any spatial autocorrelation:

$$
\begin{aligned}
L_{\mathrm{RE}}(\boldsymbol{\beta}, \sigma_\nu^2, \sigma_\mu^2) &= -\tfrac{NT}{2} \ln 2\pi\sigma_\nu^2 - \tfrac{N}{2} \ln \tfrac{\sigma_1^2}{\sigma_\nu^2} - \tfrac{1}{2}\mathbf{u}'\boldsymbol{\Omega}_{u,\mathrm{RE}}^{-1}\mathbf{u} \qquad (9) \\
\boldsymbol{\Omega}_{u,\mathrm{RE}}^{-1} &= \tfrac{1}{T\sigma_\mu^2+\sigma_\nu^2}(\overline{\mathbf{J}}_T \otimes \mathbf{I}_N) + \tfrac{1}{\sigma_\nu^2}(\mathbf{E}_T \otimes \mathbf{I}_N).
\end{aligned}
$$

The pretest estimator is based on a sequence of LM-tests derived by Baltagi, Egger and Pfaffermayr (2006). Specifically, the following hypotheses were considered:

$$
\begin{aligned}
H_0^A &: \rho_1 = \rho_2 = 0 \text{ vs. } H_1^A: \text{at least one of the } \rho_1 \text{ or } \rho_2 \neq 0 \qquad (10) \\
H_0^B &: \rho_1 = \rho_2 \text{ vs. } H_1^B: \rho_1 \neq \rho_2 \\
H_0^C &: \rho_1 = 0 \text{ vs. } H_1^C: \rho_1 \neq 0
\end{aligned}
$$

First, we test $H_0^A; \rho_1 = \rho_2 = 0$, to see whether there is no spatial correlation in the error term. If H_0^A is not rejected, the pretest estimator reverts to the random effects MLE. In case H_0^A is rejected, we test $H_0^B; \rho_1 = \rho_2$. If H_0^B

is not rejected, the pretest estimator reverts to the KKP MLE. Otherwise, $\rho_1 \neq 0$ or $\rho_2 \neq 0$ and $\rho_1 \neq \rho_2$. Next, we test $H_0^C; \rho_1 = 0$. In case H_0^C is not rejected, the pretest estimator reverts to the Anselin MLE. If H_0^C is rejected, the pretest estimator reverts to the MLE of the general model considered by Baltagi, et al. (2006). In other words,

$$\begin{aligned} \widehat{\boldsymbol{\beta}}_{pretest} &= \widehat{\boldsymbol{\beta}}_{RE,MLE} \text{ if } H_0^A \text{ is not rejected} \\ &= \widehat{\boldsymbol{\beta}}_{KKP,MLE} \text{ if } H_0^A \text{ is rejected, and } H_0^B \text{ is not rejected} \\ &= \widehat{\boldsymbol{\beta}}_{Anselin,MLE} \text{ if } H_0^A \text{ and } H_0^B \text{ are rejected, and } H_0^C \text{ is not rejected} \\ &= \widehat{\boldsymbol{\beta}}_{General,MLE} \text{ if } H_0^A \text{ and } H_0^B \text{ and } H_0^C \text{ are rejected.} \end{aligned} \tag{11}$$

It has to be emphasized that the pretest estimator becomes the MLE of the general model when all three hypotheses are rejected. Also, it is the MLE of the RE model when H_0^A is not rejected. Hence changing the sequence of tests for H_0^B and H_0^C will not affect the number of times the pretest estimator reverts to the MLE of the RE or General model. This affects only the number of times the pretest estimator reverts to the Anselin or KKP ML estimators. In using the same data set to select the estimator to use based on a series of tests makes the statistical properties of the resulting pretest estimator difficult to derive. In our Monte Carlo experiments below, we examine how this affects the corresponding MSE of the pretest estimator.[3]

LM-tests for these hypotheses were derived by Baltagi, et al. (2006) under

[3] Pretest estimators in econometrics are surveyed in Giles and Giles (1993) and Magnus (1999).

the assumption of normality. For H_0^A the LM-test statistic is given by

$$LM_A = \frac{1}{2b_A\widetilde{\sigma}_1^4}G_A^2 + \frac{1}{2b_A(T-1)\widetilde{\sigma}_\nu^4}M_A^2, \tag{12}$$

where $\widetilde{\sigma}_1^2 = T\widetilde{\sigma}_\mu^2 + \widetilde{\sigma}_\nu^2$, $b_A = tr[(\mathbf{W}'_N + \mathbf{W}_N)^2]$, $G_A = \widetilde{\mathbf{u}}'\{\overline{\mathbf{J}}_T \otimes (\mathbf{W}'_N + \mathbf{W}_N)\}\widetilde{\mathbf{u}}$, and $M_A = \widetilde{\mathbf{u}}'\{\mathbf{E}_T \otimes (\mathbf{W}'_N + \mathbf{W}_N)\}\widetilde{\mathbf{u}}$. Here, $\widetilde{\mathbf{u}} = \mathbf{y} - \mathbf{X}\widetilde{\boldsymbol{\beta}}_{mle,re}$ denotes the vector of restricted ML residuals under H_0^A. Baltagi, et al. (2006) show that under H_0^A, the LM_A statistic is asymptotically distributed as χ_2^2.

For H_0^B, the LM-test statistic is given by

$$LM_B = \frac{1}{2b_B\overline{\sigma}_1^4}G_B^2 + \frac{1}{2b_B\overline{\sigma}_\nu^4(T-1)}M_B^2, \tag{13}$$

with $G_B = \overline{\mathbf{u}}'(\overline{\mathbf{J}}_T \otimes \mathbf{F})\overline{\mathbf{u}} - \overline{\sigma}_1^2 tr[\mathbf{D}]$, $M_B = \overline{\mathbf{u}}'(\mathbf{E}_T \otimes \mathbf{F})\overline{\mathbf{u}} - \overline{\sigma}_\nu^2(T-1)tr[\mathbf{D}]$, $\mathbf{D} = (\mathbf{W}'_N\overline{\mathbf{A}} + \overline{\mathbf{A}}'\mathbf{W}_N)(\overline{\mathbf{A}}'\overline{\mathbf{A}})^{-1}$ and $\mathbf{F} = \mathbf{W}'_N\overline{\mathbf{A}} + \overline{\mathbf{A}}'\mathbf{W}_N$. Also, $b_B = tr[\mathbf{D}^2] - (tr[\mathbf{D}])^2/N$, $\overline{\sigma}_1^2 = \frac{\overline{\mathbf{u}}'\{\overline{\mathbf{J}}_T \otimes (\overline{\mathbf{A}}'\overline{\mathbf{A}})\}\overline{\mathbf{u}}}{N}$ and $\overline{\sigma}_\nu^2 = \frac{\overline{\mathbf{u}}'\{\mathbf{E}_T \otimes (\overline{\mathbf{A}}'\overline{\mathbf{A}})\}\overline{\mathbf{u}}}{N(T-1)}$. Here, $\overline{\mathbf{u}} = \mathbf{y} - \mathbf{X}\widetilde{\boldsymbol{\beta}}_{mle,KKP}$ denotes the vector of restricted ML residuals under H_0^B. The LM_B statistic is asymptotically distributed as χ_1^2 under H_0^B.

Finally, to test H_0^C, we let $\mathbf{C}_1 = [T\widehat{\sigma}_\mu^2\mathbf{I}_N + \widehat{\sigma}_\nu^2(\widehat{\mathbf{B}}'\widehat{\mathbf{B}})^{-1}]^{-1}$, and $\mathbf{C}_2 = (\mathbf{W}'_N + \mathbf{W}_N)$. The corresponding LM test for H_0^C, which has no simple closed form representation is given by:

$$LM_C = \widehat{d}_{\rho_1}^2 J_{33}^{-1}, \tag{14}$$

where

$$\widehat{d}_{\rho_1} = \left.\frac{\partial L}{\partial \rho_1}\right|_{H_0^B} = -\tfrac{1}{2}T\widehat{\sigma}_\mu^2 tr[\mathbf{C}_1\mathbf{C}_2] + \tfrac{1}{2}\widehat{\sigma}_\mu^2\widehat{\mathbf{u}}'\{\mathbf{J}_T \otimes \mathbf{C}_1\mathbf{C}_2\mathbf{C}_1\}\widehat{\mathbf{u}},$$

$\widehat{\mathbf{u}} = \mathbf{y} - \mathbf{X}\widehat{\boldsymbol{\beta}}_{mle,Anselin}$ denotes the vector of restricted ML residuals under H_0^C, i.e., the Anselin model, and J_{33}^{-1} is the (3,3) element of the inverse of the information matrix described in Baltagi, et al. (2006).

