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Abstract

This paper considers a Hausman and Taylor (1981) panel data model that exhibits a Cliff and Ord (1973) spatial error structure. We analyze the small sample properties of a generalized moments estimation approach for that model. This spatial Hausman-Taylor estimator allows for endogeneity of the time-varying and time-invariant variables with the individual effects. For this model, the spatial effects estimator is known to be consistent, but its disadvantage is that it wipes out the effects of time-invariant variables, which are important for most empirical studies. Monte Carlo results show that the spatial Hausman-Taylor estimator performs well in small samples.

JEL No. C23, C31

Key Words: Hausman-Taylor estimator; Spatial random effects; Small sample properties

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1 Introduction

Hausman and Taylor (1981) proposed a random effects panel data model which allows for endogeneity of time-varying and time-invariant variables with the individual effects. For this model, fixed effects (FE) is known to be consistent, but its disadvantage is that it wipes out the effects of time-invariant variables which are important for most empirical studies. In an earnings equation, the time-invariant variable could be schooling and this is correlated with the unobservable individual effect, see Cornwell and Rupert (1988). In this case, FE would not deliver an estimate of the returns to schooling, but the alternative Hausman-Taylor estimator will provide an asymptotically efficient estimator of this effect. The order condition of identification requires that there are as many exogenous time-variant regressors as there are endogenous time-invariant regressors. Other applications of this estimator include the effect of an individual's birth year on wages (see Light and Ureta, 1995); the effect of health on wages (Contoyannis and Rice, 2001); the effect of distance on bilateral trade (Egger, 2004) or foreign direct investment (Egger and Pfaffermayr, 2004); the effect of common language on bilateral trade (Serlenga and Shin, 2007); the effect of public ownership of firms on productivity (Baltagi, Egger, and Kesina, 2011). The last paper introduces spatial spillovers in total factor productivity by allowing the error term across firms to be spatially interdependent. This model is estimated by extending the Hausman-Taylor estimator to allow for spatial correlation in the error term. Baltagi, Egger, and Kesina (2011) find evidence of positive spillovers across firms and a large and significant detrimental effect of public ownership on total factor productivity.

This is a follow up paper that studies the small sample performance of various estimators applied to this *spatial* Hausman-Taylor model using Monte

Carlo experiments. We will refer to the spatial Hausman-Taylor model by the acronym SHT. This paper also studies the small sample performance of a pretest estimator which is based on two Hausman tests usually carried out by the empirical researcher in practice. It is well known, that the choice between fixed effects (FE) and random effects (RE) estimators can be based on the Hausman (1978) test. Baltagi, Bresson, and Pirotte (2003) suggest an alternative pretest estimator based on the Hausman and Taylor model. This pretest estimator reverts to the RE estimator if the standard Hausman test based on the FE versus the RE estimators is not rejected. It reverts to the HT estimator if the choice of strictly exogenous regressors is not rejected by a second Hausman over-identification test based on the difference between the FE and HT estimators. If both tests are rejected, then the pretest estimator reverts to the FE estimator. See Baltagi (2008) for a textbook treatment of this subject. This paper generalizes this pretest estimator to account for spatial correlation. In the first step, a standard Hausman (1978) test is performed based on the contrast between spatial fixed effects (SFE) and spatial random effects (SRE),[1] and in the second step a Hausman-Taylor over-identification test is performed based on the contrast between SFE and the SHT estimator. The spatial pretest (SPT) estimator becomes the SRE estimator if the Hausman test is not rejected in the first step. It becomes the SHT estimator if the first Hausman test is rejected but the second Hausman-Taylor over-identification test is not rejected. If both tests are rejected, then the SPT estimator reverts to the SFE estimator.

This paper performs Monte Carlo experiments to compare the perfor-

[1]See Mutl and Pfaffermayr (2011) for the large and small sample properties of the Hausman test statistic in a Cliff and Ord type spatial panel data model. See also Debarsy (2012), who tested for the endogeneity of the regressors and their spatially weighted counterparts with the individual effects using a likelihood ratio test.

mance of this SPT estimator with the spatial panel data estimators under various designs. The estimators considered are: OLS, spatial fixed effects (SFE), spatial random effects (SRE), and spatial Hausman–Taylor (SHT), respectively.

In the experiments, we let some regressors be correlated with the individual effects and the error to be spatially correlated, i.e., a spatial Hausman-Taylor world. Our results show that the SPT estimator is a viable estimator and performs reasonably well in terms of root mean squared error (RMSE). However, it does not perform well for simple tests of hypotheses. The SFE estimator is a consistent estimator in the SHT world but its disadvantage is that it does not allow the estimation of the coefficients of the time-invariant regressors. When there is endogeneity among the regressors, we show that there is a substantial bias in the OLS and SRE estimators and both yield misleading inference.

The remainder of the paper is organized as follows. Section 2 briefly reviews the estimator for the spatial Hausman-Taylor model which will be employed in the Monte Carlo analysis. Section 3 introduces the Monte Carlo design and discusses the results. The last section concludes with a brief summary of our main findings.

2 Econometric Model

In this section, we briefly review the Hausman and Taylor (1981) model with spatial correlation (see Baltagi, Egger, and Kesina, 2011). Let $i = 1, ..., N$ refer to individual units and $t = 1, ..., T$ refer to time periods. In what follows, we are interested in analyzing a Cliff and Ord (1973) spatial model for period t of the form

$$\mathbf{y}_t = \mathbf{X}_t\beta + \mathbf{Z}\gamma + \mathbf{u}_t = \mathfrak{Z}_t\delta + \mathbf{u}_t \quad (1)$$

$$\mathbf{u}_t = \rho\mathbf{W}\mathbf{u}_t + \varepsilon_t, \quad \varepsilon_t = \mu + \nu_t \quad (2)$$

where $\mathfrak{Z}_t = [\mathbf{X}_t, \mathbf{Z}]$, and $\delta = [\beta', \gamma']'$. Here, $\mathbf{y}_t = (y_{1t}, ..., y_{Nt})'$ is an $N \times 1$ vector of observations on the dependent variable at time t, $\mathbf{X}_t$ is an $N \times K$ matrix of time-varying regressors for period t, $\mathbf{Z}$ is an $N \times R$ matrix of time-invariant regressors. The regressors may be decomposed into $\mathbf{X}_t = [\mathbf{X}_{Ut}, \mathbf{X}_{Ct}]$ and $\mathbf{Z} = [\mathbf{Z}_U, \mathbf{Z}_C]$, where subindex C denotes regressors which are *correlated* with μ while subindex U indicates regressors which are *uncorrelated* with μ. $\mathbf{W}$ is an $N \times N$ observed non-stochastic spatial weights matrix. $\mathbf{u}_t = (u_{1t}, ..., u_{Nt})'$ is the $N \times 1$ vector of disturbances, and $\varepsilon_t = (\varepsilon_{1t}, ..., \varepsilon_{Nt})'$ is an $N \times 1$ vector of innovations which consists of two components: a time-invariant $\mu = (\mu_1, ..., \mu_N)'$ and a time-variant $\nu_t = (\nu_{1t}, ..., \nu_{Nt})'$ component, where $\mu \sim IIN(0, \sigma_\mu^2)$ and $\nu \sim IIN(0, \sigma_\nu^2)$. The vector $\mathbf{W}\mathbf{u}_t$ represents a spatial lag of $\mathbf{u}_t$. The scalar ρ denotes the spatial auto-regressive parameter, while β and γ are $K \times 1$ and $R \times 1$ vectors of regression parameters.[2]

When stacking the model for all time periods $t = 1, .., T$, it reads

$$\mathbf{y} = \mathbf{X}\beta + (\iota_T \otimes \mathbf{Z})\gamma + \mathbf{u} = \mathfrak{Z}\delta + \mathbf{u} \quad (3)$$

$$\mathbf{u} = \rho(\mathbf{I}_T \otimes \mathbf{W})\mathbf{u} + \varepsilon, \quad \varepsilon = \mathbf{Z}_\mu\mu + \nu, \quad (4)$$

where $\mathbf{X} = [\mathbf{x}_1', ..., \mathbf{x}_T']'$, $\mathfrak{Z} = [\mathfrak{Z}_1', .., \mathfrak{Z}_T']'$, $\mathbf{u} = [\mathbf{u}_1', .., \mathbf{u}_T']'$ and $\varepsilon = [\varepsilon_1', .., \varepsilon_T']'$.

[2]We aim at extending the Hausman-Taylor (1981) estimator and thus focus on spatial autocorrelation in the error term. In the spirit of Hausman and Taylor there is no other endogeneity besides the correlation of the regressors with the individual effects. Including a spatial lag of the dependent variable in the model is realistic and important (see Ertur and Koch, 2007, 2011; Pfaffermayr, 2009), but causes additional endogeneity and is not in the spirit of Hausman and Taylor (1981).

ι_T denotes a $T \times 1$ vector of ones and $\mathbf{I}_T$ denotes a $T \times T$ identity matrix. $\mathbf{Z}_\mu = \iota_T \otimes \mathbf{I}_N$ is an $NT \times N$ selector matrix of ones and zeroes.

