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Trends in statistically based quarterly cash-flow prediction models

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ABSTRACT

This paper provides a succinct review and synthesis of the literature on statistically based quarterly cash-flow prediction models. It reviews extant work on quarterly cash-flow prediction models including: (1) complex, cross-sectionally estimated disaggregated-accrual models attributed to Wilson (1986, 1987) and Bernard and Stober (1989), (2) parsimonious ARIMA models attributed to Hopwood and McKeown (1992), (3) disaggregated-accrual, time-series regression models attributed to Lorek and Willinger (1996), and (4) parsimonious ARIMA models with both adjacent and seasonal characteristics attributed to Lorek and Willinger (2008, 2011). Due to the unavailability of long-term cash-flow forecasts attributed to analysts, increased importance has been placed upon the development of statistically based cash-flow prediction models given their use in firm valuation. Specific recommendations are also provided to enhance future research efforts in refining extant statistically based quarterly cash-flow prediction models.

1. Introduction

This paper provides an overview and synthesis of research devoted to statistically based, quarterly cash-flow prediction models, a topic of considerable interest to academic researchers in accounting and finance, financial analysts, standard-setting boards like the Financial Accounting Standards Board (FASB) and the International Accounting Standards Board (IASB), and retail investors. It is timely to undertake this task due to recent empirical findings (e.g., Lorek & Willinger, 2011) that have considerably altered the understanding of: (1) the key time-series properties of reported quarterly cash-flow from operations (CFO), (2) the joint impact of quarter-to-quarter (adjacent) and quarter-by-quarter (seasonal) autocorrelation in the time series of quarterly CFO, (3) and the recommended structural form(s) of statistically based quarterly CFO prediction model(s). Finally, it also provides a set of recommendations for future research seeking to refine extant statistically based quarterly CFO prediction models.

The current paper is directly related to Nurnberg (2006) and Herrmann, Saudagaran, and Thomas (2006). Nurnberg provides a cautionary note pertaining to the use of the CFO series in valuation contexts similar to those that we describe. He questions the inherent superiority of CFO vis-à-vis the earnings series. While there is no question that earnings numbers are more readily subject to manipulation by opportunistic managers, the CFO series, nevertheless, may also be managed using acquisition and disposition transactions as discussed by Nurnberg. Such distortions serve to undermine the pristine nature of the CFO series and reduce the usefulness of CFO numbers in the valuation contexts described herein. Moreover, they provide a cautionary note and underscore a potential limitation of employing CFO numbers in firm valuations.

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Herrmann et al. (2006) argue that the use of fair value measures for property, plant, and equipment vis-à-vis historical cost may serve to enhance the predictive value of accounting series. If Hermann et al.'s analytical reasoning is substantiated via empirical testing, then the inherent advantages of CFO versus earnings in valuation settings may be mitigated. Herrmann et al. (2006) suggest further that the use of historical costs for valuing property, plant, and equipment in the United States, unless such assets are impaired, may serve to undermine the usefulness of accounting numbers for economic decisions. To the extent that fair value measures replace historical costs across diverse asset classes, the importance of the predictive performance of the CFO models described herein may be diminished.

2. Background

In some ways, the current paper is reminiscent of O'Hanlon's (1995) work summarizing the univariate time-series properties of earnings data. Both papers summarize extant work on the modeling of two different but important financial series – earnings and cash flows. While O'Hanlon's study focuses primarily upon earnings, both annual and quarterly, the current paper is focused on statistically based prediction models for quarterly CFO data. Kim and Kross (2005) observe that valuation models employed by analysts typically favor the use of CFO as an input series as opposed to net earnings thereby enhancing interest in specifying the time-series properties of CFO. Therefore, the objects of prediction, both of considerable importance to accounting and finance researchers and practitioners, are different. Additionally, the current paper discusses very recent research efforts highlighting novel advancements in the modeling of quarterly CFO as well as providing suggestions for future modeling efforts. Finally, the current paper provides an important linkage between the modeling of quarterly net earnings and quarterly CFO by citing recent evidence by Lorek and Willinger (2011) that the Brown–Rozeff $(100) \times (011)$ ARIMA time-series model originally popularized on quarterly earnings data some forty years ago provides the most accurate multi-step ahead quarterly CFO predictions currently.[1]

Bowen, Burgstahler, and Daley (1986) discuss several reasons why accounting researchers and members of the investment community should be interested in cash-flow forecasting. Such interest may be linked to a multitude of decision settings that rely upon CFO predictions as inputs including risk assessment, the accuracy of credit-rating predictions, and firm valuation. Moreover, domestic and international standard-setting bodies in accounting have underscored the primacy of CFO forecasting by stating the importance future cash flows have to investors and creditors and emphasizing that prediction of CFO provides a central rationale for the existence of accrual accounting (IASB/FASB, 2006, p. 18). Therefore, interest in deriving relatively accurate, long-term CFO forecasts is high among academics as well as business professionals.