3 Monte Carlo experiments

For the Monte Carlo analysis, we consider a panel data model that includes only a single explanatory variable and a constant ($K = 2$):

$$y_{it} = \alpha + \beta x_{it} + u_{it}, \quad i = 1, ..., N \text{ and } t = 1, ..., T, \tag{15}$$

where $\alpha = 5$ and $\beta = 0.5$. x_{it} is generated by $x_{it} = \zeta_i + z_{it}$ with $\zeta_i \sim$ *i.i.d.* $U[-7.5, 7.5]$ and $z_{it} \sim$ *i.i.d.* $U[-5, 5]$. The individual specific effects are drawn from a normal distribution so that $\mu_i \sim$ *i.i.d.* $N(0, 20\theta)$. For the remainder error, we assume $\nu_{it} \sim$ *i.i.d.* $N(0, 20(1-\theta))$ with $0 < \theta < 1$. Consequently, we have $\sigma_\mu^2 + \sigma_\nu^2 = 20$ and $\theta = \frac{\sigma_\mu^2}{\sigma_\mu^2 + \sigma_\nu^2}$. θ measures the proportion of the total variance due to the individual specific effects. We construct the spatial weights matrix by randomly allocating the individual units on a grid of $2N$ squares. Hence, the number of squares in the grid grows larger as the number of observations N increases. The probability for an individual to be located on a particular coordinate is equal for all coordinates on the grid. The spatial weight for a pair of units is set to 1 if they happen to be located on neighbouring cells of the grid, otherwise the weights are zero. On average, each observation has three neighbors in this design. The corresponding spatial weights matrix is row-normalized so that the elements in each row sum up to one.[4] ρ_1 and ρ_2 vary over the set $\{-0.8, -0.5, -0.2, 0, 0.2, 0.5, 0.8\}$. We consider panels with $N = 50$, $T = 5$; $N = 100$, $T = 5$ and $N = 50$, $T = 10$ assuming that the proportion of the variance due to the random individual effects, θ, takes the values 0.50. For

[4] As an alternative on could use the maximum eigenvalue or maximum row sum normalization (Kelejian and Prucha, 2005).

$N = 50$ and $T = 5$, we also consider the case of $\theta = 0.75$. In total, there are 196 experiments, each of which is run with 2000 replications.

===== Table 1 =====

Table 1 reports the number of times in 2000 replications that the pretest estimator took on the MLE of RE, KKP, Anselin or the General model, for various values of ρ_1 and ρ_2. This is done for $N = 50$, $T = 5$ and $\theta = 0.5$. The second panel shows what happens if we alter the testing sequence between H_0^B and H_0^C, while the last panel shows what happens if we relax the significance level from 5% to 10%. For example, when the true model is random effects with no spatial autocorrelation, the pretest estimator correctly reverts to the RE estimator in $1,900$ replications out of $2,000$ at the 5% significance level. In 47 replications, it is a KKP estimator and in 9 replications an Anselin estimator, while in 44 cases the general MLE is chosen. If we alter the testing sequence, the pretest estimator is the KKP estimator in 5 replications, and the Anselin estimator in 51 replications out of 2000. If we relax the significance level from 5% to 10%, the pretest estimator picks the RE estimator in 1800 replications out of 2000. It is a KKP estimator in 85 replications and an Anselin estimator in 23 replications. If the true model is the KKP model with $\rho_1 = \rho_2 > 0.2$, in absolute values, the pretest estimator reverts correctly to the KKP estimator in $1,900$ replications out of 2000 at the 5% significance level, and 1800 replications out of 2000 at the 10% significance level. If we alter the testing sequence, this changes to 1313 replications up to 1793 replications out of 2000. If the true model is the Anselin model, the right model is chosen in the majority of the cases only if $\rho_2 > 0.5$, in absolute value. This varies between 958 to 1737 replications out of 2000 at the 5% level and 1169 to 1764 at the 10% level. If we change the sequence of tests for H_0^B and H_0^C, the pretest estimator reverts correctly to the Anselin estimator in $1,900$ replications out of $2,000$ at the 5% significance level. So the choice of the pretest as Anselin MLE or KKP MLE is affected by the order of the tests. Below, we see how this affects the MSE of the corresponding regression coefficients. The pretest estimator chooses the general MLE whenever ρ_1 and ρ_2 are drastically different. For example, when $\rho_1 = -0.8$ and $\rho_2 = 0.8$, the pretest estimator picks the general MLE in 1850 replications out of 2000 at the 5% significance level, and in 1916 replications at the 10% level. Changing the sequence of tests does not affect the number of times the general MLE is chosen by the pretest estimator. If ρ_1 and ρ_2 are smaller than 0.2 in absolute value, the pretest estimator is more likely to pick the RE MLE since H_0^A is less likely to be rejected.

===== Table 2 =====

Table 2 summarizes our findings regarding the relative mean square error for β in (15). Here, relative MSE is always with respect to the MSE of the MLE of the TRUE model. Looking at the results for $N = 50$, $T = 5$ and $\theta = 0.5$, we see that the loss in MSE is less than 1.7% for the misspecified ML estimators when the true model is random effects. However, when the true model is KKP, the loss in MSE for the Anselin MLE is 9% for $\rho_1 = \rho_2 = -0.8$ and 11% for $\rho_1 = \rho_2 = 0.8$. The random effects MLE, which ignores the spatial correlation, performs the worst with big loss in MSE. In contrast, the general model MLE, which encompasses the KKP, does well and so does the pretest estimator. When the true model is Anselin, the loss for the KKP MLE in MSE is 9% for $\rho_1 = 0$ and $\rho_2 = -0.8$ and 7% for $\rho_1 = 0$ and $\rho_2 = 0.8$. The random effects estimator that ignores the spatial correlation again performs the worst with big loss in MSE. In contrast, the general model which encompasses the KKP does well and so does the pretest estimator. When the true model is the general model, the loss for the KKP MLE in MSE reaches 32% for $\rho_1 = 0.8$ and $\rho_2 = -0.5$ and the loss for the Anselin MLE reaches 26% for $\rho_1 = 0.8$ and $\rho_2 = -0.2$. The random effects estimator again performs the worst with big loss in MSE. In contrast, the pretest estimator does well with a maximum loss of MSE of 3%. Our Monte Carlo results suggest that the pretest estimator is a practical second best choice no matter what true model generated the data. In most cases considered, it performs only slightly worse than the MLE of the true model. The maximum loss in MSE is 2.7% for $\rho_1 = -0.5$ and $\rho_2 = 0.2$. Given that the applied researcher has no hope of knowing the true model, the pretest estimator seems to be a reasonable alternative.

The second panel of Table 2 shows how the relative MSE for β gets affected by doubling N to 100, holding T fixed at 5 and $\theta = 0.5$, while the last two panels show what happens when we alter the testing sequence or the significance level. Table 3 repeats this exercise now doubling T to 10, holding N fixed at 50 and $\theta = 0.5$. Also, what happens to this relative MSE for β when we increase θ to 0.75 for $N = 50$, $T = 5$. Doubling N for a fixed $T = 5$ and $\theta = 0.5$, in general, improves the relative MSE performance of the pretest estimator. This is also generally true, if we double T for a fixed $N = 50$ and $\theta = 0.5$. The performance of the pretest estimator seems to be robust to increasing θ from 0.5 to 0.75 for a fixed $N = 50$, and $T = 5$. It is also robust to increasing the significance level from 5% to 10%. However, it is sensitive to altering the testing sequence of H_0^B and H_0^C. The loss in MSE for the pretest estimator is at most 9.2% for $\rho_1 = -0.2$ and $\rho_2 = 0.8$ for $N = 50$, $T = 5$ and $\theta = 0.5$.

===== Table 3 =====

===== Table 4 =====

Table 4 shows the bias in the MLE of ρ_1 and ρ_2, under the various models considered, for $N = 50$, $T = 5$ and $\theta = 0.5$.[5] Obviously, when the wrong restriction is imposed on these ρ's, bias is introduced. For example, if the true model is the General model with $\rho_1 \neq \rho_2$, the bias for the KKP estimators of these ρ's is huge because KKP imposes falsely $\rho_1 = \rho_2$. Surprisingly, the bias for the Anselin estimator of ρ_2 (imposing falsely that $\rho_1 = 0$), is small not exceeding 0.066 in absolute terms for $\rho_1 = 0.8$ and $\rho_2 = 0.5$. If the true model is the KKP model, with $\rho_1 = \rho_2$, the maximum absolute bias in the estimate of ρ_2 for the Anselin estimator is 0.041 for $\rho_1 = \rho_2 = 0.8$. If the true model is the Anselin model, the bias of the KKP estimator of ρ_2 does not exceed 0.066 in absolute value, but the bias for ρ_1 can be as large as 0.76. The bias for the general MLE of ρ_2 never exceeds 0.01 in absolute value, while the bias of the pretest estimator does not exceed 0.06 in absolute value. For ρ_1, the bias for the general MLE does not exceed 0.085 in absolute value. This happens when $\rho_1 = 0.5$ and $\rho_2 = 0.8$. The bias of the pretest estimator,

[5] Bias results for ρ_1 and ρ_2 for other values of N, T and θ, are given in Tables A1, A2, and A3. These are available upon request from the authors.

on the other hand, can reach 0.22 for $\rho_1 = -0.5$ and $\rho_2 = 0.8$. The worst bias performance is for the KKP estimator of ρ_1 which can reach 1.55 for $\rho_1 = -0.8$ and $\rho_2 = 0.8$. How does this translate into MSE performance for MLE of ρ_1 and ρ_2? Obviously, KKP will have bad relative MSE performance when imposing the wrong restriction on the ρ's, due mainly to the large bias introduced. This can be up to 3 times as much as the MSE of the Anselin estimator of ρ_2 when the true model is $\rho_1 = 0$ and $\rho_2 = -0.8$, see Table 5. Similarly, the Anselin estimator of ρ_2 can have MSE as big as 3 times that of KKP for $\rho_1 = \rho_2 = 0.8$. When the true model is the General model with $\rho_1 \neq \rho_2$, the KKP estimators of ρ_1 and ρ_2 have large relative MSE, while the Anselin estimator of ρ_2 has a reasonable loss in MSE not exceeding 14% except in four cases. These correspond to ($\rho_1 = -0.8$ and $\rho_2 = -0.5, -0.2$) and ($\rho_1 = 0.8$ and $\rho_2 = 0.2, 0.5$). For these cases, the loss in MSE can be 3 to 4 times that of the true MLE. The MSE performance of the pretest estimator for ρ_1 and ρ_2 can be poor, but no worse than KKP or Anselin, if they are misspecified. This is true as long as ρ_1 and ρ_2 are larger than 0.2 in absolute value.[6] Fortunately, the big loss in relative MSE in the MLE of ρ_1 and ρ_2 do not translate fully into bad relative MSE performance for the corresponding MLE of β.