For estimation, we employ moment conditions derived in Kapoor, Kelejian, and Prucha (2007) for the SRE model. These moment conditions are given by $\frac{1}{N(T-1)}E(\varepsilon'\mathbf{Q}\varepsilon) = \sigma_\nu^2$, $\frac{1}{N(T-1)}E(\overline{\varepsilon}'\mathbf{Q}\overline{\varepsilon}) = \sigma_\nu^2 \frac{1}{N} tr(\mathbf{W}'\mathbf{W})$, $\frac{1}{N(T-1)}E(\overline{\varepsilon}'\mathbf{Q}\varepsilon) = 0$, $\frac{1}{N}E(\varepsilon'\mathbf{P}\varepsilon) = \sigma_1^2$, $\frac{1}{N}\overline{\varepsilon}'\mathbf{P}\overline{\varepsilon} = \sigma_1^2 \frac{1}{N} tr(\mathbf{W}'\mathbf{W})$, $\frac{1}{N}\overline{\varepsilon}'\mathbf{P}\varepsilon = 0$, where $\overline{\varepsilon} \equiv (\mathbf{I}_T \otimes \mathbf{W})\varepsilon$ and $\sigma_1^2 = T\sigma_\mu^2 + \sigma_\nu^2$. $\mathbf{P} = \mathbf{I}_N \otimes \overline{\mathbf{J}}_T$ is the (between) projection matrix, where $\overline{\mathbf{J}}_T = T^{-1}\mathbf{J}_T$ and $\mathbf{J}_T$ is a matrix of ones of dimension T. $\mathbf{Q} = \mathbf{I}_{NT} - \mathbf{P}$ denotes the within transformation matrix. The moment conditions can be rewritten in terms of $\mathbf{u}$ using the fact that $\varepsilon = (\mathbf{I}_T \otimes [\mathbf{I}_N - \rho\mathbf{W}])\mathbf{u} = \mathbf{u} - \rho\overline{\mathbf{u}}$ whereby $\overline{\mathbf{u}} \equiv (\mathbf{I}_T \otimes \mathbf{W})\mathbf{u}$ and $\overline{\varepsilon} \equiv (\mathbf{I}_T \otimes \mathbf{W})(\mathbf{I}_T \otimes [\mathbf{I}_N - \rho\mathbf{W}])\mathbf{u} = \overline{\mathbf{u}} - \rho\overline{\overline{\mathbf{u}}}$ with $\overline{\overline{\mathbf{u}}} \equiv (\mathbf{I}_T \otimes \mathbf{W})\overline{\mathbf{u}}$.

The resulting moment conditions are then stacked and solved as a solution to the system of six equations in three unknowns. More formally, $\gamma - \mathbf{\Gamma}\alpha = \mathbf{0}$, where $\alpha = (\rho, \rho^2, \sigma_\nu^2, \sigma_1^2)'$ and

$$\gamma = \begin{pmatrix} \frac{1}{N(T-1)}\mathbf{u}'\mathbf{Q}\mathbf{u} \\ \frac{1}{N(T-1)}\overline{\mathbf{u}}'\mathbf{Q}\overline{\mathbf{u}} \\ \frac{1}{N(T-1)}\mathbf{u}'\mathbf{Q}\overline{\mathbf{u}} \\ \frac{1}{N}\mathbf{u}'\mathbf{P}\mathbf{u} \\ \frac{1}{N}\overline{\mathbf{u}}'\mathbf{P}\overline{\mathbf{u}} \\ \frac{1}{N}\mathbf{u}'\mathbf{P}\overline{\mathbf{u}} \end{pmatrix}, \quad \mathbf{\Gamma} = \begin{pmatrix} \frac{2}{N(T-1)}\mathbf{u}'\mathbf{Q}\overline{\mathbf{u}} & \frac{-1}{N(T-1)}\overline{\mathbf{u}}'\mathbf{Q}\overline{\mathbf{u}} & 1 & 0 \\ \frac{2}{N(T-1)}\overline{\overline{\mathbf{u}}}'\mathbf{Q}\overline{\mathbf{u}} & \frac{-1}{N(T-1)}\overline{\overline{\mathbf{u}}}'\mathbf{Q}\overline{\overline{\mathbf{u}}} & \frac{1}{N}tr\mathbf{W}'\mathbf{W} & 0 \\ \frac{1}{N(T-1)}(\mathbf{u}'\mathbf{Q}\overline{\overline{\mathbf{u}}} + \overline{\mathbf{u}}'\mathbf{Q}\overline{\mathbf{u}}) & \frac{-1}{N(T-1)}\overline{\mathbf{u}}'\mathbf{Q}\overline{\overline{\mathbf{u}}} & 0 & 0 \\ \frac{2}{N}\mathbf{u}'\mathbf{P}\overline{\mathbf{u}} & \frac{-1}{N}\overline{\mathbf{u}}'\mathbf{P}\overline{\mathbf{u}} & 0 & 1 \\ \frac{2}{N}\overline{\overline{\mathbf{u}}}'\mathbf{P}\overline{\mathbf{u}} & \frac{-1}{N}\overline{\overline{\mathbf{u}}}'\mathbf{P}\overline{\overline{\mathbf{u}}} & 0 & \frac{1}{N}tr\mathbf{W}'\mathbf{W} \\ \frac{1}{N}(\mathbf{u}'\mathbf{P}\overline{\overline{\mathbf{u}}} + \overline{\mathbf{u}}'\mathbf{P}\overline{\mathbf{u}}) & \frac{-1}{N}\overline{\mathbf{u}}'\mathbf{P}\overline{\overline{\mathbf{u}}} & 0 & 0 \end{pmatrix}.$$

We replace $\mathbf{u}$, $\overline{\mathbf{u}}$, and $\overline{\overline{\mathbf{u}}}$ by their corresponding consistent estimates $\hat{\mathbf{u}}$, $\hat{\overline{\mathbf{u}}}$, and $\hat{\overline{\overline{\mathbf{u}}}}$. In our case, we replace them by the residuals from a standard HT estimator, ignoring the spatial correlation. This is a consistent but not efficient estimator in the presence of spatial autocorrelation. Kapoor, Kelejian, and Prucha (2007) used standard OLS residuals for their SRE estimator. This estimator is consistent but not efficient in that context. In our case, it would be inconsistent due to the endogeneity of the regressors and the individual effects.

Following Kapoor, Kelejian, and Prucha (2007), we first estimate an initial $\tilde{\rho}$ using only three of the six moment conditions where each moment condition is weighted equally. Define γ_3 and α_3 as the 3×1 subvectors containing the first three elements of γ and α, respectively, and $\mathbf{\Gamma}_3$ as the 3×3 submatrix containing the upper left bloc of elements of $\mathbf{\Gamma}$. Now, solve the first three of the above moment conditions for

$$\tilde{\rho} = \arg \min_{\sigma_\nu^2 \in S_\nu, \rho \in S_\rho} \left[\left(\hat{\gamma}_3 - \hat{\mathbf{\Gamma}}_3 \hat{\alpha}_3 \right)' \mathbf{I}_3 \left(\hat{\gamma}_3 - \hat{\mathbf{\Gamma}}_3 \hat{\alpha}_3 \right) \right], \tag{5}$$

where S_ν, and S_ρ denote the respective admissible parameter spaces of σ_ν^2 and ρ (see Kapoor, Kelejian, and Prucha, 2007, for details). We can estimate $\tilde{\rho}$ and $\tilde{\sigma}_\nu^2$ consistently by nonlinear least squares. With these estimates at hand, $\tilde{\sigma}_1^2$ can be solved explicitly from the fourth moment condition as $\tilde{\sigma}_1^2 = \frac{1}{N}\hat{\mathbf{u}}'\mathbf{P}\hat{\mathbf{u}} - \frac{2\tilde{\rho}}{N}\hat{\mathbf{u}}'\mathbf{P}\hat{\bar{\mathbf{u}}} + \frac{\tilde{\rho}^2}{N}\hat{\bar{\mathbf{u}}}'\mathbf{P}\hat{\bar{\mathbf{u}}}$. In a second step, following Kapoor, Kelejian, and Prucha (2007) again, we apply a generalized methods of moments estimator using all six moment conditions and the weighting matrix $\hat{\Upsilon}$

$$\hat{\Upsilon} = \begin{pmatrix} \frac{1}{T-1}\tilde{\sigma}_v^4 & 0 \\ 0 & \tilde{\sigma}_1^4 \end{pmatrix} \otimes I_3. \tag{6}$$

Applying nonlinear least squares to

$$\hat{\rho} = \arg \min_{\sigma_\nu^2 \in S_\nu, \sigma_1^2 \in S_1, \rho \in S_\rho} \left[\left(\hat{\gamma} - \hat{\mathbf{\Gamma}} \hat{\alpha} \right)' \hat{\Upsilon} \left(\hat{\gamma} - \hat{\mathbf{\Gamma}} \hat{\alpha} \right) \right], \tag{7}$$

yields an estimate for ρ.[3] All of the subsequent Monte Carlo simulations are based on the latter procedure. Cliff and Ord type spatial panel data estimators – such as the aforementioned SFE, SHT, and SRE – apply the

[3]Kapoor, Kelejian, and Prucha (2007) illustrate that either type of weighting of the moment conditions performs well even in small samples.

Cochrane-Orcutt transformation $\mathbf{v}_* = (\mathbf{I}_T \otimes [\mathbf{I}_N - \hat{\rho}\mathbf{W}])\mathbf{v}$ to any variable $\mathbf{v}$ of size $NT \times 1$ in the model in order to avoid efficiency losses from spatial autocorrelation in the disturbances.[4] Moreover, error components type spatial estimators such as SHT or SRE then transform $\mathbf{v}_*$ to obtain $\mathbf{v}_{**} = \hat{\sigma}_\nu \hat{\boldsymbol{\Omega}}^{-1/2}\mathbf{v}_*$ with $\boldsymbol{\Omega} = E(\varepsilon\varepsilon')$ and $\hat{\sigma}_\nu \hat{\boldsymbol{\Omega}}^{-1/2} = \mathbf{Q} + \frac{\hat{\sigma}_\nu}{\hat{\sigma}_1}\mathbf{P}$. Notice that the within counterpart to the SFE estimator replaces $\hat{\sigma}_\nu \hat{\boldsymbol{\Omega}}^{-1/2}$ by $\mathbf{Q}$ to obtain $\mathbf{v}_{**}$.