This paper concentrates upon reviewing work on quarterly rather than annual CFO prediction models for several reasons. First, quarterly CFO data may potentially exhibit both quarter-to-quarter (adjacent) and quarter-by-quarter (seasonal) autocorrelations simultaneously whereas such seasonal autocorrelations are not possible in annual CFO data making the latter series basically unsuitable for extensive time-series modeling. Second, Box–Jenkins ARIMA time-series models provide a family of relatively powerful yet parsimonious prediction models that are particularly suitable for modeling quarterly data. Third, the extant time-series literature in accounting pertaining to earnings provides useful clues in precisely how ARIMA prediction models for quarterly CFO data may be identified. Specifically, researchers like Lorek (1979), among others, enhanced the predictive ability of annual earnings by employing a conditioning database of quarterly rather than annual earnings data. Similarly, relatively recent empirical work on CFO data has also employed this disaggregation approach to enhance predictive performance (see Lorek & Willinger, 2011).

The current unavailability of widely disseminated analysts' multi-step-ahead quarterly CFO forecasts has increased interest in understanding the statistical properties of quarterly CFO data (Barniv, Myring, & Thomas, 2005). Numerous financial statement analysis texts emphasize the need for such long-term CFO forecasts which serve as inputs to firm valuation models (e.g., Lundholm & Sloan, 2007; Palepu & Healy, 2008; Penman, 2007). Ironically, the multi-step-ahead quarterly CFO forecasts generated by the statistically based prediction models discussed in this paper currently represent the *only* source of long-term quarterly CFO forecasts that are presently available. Without such relatively long-term CFO forecasts, analysts and investors must resort to cruder "back of the envelope" valuation techniques perhaps employing earnings as a proxy for CFO in conjunction with average industry multiples as opposed to using a conceptually more rigorous valuation approach like discounted cash flows.

Research assessing the efficacy of statistically based quarterly cash-flow prediction models is not as extensive as that devoted to annual work. Dechow, Kothari, and Watts (1998), Barth, Cram and Nelson (2001), and Kim and Kross (2005) have examined the predictive ability of annual CFO. One advantage of annual work is the ability to obtain large samples of firms given the cross-sectional estimation procedures that the aforementioned works typically employ. A potential disadvantage, however, is that rigorous analysis of sample autocorrelation functions is precluded given the lack of time-series data. Dechow et al. (1998) speculate that since the measurement interval inherent in quarterly data is shorter, the analytics and empirics of quarterly CFO modeling are considerably more complex than that employed on annual CFO data. The potential seasonality inherent in quarterly CFO data seemingly contributes to such incremental complexity. Nevertheless, researchers have

[1] We employ customary (pdq) X (PDQ) ARIMA notation where (p,P) are regular and seasonal autoregressive parameters, respectively; (d,D) are consecutive and seasonal differences, respectively; and (q,Q) are regular and seasonal moving-average parameters.

continued to examine the time-series properties of quarterly CFO with the objective of identifying relatively accurate cash-flow prediction models. Such work has led to significant inroads with respect to achieving the aforementioned objective.

Research concentrated upon deriving the time-series properties of the quarterly CFO series prior to the passage of SFAS No. 95 in the United States (FASB, 1987) employed simplistic algorithms which added back non-cash expenses like depreciation and amortization to net income to derive a crude proxy for CFO (PCFO). Yet, Hribar and Collins (2002) provide empirical evidence uncovering systematic differences between SFAS No. 95 CFO reported data and proxies derived using algorithms. Kim and Kross (2005) argue further that the former CFO series are likely to be less noisy measures than proxy CFOs. In fact, Lorek and Willinger (2011), among others, document substantially different time-series properties of reported quarterly CFO vis-a-vis earlier work like Hopwood and McKeown (1992) and Lorek, Schaefer and Willinger (1993) that examined quarterly PCFO data. Furthermore, these differential time-series properties lead to substantially different expectation models and bring into question the external validity of early work employing the PCFO series.