[6] Relative MSE results for ρ_1 and ρ_2 for other values of N, T and θ are given in Tables 6, 7 and 8.

4 Conclusions

Baltagi, et al. (2006) suggested a generalized spatial panel data model which encompasses the models described in Anselin (1988) and Kapoor, Kelejian, and Prucha (2006). LM and LR statistics are derived that test these models as restrictions on the generalized spatial panel model. Given that the researcher does not know the true model, this paper suggests a pretest estimator that performed well in Monte Carlo experiments no matter what the true underlying model. In fact this pretest estimator was a close second in MSE performance to the true MLE. Additionally, the Monte Carlo experiments shed some light on the performance of the Anselin MLE when the true model is KKP, and vice versa. Ignoring spatial correlation in panel data and performing RE MLE leads to considerable loss in MSE efficiency. When the true model is a general spatial panel model with $\rho_1 \neq \rho_2 \neq 0$, both KKP and Anselin MLE impose wrong restrictions on the ρ parameters, which in turn, introduce bias and lead to bad MSE performance of the resulting MLEs. Fortunately, this does not translate fully into bad MSE performance for the regression coefficients. The pretest estimator of the regression coefficients always performs better than the misspecified MLE and is recommended in practice.

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Table 1: Choice of Pretest Estimator under alternative testing sequences and significance levels, N=50, T=5, θ=0.5

			Testing Sequence H_0^A, H_0^C, H_0^B (5% sig.level)					Testing Sequence H_0^A, H_0^B, H_0^C (5% sig.level)				Testing Sequence H_0^A, H_0^C, H_0^B (10% sig.level)			
True model	ρ_1	ρ_2	RE	KKP	Anselin	General	All	RE	KKP	Anselin	General	RE	KKP	Anselin	General
RE	0.0	0.0	1900	47	9	44	2000	1900	5	51	44	1800	85	23	92
KKP	-0.8	-0.8	0	1899	18	83	2000	0	1793	124	83	0	1,800	19	181
	-0.5	-0.5	0	1900	29	71	2000	0	1313	616	71	0	1,800	67	133
	-0.2	-0.2	674	1233	29	64	2000	674	249	1013	64	481	1,325	74	120
	0.2	0.2	629	1271	48	52	2000	629	276	1043	52	470	1,337	87	106
	0.5	0.5	0	1900	53	47	2000	0	1319	634	47	0	1,800	114	86
	0.8	0.8	0	1900	36	64	2000	0	1629	307	64	0	1,800	50	150
Anselin	0.0	-0.8	0	356	1610	34	2000	0	66	1900	34	0	174	1,722	104
	0.0	-0.5	0	999	958	43	2000	0	57	1900	43	0	744	1,169	87
	0.0	-0.2	837	967	152	44	2000	837	51	1068	44	618	1,035	263	84
	0.0	0.2	709	1045	178	68	2000	709	25	1198	68	529	993	349	129
	0.0	0.5	0	811	1124	65	2000	0	35	1900	65	0	507	1,364	129
	0.0	0.8	0	205	1737	58	2000	0	42	1900	58	0	74	1,764	162
General	-0.8	-0.5	0	820	8	1172	2000	0	797	31	1172	0	641	6	1353
	-0.8	-0.2	7	157	1	1835	2000	7	141	17	1835	5	95	0	1900
	-0.8	0.0	42	16	0	1942	2000	42	14	2	1942	23	8	0	1969
	-0.8	0.2	7	0	19	1974	2000	7	0	19	1974	3	0	7	1990
	-0.8	0.5	0	0	57	1943	2000	0	0	57	1943	0	0	26	1974
	-0.8	0.8	0	0	150	1850	2000	0	0	150	1850	0	0	84	1916
	-0.5	-0.8	0	1656	333	11	2000	0	1113	876	11	0	1368	434	198
	-0.5	-0.2	175	1193	1	631	2000	175	806	388	631	90	1025	1	884
	-0.5	0.0	773	125	14	1088	2000	773	91	48	1088	560	107	6	1327
	-0.5	0.2	225	103	323	1349	2000	225	0	426	1349	151	50	277	1522
	-0.5	0.5	0	30	745	1225	2000	0	0	775	1225	0	12	535	1453
	-0.5	0.8	0	3	1139	858	2000	0	1	1141	858	0	1	911	1088
	-0.2	-0.8	0	714	1269	17	2000	0	270	1713	17	0	464	1379	157
	-0.2	-0.5	0	1583	413	4	2000	0	346	1650	4	0	1333	652	15
	-0.2	0.0	1741	98	17	144	2000	1741	41	74	144	1570	128	20	282
	-0.2	0.2	609	570	484	337	2000	609	4	1050	337	415	489	571	525
	-0.2	0.5	0	274	1472	254	2000	0	7	1739	254	0	144	1420	436
	-0.2	0.8	0	48	1766	186	2000	0	4	1810	186	0	14	1662	324
	0.2	-0.8	0	76	1697	227	2000	0	6	1767	227	0	24	1604	372
	0.2	-0.5	0	365	1352	283	2000	0	10	1707	283	0	209	1357	434
	0.2	-0.2	790	485	401	324	2000	790	4	882	324	582	462	525	431
	0.2	0.0	1741	97	18	144	2000	1741	48	67	144	1584	119	29	268
	0.2	0.5	0	1435	548	17	2000	0	250	1733	17	0	1063	905	32
	0.2	0.8	0	404	1545	51	2000	0	135	1814	51	0	139	1627	234
	0.5	-0.8	0	3	663	1334	2000	0	0	666	1334	0	1	464	1535
	0.5	-0.5	0	22	456	1522	2000	0	0	478	1522	0	11	311	1678
	0.5	-0.2	198	59	216	1527	2000	198	0	275	1527	125	35	190	1650
	0.5	0.0	600	110	9	1281	2000	600	97	22	1281	427	89	6	1478
	0.5	0.2	132	1131	0	737	2000	132	789	342	737	79	937	3	981
	0.5	0.8	0	1133	733	134	2000	0	659	1207	134	0	690	838	472
	0.8	-0.8	0	0	13	1987	2000	0	0	13	1987	0	0	2	1998
	0.8	-0.5	0	0	0	2000	2000	0	0	0	2000	0	0	0	2000
	0.8	-0.2	0	0	0	2000	2000	0	0	0	2000	0	0	0	2000
	0.8	0.0	3	4	0	1993	2000	3	4	0	1993	2	2	0	1996
	0.8	0.2	0	25	0	1975	2000	0	25	0	1975	0	18	0	1982
	0.8	0.5	0	439	13	1548	2000	0	432	20	1548	0	334	7	1659

Table 2: Relative mean square error of alternative spatial panel data estimators of β, T=5, θ=0.5