Besides the aforementioned estimators, we additionally consider the performance of a spatial pretest (SPT) estimator that decides between SFE, SRE, and SHT in the spirit of Baltagi, Bresson, and Pirotte (2003) but allowing for spatial correlation. This estimator is based on two Hausman test statistics. In the first step, a standard Hausman (1978) test is performed based on the contrast between spatial fixed effects (SFE) and spatial random effects (SRE), and in the second step a Hausman-Taylor over-identification test is performed based on the contrast between SFE and the SHT estimator. The SPT estimator becomes the SRE estimator if the Hausman test is not rejected in the first step. It becomes the SHT estimator if the first Hausman test is rejected but the second Hausman-Taylor over-identification test is not rejected. If both tests are rejected, then the SPT estimator reverts to the SFE estimator.

[4] The SFE estimates of ρ and σ_ν^2 are based on the first three moment conditions in (5) and replacing $\mathbf{u}$ by the FE residuals ignoring the spatial correlation. The SRE estimates of ρ, σ_ν^2, and σ_1^2 are based on all six moment conditions in (7) and replacing $\mathbf{u}$ by OLS residuals ignoring the spatial correlation as in Kapoor, Kelejian, and Prucha (2007).

3 Monte Carlo Analysis

3.1 Design

For an assessment of the various estimators of the SHT model including the SPT estimator in small samples, we follow a design which is similar to the one in Baltagi, Bresson, and Pirotte (2003) but we allow for spatial correlation:

$$\mathbf{y}_t = \mathbf{X}_{U1t}\beta_1 + \mathbf{X}_{U2t}\beta_2 + \mathbf{X}_{Ct}\beta_3 + \mathbf{Z}_U\gamma_1 + \mathbf{Z}_C\gamma_2 + \mathbf{u}_t \quad (8)$$

$$\mathbf{u}_t = \rho\mathbf{W}\mathbf{u}_t + \varepsilon_t, \quad \varepsilon_t = \mu + \nu_t \quad (9)$$

where $\mu \sim IIN(0, \sigma_\mu^2)$, $\nu \sim IIN(0, \sigma_\nu^2)$, and $\mathbf{W}$ is specified as an $N \times N$ nonstochastic, row-normalized spatial weights matrix which is based on the unnormalized counterpart $\mathbf{W}_0$. The latter exhibits zero diagonal elements and otherwise a three-before-and-three-behind neighborhood structure as specified in the Appendix. Here, $\mathbf{y}_t = (y_{1t}, ..., y_{Nt})'$ is an $N \times 1$ vector of observations on the dependent variable at time t, $\mathbf{X}_{U1t}$ and $\mathbf{X}_{U2t}$ are two $N \times 1$ vectors of time-varying regressors which are *uncorrelated* with μ, the $N \times 1$ vector $\mathbf{X}_{Ct}$ is *correlated* with μ, and $\mathbf{Z}_U$ is an $N \times 1$ time-invariant regressor which is uncorrelated with μ, while $\mathbf{Z}_C$ is an $N \times 1$ time-invariant regressor which is correlated with μ.

We specify the covariates as follows:

- $\mathbf{X}_{U1t} = 0.7\mathbf{X}_{U1,t-1} + \delta + \zeta_t$, where δ is time-invariant and uniform on $[-2, 2]$ and ζ_t is time-variant and uniform on $[-2, 2]$; the initial value $\mathbf{X}_{U1,1}$ is defined as $\mathbf{X}_{U1,1}$=$\zeta_1/(1-0.7^2)^{1/2} + \delta/(1-0.7)$.

- $\mathbf{X}_{U2t} = 0.7\mathbf{X}_{U2,t-1} + \eta + \kappa_t$, where η is time-invariant and uniform on $[-2, 2]$ and κ_t is time-variant and uniform on $[-2, 2]$; the initial value $\mathbf{X}_{U2,1}$ is defined as $\mathbf{X}_{U2,1}$=$\kappa_1/(1-0.7^2)^{1/2} + \eta/(1-0.7)$.

- $\mathbf{Z}_U = \iota_N$, and, hence, it is a constant as in Baltagi, Bresson, and Pirotte (2003).

Regarding the regression coefficients, we assume $\beta_1 = \beta_2 = \beta_3 = \gamma_1 = \gamma_2 = 1$. We allow for different intensities of spatial autocorrelation and use $\rho \in \{0; 0.2; 0.4; 0.6\}$.

We consider three different sample sizes $N \in \{100; 200; 300\}$ and two time horizons $T \in \{3; 5\}$. We generally set $\sigma_\mu^2 + \sigma_\nu^2 = 3$ but allow the proportion of total variance due to the individual effect to vary by way of $\phi \equiv \frac{\sigma_\mu^2}{\sigma_\mu^2 + \sigma_\nu^2} \in \{0; 0.25; 0.50; 0.75\}$.

In what follows, we consider an (S)HT world where both $\mathbf{X}_{Ct}$ and $\mathbf{Z}_C$ are correlated with the individual effect μ, and we allow the intensity of this correlation to vary.

- $\mathbf{X}_{Ct} = 0.7\mathbf{X}_{C,t-1} + B + \lambda_t$, where λ_t is time-variant and uniform on $[-2, 2]$ and and the initial value $\mathbf{X}_{C,1}$ is defined as $\mathbf{X}_{C,1}$=$\lambda_1/(1 - 0.7^2)^{1/2} + B/(1 - 0.7)$.
  $B = \frac{\psi\mu + (1-\psi)\theta}{\sqrt{\psi^2 + (1-\psi)^2}}$ with $\mu \sim IIN(0, \sigma_\mu^2)$, $\theta \sim IIN(0, \sigma_\theta^2)$, and μ and θ are independent of each other. When σ_θ^2 equals σ_μ^2, which is what we use in this paper, then $B \sim IIN(0, \sigma_\mu^2)$. The parameter ψ accounts for the correlation between $\mathbf{X}_{Ct}$ and $\mathbf{Z}_C$ with the individual effect μ. We allow the intensity to vary and consider $\psi \in \{0; 0.10; 0.25; 0.50; 0.75; 1\}$. Obviously, the case where $\psi = 0$ corresponds to an (S)RE world where the use of instrumental variables unnecessarily reduces efficiency and induces a small sample bias.

- $\mathbf{Z}_C = \delta + \eta + B + \xi$, where ξ is uniform on $[-2, 2]$ and B is defined above.

In the next section, we focus on the bias, the root mean squared error

(RMSE), and the size of tests for $H_0^a : \beta_3 = 1$, and $H_0^b : \gamma_2 = 1$ at the 5% significance level. We focus on β_3 and γ_2, since they are the coefficients of the endogenous time-variant regressor, and the endogenous time-invariant regressor, respectively.

3.2 Results for bias and RMSE

Table 1 gives the bias, RMSE, and size of tests for $H_0^a : \beta_3 = 1$, and $H_0^b : \gamma_2 = 1$ at the 5% significance level. This is done for $(N = 100, T = 3)$ in an SHT world where $\psi = 1$ in the upper panel of Table 1 and an SRE world where $\psi = 0$ in the lower panel of Table 1. Consider the SHT world configuration where $\rho = 0$ (no spatial correlation) and increasing heterogeneity through $\phi \in \{0; 0.25; 0.50; 0.75\}$ in Table 1. Obviously, with correlation between some regressors and the individual effects, OLS and SRE are consistent only if $\phi = 0$ (no random individual effects correlated with the regressors). If $\phi > 0$, the endogeneity of $\mathbf{X}_{Ct}$ and $\mathbf{Z}_C$ will lead to parameter bias. Note that the bias and RMSE for OLS and SRE increase with ϕ and the size of the tests for $H_0^a : \beta_3 = 1$ and $H_0^b : \gamma_2 = 1$ is unacceptable, rejecting the null when true up to 100% of the time, especially when $\phi > 0.5$. This confirms the results in Baltagi, Bresson, and Pirotte (2003). SFE performs well for β_3 but *does* not yield estimates for γ_2. The SHT estimator yields a low RMSE for both β_3 and γ_2.

If $\rho \neq 0$ (spatial correlation), OLS is consistent but inefficient at $\phi = 0$. Of course, OLS is inconsistent if $\phi > 0$ with endogenous regressors. SHT delivers consistent and asymptotically efficient estimates of both β_3 and γ_2 at $\phi > 0$ and $\rho \neq 0$, while SFE yields consistent estimates for β_3 only. In Table 1, for $\rho = 0.6$ and $\phi = 0.5$, the RMSE of β_3 for OLS is 1.156 compared to 0.136 for SFE, 1.360 for SRE, and 0.144 for SHT. The corresponding

RMSE of γ_2 for OLS is 0.286 compared to 0.368 for SRE and 0.145 for SHT. Tests of hypotheses are misleading with OLS and SRE unless $\phi = 0$ but are properly sized for SFE and SHT at $\phi > 0$ and $\rho \neq 0$.

In an SRE world as in the lower panel of Table 1, there is no correlation between the regressors and the individual effects ($\psi = 0$). In this case, the SRE estimator gives a lower RMSE for β_3 than OLS, SFE, or SHT, especially with $\phi > 0$ and as ϕ increases. This is also true for γ_2 when comparing SRE to OLS or SHT. However, SHT is not far behind SRE in RMSE performance even if the true world is SRE.

In Table 2, we hold N constant at 100 and increase T from 3 to 5, while in Table 3, we hold T constant at 3 but increase N from 100 to 300. The purpose of these tables is to see how different sample sizes and time periods affect the performance of the estimators. By and large, we observe the same results as in Table 1, but with different bias and RMSE magnitudes. In general, the SHT and SFE estimators perform best in an SHT world, and the SRE and SHT estimators perform best in an SRE world in terms of RMSE.