While this paper concentrates upon statistically based quarterly CFO prediction models that may be used by analysts, investors, and researchers in a diverse set of economic decision contexts including firm valuation, we recognize that there are a host of competing valuation approaches that may be employed by users in such settings. These include: (1) asset-based valuation models that aggregate the current market value of individual component assets and liabilities; (2) the abnormal or residual earnings valuation model attributed to Ohlson (1995) which is based upon summing book values and the present value of the abnormal or residual earnings series; and (3) industry multiples based on extrapolations of reported earnings. While finance theory argues for the theoretical propriety of using discounted cash flows to value the firm, Liu, Nissim, and Thomas (2007) provide some interesting empirical evidence on how “quick and dirty” earnings multiples provide very useful summary measures of firm value. We also note that the use of asset-based valuation models changes the focus from concentrating solely upon CFO predictions to the use of fair value measures across diverse asset classes. Nevertheless, we reiterate that identification of best-performing statistically based CFO prediction models is of importance to analysts, investors and researchers.

3. Overview of salient research findings

Much of the impetus for developing quarterly CFO prediction models can be traced to the work of Wilson (1986, 1987) and Bernard and Stober (1989). Specifically, they developed a multivariate CFO prediction model for quarterly CFO that used fifteen independent variables whose parameters were estimated cross-sectionally. Moreover, they employed the dual evaluative criteria originally popularized by the seminal work of Foster (1977); namely, predictive ability and capital market association testing. In order to operationalize the latter criterion, an expectation model for CFO was developed. Unfortunately, it employed lagged values (i.e., $t-1$, $t-2$, $t-3$, $t-4$) for sales, CFO, current and noncurrent accruals without explicit justification for the specific nature of the lag structure for the independent variables. Perhaps more importantly, it also employed contemporaneous values of independent and dependent variables in model estimation. By using such values for sales and net earnings as independent variables, their CFO prediction models were not operational in a true *ex-ante* fashion since forecasts of CFO at time $t+1$ could not be generated without knowledge of the realization of the independent variables at time $t+1$. Finally, they employed cross-sectional estimation procedures that restrict coefficients to be identical across firms and time preventing firm-specific contextual estimation of parameters. Nevertheless, Wilson and Bernard and Stober should be credited with providing an early impetus and framework for the statistical modeling of quarterly CFO.

Subsequent work in quarterly CFO modeling relied instead upon univariate Box–Jenkins time-series analysis to identify the time-series properties of quarterly PCFO data. Initial results suggested that the time-series properties of quarterly PCFO stood in marked contrast to the time-series properties of quarterly earnings-per-share (EPS). The latter series exhibits both quarter-to-quarter (adjacent) and quarter-by-quarter (seasonal) characteristics while analysis of sample autocorrelations of the former series exhibited only seasonal autocorrelations. Specifically, Hopwood and McKeown (1992) used an algorithm to create a quarterly PCFO series for a relatively small sample ($n=60$) of manufacturing firms across the 1976–1987 period. Examination of sample autocorrelation functions for the quarterly PCFO and EPS series revealed higher levels of autocorrelation in the EPS series. A major conclusion of their study was that the CFO series was considerably less predictable than the EPS series. While Hopwood and McKeown correctly point out that the two series have divergent time-series properties, they called upon future research to answer the question – which ARIMA model structure best describes quarterly PCFO.

Unlike Hopwood and McKeown (1992), Lorek et al. (1993) identified ARIMA models specific to the cash-flow series using statistical goodness of fit criteria; namely, a seasonal autoregressive model (SAR), $(000)\times(100)$ in Box–Jenkins notation, as well as a seasonal moving-average model (SMA), $(000)\times(011)$. They propose these dual ARIMA structures as possible candidate models for the quarterly PCFO series. Consistent with Hopwood and McKeown, Lorek et al.’s descriptive evidence suggests that the time-series behavior of the quarterly PCFO series stands in marked contrast to that evidenced by quarterly EPS. Lorek et al. also employed an algorithm by which quarterly PCFO data were constructed from balance sheet and/or income statement subcomponents across the 1976–1986 time period. They provide empirical results that show the ARIMA time-series models outperform the more complex, cross-sectionally estimated regression-based models that Wilson (1986, 1987) and Bernard and Stober (1989) developed. Unfortunately, the external validity of Lorek, Schaefer and Willinger’s findings may be suspect for at least two reasons. First, their predictive results are based on relatively small samples; 80 and 66 firms in the two forecast horizons that they used, 1985 and 1986, respectively. Second, their use of a proxy series (quarterly PCFO) may have introduced measurement error given Hribar and Collins’ findings referred to earlier.

