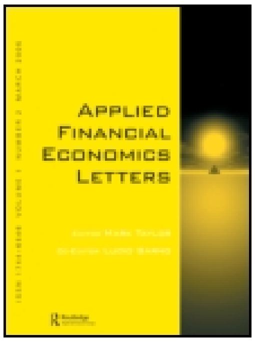

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Statistical analysis of municipal bond ratings under spatial correlation

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This study uses a spatial logit model to evaluate the statistical effect of conditions of communities on municipal bond ratings. It finds that private (non-farm) earnings in the community positively explain bond ratings with statistical significance, while earnings from personal transfers negatively affect ratings. Own source of revenues of local governments (local taxes) increase ratings and inter-governmental revenues (transfers to local governments) negatively impact ratings. Outstanding debt fails to significantly explain ratings. The composition of the local economy (e.g., the service sector) weights heavily in a rating, and proximity of the local government to areas with high municipal bond ratings increases ratings.

I. Introduction

To borrow resources needed for capital investment, communities often issue bonds to the public. The yield of the bond depends on the current prime rate and on the risk of default of the debt. Standard & Poor's Ratings Service, for example, extracts information on risk for investors in municipal bonds (Public Securities Association, 1998). A lower rating increases borrowing costs and limits fund-raising options. By definition, agency ratings of municipal public finances depend on the local government ability to pay its obligations held on bonds (Gailen and Warga, 1987; Ederington *et al*., 1987). Furthermore, since economic conditions are largely regional (e.g., Dubin, 1995; Sarmiento, 2005), the location of a community relative to others may influence a rating.

To evaluate the statistical effect of conditions of communities on municipal bond ratings, this study implements an *ordered* logit model that accounts for spatial correlation in the ratings of local government bonds. The model distinguishes the effect of local government own revenues (local taxes) from inter-governmental revenues on ratings (transfers from the federal and state governments to local governments) and captures the relation between outstanding debt and municipal bond ratings. Municipal bond ratings are also defined in terms of community characteristics. These include earnings from the production of goods and services, dependency on earnings from personal transfers to individuals, and the type of economic sector that dominates the local economy. In addition to the characteristics of the municipality, the spatial logit model allows the geographical distance to neighbouring municipalities and their characteristics (ratings) to explain bond ratings.

II. A Spatial Model of Bond Ratings

A Standard & Poor's rating is an opinion on the creditworthiness of the municipality. The rating is not a recommendation to purchase or sell, but rather

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a recommendation on credit suitability to the investor. The main component of the rating is the municipality capacity to pay its obligations. An obligation rated ‘AAA’ has the highest rating assigned in Standard & Poor’s system. A rating of ‘AA’ only differs from ‘AAA’ to a small degree with municipality’s capacity to pay the bond at very high level. An obligation of ‘A’ is more susceptible to changes of circumstances and economic conditions, whereas a rating of ‘BBB’ is even more susceptible to changes of those conditions. Bonds with ratings lower than ‘BBB’ are considered speculative investments. Aitchison and Silvey (1957) first considered an ordered-response model to estimate marginal response to problems that involve rankings or an order of choice, whereas Cox (1970) first discussed the ordered logit model.

To measure the determinants of bond ratings, an *ordered* discrete choice model is specified with the Standard & Poor’s rating of the municipality as the dependent variable. This rating depends on the economic and financial conditions of the community (Kaplan and Urwitz, 1978). The risk on debt acquired by a local government is related to its outstanding debt D, as well as sources of revenue from local sources (local taxes) R and intergovernmental revenues T (transfers from the centre to the local government).[1] The solvency of local government finances is also likely to depend on the municipal per capita income Y and population P. The composition of the local economy (e.g., service sector) also explains risks related to earnings in the region, which introduces uncertainty to local government revenues. Municipal bond ratings may thus depend on whether the main sector of the local (municipal) economy is manufacture M, services S, or non-specialized, NS. Furthermore, to explain ratings, total private (non-farm) earnings are included in the municipality PE, total farm earnings FE, as well as earnings from personal transfers to individuals TE. Earnings to the local economy from personal transfers TE include health insurance payments, unemployment benefits, Medicare, and Medicaid.