			N=50					N=100					Pretest estimator under alternative test sequence		Pretest estimator under α =0.10	
True model	ρ_1	ρ_2	RE	KKP	Anselin	General	Pretest	RE	KKP	Anselin	General	Pretest	N=50	N=100	N=50	N=100
RE	0.0	0.0	1.000	1.005	1.010	1.017	1.003	1.000	1.003	1.001	1.005	1.002	1.002	1.003	1.003	1.000
KKP	-0.8	-0.8	2.469	1.000	1.093	1.008	1.004	2.103	1.000	1.121	0.998	1.000	1.082	1.115	1.006	0.998
	-0.5	-0.5	1.351	1.000	1.035	1.007	1.004	1.382	1.000	1.057	1.004	1.003	1.025	1.049	1.003	1.002
	-0.2	-0.2	1.040	1.000	1.007	1.003	1.011	1.042	1.000	1.005	1.007	1.005	1.014	1.002	1.008	1.004
	0.2	0.2	1.064	1.000	1.007	1.001	1.015	1.047	1.000	1.004	1.003	1.002	1.015	1.003	1.011	1.002
	0.5	0.5	1.490	1.000	1.046	1.004	1.002	1.550	1.000	1.065	1.005	1.002	1.033	1.058	1.006	1.006
	0.8	0.8	4.872	1.000	1.109	0.996	1.000	4.694	1.000	1.099	1.002	1.002	1.100	1.090	0.997	1.001
Anselin	0.0	-0.8	1.947	1.093	1.000	1.006	1.017	1.702	1.163	1.000	1.004	1.007	1.083	1.153	1.006	1.003
	0.0	-0.5	1.252	1.059	1.000	1.002	1.023	1.177	1.065	1.000	1.007	1.016	1.056	1.065	1.020	1.013
	0.0	-0.2	1.033	1.011	1.000	1.001	1.025	1.020	1.016	1.000	1.011	1.016	1.027	1.018	1.015	1.017
	0.0	0.2	1.059	1.010	1.000	1.013	1.024	1.039	1.002	1.000	1.012	1.011	1.029	1.009	1.022	1.005
	0.0	0.5	1.352	1.029	1.000	1.007	1.013	1.313	1.042	1.000	1.003	1.011	1.030	1.040	1.007	1.003
	0.0	0.8	2.897	1.068	1.000	1.007	1.007	2.703	1.053	1.000	1.003	1.002	1.067	1.056	1.005	1.003
General	-0.8	-0.5	1.502	1.014	1.127	1.000	1.007	1.477	1.021	1.164	1.000	1.005	1.052	1.046	1.006	1.002
	-0.8	-0.2	1.194	1.065	1.140	1.000	1.006	1.227	1.103	1.201	1.000	1.000	1.015	1.001	1.002	1.000
	-0.8	0.0	1.148	1.145	1.151	1.000	1.003	1.157	1.132	1.162	1.000	1.000	1.003	1.000	1.003	1.000
	-0.8	0.2	1.201	1.202	1.163	1.000	1.003	1.179	1.180	1.139	1.000	1.000	1.004	1.000	1.001	1.000
	-0.8	0.5	1.598	1.235	1.113	1.000	1.002	1.465	1.187	1.089	1.000	1.000	1.006	1.000	1.001	1.000
	-0.8	0.8	3.489	1.196	1.074	1.000	1.002	3.239	1.168	1.055	1.000	1.000	1.010	1.001	1.000	1.000
	-0.5	-0.8	2.148	1.009	1.025	1.000	1.010	1.848	1.015	1.035	1.000	1.016	1.013	1.020	1.012	1.008
	-0.5	-0.2	1.054	1.011	1.037	1.000	1.013	1.103	1.013	1.061	1.000	1.011	1.021	1.032	1.006	1.007
	-0.5	0.0	1.016	1.015	1.026	1.000	1.025	1.030	1.033	1.038	1.000	1.007	1.025	1.007	1.016	1.003
	-0.5	0.2	1.078	1.080	1.049	1.000	1.027	1.083	1.070	1.040	1.000	0.999	1.031	1.003	1.021	1.000
	-0.5	0.5	1.416	1.103	1.014	1.000	1.007	1.423	1.144	1.038	1.000	1.006	1.037	1.029	1.009	1.003
	-0.5	0.8	2.784	1.151	1.030	1.000	1.014	2.902	1.143	1.023	1.000	1.009	1.088	1.055	1.009	1.004
	-0.2	-0.8	1.954	1.052	1.000	1.000	1.018	1.680	1.092	1.000	1.000	1.006	1.047	1.078	1.009	1.000
	-0.2	-0.5	1.270	1.006	1.000	1.000	1.005	1.229	1.021	1.006	1.000	1.008	1.008	1.019	1.009	1.012
	-0.2	0.0	0.995	1.004	1.007	1.000	0.998	1.009	1.010	1.015	1.000	1.014	0.998	1.015	0.998	1.011
	-0.2	0.2	1.024	1.009	0.991	1.000	1.011	1.047	1.035	1.011	1.000	1.018	1.017	1.029	1.011	1.007
	-0.2	0.5	1.300	1.047	0.998	1.000	1.000	1.350	1.078	1.007	1.000	1.008	1.032	1.063	1.000	1.006
	-0.2	0.8	2.837	1.097	0.996	1.000	0.999	2.642	1.075	0.997	1.000	0.996	1.092	1.056	0.999	0.996
	0.2	-0.8	1.880	1.120	0.996	1.000	1.003	1.622	1.219	1.012	1.000	1.005	1.101	1.156	1.001	1.004
	0.2	-0.5	1.267	1.062	0.996	1.000	1.010	1.202	1.116	1.009	1.000	1.008	1.057	1.084	1.007	1.007
	0.2	-0.2	1.030	1.029	1.005	1.000	1.031	1.015	1.026	1.010	1.000	1.005	1.032	1.013	1.026	1.008
	0.2	0.0	1.002	1.004	1.006	1.000	0.999	1.004	1.003	1.008	1.000	1.009	0.999	1.009	0.998	1.003
	0.2	0.5	1.390	1.000	0.997	1.000	1.000	1.343	1.016	0.993	1.000	1.003	1.002	1.005	1.006	1.004
	0.2	0.8	2.819	1.025	1.008	1.000	1.009	2.804	1.043	0.999	1.000	1.001	1.027	1.038	1.004	1.003
	0.5	-0.8	2.244	1.222	1.040	1.000	1.015	1.897	1.431	1.092	1.000	1.004	1.086	1.031	1.008	1.002
	0.5	-0.5	1.322	1.174	1.060	1.000	1.008	1.313	1.242	1.075	1.000	1.002	1.027	1.009	1.005	1.003
	0.5	-0.2	1.067	1.069	1.040	1.000	1.008	1.127	1.138	1.098	1.000	1.002	1.009	1.002	1.007	1.000
	0.5	0.0	1.055	1.043	1.059	1.000	1.009	1.057	1.041	1.061	1.000	1.002	1.010	1.003	1.008	1.000
	0.5	0.2	1.116	1.023	1.066	1.000	1.009	1.153	1.027	1.092	1.000	1.005	1.026	1.023	1.005	1.003
	0.5	0.8	2.981	1.014	1.023	1.000	1.019	3.152	1.017	1.028	1.000	1.001	1.017	1.024	1.013	1.005
	0.8	-0.8	2.435	1.239	1.119	1.000	1.000	2.334	1.410	1.177	1.000	1.000	1.001	1.000	1.000	1.000
	0.8	-0.5	1.521	1.318	1.192	1.000	1.000	1.531	1.410	1.215	1.000	1.000	1.000	1.000	1.000	1.000
	0.8	-0.2	1.300	1.314	1.260	1.000	1.000	1.339	1.360	1.294	1.000	1.000	1.000	1.000	1.000	1.000
	0.8	0.0	1.239	1.224	1.243	1.000	1.000	1.313	1.232	1.314	1.000	1.000	0.999	1.000	1.000	1.000
	0.8	0.2	1.325	1.113	1.238	1.000	1.000	1.406	1.126	1.312	1.000	1.000	1.000	1.000	1.000	1.000
	0.8	0.5	1.833	1.028	1.190	1.000	1.002	1.848	1.032	1.223	1.000	1.002	1.026	1.017	1.001	1.000

Table 3: Relative mean square error of alternative spatial panel data estimators of β