Nevertheless, it is interesting that firm-specific parameter estimation used in the ARIMA models enhanced predictive performance vis-à-vis the cross-sectional estimation procedures employed in the regression-based models of Wilson and Bernard and Stober.

Lorek and Willinger (1996) developed a disaggregated-accrual multivariate time-series prediction model (MULT) that employs past values of earnings, short-term accruals, and cash flows in a time-series regression framework rather than restricting the set of explanatory variables to past cash-flow data as in the univariate SAR and SMA ARIMA time-series models. Similar to Hopwood and McKeown as well as Lorek, Schaefer and Willinger, they used an algorithm to create a quarterly PCFO time series for a varying sample of 51–62 firms. The MULT model is intuitively appealing relative to either the SAR and/or SMA univariate ARIMA time-series models in the sense that it employs lagged accrual and cash-flow variables whereas the ARIMA models are purely univariate in nature; that is, they use past PCFO data to predict future PCFO data. The selection of the independent variables in MULT was influenced by a desire to construct a more parsimonious cash-flow prediction model than Wilson (1986, 1987) or Bernard and Stober (1989) who employed a set of fifteen independent variables. While Finger (1994) cautions that the benefits of adding additional variables to any prediction model may be outweighed by a loss of degrees of freedom, Lorek and Willinger provide empirical results which show that the MULT model outperforms the aforementioned ARIMA models in one step-ahead quarterly cash-flow predictions during the 1989–1991 holdout period.

In marked contrast to the aforementioned studies, Lorek and Willinger (2008) provide descriptive and predictive evidence on quarterly CFO data reported in accordance with SFAS No. 95. This is an important advancement considering the evidence provided by Hribar and Collins (2002) cited above which documented significant differences between the descriptive characteristics of the proxy series and reported CFO data. SFAS No. 95 required firms in the United States to present a statement of cash flows for fiscal years ending after July 15, 1988. While previous work was forced to rely exclusively upon proxies for the CFO series computed using algorithms that employed a diverse set of quarterly financial statement subcomponents, Lorek and Willinger were able to obtain a sufficiently long time series of quarterly CFO (1989–2005) reported in accordance with SFAS No. 95. Their primary finding was that reported quarterly CFO exhibit substantially different time-series properties than proxy-generated, quarterly CFO consistent with Hribar and Collins (2002). That is, reported quarterly CFO exhibit *both* quarter-to-quarter (adjacent) and quarter-by-quarter (seasonal) autocorrelation unlike the exclusively seasonal time-series properties documented by earlier work employing the proxy quarterly CFO series.

These new time-series properties of reported quarterly CFO uncovered by Lorek and Willinger (2008) have direct implications for the development of a CFO prediction model. Unlike Lorek, Schaefer and Willinger (1993) who developed purely seasonal ARIMA models, Lorek and Willinger identified the (100) × (011) ARIMA model originally attributed to Brown and Rozeff (1979) as a candidate model for quarterly EPS. In fact, the (100) × (011) ARIMA model significantly outperformed the MULT disaggregated-accrual model in one-step ahead quarterly CFO predictions during the 2003–2005 holdout period. Supplementary analyses revealed that the forecast errors of larger firms were significantly smaller than those of smaller firms. The predictive findings were also robust across an expanded sample of firms ($n = 745$) enhancing the external validity of these findings.

