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# In search of robust methods for dynamic panel data models in empirical corporate finance

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ABSTRACT

We examine which methods are appropriate for estimating dynamic panel data models in empirical corporate finance. Our simulations show that the instrumental variable and GMM estimators are unreliable, and sensitive to the presence of unobserved heterogeneity, residual serial correlation, and changes in control parameters. The bias-corrected fixed-effects estimators, based on an analytical, bootstrap, or indirect inference approach, are found to be the most appropriate and robust methods. These estimators perform reasonably well even in models with fractional dependent variables censored at [0,1]. We verify these results in two empirical applications, on dynamic capital structure and cash holdings.


## 1. Introduction

Many empirical studies in corporate finance use dynamic panel data models to investigate the dynamic behavior of a financial policy of interest. In the corporate payout literature, several studies have examined the degree of dividend smoothing by estimating Lintner's (1956) partial adjustment model (e.g., Brav et al., 2005; Skinner, 2008; Andres et al., 2009). In the capital structure literature, researchers have used this dynamic model extensively to study how quickly firms adjust toward their long-run target leverage ratios.[3] The use of dynamic panels is also common in other areas of corporate finance.[4]

Despite the growing popularity of dynamic panel data models, they are difficult to estimate due to the likely presence of firm fixed effects and several complexities in empirical corporate finance, such as unobserved heterogeneity and endogeneity, residual serial correlation, and the fractional nature of the dependent variable. To begin with, due to the correlation between the fixed effects and the lagged dependent variable, the pooled OLS (hereafter POLS) estimator is biased and inconsistent. The fixed-effects (hereafter FE) method also estimates these models with a finite-sample bias (Nickell, 1981). Previous simulation results (e.g., Judson and Owen, 1999) suggest that this bias is likely to be substantial for corporate finance studies, which typically analyze annual company data over a relatively short period. The econometrics literature has advanced two main approaches to deal with this bias. The first involves using instruments for the lagged dependent variable, and comprises five methods: the just-identified instrumental variable estimator (hereafter AH-IV) (Anderson and Hsiao, 1981), the first-difference generalized methods of moments estimator (hereafter FD-GMM) (Arellano and Bond, 1991), the system GMM estimator (hereafter SYS-GMM) (Blundell and Bond, 1998), and the long-difference GMM estimator (hereafter LD-GMM or LDP-GMM, depending on long-difference parameters used) (Hahn et al., 2007; Huang and Ritter, 2009). The second approach, consisting of three estimators, corrects for the estimation bias

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[1] Tel.: +44 (0)161 275 0438.
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[3] See Jalilvand and Harris (1984); Ozkan (2001); de Miguel and Pindado (2001); Fama and French (2002); Flannery and Rangan (2006); Kayhan and Titman (2007); Antoniou et al. (2008); Lemmon et al. (2008); Byoun (2008); Huang and Ritter (2009); Öztekin and Flannery (2012); Faulkender et al. (2012); and Warr et al. (2012).
[4] See, for example, studies of cash holdings by Opler et al. (1999); Ozkan and Ozkan (2004); and Bates et al. (2009), studies of corporate investment by Aivazian et al. (2005a); Aivazian et al. (2005b), studies of debt maturity by Ozkan (2000) and Antoniou et al. (2006), and studies of corporate governance by Wintoki et al. (2012).

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either analytically, or by simulation. Specifically, these estimators either develop bias correction formulas in the (fixed-effects) least-squares dummy variable model (hereafter LSDVC) (Kiviet, 1995; Bruno, 2005), or approximate the bias function and search for unbiased estimates using an iterative bootstrap-based correction procedure (hereafter BC) (Everaert and Pozzi, 2007), or a simulation-based indirect inference method (hereafter II) (e.g., Gouriéroux et al., 2010). Although these advanced methods should, in theory, reduce the POLS and FE bias, little is known about their performance in the presence of the complex issues listed above. In what follows, we briefly discuss the possible sources of those issues and their effects on the IV/GMM and bias-corrected estimators.

First, unobserved heterogeneity and endogeneity, caused by non-zero correlation between the firm fixed effects and a regressor, is a common problem in corporate research (Roberts and Whited, 2011; Wintoki et al., 2012). This problem may affect the performance of the estimators that assume the strict exogeneity of the explanatory variables. The second issue is the likely presence of residual autocorrelation, which violates one of the most important assumptions of the IV/GMM estimators, and renders their instruments invalid (Arellano and Bond, 1991). In empirical corporate research, serial correlation may be caused by the persistence of the financial variable (Lemmon et al., 2008), the presence of measurement errors (Welch, 2011; Roberts and Whited, 2011), or the use of an incorrect functional form (e.g., non-linear versus linear models).[5] The third problem concerns the measurement of the dependent financial variable. The financial policy variable under consideration (e.g., leverage or debt maturity) can be a ratio bounded by the unit interval [0, 1]. Since the IV/GMM and bias-corrected approaches listed above were originally developed for continuous, unbounded dependent variables, their properties may be affected if the dependent variable is fractional (Loudermilk, 2007).