			N=50, T=10, θ=0.50					N=50, T=5, θ=0.75					Pretest estimator under alternative test sequence		Pretest estimator under α =0.10	
True model	ρ_1	ρ_2	RE	KKP	Anselin	General	Pretest	RE	KKP	Anselin	General	Pretest	N=50, T=10, θ=0.5	N=50, T=5, θ=0.75	N=50, T=10, θ=0.5	N=50, T=5, θ=0.75
RE	0.0	0.0	1.000	1.003	1.003	1.012	1.001	1.000	1.011	1.012	1.016	1.003	1.001	1.002	1.004	1.004
KKP	-0.8	-0.8	2.770	1.000	1.084	1.001	1.001	2.708	1.000	1.054	1.007	1.003	1.074	1.054	1.001	1.004
	-0.5	-0.5	1.419	1.000	1.030	1.009	1.002	1.337	1.000	1.013	1.005	1.005	1.022	1.020	1.003	1.004
	-0.2	-0.2	1.049	1.000	1.014	1.012	1.004	1.045	1.000	1.005	1.007	1.014	1.005	1.016	1.003	1.013
	0.2	0.2	1.075	1.000	1.016	1.010	1.001	1.061	1.000	1.007	1.003	1.015	1.003	1.018	1.000	1.011
	0.5	0.5	1.548	1.000	1.054	1.007	1.002	1.560	1.000	1.039	1.001	1.000	1.039	1.031	1.005	1.001
	0.8	0.8	4.153	1.000	1.088	1.002	1.003	5.055	1.000	1.044	0.999	1.000	1.080	1.041	1.004	0.999
Anselin	0.0	-0.8	2.279	1.089	1.000	1.003	1.005	2.295	1.059	1.000	1.002	1.006	1.088	1.056	1.003	1.003
	0.0	-0.5	1.328	1.034	1.000	1.007	1.015	1.317	1.041	1.000	1.004	1.014	1.029	1.039	1.011	1.011
	0.0	-0.2	1.032	1.009	1.000	1.003	1.007	1.027	0.999	1.000	1.006	1.018	1.008	1.015	1.007	1.013
	0.0	0.2	1.062	1.001	1.000	1.004	1.006	1.065	1.009	1.000	1.008	1.030	1.007	1.030	1.007	1.021
	0.0	0.5	1.401	1.026	1.000	1.005	1.009	1.487	1.034	1.000	1.005	1.013	1.028	1.030	1.004	1.010
	0.0	0.8	3.274	1.053	1.000	1.005	1.001	3.721	1.050	1.000	1.005	1.003	1.047	1.051	1.002	1.001
General	-0.8	-0.5	1.471	1.015	1.099	1.000	1.004	1.439	1.012	1.067	1.000	1.003	1.032	1.020	1.003	1.003
	-0.8	-0.2	1.171	1.073	1.120	1.000	1.000	1.097	1.031	1.048	1.000	1.001	1.001	1.001	1.000	1.001
	-0.8	0.0	1.137	1.134	1.142	1.000	1.001	1.042	1.086	1.060	1.000	1.002	1.001	1.002	1.001	1.001
	-0.8	0.2	1.137	1.105	1.076	1.000	1.000	1.133	1.136	1.070	1.000	1.000	1.000	1.000	1.000	1.000
	-0.8	0.5	1.653	1.155	1.080	1.000	1.001	1.679	1.148	1.059	1.000	1.001	1.002	1.001	1.000	1.000
	-0.8	0.8	3.998	1.116	1.049	1.000	1.001	4.390	1.058	1.015	1.000	1.000	1.004	1.001	1.000	1.000
	-0.5	-0.8	2.402	1.021	1.013	1.000	1.021	2.390	1.012	1.008	1.000	1.014	1.006	1.003	1.019	1.011
	-0.5	-0.2	1.078	1.007	1.034	1.000	1.009	1.043	1.013	1.030	1.000	1.016	1.021	1.021	1.010	1.009
	-0.5	0.0	1.027	1.024	1.024	1.000	1.015	1.001	1.011	1.006	1.000	1.005	1.015	1.005	1.010	1.001
	-0.5	0.2	1.087	1.069	1.042	1.000	1.015	1.058	1.046	1.024	1.000	1.009	1.023	1.010	1.010	1.006
	-0.5	0.5	1.489	1.096	1.025	1.000	1.010	1.558	1.083	1.020	1.000	1.003	1.035	1.021	1.005	1.003
	-0.5	0.8	3.353	1.145	1.036	1.000	1.015	4.030	1.054	1.002	1.000	0.999	1.065	1.016	1.009	1.001
	-0.2	-0.8	2.279	1.036	1.008	1.000	1.010	2.357	1.039	1.002	1.000	1.004	1.035	1.034	1.009	1.005
	-0.2	-0.5	1.331	1.015	1.001	1.000	1.010	1.299	1.004	0.999	1.000	1.007	1.019	1.004	1.005	1.002
	-0.2	0.0	1.000	1.007	1.007	1.000	1.000	0.992	0.998	1.001	1.000	0.997	1.000	0.997	1.001	0.999
	-0.2	0.2	1.035	1.002	0.994	1.000	1.004	1.042	1.013	1.003	1.000	1.008	1.006	1.011	1.001	1.009
	-0.2	0.5	1.421	1.057	0.999	1.000	1.008	1.555	1.041	0.997	1.000	1.003	1.054	1.031	1.001	0.997
	-0.2	0.8	3.236	1.070	0.997	1.000	0.998	3.855	1.048	0.994	1.000	0.998	1.064	1.050	1.000	0.997
	0.2	-0.8	2.224	1.087	1.000	1.000	1.002	2.197	1.091	1.006	1.000	1.004	1.080	1.076	1.001	1.004
	0.2	-0.5	1.343	1.054	0.996	1.000	1.009	1.352	1.054	1.007	1.000	1.007	1.050	1.046	1.005	1.007
	0.2	-0.2	1.037	1.015	1.002	1.000	1.009	1.035	1.017	1.005	1.000	1.019	1.015	1.018	1.006	1.015
	0.2	0.0	1.001	1.002	1.002	1.000	0.995	0.990	0.998	1.002	1.000	0.995	0.995	0.994	0.996	0.997
	0.2	0.5	1.454	1.013	1.004	1.000	1.005	1.578	1.013	1.001	1.000	1.005	1.012	1.015	1.005	1.004
	0.2	0.8	3.301	1.041	1.002	1.000	1.004	3.862	1.037	0.996	1.000	1.003	1.040	1.031	1.000	1.004
	0.5	-0.8	2.358	1.160	1.034	1.000	1.007	2.407	1.123	1.028	1.000	1.003	1.046	1.025	1.002	1.000
	0.5	-0.5	1.382	1.109	1.038	1.000	1.003	1.399	1.120	1.043	1.000	1.002	1.013	1.013	1.000	1.002
	0.5	-0.2	1.086	1.077	1.046	1.000	1.005	1.075	1.066	1.031	1.000	1.007	1.010	1.009	1.004	1.004
	0.5	0.0	1.027	1.031	1.035	1.000	1.004	1.029	1.035	1.039	1.000	1.003	1.004	1.003	1.002	1.000
	0.5	0.2	1.102	1.011	1.038	1.000	1.002	1.101	1.000	1.025	1.000	0.998	1.009	1.008	1.000	1.002
	0.5	0.8	3.610	1.012	1.024	1.000	1.015	4.254	1.025	1.013	1.000	1.006	1.012	1.025	1.009	1.001
	0.8	-0.8	2.762	1.173	1.103	1.000	1.000	2.684	1.157	1.089	1.000	1.000	1.000	1.000	1.000	1.000
	0.8	-0.5	1.589	1.199	1.126	1.000	1.000	1.422	1.171	1.085	1.000	1.000	1.000	1.000	1.000	1.000
	0.8	-0.2	1.229	1.203	1.168	1.000	1.000	1.121	1.169	1.101	1.000	1.000	1.000	1.000	1.000	1.000
	0.8	0.0	1.133	1.128	1.132	1.000	1.000	1.090	1.133	1.103	1.000	1.000	1.000	1.000	1.000	1.000
	0.8	0.2	1.204	1.098	1.147	1.000	1.000	1.179	1.085	1.121	1.000	1.000	1.001	1.001	1.000	1.000
	0.8	0.5	1.730	1.021	1.135	1.000	1.004	1.704	1.020	1.098	1.000	1.000	1.027	1.015	1.001	1.002

Table 4: Bias of alternative spatial panel data estimators of ρ_1 and ρ_2 (N=50, T=5, θ=0.5)

			ρ_1			ρ_2			
True model	ρ_1	ρ_2	KKP	General	Pretest	KKP	Anselin	General	Pretest
RE	0.0	0.0	-0.010	-0.045	-0.004	-0.010	-0.007	-0.006	0.000
KKP	-0.8	-0.8	0.004	0.031	0.006	0.004	-0.038	0.007	0.006
	-0.5	-0.5	-0.004	-0.008	-0.007	-0.004	-0.023	0.001	-0.002
	-0.2	-0.2	-0.004	-0.027	0.029	-0.004	-0.007	0.000	0.040
	0.2	0.2	-0.013	-0.053	-0.049	-0.013	-0.003	-0.010	-0.047
	0.5	0.5	-0.010	-0.064	-0.018	-0.010	0.020	-0.006	-0.010
	0.8	0.8	-0.006	-0.054	-0.021	-0.006	0.041	-0.004	-0.006
Anselin	0.0	-0.8	-0.738	-0.054	-0.124	0.062	0.005	0.007	0.014
	0.0	-0.5	-0.434	-0.037	-0.208	0.066	0.001	0.003	0.025
	0.0	-0.2	-0.176	-0.045	-0.106	0.024	-0.004	-0.002	0.064
	0.0	0.2	0.161	-0.052	0.092	-0.039	-0.006	-0.006	-0.064
	0.0	0.5	0.440	-0.058	0.159	-0.060	-0.008	-0.008	-0.025
	0.0	0.8	0.762	-0.009	0.067	-0.038	-0.007	-0.008	-0.010
General	-0.8	-0.5	0.229	0.018	0.075	-0.071	-0.061	0.002	-0.013
	-0.8	-0.2	0.462	0.027	0.047	-0.138	-0.024	-0.004	-0.008
	-0.8	0.0	0.637	0.029	0.040	-0.163	-0.018	-0.007	-0.008
	-0.8	0.2	0.836	0.029	0.034	-0.164	-0.015	-0.009	-0.009
	-0.8	0.5	1.177	0.042	0.053	-0.123	-0.014	-0.009	-0.010
	-0.8	0.8	1.548	0.051	0.083	-0.052	-0.010	-0.007	-0.007
	-0.5	-0.8	-0.267	-0.003	-0.138	0.033	-0.009	0.008	0.025
	-0.5	-0.2	0.242	-0.003	0.127	-0.058	-0.018	-0.003	-0.015
	-0.5	0.0	0.414	-0.005	0.148	-0.086	-0.015	-0.004	-0.007
	-0.5	0.2	0.599	0.002	0.110	-0.101	-0.015	-0.006	-0.021
	-0.5	0.5	0.907	0.009	0.131	-0.093	-0.014	-0.008	-0.011
	-0.5	0.8	1.255	0.040	0.222	-0.045	-0.009	-0.007	-0.008
	-0.2	-0.8	-0.551	-0.037	-0.070	0.049	0.000	0.006	0.016
	-0.2	-0.5	-0.262	-0.035	-0.168	0.038	-0.008	0.002	0.022
	-0.2	0.0	0.159	-0.028	0.152	-0.041	-0.013	-0.008	-0.005
	-0.2	0.2	0.334	-0.032	0.167	-0.066	-0.014	-0.009	-0.056
	-0.2	0.5	0.627	-0.019	0.187	-0.073	-0.013	-0.010	-0.018
	-0.2	0.8	0.960	0.004	0.164	-0.040	-0.008	-0.007	-0.009
	0.2	-0.8	-0.928	-0.062	-0.176	0.072	0.007	0.005	0.008
	0.2	-0.5	-0.604	-0.055	-0.214	0.096	0.009	0.005	0.017
	0.2	-0.2	-0.339	-0.046	-0.182	0.061	0.003	-0.001	0.061
	0.2	0.0	-0.172	-0.052	-0.161	0.028	0.005	0.000	0.004
	0.2	0.5	0.256	-0.063	0.121	-0.044	-0.001	-0.008	-0.029
	0.2	0.8	0.565	-0.057	-0.041	-0.035	-0.005	-0.008	-0.012
	0.5	-0.8	-1.205	-0.067	-0.150	0.095	0.011	0.006	0.008
	0.5	-0.5	-0.857	-0.056	-0.115	0.143	0.009	0.000	0.002
	0.5	-0.2	-0.573	-0.055	-0.116	0.127	0.011	0.000	0.013
	0.5	0.0	-0.411	-0.059	-0.151	0.089	0.009	-0.005	-0.001
	0.5	0.2	-0.251	-0.058	-0.142	0.049	0.015	-0.004	0.006
	0.5	0.8	0.273	-0.085	-0.032	-0.027	0.003	-0.006	-0.016
	0.8	-0.8	-1.482	-0.042	-0.045	0.118	0.010	0.004	0.004
	0.8	-0.5	-1.076	-0.040	-0.040	0.224	0.009	0.003	0.003
	0.8	-0.2	-0.755	-0.037	-0.037	0.245	0.006	-0.003	-0.003
	0.8	0.0	-0.580	-0.039	-0.040	0.220	0.011	-0.002	-0.002
	0.8	0.2	-0.427	-0.037	-0.039	0.173	0.018	-0.002	-0.001
	0.8	0.5	-0.228	-0.038	-0.065	0.072	0.066	-0.006	0.003