Most recently, Lorek and Willinger (2011) provide new evidence on relatively long-term CFO predictions rather than restricting the forecast horizon to one-step-ahead like all previous work. They argue that a critical need exists for long-term CFO forecasts due to their use as inputs in firm valuation models. In addition, Givoly, Hayn, and Lehavy (2009) speculate that investors are increasingly concerned with the apparent shortcomings of accrual accounting and prefer to work with the more pristine CFO series when performing firm valuations. While Givoly et al. (2009) document an increasing trend in analysts providing one-year ahead annual CFO forecasts, multi-step ahead quarterly CFO forecasts attributed to analysts are virtually non-existent. The unavailability of long-term CFO forecasts attributed to analysts provides a strong incentive for academic researchers to examine the time-series properties of quarterly CFO and identify statistically based prediction models which can be used to generate such forecasts. Lorek and Willinger (2011) also corroborate the descriptive finding that quarterly CFO reported in accordance with SFAS No. 95 requirements exhibit time-series properties at variance with proxy quarterly CFO series created via algorithms. That is, reported quarterly CFO exhibit *both* quarter-to-quarter (adjacent) as well as quarter-by-quarter (seasonal) relationships. This descriptive finding led them to identify the (100) × (011) ARIMA model consistent with the work of Lorek and Willinger (2008).

Despite the concerns raised by Dechow et al. (1998) regarding the complexity of modeling quarterly CFO vis-à-vis annual CFO series, disaggregation of annual CFO into quarterly CFO enabled Lorek and Willinger to identify autocorrelation patterns in the quarterly series that were masked in the annual series. These inroads in statistical modeling are somewhat reminiscent of research on the time-series properties of quarterly EPS data in the 1970s–1980s where disaggregation of the annual EPS series into quarterly EPS series resulted in the identification of premier ARIMA models for quarterly EPS attributed to Foster (1977) and Brown and Rozeff (1979), among others, supplanting the random walk model for annual EPS. Lorek and Willinger's (2011) predictive findings support the superiority of the Brown–Rozeff (100) × (011) ARIMA model vis-à-vis the disaggregated-accrual MULT model in relatively long-term, one thru twenty step-ahead quarterly CFO predictions during the 2003–2007 time interval. This finding is consistent with Dechow and Dichev (2002) who argue that subjectivity inherent in accruals may introduce noise in the estimation of models like MULT that employ such variables. Recall that the (100) × (011) ARIMA model is univariate in nature and relies upon past quarterly CFO data to predict future quarterly CFO data. Additionally, Lorek and Willinger provide new descriptive evidence that the autoregressive and moving-average parameters in the (100) × (011) ARIMA model are systematically smaller for the quarterly CFO models versus the same models estimated on the quarterly EPS series. This finding is consistent with Beaver (1970) who provides an insightful discussion on how accounting conventions (i.e., inventory flow assumptions and depreciation/amortization methods) induce artifactual autocorrelation in the EPS series that is not present in the CFO series.

4. Structural equations of statistically based quarterly CFO prediction models

This section summarizes the specific structural equations of prediction models of choice for the quarterly CFO series. The aforementioned studies have popularized the employment of the following statistically based, quarterly CFO prediction models: the SAR ARIMA time-series model [Eq. (3)], the SMA ARIMA time-series model [Eq. (4)], the MULT time-series regression model [Eq. (5)], and the Brown–Rozeff (BR) ARIMA time-series model [Eq. (6)] which are stipulated below:

$$\text{SAR}(000) \times (100): \quad \text{CFO}_t = \varphi\,\text{CFO}_{t-4} + a_t \tag{3}$$

$$\text{SMA}(000) \times (011): \quad \text{CFO}_t = \text{CFO}_{t-4} + a_t - \Theta a_{t-4} \tag{4}$$

$$\begin{aligned}\text{MULT}: \quad \text{CFO}_t &= a + b_1\ \text{CFO}_{t-1} + b_2\ \text{CFO}_{t-4} + b_3\ \text{OIBD}_{t-1} + b_4\ \text{OIBD}_{t-4}\\ &\quad + b_5\ \text{REC}_{t-1} + b_6\ \text{INV}_{t-1} + b_7\ \text{PAY}_{t-1} + a_t\end{aligned} \tag{5}$$

where OIBD is operating income before depreciation, REC is accounts receivable, INV is inventory, PAY is accounts payable, a_t is a current disturbance term, φ is a seasonal autoregressive parameter, and θ is a seasonal moving average parameter.

$$\text{BR ARIMA} \quad \text{CFO}_t = \text{CFO}_{t-4} + \varphi_1(\text{CFO}_{t-1} - \text{CFO}_{t-5}) + a_t - \Theta_1(a_{t-4}) \tag{6}$$

where CFO_t = operating cash flows at time t; φ_1 = autoregressive parameter; θ_1 = seasonal moving-average parameter; a_t = current disturbance term.