The probability of a rating k in an *ordered* logit model (Maddala, 1996, p. 48) is:

$$\text{Prob}(Y_{jk} = 1) = \Gamma(\alpha_k - I_j) - \Gamma(\alpha_{k-1} - I_j) \qquad (1)$$

where

$$I_j = \alpha + \beta_1 FE_j + \beta_2 PE_j + \beta_3 TE_j + \beta_4 P_j + \beta_5 Y_j + \beta_6 D_j + \beta_7 R_j + \beta_8 T_j \beta_9 M_j + \beta_{10} S_j + \beta_{11} NS_j$$

and, if $\Gamma(\cdot)$ is a logistic distribution (Cox, 1970), then

$$\Lambda_{j1} = \text{Prob}\,(Y_{j1} = 1) = \frac{1}{1+\exp(-\alpha_1 + I_j)}, \text{ and}$$

$$\Lambda_{jk} = \text{Prob}\,(Y_{jk} = 1) = \frac{1}{1+\exp(-\alpha_k + I_j)} - \frac{1}{1+\exp(-\alpha_{k-1} + I_j)}, \quad \text{for } k > 1,$$

where $\alpha_k > \alpha_{k-1} \geq \alpha_1 = 0$; and $Y_{jk} = 1$ if the bond rating of observation j is k, and $Y_{jk} = 0$, otherwise.[2]

The probability of a given rating may also depend on whether neighbouring municipalities received the same rating. A spatial discrete lagged dependent variable may thus be needed in the index function of Equation 1:

$$SL_j = \sum_{h \neq j} D_{jh} \exp(-Dist_{jh}/\gamma) \qquad (2)$$

where $D_{jh} = 1$ if municipality j receives the same ratings than municipality h, and $D_{jh} = 0$ otherwise; and $Dist_{jh}$ is the distance between municipalities j and h. The logistic regression with spatial correlation in the choice set, therefore, uses

$$I_j^* = I_j + \beta_{12} SL_j(\gamma) = \mathbf{X}_j(\gamma)\boldsymbol{\beta} \qquad (3)$$

where if $\beta_{12} > 0$, then the probability of a rating k increase if neighbouring municipalities also receive a rating k; and the parameter γ is the scale parameter for distance. A positive value for γ is consistent with the premise that transportation costs increase at a decreasing rate.

To estimate spatial correlation, Sarmiento and Wilson (2005, 2006) derive the concentrated likelihood function in terms of the spatial correlation coefficient in a *bivariate* choice model. This study, instead, concentrates the likelihood function of the *ordered* logistic model in terms of the non-linear coefficient in the spatial correlation function, which results in an algorithm that converges easily. In particular, the estimator of Equation 1 with the index function in Equation 3 is obtained by solving the optimization:

$$\underset{\gamma}{\text{Max}} \ln L(\gamma) \qquad (4)$$

$$\text{s.t.} \sum_{j=1}^{n}\sum_{k=1}^{m} Y_{jk}\frac{\phi_{jk}}{\Lambda_{jk}} X_j(\gamma) = \mathbf{0}, \quad \text{for } \phi_{jk} = \partial\Lambda_{jk}/\partial I_j$$

$$\sum_{j=1}^{n}\sum_{k=1}^{m} Y_{jk}\frac{f_{jkw}}{\Lambda_{ik}} = 0, \quad \text{for } f_{jkw} = \partial\Lambda_{jk}/\partial\alpha_w \text{ and } w > 1,$$

[1] These refer to intergovernmental revenues received from the state and Federal governments.
[2] A larger number rating reflects a higher bond rating.

Table 1. Summary statistics

Variables	Mean	Standard deviation
AAA Rating	0.08	NA
AA Rating	0.39	NA
A Rating	0.46	NA
BBB or lower Rating	0.07	NA
FE_j – Farm Earnings (millions dollars)	20.96	35.06
PE_j – Priv. Earnings (millions dollars)	3728.39	5495.38
TE_j – Personal Trans. (millions dollars)	604.09	594.84
P_j – Population (thousands)	189.25	189.05
Y_j – Income (thousands dollars)	31.47	8.02
D_j – Debt (millions dollars)	103.44	126.60
R_j – Local Revenues (millions dollars)	91.05	94.58
T_j – Transfers (millions dollars)	52.98	59.66
M_j – Manufacturing Code	0.358	NA
S_j – Services Code	0.28	NA
NS_j – Non-specialized Code	0.239	NA

Table 2. Estimated log-likelihood function for different values of the scale parameter for distance

γ	Log-likelihood
1	−126.97
2	−126.97
3	−126.97
5	−126.64
7	−125.60
8	−125.10
9	−124.77
10	−124.59
11	−124.53
11.5	−124.520
12	−124.524
12.5	−124.53
13	−124.55
14	−124.58
15	−124.61
16	−124.65
17	−124.67
20	−124.74
30	−124.78
100	−125.50
1000	−126.14

where

$$\ln L(\gamma) = \sum_{j=1}^{n}\sum_{k=1}^{m} Y_{jk} \ln\{\Lambda_{jk}\}$$

and $Y_{jk} = 1$ if the bond rating of observation j is k, and $Y_{jk} = 0$, otherwise.

III. Data

The statistical analysis of municipal bond ratings uses Standard & Poor's bond ratings collected from 380 communities that issued debt (available from S&P ratings direct) and that had local government finance surveyed in the *Statistical Abstract of the United States 2003* (CD-ROM version). Data on local government include intergovernmental revenues (transfers from state/Federal government to local governments), outstanding debt, and own sources of local government revenues (local taxes). Economic indicators for each of these communities were extracted from the *US Bureau of Economic Analysis*. These include local per capita income and population, and composition of earnings of the local economy. Information on economic typology (code of the municipality with respect to main economic sector) at each municipality was extracted from the *US Census*. Distances from the centre of each municipality to other municipalities are measured with Arc-GIS.