In Tables 1-3, we considered the two cases of $\psi = 0$ or 1. In Table 4, we repeat the results from those tables for two alternative values of spatial autocorrelation, $\rho \in \{0.2, 0.4\}$, and for a sample size of $N = 100$ and $T = 3$ but at values of $\psi \in \{0, 0.1, 0.25, 0.5, 1\}$. The purpose of this table is to illustrate how the performance of the estimators changes with the degree of correlation between the regressors and the individual effects. In fact, the average correlation between μ and X_c and Z_c amounts to 0.928 and 0.519, respectively, at a true value of $\psi = 1$ and $\phi = 0.5$ and to 0.652 and 0.365, respectively, at a true value of $\psi = 0.5$ and $\phi = 0.5$. The results suggest that the SHT estimator outperforms the SRE and OLS estimators as ψ increases.

3.3 The Spatial Pretest Estimator

Table 5 shows the choice of the SPT estimator for various values of ρ and ϕ corresponding to the results in Tables 1-3 at values of $\psi = 1$ (SHT world) and $\psi = 0$ (SRE world). The upper left panel in Table 5 provides the results for $(N = 100, T = 3)$ for an SHT world. For example, at $\rho = 0.4$ and $\phi = 0.75$, the SPT estimator is an SHT estimator in 875 out of 1,000 replications, an SFE estimator in 51 replications, and an SRE estimator in the remaining 74 replications. As ϕ, N or T increases, the SPT estimator picks the SHT estimator more frequently. The performance of the SPT estimator reported in the upper panel of Table 1 is in between the SHT and the SRE estimators in terms of RMSE for both β_3 and γ_2. The size of tests for $H_0^a : \beta_3 = 1$, and $H_0^b : \gamma_2 = 1$ for SPT are obviously affected by the pretesting and are not recommended in practice.[5]

In the lower panel of Table 5, we show the choice of the SPT estimator for various values of ρ and ϕ corresponding to the results in Tables 1-3 in an SRE world. For example, at $\rho = 0.4$, $\phi = 0.75$, and $(N = 100, T = 3)$, the SPT estimator is an SRE estimator in 940 out of 1,000 replications, an SFE estimator in 18 replications, and an SHT estimator in the remaining 42 replications. As N or T increases, the SPT estimator picks the SRE estimator more frequently. The performance of the SPT estimator reported

[5] It is well known that the pretest estimator (based on the Hausman test in the first step and a simple hypothesis test in the second step) displays poor size and power properties, see Guggenberger (2010). This is confirmed by Baltagi, Bresson, and Pirotte (2003) using standard panel data Monte Carlo experiments and by our results here for their spatial counterparts. In fact, Guggenberger's (2010) recommendation of using a (one-step) t-test procedure based on the fixed effects estimator instead of a two-step procedure is a good idea even under the presence of spatial correlation. In this case, the researcher would use the t-test based on the SFE estimator instead of the two-stage procedure.

in the lower panel of Table 1 is in between the SRE and the SFE estimator in terms of RMSE for β_3. Again, the size of tests for $H_0^a : \beta_3 = 1$, and $H_0^b : \gamma_2 = 1$ for SPT are obviously affected by the pretesting.

4 Conclusions

This paper provides Monte Carlo evidence on the small sample performance of Cliff and Ord (1973) type spatial panel data estimators. We focus on Hausman and Taylor (1981) type panel data models with spatial disturbances. We find that the spatial Hausman and Taylor type estimator performs well in terms of root mean squared error in comparison to the spatial fixed effects, the spatial random effects, and the OLS estimators. An added advantage of the spatial Hausman-Taylor estimator is that it delivers estimates of endogenous time-invariant variables, unlike the spatial fixed effects model. Unlike the spatial random effects or the pooled OLS model, it allows regressors in the model to be correlated with the individual-specific effects.

We also investigate the performance of a spatial pretest estimator based on two Hausman tests. We find that the spatial pretest estimators perform particularly well if the heterogeneity due to the individual effects is relatively important and the associated problem of endogeneity of the regressors with the individual effects becomes more pertinent. The spatial pretest estimator guards against a possible misspecified choice of estimator and its RMSE performance is satisfactory, but tests of hypotheses using the SHT estimator are not recommended. Instead one should use the one-step SFE in practice, but unfortunately this applies to the time-varying regressor coefficients only.[6]

[6]Modern approaches to causal influence queries should be defined dynamically and should recognize the role of time in causality. This is an important problem for future research but is beyond the scope of this paper.

Appendix

All of the Monte Carlo runs are based on the following unnormalized weights matrix based on a three-before-and-three-behind design of neighborhood

$$\mathbf{W_0} = \begin{pmatrix} 0 & 1 & 1 & 1 & 0 & \cdots & 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 & 0 & \cdots & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 & 1 & 0 & \cdots & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & \cdots & 0 \\ 0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & 0 & \vdots & \vdots & \vdots & \vdots \\ 0 & \cdots & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & \cdots & 0 & 1 & 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & \cdots & 0 & 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & \cdots & 0 & 1 & 1 & 1 & 0 \end{pmatrix}.$$

Each row of this matrix exhibits a row-sum of 6. Hence, the row-normalized as well as the maximum row-sum normalized counterpart of that matrix is

$$\mathbf{W} = \begin{pmatrix} 0 & 1/6 & 1/6 & 1/6 & 0 & \cdots & 0 & 1/6 & 1/6 & 1/6 \\ 1/6 & 0 & 1/6 & 1/6 & 1/6 & 0 & \cdots & 0 & 1/6 & 1/6 \\ 1/6 & 1/6 & 0 & 1/6 & 1/6 & 1/6 & 0 & \cdots & 0 & 1/6 \\ 1/6 & 1/6 & 1/6 & 0 & 1/6 & 1/6 & 1/6 & 0 & \cdots & 0 \\ 0 & 1/6 & 1/6 & 1/6 & 0 & 1/6 & 1/6 & 1/6 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & 0 & \vdots & \vdots & \vdots & \vdots \\ 0 & \cdots & 0 & 1/6 & 1/6 & 1/6 & 0 & 1/6 & 1/6 & 1/6 \\ 1/6 & 1/6 & \cdots & 0 & 1/6 & 1/6 & 1/6 & 0 & 1/6 & 1/6 \\ 1/6 & 1/6 & 0 & \cdots & 0 & 1/6 & 1/6 & 1/6 & 0 & 1/6 \\ 1/6 & 1/6 & 1/6 & 0 & \cdots & 0 & 1/6 & 1/6 & 1/6 & 0 \end{pmatrix}.$$

The latter is employed in all experiments in that paper.

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Table 1 - Bias, RMSE and 5% test size, N=100 and T=3

Estimators for HT world with ψ=1

		OLS						Fixed effects (SFE)			Random effects (SRE)						Hausman-Taylor (SHT)						Pretest (SPT)					
		β_3			γ_2			β_3			β_3			γ_2			β_3			γ_2			β_3			γ_2		
ρ	ϕ	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size
0	0	0.001	0.145	3.9	0.000	0.176	4.8	0.003	0.144	3.7	0.000	0.144	3.3	0.000	0.177	4.8	0.003	0.143	4.4	-0.008	0.151	5.2	0.000	0.144	3.3	0.000	0.176	4.8
	0.25	0.205	0.971	100	0.096	0.289	31.3	-0.006	0.155	6	0.202	0.947	100	0.098	0.298	29.9	-0.005	0.155	6.1	0.006	0.152	5.5	0.124	0.648	64.6	0.066	0.246	21.4
	0.5	0.231	1.492	100	0.107	0.344	49.2	-0.004	0.155	6	0.227	1.444	100	0.111	0.364	46.5	-0.003	0.156	6.3	0.002	0.144	5	0.085	0.650	42.3	0.047	0.234	21.9
	0.75	0.241	2.246	100	0.111	0.419	74.1	-0.003	0.155	6	0.235	2.096	100	0.121	0.493	74.7	-0.001	0.156	6.1	-0.002	0.135	4.5	0.014	0.276	11.9	0.006	0.158	9.2
0.2	0	0.001	0.140	3.7	0.000	0.173	4.8	0.003	0.146	3.7	0.000	0.145	3.8	0.000	0.178	5	0.003	0.145	4.1	-0.007	0.152	5.2	0.000	0.145	3.8	-0.001	0.177	5.0
	0.25	0.206	0.965	100	0.096	0.291	30.9	-0.005	0.150	5.8	0.201	0.930	100	0.098	0.300	29.3	-0.005	0.155	6.4	0.006	0.153	5.5	0.125	0.646	65.6	0.066	0.250	21.1
	0.5	0.232	1.480	100	0.107	0.347	48.4	-0.004	0.150	5.8	0.225	1.487	100	0.111	0.372	47.5	-0.003	0.155	6.5	0.002	0.144	5.2	0.086	0.673	42.8	0.047	0.238	22.6
	0.75	0.242	2.225	100	0.111	0.430	72.9	-0.003	0.150	5.8	0.232	2.068	100	0.121	0.496	73.4	-0.001	0.153	6.1	-0.002	0.134	4.5	0.015	0.285	12.6	0.007	0.161	9.6
0.4	0	0.001	0.135	3.3	0.001	0.171	4.9	0.002	0.149	3.9	0.000	0.147	3.9	-0.001	0.179	5.3	0.002	0.147	4.3	-0.006	0.155	5.4	0.001	0.147	3.9	-0.001	0.178	5.3
	0.25	0.211	0.890	100	0.098	0.286	30.1	-0.004	0.143	5.8	0.197	0.915	100	0.096	0.298	29.3	-0.004	0.153	5.9	0.006	0.152	5.7	0.125	0.644	66.5	0.066	0.250	21.4
	0.5	0.238	1.390	100	0.110	0.336	44.6	-0.004	0.143	5.8	0.220	1.472	100	0.110	0.369	46.2	-0.002	0.153	5.9	0.001	0.145	4.6	0.089	0.690	44.3	0.048	0.240	22.3
	0.75	0.248	2.096	100	0.114	0.410	69.1	-0.002	0.143	5.8	0.226	1.947	100	0.121	0.490	71.9	0.000	0.148	5.7	-0.003	0.134	4.7	0.016	0.280	12.7	0.007	0.162	9.9
0.6	0	0.001	0.130	3.7	0.001	0.171	4.8	0.002	0.153	4	0.000	0.151	3.7	-0.001	0.178	5	0.002	0.151	5	-0.004	0.158	5.1	0.001	0.151	3.7	-0.001	0.177	5.0
	0.25	0.223	0.745	100	0.102	0.250	26.4	-0.004	0.136	5.6	0.191	0.902	100	0.094	0.298	29.1	-0.004	0.147	5.6	0.005	0.152	4.9	0.123	0.640	67.2	0.065	0.250	21.1
	0.5	0.252	1.156	100	0.115	0.286	38.6	-0.003	0.136	5.6	0.213	1.360	100	0.108	0.368	44	-0.002	0.144	5.8	0.001	0.145	4.5	0.089	0.662	45.9	0.049	0.244	22.1
	0.75	0.263	1.483	100	0.120	0.317	57.9	-0.002	0.136	5.6	0.217	1.780	100	0.121	0.475	68.4	0.000	0.141	5.8	-0.004	0.134	4.7	0.019	0.290	14.4	0.008	0.166	10.7