It appears that the SAR and SMA ARIMA time-series models, while clearly the most parsimonious in nature, are unable to fully capture the quarter-to-quarter (adjacent) autocorrelations present in the quarterly CFO series. On the other hand, the inherent complexity of the MULT model with its host of lagged accrual-based independent variables does not result in enhanced predictive performance perhaps due to potential misspecification of either the set of independent variables and/or the lag structure employed. Finally, the Brown–Rozeff ARIMA time-series model appears to capture both the quarter-to-quarter (adjacent) and quarter-by-quarter (seasonal) autocorrelation in the quarterly CFO series in a relatively parsimonious manner while enhancing predictive performance versus the other candidate models.

5. Methodological considerations, and recommendations for future research

This section includes a brief discussion of methodological issues germane to researchers interested in further refining extant statistically based quarterly CFO prediction models discussed above, and includes specific recommendations for precisely how future research should proceed. Pertinent methodological issues include: (1) data considerations, namely use of SFAS #95 reported CFO data versus algorithmic proxies, (2) univariate versus multivariate modeling efforts, and (3) cross-sectional versus time-series estimation procedures.

5.1. SFAS #95 CFO Data

Collins and Hribar's (2002) empirical finding that CFO proxies (obtained via algorithms whereby financial statement subcomponents are added/subtracted from EPS) exhibit different statistical properties than quarterly CFO reported in accordance with SFAS #95 are especially salient. This finding prompted Lorek and Willinger (2008) to compare autocorrelation in the quarterly PCFO series with that exhibited by the quarterly CFO series reported in accordance with SFAS #95 requirements. While the quarterly PCFO series exhibit purely seasonal autocorrelation leading to the identification of the SAR ARIMA model (000) × (100) and/or the SMA ARIMA model (000) × (011), the autocorrelation in the quarterly CFO series is considerably more complex leading to the identification of the BR ARIMA model (100) × (011). Autocorrelation in the quarterly CFO series exhibits both quarter-to-quarter (adjacent) and quarter-by-quarter (seasonal) patterns resulting in the adoption of the BR ARIMA model structure. This model has both a regular autoregressive parameter capturing adjacent autocorrelation patterns as well as seasonal differencing in conjunction with a seasonal moving-average parameter capturing seasonal autocorrelation patterns.

Future work refining statistically based quarterly cash-flow prediction models should employ CFO data reported in accordance with SFAS #95 to avoid the measurement error evidently induced by the algorithmic proxies. This should not pose a data problem given the widespread adoption of SFAS #95 in the United States. In fact, studies like Lorek and Willinger (2008, 2011) were able to construct sufficiently long time-series databases of quarterly CFO not only for model identification purposes but also to assess predictive performance in an inter-temporal holdout period not used for model estimation. Care must be used, however, in comparing earlier work using algorithmic proxies for CFO versus later work employing CFO reported in accordance with SFAS #95.

5.2. Univariate versus multivariate CFO prediction models

The literature pertaining to quarterly CFO prediction models has undergone several distinct phases with regard to model complexity. Initially, Wilson (1986, 1987) and Bernard and Stober (1989) identified very complex, disaggregated-accrual, regression-based quarterly CFO prediction models that seemingly outperformed a series of naïve benchmark models. In fact, their model actually employed a set of 15 independent variables comprised of both contemporaneous and lagged CFO and accrual-based variables. However, the dominance of this model was relatively short-lived. Lorek, Schaefer, and Willinger (1993) identified the parsimonious SAR and SMA univariate ARIMA time-series models that significantly outperformed the disaggregated-accrual, regression-based models.

Lorek et al.'s (1993)findings were both interesting and perplexing. They were interesting in that relatively parsimonious ARIMA-based models outperformed the considerably more complex regression-based models. Such findings are consistent with Occam's razor and the principle of parsimony which mitigate against the use of very complex model structures that might be subject to data overfitting and structural change consistent with Finger (1994). Nevertheless, the findings were also perplexing in the sense that the ARIMA-based models relied exclusively upon relatively stale, seasonal data four quarters old and were univariate in nature. It appears that the incremental information obtained via firm-specific parameter estimation employed in the ARIMA-based models outweighs the information obtained via cross-sectional estimation used in the regression-based models of Wilson and Bernard and Stober.