Table 5: Mean square error of alternative spatial panel data estimators (N=50, T=5, θ=0.50)

			β					ρ_1			ρ_2			
True model	ρ_1	ρ_2	RE	KKP	Anselin	General	Pretest	KKP	General	Pretest	KKP	Anselin	General	Pretest
RE	0.00	0.00	1.00	1.01	1.01	1.02	1.00	-	-	-	-	-	-	-
KKP	-0.80	-0.80	2.47	1.00	1.09	1.01	1.00	1.00	9.05	4.32	1.00	1.98	1.27	1.14
	-0.50	-0.50	1.35	1.00	1.04	1.01	1.00	1.00	6.99	2.52	1.00	1.47	1.23	1.07
	-0.20	-0.20	1.04	1.00	1.01	1.00	1.01	1.00	6.61	3.97	1.00	1.25	1.24	3.03
	0.20	0.20	1.06	1.00	1.01	1.00	1.02	1.00	7.68	3.97	1.00	1.15	1.15	2.87
	0.50	0.50	1.49	1.00	1.05	1.00	1.00	1.00	10.28	3.46	1.00	1.42	1.16	1.06
	0.80	0.80	4.87	1.00	1.11	1.00	1.00	1.00	21.86	16.30	1.00	3.10	1.13	1.10
Anselin	0.00	-0.80	1.95	1.09	1.00	1.01	1.02	-	-	-	3.20	1.00	1.06	1.36
	0.00	-0.50	1.25	1.06	1.00	1.00	1.02	-	-	-	1.82	1.00	1.00	1.35
	0.00	-0.20	1.03	1.01	1.00	1.00	1.03	-	-	-	0.95	1.00	0.99	2.83
	0.00	0.20	1.06	1.01	1.00	1.01	1.02	-	-	-	1.14	1.00	0.99	2.77
	0.00	0.50	1.35	1.03	1.00	1.01	1.01	-	-	-	2.03	1.00	1.01	1.41
	0.00	0.80	2.90	1.07	1.00	1.01	1.01	-	-	-	2.88	1.00	1.07	1.32
General	-0.80	-0.50	1.50	1.01	1.13	1.00	1.01	4.76	1.00	2.60	1.70	2.88	1.00	1.25
	-0.80	-0.20	1.19	1.07	1.14	1.00	1.01	16.58	1.00	2.16	3.86	1.42	1.00	1.12
	-0.80	0.00	1.15	1.15	1.15	1.00	1.00	30.51	1.00	1.91	5.39	1.11	1.00	1.02
	-0.80	0.20	1.20	1.20	1.16	1.00	1.00	49.26	1.00	1.41	6.30	1.07	1.00	1.01
	-0.80	0.50	1.60	1.24	1.11	1.00	1.00	76.10	1.00	1.71	5.87	1.07	1.00	1.00
	-0.80	0.80	3.49	1.20	1.07	1.00	1.00	105.68	1.00	2.59	4.75	1.14	1.00	1.01
	-0.50	-0.80	2.15	1.01	1.03	1.00	1.01	1.90	1.00	2.66	1.46	0.88	1.00	1.33
	-0.50	-0.20	1.05	1.01	1.04	1.00	1.01	2.30	1.00	2.36	1.33	1.09	1.00	1.69
	-0.50	0.00	1.02	1.02	1.03	1.00	1.03	6.00	1.00	4.00	2.04	1.06	1.00	0.93
	-0.50	0.20	1.08	1.08	1.05	1.00	1.03	12.03	1.00	3.48	2.81	1.06	1.00	1.51
	-0.50	0.50	1.42	1.10	1.01	1.00	1.01	21.73	1.00	3.15	3.78	1.05	1.00	1.06
	-0.50	0.80	2.78	1.15	1.03	1.00	1.01	30.90	1.00	3.11	3.60	1.06	1.00	1.04
	-0.20	-0.80	1.95	1.05	1.00	1.00	1.02	5.64	1.00	2.50	2.32	0.91	1.00	1.40
	-0.20	-0.50	1.27	1.01	1.00	1.00	1.01	1.69	1.00	1.57	1.18	1.02	1.00	1.12
	-0.20	0.00	1.00	1.00	1.01	1.00	1.00	0.82	1.00	1.22	1.09	1.03	1.00	0.39
	-0.20	0.20	1.02	1.01	0.99	1.00	1.01	2.76	1.00	2.00	1.68	1.02	1.00	2.55
	-0.20	0.50	1.30	1.05	1.00	1.00	1.00	8.41	1.00	2.10	2.59	1.03	1.00	1.22
	-0.20	0.80	2.84	1.10	1.00	1.00	1.00	13.31	1.00	1.05	3.16	1.01	1.00	1.10
	0.20	-0.80	1.88	1.12	1.00	1.00	1.00	17.71	1.00	1.54	4.04	1.01	1.00	1.11
	0.20	-0.50	1.27	1.06	1.00	1.00	1.01	8.79	1.00	2.50	2.76	1.01	1.00	1.21
	0.20	-0.20	1.03	1.03	1.01	1.00	1.03	3.07	1.00	1.89	1.40	1.00	1.00	2.76
	0.20	0.00	1.00	1.00	1.01	1.00	1.00	0.92	1.00	1.08	0.94	1.01	1.00	0.34
	0.20	0.50	1.39	1.00	1.00	1.00	1.00	1.36	1.00	1.28	1.46	0.96	1.00	1.33
	0.20	0.80	2.82	1.03	1.01	1.00	1.01	4.34	1.00	1.33	2.34	0.89	1.00	1.32
	0.50	-0.80	2.24	1.22	1.04	1.00	1.02	43.00	1.00	2.72	6.15	1.10	1.00	1.04
	0.50	-0.50	1.32	1.17	1.06	1.00	1.01	26.84	1.00	2.63	5.24	1.03	1.00	1.04
	0.50	-0.20	1.07	1.07	1.04	1.00	1.01	12.33	1.00	2.70	3.31	1.04	1.00	1.39
	0.50	0.00	1.06	1.04	1.06	1.00	1.01	6.35	1.00	3.18	2.05	1.05	1.00	0.91
	0.50	0.20	1.12	1.02	1.07	1.00	1.01	2.44	1.00	2.01	1.25	1.10	1.00	1.52
	0.50	0.80	2.98	1.01	1.02	1.00	1.02	1.28	1.00	2.27	1.77	0.84	1.00	1.43
	0.80	-0.80	2.44	1.24	1.12	1.00	1.00	206.95	1.00	1.28	9.65	1.14	1.00	1.00
	0.80	-0.50	1.52	1.32	1.19	1.00	1.00	131.27	1.00	1.00	11.54	1.06	1.00	1.00
	0.80	-0.20	1.30	1.31	1.26	1.00	1.00	72.40	1.00	1.00	10.03	1.05	1.00	1.00
	0.80	0.00	1.24	1.22	1.24	1.00	1.00	41.54	1.00	1.12	8.09	1.11	1.00	1.01
	0.80	0.20	1.33	1.11	1.24	1.00	1.00	24.87	1.00	1.25	6.16	1.30	1.00	1.01
	0.80	0.50	1.83	1.03	1.19	1.00	1.00	6.64	1.00	2.49	2.14	4.27	1.00	1.27

Table 6: Mean square error of alternative spatial panel data estimators (N=100, T=5, θ=0.50)