Estimators for RE world with ψ=0

		OLS						Fixed effects (SFE)			Random effects (SRE)						Hausman-Taylor (SHT)						Pretest (SPT)					
		β_3			γ_2			β_3			β_3			γ_2			β_3			γ_2			β_3			γ_2		
ρ	ϕ	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size
0	0	0.001	0.145	3.9	0.000	0.176	4.8	0.003	0.144	3.7	0.000	0.144	3.3	0.000	0.177	4.8	0.003	0.143	4.4	-0.008	0.151	5.2	0.000	0.144	3.3	0.000	0.176	4.8
	0.25	0.002	0.147	10.1	0.000	0.165	10.9	-0.006	0.155	6	0.001	0.150	5.3	0.001	0.157	4.4	-0.006	0.154	5.7	0.007	0.166	4.8	0.001	0.150	5.3	0.001	0.158	4.4
	0.5	0.002	0.146	14.8	-0.001	0.161	15.8	-0.004	0.155	6	0.001	0.137	4.5	0.001	0.152	5.3	-0.005	0.154	5.6	0.004	0.160	4.5	0.001	0.138	4.6	0.001	0.152	5.3
	0.75	0.003	0.153	19.4	-0.003	0.155	20	-0.003	0.155	6	0.001	0.128	4.7	0.000	0.150	5.5	-0.004	0.153	5.4	0.000	0.151	4.2	0.000	0.129	4.8	0.000	0.150	5.4
0.2	0	0.001	0.140	3.7	0.000	0.173	4.8	0.003	0.146	3.7	0.000	0.145	3.8	0.000	0.178	5	0.003	0.145	4.1	-0.007	0.152	5.2	0.000	0.145	3.8	-0.001	0.177	5.0
	0.25	0.002	0.148	9.6	0.000	0.162	11.3	-0.005	0.150	5.8	0.002	0.149	4.6	0.001	0.156	4.2	-0.006	0.154	5.8	0.008	0.163	5.4	0.001	0.149	4.7	0.002	0.156	4.3
	0.5	0.002	0.147	14.7	-0.002	0.158	16.4	-0.004	0.150	5.8	0.001	0.133	4.8	0.001	0.149	4.6	-0.005	0.153	5.5	0.004	0.156	4.4	0.001	0.134	4.8	0.001	0.149	4.6
	0.75	0.003	0.154	19.3	-0.003	0.154	20.4	-0.003	0.150	5.8	0.001	0.123	4.8	0.000	0.151	5	-0.003	0.152	5.3	0.001	0.151	4.4	0.001	0.125	4.8	0.000	0.151	5.0
0.4	0	0.001	0.135	3.3	0.001	0.171	4.9	0.002	0.149	3.9	0.000	0.147	3.9	-0.001	0.179	5.3	0.002	0.147	4.3	-0.006	0.155	5.4	0.001	0.147	3.9	-0.001	0.178	5.3
	0.25	0.002	0.150	9.4	0.000	0.160	10.9	-0.004	0.143	5.8	0.002	0.149	4.8	0.001	0.155	4	-0.005	0.153	5.6	0.008	0.161	5.1	0.001	0.149	4.9	0.002	0.155	4.0
	0.5	0.003	0.149	14.2	-0.002	0.156	16.6	-0.004	0.143	5.8	0.001	0.131	4.5	0.001	0.147	4.9	-0.004	0.153	5.3	0.005	0.155	4.4	0.001	0.132	4.6	0.001	0.147	4.9
	0.75	0.003	0.155	20	-0.003	0.153	20.4	-0.002	0.143	5.8	0.001	0.120	5.1	0.000	0.153	4.5	-0.003	0.151	5.5	0.001	0.152	4.6	0.001	0.122	5.1	0.000	0.153	4.5
0.6	0	0.001	0.130	3.7	0.001	0.171	4.8	0.002	0.153	4	0.000	0.151	3.7	-0.001	0.178	5	0.002	0.151	5	-0.004	0.158	5.1	0.001	0.151	3.7	-0.001	0.177	5.0
	0.25	0.002	0.151	9.5	-0.001	0.161	10.3	-0.004	0.136	5.6	0.002	0.151	5.3	0.002	0.155	3.7	-0.005	0.147	5.7	0.008	0.161	5.2	0.001	0.150	5.3	0.002	0.155	3.8
	0.5	0.003	0.150	14.6	-0.003	0.157	16.7	-0.003	0.136	5.6	0.001	0.130	4.4	0.001	0.146	4.4	-0.004	0.146	5.7	0.005	0.155	4.5	0.001	0.131	4.5	0.001	0.146	4.4
	0.75	0.003	0.156	20.6	-0.004	0.157	21.4	-0.002	0.136	5.6	0.001	0.118	4.7	0.000	0.151	4.5	-0.003	0.143	5.9	0.001	0.152	4	0.001	0.119	4.8	0.000	0.151	4.5

Table 2 - Bias, RMSE and 5% test size, N=100 and T=5

		Estimators for HT world with ψ=1																										
		OLS						Fixed effects (SFE)			Random effects (SRE)						Hausman-Taylor (SHT)						Pretest (SPT)					
		β_3			γ_2			β_3			β_3			γ_2			β_3			γ_2			β_3			γ_2		
ρ	ϕ	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size
0	0	-0.003	0.158	4.8	0.002	0.163	4.8	-0.006	0.152	4.7	-0.003	0.159	5	0.002	0.162	4.9	-0.006	0.153	5.1	-0.002	0.159	5.2	-0.003	0.159	5.0	0.002	0.162	4.9
	0.25	0.205	1.209	100	0.095	0.311	46.3	0.000	0.164	4.9	0.199	1.180	100	0.100	0.318	44.2	0.001	0.166	5	0.000	0.145	4	0.041	0.370	24.1	0.022	0.182	12.6
	0.5	0.231	1.822	100	0.107	0.381	70.7	0.000	0.164	4.9	0.223	1.703	100	0.116	0.413	69.8	0.002	0.165	5.1	0.000	0.146	4.4	0.008	0.211	7.9	0.004	0.154	6.5
	0.75	0.241	2.609	100	0.111	0.478	90.6	0.000	0.164	4.9	0.228	2.239	100	0.131	0.568	94.3	0.002	0.165	5.1	0.000	0.121	5.6	0.002	0.165	5.1	0.000	0.121	5.6
0.2	0	-0.003	0.157	4.9	0.002	0.162	4.4	-0.006	0.153	4.7	-0.003	0.160	5.3	0.002	0.162	5.1	-0.006	0.157	5	-0.002	0.161	5.1	-0.003	0.159	5.3	0.002	0.162	5.1
	0.25	0.206	1.240	100	0.096	0.290	46.3	-0.001	0.162	4.9	0.197	1.192	100	0.099	0.321	44.1	0.001	0.162	5.4	0.000	0.148	3.6	0.040	0.368	24.3	0.021	0.185	12.2
	0.5	0.232	1.993	100	0.108	0.344	69.4	-0.001	0.162	4.9	0.221	1.683	100	0.116	0.413	69.3	0.001	0.161	5.3	-0.001	0.142	4.6	0.009	0.217	8.8	0.004	0.152	7.2
	0.75	0.242	2.733	100	0.112	0.414	90.4	0.000	0.162	4.9	0.225	2.194	100	0.132	0.568	94.2	0.002	0.161	5.3	-0.001	0.117	4.9	0.002	0.161	5.3	-0.001	0.117	4.9
0.4	0	-0.003	0.158	4.5	0.002	0.164	4	-0.005	0.149	4.6	-0.002	0.161	5.2	0.002	0.160	5.1	-0.005	0.157	4.4	-0.002	0.163	4.7	-0.003	0.161	5.2	0.002	0.160	5.1
	0.25	0.211	1.224	100	0.099	0.265	45.2	-0.001	0.158	5	0.193	1.168	100	0.098	0.327	43.2	0.000	0.158	5.5	-0.001	0.152	3.8	0.040	0.366	24.9	0.021	0.190	12.3
	0.5	0.237	1.950	100	0.111	0.303	67.8	-0.001	0.158	5	0.215	1.649	100	0.116	0.423	68.7	0.001	0.157	5.6	-0.002	0.138	4.2	0.010	0.218	9.4	0.004	0.150	7.0
	0.75	0.248	2.487	100	0.115	0.351	85.5	-0.001	0.158	5	0.217	2.109	100	0.135	0.591	93.1	0.002	0.158	5.4	-0.002	0.114	5	0.001	0.158	5.4	-0.002	0.114	5.0
0.6	0	-0.004	0.160	4.6	0.002	0.166	4.2	-0.005	0.147	4.5	-0.002	0.162	5.1	0.002	0.159	4.8	-0.005	0.159	4.7	-0.002	0.162	5.3	-0.002	0.162	5.1	0.002	0.159	4.8
	0.25	0.223	1.136	100	0.105	0.234	41.1	-0.001	0.155	5	0.186	1.127	100	0.096	0.335	41.7	0.000	0.155	5.1	-0.001	0.153	4.1	0.041	0.373	26.4	0.022	0.196	12.9
	0.5	0.251	1.520	100	0.118	0.259	60.7	-0.001	0.155	5	0.206	1.600	100	0.115	0.441	66.8	0.001	0.154	4.9	-0.002	0.135	4	0.011	0.223	9.5	0.004	0.151	7.2
	0.75	0.262	1.819	100	0.123	0.290	74.9	-0.001	0.155	5	0.205	1.965	100	0.138	0.600	93.1	0.001	0.154	5.3	-0.003	0.111	4.7	0.001	0.154	5.3	-0.003	0.111	4.7