With the extracted data summarized in Table 1, the non-linear logit model in Equation 4 is estimated. Table 2 shows convergence of the estimate of γ at the maximum likelihood using GAUSS. For the estimated scale parameter γ (Table 2) the degree of municipality inter-relation intensifies as municipalities are more closely located to each other. Table 3 reports coefficient estimates of the spatial ordered logit model in Equation 1.

IV. Results

Municipal bond ratings depend on the solvency of local public finances as well as the risk that a local government would default debt. A larger tax base, for example, is likely to generate higher ratings because the debt service is primarily paid from future revenues locally collected. Table 3 shows that a larger local tax base generates higher bond ratings. Intergovernmental revenues, however, have a negative effect on bond ratings at the 95% confidence level. Intergovernmental revenues consist of inflow transfers (from the Federal and state governments) to local governments. The results, moreover, fail to demonstrate that the debt

Table 3. Maximum likelihood estimates of the spatial ordered logistic for bond ratings

Variables	Coefficient estimate	*t*-value
Constant	−4.118	−4.02*
FE_j – Farm earnings	0.006	0.99
PE_j – Private earnings	0.001	2.59*
TE_j – Personal transfers	−0.009	−5.26*
P_j – Population	0.103	2.82*
Y_j – Income	0.087	2.2*
D_j – Debt	−0.001	−0.48
R_j – Local revenues	0.016	3.43*
T_j –Transfers	−0.020	−3.24*
M_j – Manufac. code	−0.160	−0.42
S_j – Services code	1.185	2.74*
NS_j – Non-Spec. code	−0.442	−0.95
$SL_j(\gamma)$ – Spatial lag	0.100	2.18*
Log-likelihood	−124.52	

Notes: The asterisk (*) indicates statistical significance at the 95% confidence level.

outstanding is statistically correlated with bond ratings at the 95% confidence level.

Economic conditions of the communities also explain municipal bond ratings. Table 3 shows that municipal bond ratings increase with the population of the municipality and the local economy capacity to generate earnings from the production of goods and services. Private non-farm earnings explain higher bond ratings at the 95% confidence level. Other forms of earnings to individuals are personal transfers. Personal transfers include insurance benefits and federal aid for the poor and disadvantaged (e.g., unemployment benefits and Medicaid). More broadly, these transfers capture economies dependency on government programs that support segments of society that do not directly contribute to the production of goods and services. From Table 3, earnings from personal transfers negatively affect the rating. Agency ratings then reflect the criteria that government transfers to dependent population in the municipality do not contribute to local economies, but instead represent a significant risk factor on the local government finances.

Coefficient estimates on the typology codes of each region (code of the main economic sector in the municipality) show that economies with large share of earnings from the service sector receive significantly higher ratings. This may arise because the service sector is the most competitive sector in the US economy. For example, in 2000, the US trade deficit was $450 billion, while the US trade in services ran a surplus of $80 billion. The service sector is also more robust against economic cycles and less vulnerable to over-investment than other sectors (e.g., the manufacturing sector). Farm earnings do not significantly explain ratings at the 95% confidence level presumably because of the relative size of the farm sector in the US economy.

In addition to the characteristics of the municipality, the geographical distance to neighbouring municipalities and their characteristics (ratings) may explain bond ratings. For example, the workplace is often in a different municipality to the place of residence. Industries are also often vertically and horizontally integrated across space. From Table 3, the estimated sign of the spatial correlation indicates that a high rating in a municipality increases with statistical significance the probability that the neighbouring location also has a high rating at the 95% confidence level. Rating agencies thus perceive regional links to well functioning economies to be a source of solvency in local government finances, increasing ratings. Furthermore, from the spatial correlation coefficient, an economic shock that leads to an upgrade (or downgrade) of the rating in a municipality is likely to have a spill-over effect.

V. Conclusion

In the spatial ordered logit model, it was found that private (non-farm) earnings in the community positively explain bond ratings with statistical significance, while earnings from personal transfers negatively affect the rating. Own source of revenues of local governments (local taxes) increase ratings, and inter-governmental revenues (transfers to local governments) negatively affect ratings. Somewhat surprisingly, outstanding debt fails to significantly explain lower ratings. The composition of the local economy (e.g., the service sector) weights heavily in a rating, and proximity of the local government to areas with high municipal bond ratings increases ratings. Statistically, it was found that the most important factors in explaining ratings are local government's own sources of revenues and personal transfers to individuals. Agency ratings, in particular, reflect the criteria that government transfers to dependent population in the municipality do not contribute to the local economies, but instead represent a significant risk factor on the local government finances.

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