Lorek and Willinger's (1996) development of the disaggregated-accrual, time-series regression model (MULT) seemingly bridged the gap between the disparate findings discussed above. The MULT model (see Section 4) was considerably less complex than Wilson's regression model employing less than half of Wilson's independent variables. Yet, MULT was considerably more complex than the SAR and SMA univariate ARIMA time-series models since it employed lagged values (both adjacent and seasonal) of operating income as well as subcomponents of the balance sheet – all estimated on a time-series basis. Lorek and Willinger (1996) report empirical evidence that MULT provided significantly more accurate one-step-ahead cash-flow predictions than all the other cash-flow prediction models discussed above. Unfortunately, the aforementioned studies all employed proxies for the quarterly CFO series and were conducted prior to the issuance of SFAS #95 in 1988. Interestingly, MULT's predictive superiority disappeared entirely when Lorek and Willinger (2008, 2011) assessed it vis-à-vis ARIMA-based models using quarterly CFO data reported in accordance with SFAS #95.

Based upon this new descriptive evidence, Lorek and Willinger (2008, 2011) identified the Brown–Rozeff (100) × (011) ARIMA time-series model which is considerably more complex than the purely seasonal ARIMA time-series models (SAR and SMA) identified on the proxy PCFO series. Yet, the relatively more complex MULT model with its disaggregated-accrual set of independent variables fared poorly when estimated on CFO data reported in accordance with SFAS #95. While these results are consistent with the principle of parsimony, they are also suggestive that the lag structure of the MULT model may be misspecified. Future research examining alternative model lag structures (i.e., adjacent and seasonal) and diverse sets of accrual-based independent variables (i.e., receivables, payables, and inventory) is necessary to identify the next generation of multivariate quarterly CFO prediction models. Additionally, capturing cost structure variables such as profit margins, earnings/sales revenue, and diverse cost categories should also be considered to augment potential independent variables in CFO prediction models like MULT. Wild (1987) provides such a structural model assessing the predictive performance of a host of subcomponent accounting numbers in a case study setting. Expansion of MULT's set of independent variables by capturing firm-specific values for profit margins and/or cost structures appears especially worthwhile. Yet, the comments of Dechow et al. (1998) pertaining to econometric difficulties associated with the modeling of quarterly CFO data and Finger's (1994) concerns about the tradeoffs between model simplicity and complexity are especially relevant here.

5.3. Cross-sectional versus time-series estimation

Wilson and Bernard and Stober's disaggregated-accrual, quarterly CFO prediction model was estimated cross-sectionally forcing all parameters to be identical across firms and time. To the extent that the time-series behavior of quarterly CFO is contextual, cross-sectional estimation masks inherent firm-specific variability. Lorek and Willinger (2009) provide empirical evidence that the parameters in CFO prediction models exhibit considerable firm-specific variability. Therefore, the benefits of cross-sectional estimation such as the ability to build extremely large samples of firms due to limited time-series data constraints appear to be outweighed by the inability to capture this documented firm-specific variability. This may be precisely why ARIMA-based time-series models, while relatively parsimonious in nature and ignoring the information content in accrual-based variables, still exhibit superior predictive ability vis-à-vis more complex disaggregated-accrual regression-based models. Firm-specific estimation of the autoregressive and seasonal moving-average parameters in the ARIMA models evidently compensates for the univariate nature of the models.

6. Concluding remarks

While considerable strides have been made in the development of statistically based quarterly cash-flow prediction models, additional research is necessary to refine extant models. Particularly curious is why univariate ARIMA time-series models like the Brown–Rozeff (100) × (011) ARIMA model outperform disaggregated-accrual regression-based models in multi-step-ahead quarterly CFO predictions. While such findings are consistent with the principle of parsimony, future research examining both the potentially rich set of accrual-based independent variables and the lag structure inherent in the multivariate models may lead to the next generation of disaggregated-accrual cash flow prediction models. Specifically, future work should factor in the adjacent and seasonal lag structure in the Brown–Rozeff ARIMA time-series model when specifying lead/lag relationships using disaggregated-accrual regression models like MULT. Moreover, the regular and seasonal moving-average parameters in the Brown–Rozeff ARIMA time-series model for the quarterly CFO series may also serve as proxies for the persistence of CFO in a valuation context.

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