			β					ρ_1			ρ_2			
True model	ρ_1	ρ_2	RE	KKP	Anselin	General	Pretest	KKP	General	Pretest	KKP	Anselin	General	Pretest
RE	0.00	0.00	1.00	1.00	1.00	1.01	1.00	-	-	-	-	-	-	-
KKP	-0.80	-0.80	2.10	1.00	1.12	1.00	1.00	1.00	8.18	3.72	1.00	2.74	1.23	1.09
	-0.50	-0.50	1.38	1.00	1.06	1.00	1.00	1.00	6.58	3.35	1.00	1.45	1.21	1.07
	-0.20	-0.20	1.04	1.00	1.01	1.01	1.01	1.00	6.82	3.42	1.00	1.25	1.21	2.21
	0.20	0.20	1.05	1.00	1.00	1.00	1.00	1.00	7.59	2.69	1.00	1.23	1.23	1.97
	0.50	0.50	1.55	1.00	1.07	1.01	1.00	1.00	9.49	6.20	1.00	1.83	1.24	1.09
	0.80	0.80	4.69	1.00	1.10	1.00	1.00	1.00	13.86	10.89	1.00	6.08	1.20	1.09
Anselin	0.00	-0.80	1.70	1.16	1.00	1.00	1.01	-	-	-	4.70	1.00	1.03	1.08
	0.00	-0.50	1.18	1.07	1.00	1.01	1.02	-	-	-	2.38	1.00	1.01	1.29
	0.00	-0.20	1.02	1.02	1.00	1.01	1.02	-	-	-	1.05	1.00	1.00	2.48
	0.00	0.20	1.04	1.00	1.00	1.01	1.01	-	-	-	1.15	1.00	1.01	2.33
	0.00	0.50	1.31	1.04	1.00	1.00	1.01	-	-	-	2.55	1.00	1.01	1.23
	0.00	0.80	2.70	1.05	1.00	1.00	1.00	-	-	-	3.77	1.00	1.03	1.03
General	-0.80	-0.50	1.48	1.02	1.16	1.00	1.01	6.53	1.00	2.50	2.23	3.13	1.00	1.19
	-0.80	-0.20	1.23	1.10	1.20	1.00	1.00	25.09	1.00	1.28	5.44	1.40	1.00	1.03
	-0.80	0.00	1.16	1.13	1.16	1.00	1.00	49.43	1.00	1.01	7.53	1.14	1.00	1.00
	-0.80	0.20	1.18	1.18	1.14	1.00	1.00	72.78	1.00	1.03	8.91	1.09	1.00	1.00
	-0.80	0.50	1.47	1.19	1.09	1.00	1.00	139.64	1.00	1.02	8.98	1.11	1.00	1.00
	-0.80	0.80	3.24	1.17	1.06	1.00	1.00	192.09	1.00	1.20	6.98	1.19	1.00	1.00
	-0.50	-0.80	1.85	1.02	1.04	1.00	1.02	3.05	1.00	3.58	1.64	0.92	1.00	1.34
	-0.50	-0.20	1.10	1.01	1.06	1.00	1.01	3.45	1.00	2.25	1.51	1.11	1.00	1.29
	-0.50	0.00	1.03	1.03	1.04	1.00	1.01	9.86	1.00	3.01	2.58	1.07	1.00	1.05
	-0.50	0.20	1.08	1.07	1.04	1.00	1.00	18.12	1.00	2.30	3.75	1.07	1.00	1.11
	-0.50	0.50	1.42	1.14	1.04	1.00	1.01	34.68	1.00	2.38	5.44	1.11	1.00	1.01
	-0.50	0.80	2.90	1.14	1.02	1.00	1.01	51.01	1.00	3.09	5.73	1.12	1.00	1.04
	-0.20	-0.80	1.68	1.09	1.00	1.00	1.01	9.83	1.00	2.20	3.17	0.92	1.00	1.15
	-0.20	-0.50	1.23	1.02	1.01	1.00	1.01	2.95	1.00	2.52	1.39	1.03	1.00	1.24
	-0.20	0.00	1.01	1.01	1.02	1.00	1.01	1.28	1.00	1.80	1.11	1.01	1.00	0.42
	-0.20	0.20	1.05	1.04	1.01	1.00	1.02	4.53	1.00	2.65	1.89	1.02	1.00	2.09
	-0.20	0.50	1.35	1.08	1.01	1.00	1.01	13.42	1.00	1.80	3.48	1.03	1.00	1.10
	-0.20	0.80	2.64	1.08	1.00	1.00	1.00	20.06	1.00	1.10	4.37	1.03	1.00	1.02
	0.20	-0.80	1.62	1.22	1.01	1.00	1.01	33.83	1.00	1.55	6.53	1.04	1.00	1.02
	0.20	-0.50	1.20	1.12	1.01	1.00	1.01	16.92	1.00	2.07	4.01	1.01	1.00	1.06
	0.20	-0.20	1.02	1.03	1.01	1.00	1.01	5.62	1.00	2.79	1.90	1.01	1.00	2.32
	0.20	0.00	1.00	1.00	1.01	1.00	1.01	1.49	1.00	1.77	1.06	1.02	1.00	0.43
	0.20	0.50	1.34	1.02	0.99	1.00	1.00	2.70	1.00	2.09	1.71	0.99	1.00	1.39
	0.20	0.80	2.80	1.04	1.00	1.00	1.00	7.75	1.00	1.12	3.09	0.90	1.00	1.02
	0.50	-0.80	1.90	1.43	1.09	1.00	1.00	87.93	1.00	1.77	10.41	1.13	1.00	1.01
	0.50	-0.50	1.31	1.24	1.08	1.00	1.00	45.90	1.00	1.63	9.36	1.09	1.00	1.00
	0.50	-0.20	1.13	1.14	1.10	1.00	1.00	24.88	1.00	1.63	5.35	1.06	1.00	1.07
	0.50	0.00	1.06	1.04	1.06	1.00	1.00	12.62	1.00	2.19	3.35	1.10	1.00	1.02
	0.50	0.20	1.15	1.03	1.09	1.00	1.01	4.53	1.00	2.20	1.65	1.15	1.00	1.27
	0.50	0.80	3.15	1.02	1.03	1.00	1.00	3.02	1.00	4.22	2.10	0.94	1.00	1.32
	0.80	-0.80	2.33	1.41	1.18	1.00	1.00	476.04	1.00	1.00	18.91	1.19	1.00	1.00
	0.80	-0.50	1.53	1.41	1.22	1.00	1.00	247.49	1.00	1.00	22.89	1.09	1.00	1.00
	0.80	-0.20	1.34	1.36	1.29	1.00	1.00	129.40	1.00	1.00	19.14	1.07	1.00	1.00
	0.80	0.00	1.31	1.23	1.31	1.00	1.00	75.06	1.00	1.00	15.44	1.15	1.00	1.00
	0.80	0.20	1.41	1.13	1.31	1.00	1.00	42.32	1.00	1.00	10.61	1.27	1.00	1.00
	0.80	0.50	1.85	1.03	1.22	1.00	1.00	11.84	1.00	1.63	3.72	7.13	1.00	1.08

Table 7: Mean square error of alternative spatial panel data estimators (N=50, T=10, θ=0.50)

			β					ρ_1			ρ_2			
True model	ρ_1	ρ_2	RE	KKP	Anselin	General	Pretest	KKP	General	Pretest	KKP	Anselin	General	Pretest
RE	0.00	0.00	1.00	1.00	1.00	1.01	1.00	-	-	-	-	-	-	-
KKP	-0.80	-0.80	2.77	1.00	1.08	1.00	1.00	1.00	13.62	5.13	1.00	1.91	1.10	1.05
	-0.50	-0.50	1.42	1.00	1.03	1.01	1.00	1.00	12.16	3.91	1.00	1.17	1.13	1.05
	-0.20	-0.20	1.05	1.00	1.01	1.01	1.00	1.00	11.38	3.80	1.00	1.11	1.11	1.74
	0.20	0.20	1.08	1.00	1.02	1.01	1.00	1.00	13.57	3.00	1.00	1.08	1.07	1.49
	0.50	0.50	1.55	1.00	1.05	1.01	1.00	1.00	15.58	6.13	1.00	1.12	1.07	1.02
	0.80	0.80	4.15	1.00	1.09	1.00	1.00	1.00	24.32	14.46	1.00	3.02	1.05	1.03
Anselin	0.00	-0.80	2.28	1.09	1.00	1.00	1.01	-	-	-	2.19	1.00	1.01	1.07
	0.00	-0.50	1.33	1.03	1.00	1.01	1.02	-	-	-	1.47	1.00	1.00	1.14
	0.00	-0.20	1.03	1.01	1.00	1.00	1.01	-	-	-	1.01	1.00	1.00	1.98
	0.00	0.20	1.06	1.00	1.00	1.00	1.01	-	-	-	1.11	1.00	1.00	1.71
	0.00	0.50	1.40	1.03	1.00	1.01	1.01	-	-	-	1.63	1.00	1.00	1.15
	0.00	0.80	3.27	1.05	1.00	1.01	1.00	-	-	-	2.00	1.00	1.01	1.02
General	-0.80	-0.50	1.47	1.02	1.10	1.00	1.00	6.21	1.00	2.43	1.53	1.10	1.00	1.09
	-0.80	-0.20	1.17	1.07	1.12	1.00	1.00	23.57	1.00	1.61	2.71	1.03	1.00	1.02
	-0.80	0.00	1.14	1.13	1.14	1.00	1.00	46.12	1.00	1.59	3.26	1.02	1.00	1.00
	-0.80	0.20	1.14	1.11	1.08	1.00	1.00	72.71	1.00	1.12	3.34	1.02	1.00	1.00
	-0.80	0.50	1.65	1.16	1.08	1.00	1.00	98.00	1.00	1.25	3.22	1.02	1.00	1.00
	-0.80	0.80	4.00	1.12	1.05	1.00	1.00	142.55	1.00	1.81	2.50	1.05	1.00	1.01
	-0.50	-0.80	2.40	1.02	1.01	1.00	1.02	2.76	1.00	3.75	1.30	0.98	1.00	1.22
	-0.50	-0.20	1.08	1.01	1.03	1.00	1.01	3.00	1.00	2.39	1.24	1.02	1.00	1.25
	-0.50	0.00	1.03	1.02	1.02	1.00	1.02	8.72	1.00	4.17	1.65	1.01	1.00	0.86
	-0.50	0.20	1.09	1.07	1.04	1.00	1.02	15.69	1.00	3.25	2.18	1.02	1.00	1.15
	-0.50	0.50	1.49	1.10	1.03	1.00	1.01	30.94	1.00	2.82	2.41	1.01	1.00	1.01
	-0.50	0.80	3.35	1.15	1.04	1.00	1.02	41.64	1.00	2.92	2.33	1.04	1.00	1.02
	-0.20	-0.80	2.28	1.04	1.01	1.00	1.01	7.99	1.00	2.54	1.85	0.96	1.00	1.11
	-0.20	-0.50	1.33	1.02	1.00	1.00	1.01	2.50	1.00	2.16	1.12	1.01	1.00	1.10
	-0.20	0.00	1.00	1.01	1.01	1.00	1.00	1.08	1.00	1.42	1.07	1.00	1.00	0.37
	-0.20	0.20	1.04	1.00	0.99	1.00	1.00	4.09	1.00	2.69	1.40	1.00	1.00	1.58
	-0.20	0.50	1.42	1.06	1.00	1.00	1.01	12.09	1.00	1.99	1.96	1.01	1.00	1.06
	-0.20	0.80	3.24	1.07	1.00	1.00	1.00	17.12	1.00	1.03	2.10	1.01	1.00	1.01
	0.20	-0.80	2.22	1.09	1.00	1.00	1.00	23.53	1.00	1.22	2.56	1.01	1.00	1.02
	0.20	-0.50	1.34	1.05	1.00	1.00	1.01	11.96	1.00	2.24	2.04	1.00	1.00	1.07
	0.20	-0.20	1.04	1.02	1.00	1.00	1.01	4.33	1.00	2.69	1.28	1.00	1.00	1.83
	0.20	0.00	1.00	1.00	1.00	1.00	1.00	1.18	1.00	1.29	0.96	1.00	1.00	0.32
	0.20	0.50	1.45	1.01	1.00	1.00	1.01	2.08	1.00	1.65	1.31	1.00	1.00	1.19
	0.20	0.80	3.30	1.04	1.00	1.00	1.00	6.64	1.00	1.13	1.76	0.96	1.00	1.04
	0.50	-0.80	2.36	1.16	1.03	1.00	1.01	57.19	1.00	2.38	3.25	1.04	1.00	1.01
	0.50	-0.50	1.38	1.11	1.04	1.00	1.00	37.55	1.00	2.43	3.19	1.01	1.00	1.00
	0.50	-0.20	1.09	1.08	1.05	1.00	1.01	18.18	1.00	2.52	2.41	1.01	1.00	1.14
	0.50	0.00	1.03	1.03	1.04	1.00	1.00	9.65	1.00	3.06	1.71	1.01	1.00	0.89
	0.50	0.20	1.10	1.01	1.04	1.00	1.00	3.57	1.00	2.10	1.15	1.01	1.00	1.13
	0.50	0.80	3.61	1.01	1.02	1.00	1.02	2.25	1.00	3.33	1.47	1.02	1.00	1.23
	0.80	-0.80	2.76	1.17	1.10	1.00	1.00	253.07	1.00	1.05	4.10	1.05	1.00	1.00
	0.80	-0.50	1.59	1.20	1.13	1.00	1.00	177.10	1.00	1.00	4.95	1.02	1.00	1.00
	0.80	-0.20	1.23	1.20	1.17	1.00	1.00	94.39	1.00	1.10	5.13	1.00	1.00	1.00
	0.80	0.00	1.13	1.13	1.13	1.00	1.00	64.88	1.00	1.08	5.25	1.02	1.00	1.00
	0.80	0.20	1.20	1.10	1.15	1.00	1.00	34.56	1.00	1.10	3.93	1.03	1.00	1.00
	0.80	0.50	1.73	1.02	1.14	1.00	1.00	9.13	1.00	1.88	1.98	1.07	1.00	1.04