		Estimators for RE world with ψ=0																										
		OLS						Fixed effects (SFE)			Random effects (SRE)						Hausman-Taylor (SHT)						Pretest (SPT)					
		β_3			γ_2			β_3			β_3			γ_2			β_3			γ_2			β_3			γ_2		
ρ	ϕ	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size
0	0	0.002	0.131	4.4	0.001	0.159	4.9	0.000	0.154	4.6	0.002	0.131	4.4	0.001	0.155	4.8	0.000	0.154	4.7	0.005	0.150	4.6	0.002	0.132	4.4	0.002	0.155	4.8
	0.25	0.000	0.157	14.8	-0.002	0.157	15.8	0.001	0.156	5.5	0.000	0.132	6.2	-0.003	0.154	5.7	0.001	0.155	5.7	-0.006	0.161	5.4	0.000	0.133	6.2	-0.003	0.154	5.7
	0.5	0.000	0.156	23.4	-0.003	0.151	24	0.001	0.156	5.5	0.000	0.129	5.8	-0.004	0.150	5.1	0.001	0.156	5.9	-0.006	0.162	5	0.000	0.130	5.8	-0.004	0.151	5.1
	0.75	0.000	0.157	29.6	-0.004	0.152	31.1	0.000	0.156	5.5	0.000	0.132	5.5	-0.005	0.152	5.5	0.000	0.156	5.9	-0.005	0.146	4.9	0.000	0.134	5.5	-0.005	0.152	5.5
0.2	0	0.002	0.130	4	0.001	0.153	4.6	0.000	0.152	4.6	0.002	0.133	4.3	0.002	0.163	4.6	0.000	0.152	5	0.006	0.151	4.9	0.002	0.134	4.3	0.002	0.162	4.6
	0.25	0.000	0.156	15.5	-0.002	0.154	15.6	0.001	0.153	5.5	0.000	0.133	6.1	-0.003	0.158	5.7	0.001	0.153	5.8	-0.006	0.161	5.2	0.000	0.134	6.1	-0.003	0.158	5.7
	0.5	0.000	0.154	22.9	-0.003	0.148	24.6	0.001	0.153	5.5	0.000	0.130	5.7	-0.004	0.151	4.9	0.001	0.153	5.8	-0.006	0.161	5.2	0.000	0.131	5.7	-0.004	0.152	4.9
	0.75	0.000	0.153	29.6	-0.004	0.149	31.9	0.000	0.153	5.5	0.000	0.133	5.3	-0.005	0.152	5.5	0.000	0.153	5.9	-0.005	0.148	4.7	0.000	0.134	5.3	-0.005	0.152	5.5
0.4	0	0.002	0.130	4.6	0.001	0.149	4.8	0.000	0.150	4.6	0.002	0.135	4.3	0.002	0.164	4.4	0.000	0.150	5	0.007	0.153	4.7	0.002	0.136	4.3	0.002	0.164	4.4
	0.25	0.000	0.156	15.7	-0.002	0.151	15.7	0.001	0.152	5.5	0.000	0.134	5.7	-0.003	0.160	5.7	0.001	0.151	5.9	-0.005	0.162	5.2	0.000	0.135	5.7	-0.003	0.161	5.7
	0.5	0.000	0.152	23.3	-0.003	0.146	23.8	0.001	0.152	5.5	0.000	0.132	5.4	-0.004	0.153	4.9	0.001	0.151	5.7	-0.005	0.158	5.2	0.000	0.133	5.4	-0.004	0.153	4.9
	0.75	0.001	0.150	29.3	-0.003	0.147	32.8	0.001	0.152	5.5	0.000	0.132	5.1	-0.005	0.152	5	0.001	0.152	5.8	-0.005	0.150	4.4	0.000	0.133	5.1	-0.005	0.152	5.0
0.6	0	0.002	0.134	4.7	0.000	0.138	4.4	0.000	0.150	4.8	0.002	0.140	4.1	0.002	0.161	4.3	0.000	0.150	5.1	0.007	0.153	4.8	0.001	0.140	4.2	0.002	0.161	4.3
	0.25	0.000	0.157	14.8	-0.001	0.147	16	0.001	0.152	5.5	0.000	0.136	5.5	-0.003	0.161	5.4	0.001	0.151	5.8	-0.005	0.162	5.1	0.000	0.137	5.5	-0.003	0.161	5.4
	0.5	0.000	0.150	22.2	-0.002	0.144	23.6	0.001	0.152	5.5	0.000	0.132	5.1	-0.004	0.151	5	0.001	0.151	5.9	-0.005	0.153	5.1	0.000	0.133	5.1	-0.004	0.151	5.0
	0.75	0.001	0.145	27.9	-0.003	0.143	32	0.001	0.152	5.5	0.000	0.132	4.9	-0.005	0.150	5.1	0.001	0.151	5.8	-0.005	0.148	4.1	0.000	0.133	4.9	-0.005	0.150	5.1

Table 3 - Bias, RMSE and 5% test size, N=300 and T=3

Estimators for HT world with ψ=1

		OLS						Fixed effects (SFE)			Random effects (SRE)						Hausman-Taylor (SHT)						Pretest (SPT)					
		β_3			γ_2			β_3			β_3			γ_2			β_3			γ_2			β_3			γ_2		
ρ	ϕ	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size
0	0	-0.001	0.165	4.8	0.001	0.176	6.8	-0.002	0.167	6.3	-0.001	0.166	4.9	0.001	0.176	5.9	-0.002	0.168	6.5	0.001	0.142	5	-0.001	0.166	5.0	0.001	0.175	5.9
	0.25	0.207	1.615	100	0.095	0.454	71.8	-0.003	0.157	4.8	0.204	1.596	100	0.097	0.477	70.9	-0.002	0.155	5.1	0.003	0.162	5	0.031	0.390	20.5	0.020	0.217	16.7
	0.5	0.232	2.492	100	0.106	0.591	91.5	-0.002	0.157	4.8	0.228	2.496	100	0.110	0.619	91.6	-0.002	0.156	5.1	0.003	0.167	4.5	0.001	0.179	6.0	0.004	0.172	5.4
	0.75	0.242	3.735	100	0.110	0.755	99.7	-0.002	0.157	4.8	0.236	3.558	100	0.120	0.796	99.7	-0.001	0.157	4.9	0.003	0.171	4.5	-0.001	0.157	4.9	0.003	0.171	4.5
0.2	0	-0.001	0.167	4.9	0.001	0.173	6.4	-0.002	0.166	5.7	-0.001	0.167	5.2	0.000	0.177	5.9	-0.002	0.167	5.9	0.000	0.142	5.2	-0.001	0.167	5.2	0.000	0.175	5.9
	0.25	0.208	1.622	100	0.096	0.461	71.6	-0.003	0.152	5.4	0.203	1.585	100	0.096	0.459	70.6	-0.003	0.151	5.7	0.003	0.160	4.9	0.031	0.385	21.1	0.019	0.212	16.2
	0.5	0.233	2.507	100	0.107	0.583	90.9	-0.002	0.152	5.4	0.227	2.400	100	0.110	0.618	90.3	-0.002	0.152	5.6	0.003	0.160	4.9	0.001	0.176	6.6	0.004	0.165	5.9
	0.75	0.243	3.729	100	0.111	0.746	99.5	-0.002	0.152	5.4	0.233	3.486	100	0.120	0.794	99.7	-0.001	0.152	5.4	0.003	0.162	5.1	-0.001	0.152	5.4	0.003	0.162	5.1
0.4	0	-0.001	0.172	5.5	0.001	0.172	6.2	-0.002	0.167	5.1	-0.001	0.169	5	0.000	0.176	5.4	-0.002	0.167	5.6	-0.001	0.142	5.6	-0.001	0.169	5.0	0.000	0.175	5.4
	0.25	0.214	1.559	100	0.098	0.450	69.5	-0.003	0.149	5.4	0.199	1.534	100	0.094	0.441	69.3	-0.003	0.149	5.8	0.002	0.156	4.8	0.031	0.380	21.5	0.018	0.206	16.1
	0.5	0.240	2.453	100	0.110	0.561	89.5	-0.003	0.149	5.4	0.222	2.317	100	0.108	0.591	89.1	-0.002	0.149	5.7	0.002	0.154	5	0.001	0.179	7.0	0.004	0.160	6.2
	0.75	0.250	3.481	100	0.114	0.649	98.2	-0.002	0.149	5.4	0.227	3.365	100	0.119	0.787	99.6	-0.001	0.149	5.8	0.002	0.155	5.2	-0.001	0.149	5.8	0.002	0.155	5.2
0.6	0	-0.001	0.163	4.9	0.002	0.172	6.4	-0.002	0.167	5.3	-0.001	0.167	5.2	0.000	0.174	4.7	-0.002	0.166	5.7	-0.002	0.142	5.8	-0.001	0.167	5.2	0.000	0.173	4.7
	0.25	0.227	1.473	100	0.105	0.412	64	-0.003	0.147	5.5	0.192	1.500	100	0.091	0.422	66.3	-0.003	0.147	5.8	0.002	0.152	4.7	0.030	0.380	22.0	0.018	0.200	15.8
	0.5	0.255	2.243	100	0.117	0.475	83.1	-0.003	0.147	5.5	0.214	2.284	100	0.105	0.564	87.3	-0.002	0.147	5.8	0.002	0.148	5.5	0.002	0.188	7.6	0.004	0.157	7.1
	0.75	0.265	2.567	100	0.122	0.514	93.8	-0.002	0.147	5.5	0.217	3.357	100	0.118	0.784	99.5	-0.001	0.147	5.7	0.002	0.150	5.2	-0.001	0.147	5.7	0.002	0.150	5.2