In this paper, we examine which of the existing estimators are most appropriate and robust for dynamic panels in empirical corporate finance, especially in the likely presence of unobserved heterogeneity, autocorrelation, and fractional dependent variables. As mentioned above, we consider five IV/GMM estimators, AH-IV, FD-, SYS-, LD-, and LDP-GMM, as well as three bias-corrected estimators, LSDVC, BC, and II. We also examine an augmented doubly-censored Tobit estimator (termed DPF by Elsas and Florysiak (2015)) that accounts for the fractional nature of the dependent variable (Loudermilk, 2007). We conduct Monte Carlo simulation studies and empirical applications in order to examine the performance of these estimators.

Our simulation studies show that the bias-corrected estimators, LSDVC, BC, and II, are generally the most appropriate and robust methods for dynamic panel data models in empirical corporate finance. These estimators estimate the coefficient on the lagged dependent variable (i.e., the autoregressive coefficient) and those on the explanatory variables with the most accuracy and efficiency. Among the three, BC performs well in regressions with residual autocorrelation and in specifications with high lag orders. In a special case where the dependent variable is a ratio, censored at 0 and 1, LSDVC, BC, and II may still provide reasonable estimates with a moderate amount of bias, although, at a high percentage of censoring (e.g., more than 20%), DPF emerges as the most robust method.

Our results further suggest that the IV/GMM estimators are outperformed by the bias-corrected methods. The IV/GMM estimates, especially those for the autoregressive coefficient, tend to be unreliable in most of our simulation experiments. Crucially, these methods are very sensitive to the presence of unobserved heterogeneity and serially correlated errors where their instruments become invalid. There are only a few conditions under which these methods would be useful. For example, SYS-GMM could be used for regressions without unobserved heterogeneity, endogeneity, and autocorrelation. In empirical research, however, these conditions are rather restrictive and unlikely to be met. In short, our paper highlights the potential drawbacks of using the IV/GMM estimators in empirical corporate finance.

We verify our simulation results using two empirical applications to dynamic capital structure and cash holdings. In the first application, the dependent variable, leverage, is a ratio bounded by the unit interval, while, in the second, the dependent variable, cash holdings, is measured by the natural logarithm of the cash-to-net-assets ratio, i.e., a continuous, unbounded variable. In these applications, one of our main objectives is to estimate the speeds with which firms adjust toward their target leverage and cash holdings, respectively. We find that LSDVC, BC, and II produce the most plausible estimates of the speeds of dynamic leverage and cash adjustments, as well as the most reasonable coefficients on the explanatory variables, consistent with prior theoretical predictions. In the leverage application, these bias-corrected methods obtain similar speeds of leverage adjustment, ranging between 24% and 28%. DPF, the only method that explicitly accounts for the fractional nature of leverage, yields a similar estimate of 27%. The estimates obtained using FD-, SYS-, and LD-GMM vary between 15% and 18%, putting them very close to the (biased) POLS estimate; these estimates are unreliable because their fundamental assumptions of instrument validity and no autocorrelation are both violated according to our diagnostic tests. In the cash application, we find similar results regarding the performance of the estimators: LSDVC, BC, and II again produce similar estimates of the speed of cash adjustment, at 48–49%.

Our study is related to previous simulation studies in the econometrics literature (Kiviet, 1995; Judson and Owen, 1999; Bun and Kiviet, 2003; Bruno, 2005; Bun and Carree, 2006; Everaert and Pozzi, 2007). Our simulations maintain the rigor of these studies in terms of properly controlling for two key parameters in dynamic panel data models, namely the magnitude of the fixed effects relative to that of the idiosyncratic error (i.e., the loading factor) and the explanatory power of the regressors relative to that of the disturbances (i.e., the signal-to-noise ratio).[6] However, we extend these general simulation studies by considering issues relevant to empirical corporate finance. We use data-generating processes that mimic actual company panel data and, moreover, explicitly allow for unobserved heterogeneity, endogeneity, and residual serial correlation. We also conduct additional simulation experiments to examine the properties of the alternative econometric methods when the dependent financial variable of interest is fractional and bounded by the unit interval. Hence, our findings and conclusions are directly applicable to empirical research in corporate finance.

Finally, our study is related to a recent simulation study by Flannery and Hankins (2013, hereafter FH).[7] However, our study differs from, and improves on, their analysis in many important

[5] There is evidence of residual autocorrelation in empirical research. The results of our studies on capital structure and cash holdings confirm that the test for no serial correlation is frequently rejected.

[6] In empirical capital structure research, Lemmon et al. (2008) show that the variation in leverage is mainly explained by the firm fixed effects (60%), as opposed to the independent variables (18%). Hence, it is important to examine the impact of the relative magnitude of the fixed effects on the properties of the estimators.

[7] In a contemporaneous study, Zhou et al. (2014) examine a method of (linear) bias correction for the estimate of the speed of adjustment (SOA) in dynamic capital structure models. They further propose a global minimum variance (GMV) combined estimator to approximate a consensus SOA estimate, which is a GMV-weighted average of the (bias-corrected) estimates obtained using six popular baseline estimators, including OLS, FE, FD-, SYS-, LD-GMM, and LSDVC. This pooled estimation approach is, however, different from ours, which is to evaluate the relative performance of single estimation methods. Further, it mainly focuses on reducing the bias in the autoregressive coefficient (i.e., the SOA) and does not consider three recently developed bias-corrected estimators, namely BC, II, and DPF.