Table 8: Mean square error of alternative spatial panel data estimators (N=50, T=5, θ=0.75)

			β					ρ1			ρ2			
True model	ρ1	ρ2	RE	KKP	Anselin	General	Pretest	KKP	General	Pretest	KKP	Anselin	General	Pretest
RE	0.00	0.00	1.00	1.01	1.01	1.02	1.00	-	-	-	-	-	-	-
KKP	-0.80	-0.80	2.71	1.00	1.05	1.01	1.00	1.00	6.92	3.81	1.00	2.60	1.23	1.09
	-0.50	-0.50	1.34	1.00	1.01	1.01	1.01	1.00	5.42	2.40	1.00	1.31	1.23	1.08
	-0.20	-0.20	1.05	1.00	1.01	1.01	1.01	1.00	5.65	3.97	1.00	1.22	1.21	2.99
	0.20	0.20	1.06	1.00	1.01	1.00	1.02	1.00	6.19	3.39	1.00	1.21	1.21	2.89
	0.50	0.50	1.56	1.00	1.04	1.00	1.00	1.00	7.91	4.00	1.00	1.24	1.16	1.04
	0.80	0.80	5.06	1.00	1.04	1.00	1.00	1.00	11.15	6.66	1.00	5.35	1.15	1.08
Anselin	0.00	-0.80	2.30	1.06	1.00	1.00	1.01	-	-	-	3.75	1.00	1.01	1.11
	0.00	-0.50	1.32	1.04	1.00	1.00	1.01	-	-	-	2.01	1.00	1.00	1.32
	0.00	-0.20	1.03	1.00	1.00	1.01	1.02	-	-	-	0.95	1.00	1.00	2.84
	0.00	0.20	1.07	1.01	1.00	1.01	1.03	-	-	-	1.15	1.00	1.00	2.80
	0.00	0.50	1.49	1.03	1.00	1.01	1.01	-	-	-	2.35	1.00	1.00	1.35
	0.00	0.80	3.72	1.05	1.00	1.01	1.00	-	-	-	3.14	1.00	1.02	1.04
General	-0.80	-0.50	1.44	1.01	1.07	1.00	1.00	5.25	1.00	2.42	2.01	1.67	1.00	1.19
	-0.80	-0.20	1.10	1.03	1.05	1.00	1.00	20.61	1.00	1.61	4.40	1.08	1.00	1.06
	-0.80	0.00	1.04	1.09	1.06	1.00	1.00	35.67	1.00	1.65	5.87	1.03	1.00	1.00
	-0.80	0.20	1.13	1.14	1.07	1.00	1.00	57.98	1.00	1.21	6.70	1.12	1.00	1.01
	-0.80	0.50	1.68	1.15	1.06	1.00	1.00	113.44	1.00	1.29	6.34	1.01	1.00	1.00
	-0.80	0.80	4.39	1.06	1.02	1.00	1.00	127.41	1.00	1.77	4.57	1.06	1.00	1.01
	-0.50	-0.80	2.39	1.01	1.01	1.00	1.01	2.79	1.00	4.01	1.61	1.01	1.00	1.43
	-0.50	-0.20	1.04	1.01	1.03	1.00	1.02	2.86	1.00	2.62	1.41	1.03	1.00	1.62
	-0.50	0.00	1.00	1.01	1.01	1.00	1.01	7.30	1.00	4.09	2.27	1.02	1.00	0.95
	-0.50	0.20	1.06	1.05	1.02	1.00	1.01	14.00	1.00	2.76	3.41	1.02	1.00	1.35
	-0.50	0.50	1.56	1.08	1.02	1.00	1.00	30.33	1.00	2.84	4.40	1.02	1.00	1.01
	-0.50	0.80	4.03	1.05	1.00	1.00	1.00	45.40	1.00	3.32	4.10	1.06	1.00	1.03
	-0.20	-0.80	2.36	1.04	1.00	1.00	1.00	7.96	1.00	2.58	2.86	0.96	1.00	1.26
	-0.20	-0.50	1.30	1.00	1.00	1.00	1.01	2.33	1.00	2.09	1.25	1.01	1.00	1.22
	-0.20	0.00	0.99	1.00	1.00	1.00	1.00	1.03	1.00	1.50	1.10	1.01	1.00	0.42
	-0.20	0.20	1.04	1.01	1.00	1.00	1.01	3.54	1.00	2.35	1.75	1.01	1.00	2.41
	-0.20	0.50	1.56	1.04	1.00	1.00	1.00	11.21	1.00	2.03	3.02	1.01	1.00	1.13
	-0.20	0.80	3.86	1.05	0.99	1.00	1.00	20.01	1.00	1.09	3.49	1.02	1.00	1.01
	0.20	-0.80	2.20	1.09	1.01	1.00	1.00	23.46	1.00	1.27	4.82	1.02	1.00	1.03
	0.20	-0.50	1.35	1.05	1.01	1.00	1.01	11.96	1.00	2.22	3.15	1.00	1.00	1.13
	0.20	-0.20	1.04	1.02	1.01	1.00	1.02	3.81	1.00	2.10	1.58	1.00	1.00	2.75
	0.20	0.00	0.99	1.00	1.00	1.00	1.00	1.17	1.00	1.35	0.96	1.00	1.00	0.36
	0.20	0.50	1.58	1.01	1.00	1.00	1.01	1.99	1.00	1.67	1.65	1.00	1.00	1.34
	0.20	0.80	3.86	1.04	1.00	1.00	1.00	6.38	1.00	1.05	2.75	0.95	1.00	1.03
	0.50	-0.80	2.41	1.12	1.03	1.00	1.00	55.76	1.00	2.29	6.65	1.06	1.00	1.01
	0.50	-0.50	1.40	1.12	1.04	1.00	1.00	31.32	1.00	2.10	6.11	1.00	1.00	1.00
	0.50	-0.20	1.08	1.07	1.03	1.00	1.01	15.37	1.00	2.28	3.81	1.01	1.00	1.25
	0.50	0.00	1.03	1.04	1.04	1.00	1.00	7.60	1.00	3.01	2.48	1.01	1.00	0.97
	0.50	0.20	1.10	1.00	1.03	1.00	1.00	2.96	1.00	2.11	1.30	1.01	1.00	1.41
	0.50	0.80	4.25	1.03	1.01	1.00	1.01	2.35	1.00	3.56	2.01	1.06	1.00	1.39
	0.80	-0.80	2.68	1.16	1.09	1.00	1.00	248.21	1.00	1.02	9.15	1.08	1.00	1.00
	0.80	-0.50	1.42	1.17	1.09	1.00	1.00	145.15	1.00	1.00	10.94	1.17	1.00	1.00
	0.80	-0.20	1.12	1.17	1.10	1.00	1.00	78.57	1.00	1.00	11.75	1.09	1.00	1.00
	0.80	0.00	1.09	1.13	1.10	1.00	1.00	44.27	1.00	1.08	9.12	1.01	1.00	1.00
	0.80	0.20	1.18	1.09	1.12	1.00	1.00	23.90	1.00	1.17	6.56	1.15	1.00	1.01
	0.80	0.50	1.70	1.02	1.10	1.00	1.00	6.38	1.00	1.82	2.71	1.30	1.00	1.11