Estimators for RE world with ψ=0

		OLS						Fixed effects (SFE)			Random effects (SRE)						Hausman-Taylor (SHT)						Pretest (SPT)					
		β_3			γ_2			β_3			β_3			γ_2			β_3			γ_2			β_3			γ_2		
ρ	ϕ	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size
0	0	-0.001	0.165	4.8	0.001	0.176	6.8	-0.002	0.167	6.3	-0.001	0.166	4.9	0.001	0.176	5.9	-0.002	0.168	6.5	0.001	0.142	5	-0.001	0.166	5.0	0.001	0.175	5.9
	0.25	-0.001	0.129	9.8	0.001	0.158	10.9	-0.003	0.157	4.8	-0.001	0.134	5	0.001	0.154	5.8	-0.003	0.157	5.1	0.003	0.162	5.2	-0.001	0.135	5.0	0.001	0.155	5.8
	0.5	-0.001	0.131	15.3	0.000	0.159	15.3	-0.002	0.157	4.8	-0.001	0.139	5.5	0.001	0.160	5.5	-0.002	0.157	5.1	0.003	0.159	4.5	-0.001	0.139	5.5	0.001	0.160	5.5
	0.75	-0.001	0.144	19	0.000	0.160	19.3	-0.002	0.157	4.8	-0.001	0.159	5.4	0.001	0.155	5.7	-0.002	0.157	5	0.003	0.155	4.7	-0.001	0.159	5.4	0.001	0.155	5.7
0.2	0	-0.001	0.167	4.9	0.001	0.173	6.4	-0.002	0.166	5.7	-0.001	0.167	5.2	0.000	0.177	5.9	-0.002	0.167	5.9	0.000	0.142	5.2	-0.001	0.167	5.2	0.000	0.175	5.9
	0.25	-0.001	0.128	9.3	0.001	0.154	11	-0.003	0.152	5.4	-0.001	0.133	5.5	0.001	0.161	5.5	-0.003	0.153	5.7	0.003	0.160	4.7	-0.001	0.134	5.5	0.001	0.161	5.5
	0.5	-0.001	0.129	15.6	0.001	0.154	15.2	-0.002	0.152	5.4	-0.001	0.139	5.6	0.001	0.163	5.2	-0.003	0.153	5.5	0.003	0.156	5	-0.001	0.140	5.6	0.001	0.163	5.2
	0.75	-0.001	0.141	18.8	0.000	0.159	18.9	-0.002	0.152	5.4	-0.001	0.160	5.4	0.001	0.157	5.6	-0.002	0.153	5.6	0.003	0.153	4.7	-0.001	0.159	5.4	0.001	0.156	5.6
0.4	0	-0.001	0.172	5.5	0.001	0.172	6.2	-0.002	0.167	5.1	-0.001	0.169	5	0.000	0.176	5.4	-0.002	0.167	5.6	-0.001	0.142	5.6	-0.001	0.169	5.0	0.000	0.175	5.4
	0.25	-0.001	0.129	9.2	0.001	0.150	11.2	-0.003	0.149	5.4	-0.001	0.133	5.2	0.001	0.168	5.4	-0.003	0.149	5.7	0.003	0.157	4.8	-0.001	0.134	5.2	0.001	0.168	5.4
	0.5	-0.001	0.128	15.9	0.001	0.149	14.9	-0.003	0.149	5.4	-0.001	0.141	5.3	0.001	0.165	5.5	-0.003	0.150	5.7	0.003	0.154	5	-0.001	0.141	5.3	0.001	0.164	5.5
	0.75	-0.001	0.138	20.4	0.001	0.155	19	-0.002	0.149	5.4	-0.002	0.161	5	0.001	0.159	5	-0.002	0.149	5.4	0.003	0.152	4.6	-0.002	0.160	5.0	0.001	0.159	5.0
0.6	0	0.000	0.179	4	0.000	0.138	4	-0.001	0.150	4.1	0.000	0.152	5	0.001	0.150	5.5	-0.001	0.151	4.4	0.010	0.145	4.3	0.000	0.152	5.0	0.001	0.150	5.5
	0.25	0.000	0.163	10.8	0.001	0.137	8.7	-0.002	0.145	5.7	0.000	0.157	6.2	0.001	0.125	3.5	-0.002	0.147	5.6	-0.009	0.150	4.8	0.000	0.156	6.2	0.000	0.125	3.5
	0.5	0.000	0.155	15.8	0.001	0.156	13.9	-0.001	0.145	5.7	0.000	0.151	6.2	0.000	0.134	3.2	-0.001	0.148	5.6	-0.008	0.152	4.7	0.000	0.151	6.2	0.000	0.135	3.3
	0.75	0.000	0.157	22	0.000	0.156	19.6	-0.001	0.145	5.7	0.000	0.152	5.6	0.000	0.152	3.8	-0.001	0.148	5.6	-0.007	0.154	4.2	0.000	0.151	5.6	0.000	0.152	3.8

Table 4 - Bias, RMSE and 5% test size, N=100 and T=3, at different correlation levels ψ

			Estimators																										
			OLS						Fixed effects (SFE)			Random effects (SRE)						Hausman-Taylor (SHT)						Pretest (SPT)					
			β_3			γ_2			β_3			β_3			γ_2			β_3			γ_2			β_3			γ_2		
ρ	ψ	ϕ	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size	Bias	RMSE	5% size
0.2	0	0	0.001	0.140	3.7	0.000	0.173	4.8	0.003	0.146	3.7	0.000	0.145	3.8	0.000	0.178	5	0.003	0.145	4.1	-0.007	0.152	5.2	0.000	0.145	3.8	-0.001	0.177	5.0
		0.25	0.002	0.148	9.6	0.000	0.162	11.3	-0.005	0.150	5.8	0.002	0.149	4.6	0.001	0.156	4.2	-0.006	0.154	5.8	0.008	0.163	5.4	0.001	0.149	4.7	0.002	0.156	4.3
		0.5	0.002	0.147	14.7	-0.002	0.158	16.4	-0.004	0.150	5.8	0.001	0.133	4.8	0.001	0.149	4.6	-0.005	0.153	5.5	0.004	0.156	4.4	0.001	0.134	4.8	0.001	0.149	4.6
		0.75	0.003	0.154	19.3	-0.003	0.154	20.4	-0.003	0.150	5.8	0.001	0.123	4.8	0.000	0.151	5	-0.003	0.152	5.3	0.001	0.151	4.4	0.001	0.125	4.8	0.000	0.151	5.0
	0.1	0	-0.003	0.148	5	-0.001	0.163	4.4	0.002	0.165	4.5	-0.003	0.144	4.7	-0.001	0.164	4.7	0.002	0.164	5.2	-0.015	0.144	5.9	-0.002	0.144	4.7	-0.002	0.163	4.7
		0.25	0.024	0.184	17	0.012	0.156	10.7	0.002	0.149	5.2	0.022	0.183	9.7	0.014	0.147	6.5	0.002	0.151	5	0.016	0.167	4.6	0.020	0.181	9.4	0.014	0.148	6.4
		0.5	0.026	0.192	24.3	0.014	0.156	15.6	0.002	0.149	5.2	0.022	0.200	10.6	0.019	0.143	7.3	0.002	0.151	5.1	0.014	0.169	4.5	0.021	0.197	10.3	0.019	0.144	7.2
		0.75	0.027	0.196	30.9	0.015	0.165	21.7	0.001	0.149	5.2	0.019	0.205	9.6	0.026	0.149	7.4	0.001	0.151	5.2	0.010	0.165	4.4	0.018	0.201	9.3	0.025	0.149	7.3
	0.25	0	0.001	0.140	3.7	0.000	0.173	4.8	0.003	0.146	3.7	0.000	0.145	3.8	0.000	0.178	5	0.003	0.145	4.1	-0.007	0.152	5.2	0.000	0.145	3.8	-0.001	0.177	5.0
		0.25	0.067	0.280	47.2	0.030	0.168	12.2	-0.005	0.150	5.8	0.062	0.306	32.1	0.033	0.174	6.8	-0.005	0.154	5.8	0.008	0.161	5.5	0.055	0.291	29.6	0.032	0.173	6.7
		0.5	0.075	0.310	67.4	0.031	0.166	17.6	-0.004	0.150	5.8	0.065	0.306	42.2	0.044	0.172	7.5	-0.004	0.154	5.3	0.004	0.154	4.2	0.057	0.288	37.9	0.040	0.170	7.2
		0.75	0.079	0.340	76	0.031	0.161	21.9	-0.003	0.150	5.8	0.058	0.274	41.7	0.060	0.182	9.6	-0.003	0.153	5.3	0.000	0.145	4.3	0.049	0.256	36.1	0.052	0.177	8.9
	0.5	0	0.001	0.140	3.7	0.000	0.173	4.8	0.003	0.146	3.7	0.000	0.145	3.8	0.000	0.178	5	0.003	0.145	4.1	-0.007	0.152	5.2	0.000	0.145	3.8	-0.001	0.177	5.0
		0.25	0.147	0.686	97.9	0.067	0.211	19.4	-0.005	0.150	5.8	0.139	0.633	95.1	0.071	0.225	16	-0.005	0.155	5.9	0.007	0.159	5.4	0.107	0.526	75.2	0.059	0.212	13.9
		0.5	0.165	0.812	100	0.074	0.213	26.1	-0.004	0.150	5.8	0.150	0.756	99.4	0.090	0.247	21	-0.003	0.155	5.7	0.003	0.148	4.5	0.097	0.547	66.9	0.062	0.215	15.7
		0.75	0.172	0.764	100	0.075	0.204	32	-0.003	0.150	5.8	0.141	0.742	99.6	0.118	0.279	32.6	-0.002	0.153	5.9	-0.001	0.138	4.2	0.056	0.392	43.8	0.050	0.199	16.4
	1	0	0.001	0.140	3.7	0.000	0.173	4.8	0.003	0.146	3.7	0.000	0.145	3.8	0.000	0.178	5	0.003	0.145	4.1	-0.007	0.152	5.2	0.000	0.145	3.8	-0.001	0.177	5.0
		0.25	0.206	0.965	100	0.096	0.291	30.9	-0.005	0.150	5.8	0.201	0.930	100	0.098	0.300	29.3	-0.005	0.155	6.4	0.006	0.153	5.5	0.125	0.646	65.6	0.066	0.250	21.1
		0.5	0.232	1.480	100	0.107	0.347	48.4	-0.004	0.150	5.8	0.225	1.487	100	0.111	0.372	47.5	-0.003	0.155	6.5	0.002	0.144	5.2	0.086	0.673	42.8	0.047	0.238	22.6
		0.75	0.242	2.225	100	0.111	0.430	72.9	-0.003	0.150	5.8	0.232	2.068	100	0.121	0.496	73.4	-0.001	0.153	6.1	-0.002	0.134	4.5	0.015	0.285	12.6	0.007	0.161	9.6
0.4	0	0	0.001	0.135	3.3	0.001	0.171	4.9	0.002	0.149	3.9	0.000	0.147	3.9	-0.001	0.179	5.3	0.002	0.147	4.3	-0.006	0.155	5.4	0.001	0.147	3.9	-0.001	0.178	5.3
		0.25	0.002	0.150	9.4	0.000	0.160	10.9	-0.004	0.143	5.8	0.002	0.149	4.8	0.001	0.155	4	-0.005	0.153	5.6	0.008	0.161	5.1	0.001	0.149	4.9	0.002	0.155	4.0
		0.5	0.003	0.149	14.2	-0.002	0.156	16.6	-0.004	0.143	5.8	0.001	0.131	4.5	0.001	0.147	4.9	-0.004	0.153	5.3	0.005	0.155	4.4	0.001	0.132	4.6	0.001	0.147	4.9
		0.75	0.003	0.155	20	-0.003	0.153	20.4	-0.002	0.143	5.8	0.001	0.120	5.1	0.000	0.153	4.5	-0.003	0.151	5.5	0.001	0.152	4.6	0.001	0.122	5.1	0.000	0.153	4.5
	0.1	0	-0.003	0.149	5.2	-0.002	0.165	4.5	0.002	0.167	4.4	-0.003	0.138	4.8	-0.001	0.165	4.8	0.002	0.163	5.6	-0.015	0.138	6.4	-0.002	0.139	4.8	-0.002	0.165	4.8
		0.25	0.024	0.196	16.8	0.011	0.156	10.7	0.002	0.150	4.7	0.021	0.180	9.7	0.014	0.146	6.4	0.002	0.152	5.2	0.016	0.165	4.2	0.020	0.178	9.4	0.014	0.147	6.3
		0.5	0.027	0.204	23.6	0.013	0.159	15.8	0.001	0.150	4.7	0.022	0.195	10.8	0.019	0.142	7.4	0.002	0.151	5	0.014	0.169	4.2	0.020	0.193	10.5	0.019	0.142	7.3
		0.75	0.028	0.196	29.6	0.014	0.166	21.9	0.001	0.150	4.7	0.019	0.203	9.4	0.026	0.148	7.7	0.001	0.152	5.1	0.011	0.168	4.3	0.018	0.200	9.1	0.026	0.149	7.6
	0.25	0	0.001	0.135	3.3	0.001	0.171	4.9	0.002	0.149	3.9	0.000	0.147	3.9	-0.001	0.179	5.3	0.002	0.147	4.3	-0.006	0.155	5.4	0.001	0.147	3.9	-0.001	0.178	5.3
		0.25	0.069	0.271	45.8	0.030	0.165	12	-0.004	0.143	5.8	0.061	0.305	32.3	0.033	0.179	6.9	-0.005	0.153	5.7	0.008	0.159	5.2	0.055	0.291	29.9	0.031	0.177	6.8
		0.5	0.077	0.302	66.1	0.032	0.167	17.2	-0.004	0.143	5.8	0.063	0.307	41.1	0.043	0.173	6.8	-0.004	0.153	5.4	0.004	0.153	4.1	0.056	0.289	37.0	0.039	0.171	6.5
		0.75	0.081	0.326	74	0.032	0.161	22.7	-0.002	0.143	5.8	0.057	0.270	41.1	0.059	0.182	9.4	-0.002	0.151	5.6	0.000	0.145	3.8	0.048	0.252	35.8	0.051	0.178	8.7
	0.5	0	0.001	0.135	3.3	0.001	0.171	4.9	0.002	0.149	3.9	0.000	0.147	3.9	-0.001	0.179	5.3	0.002	0.147	4.3	-0.006	0.155	5.4	0.001	0.147	3.9	-0.001	0.178	5.3
		0.25	0.150	0.657	97.9	0.068	0.205	18.2	-0.004	0.143	5.8	0.136	0.627	94.4	0.071	0.233	15.4	-0.004	0.154	5.6	0.007	0.158	5.5	0.105	0.523	74.9	0.058	0.218	13.5
		0.5	0.169	0.778	100	0.075	0.211	25.4	-0.004	0.143	5.8	0.147	0.729	99.3	0.089	0.244	20.8	-0.003	0.153	5.4	0.003	0.149	4.1	0.095	0.531	67.1	0.061	0.214	15.5
		0.75	0.176	0.734	100	0.077	0.196	31.6	-0.002	0.143	5.8	0.138	0.724	99.5	0.117	0.276	32.5	-0.001	0.150	5.5	-0.001	0.138	3.9	0.057	0.389	44.7	0.050	0.198	16.3
	1	0	0.001	0.135	3.3	0.001	0.171	4.9	0.002	0.149	3.9	0.000	0.147	3.9	-0.001	0.179	5.3	0.002	0.147	4.3	-0.006	0.155	5.4	0.001	0.147	3.9	-0.001	0.178	5.3
		0.25	0.211	0.890	100	0.098	0.286	30.1	-0.004	0.143	5.8	0.197	0.915	100	0.096	0.298	29.3	-0.004	0.153	5.9	0.006	0.152	5.7	0.125	0.644	66.5	0.066	0.250	21.4
		0.5	0.238	1.390	100	0.110	0.336	44.6	-0.004	0.143	5.8	0.220	1.472	100	0.110	0.369	46.2	-0.002	0.153	5.9	0.001	0.145	4.6	0.089	0.690	44.3	0.048	0.240	22.3
		0.75	0.248	2.096	100	0.114	0.410	69.1	-0.002	0.143	5.8	0.226	1.947	100	0.121	0.490	71.9	0.000	0.148	5.7	-0.003	0.134	4.7	0.016	0.280	12.7	0.007	0.162	9.9

Table 5 - Number of times the pretest estimator took on the spatial fixed effects (SFE), spatial random effects (SRE), and spatial Hausman-Taylor (SHT) in 1,000 simulations

		Configuration with ψ=1								
		N = 100, T = 3			N = 100, T = 5			N = 300, T = 3		
ρ	ϕ	SFE	SRE	SHT	SFE	SRE	SHT	SFE	SRE	SHT
0	0	15	947	38	19	941	40	21	943	36
	0.25	42	623	335	61	201	738	79	163	758
	0.5	57	384	559	64	30	906	69	10	921
	0.75	67	62	871	69	0	931	79	0	921
0.2	0	15	946	39	22	938	40	21	944	35
	0.25	37	633	330	58	200	742	50	163	787
	0.5	55	389	556	64	37	899	59	11	930
	0.75	62	69	869	61	0	939	66	0	934
0.4	0	17	947	36	26	934	40	21	940	39
	0.25	35	644	321	50	206	744	48	167	785
	0.5	43	408	549	52	41	907	48	14	938
	0.75	51	74	875	54	0	946	58	0	942
0.6	0	13	952	35	26	938	36	19	943	38
	0.25	27	653	320	48	224	728	43	172	785
	0.5	43	426	531	50	48	902	49	19	932
	0.75	41	91	868	52	0	948	52	0	948
		Configuration with ψ=0								
		N = 100, T = 3			N = 100, T = 5			N = 300, T = 3		
ρ	ϕ	SFE	SRE	SHT	SFE	SRE	SHT	SFE	SRE	SHT
0	0	15	947	38	26	946	28	21	943	36
	0.25	23	935	42	12	950	38	13	960	27
	0.5	19	940	41	14	951	35	16	959	25
	0.75	19	938	43	9	951	40	14	954	32
0.2	0	15	946	39	25	947	28	21	944	35
	0.25	20	934	46	10	957	33	16	957	27
	0.5	19	938	43	14	953	33	13	960	27
	0.75	16	944	40	10	954	36	15	950	35
0.4	0	17	947	36	24	946	30	21	940	39
	0.25	22	935	43	12	955	33	19	951	30
	0.5	19	940	41	11	959	30	13	956	31
	0.75	18	940	42	9	950	41	14	954	32
0.6	0	13	952	35	20	944	36	22	952	26
	0.25	19	936	45	14	950	36	16	953	31
	0.5	20	938	42	12	957	31	20	946	34
	0.75	18	936	46	11	948	41	19	943	38