Tobin's Q and Financial Policy Revisted

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ABSTRACT

Research by Chirinko (1982, 1985, 1987) makes a convincing argument that Q theory is unlikely to provide a satisfactory investment model. However, Klock, Thies, and Baum (1991) show that Q is commonly mismeasured. This finding is applicable to Chirinko's empirical research and raises the question of whether the failure of empirical Q models is the result of measurement errors. Utilizing disaggregated data with more accurately measured Q's, we test Chirinko's model. The results are improved and eliminate some of the anomalies Chirinko obtained. Since better Q data improves the performance of empirical Q models, the dismissal of Q theory may be premature.

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1. INTRODUCTION

The Q theory of investment has received considerable attention in recent years, reflecting that it is the single theory of investment which explicitly recognizes a linkage between real and financial sectors. Unfortunately, there are obstacles to applying Q in empirical research. Investment depends on marginal Q which is unobservable; thus, average Q, which is observable, is often used as a proxy for marginal Q. Hayashi (1982) has rigorously derived necessary and sufficient conditions for equating marginal and average Q. These conditions require the firm to be a price taker facing constant returns to scale.

Work by Chirinko (1982, 1985, 1987) demonstrates that, when financing decisions are endogenous, the relationship between marginal Q and average Q is ambiguous. While much of the finance literature has argued that real and financial decisions can be separated, [e.g., Modigliani and Miller (1958, 1961)] the more recent trend has been to recognize the interdependence between investment and financing decisions [e.g., Stiglitz (1974), Jensen and Meckling (1976)]. It is now widely recognized that financing decisions should be treated as endogenous due to agency, bankruptcy, and transactions costs. An implication of this endogeneity is that conventional models relating average Q to investment are misspecified--even if Hayashi's conditions hold.

Chirinko (1985, 1987) shows that a structural model relating investment to average Q can be preserved if financing decisions are incorporated in the model, and if estimates of that model's parameters are conditioned on the debt-equity ratio. Unfortunately, Chirinko's empirical work with the modified Q model, fitted to aggregate U.S. data, results in unreasonable parameter estimates. He thus concludes that Q theory is probably an unsatisfactory basis for modelling investment behavior. We believe that

Chirinko's conclusions are questionable, due to his utilization of aggregate data and rough imputations. Another test of his model--with more carefully constructed data--is vital, given the importance of the issue involved here--whether Q theory may be empirically validated, and made operational.

Klock, Thies, and Baum (1991) point out that researchers have virtually ignored the fact that average Q itself is often measured with substantial error. They provide evidence that the measurement error contained in typical Q data (e.g. Lindenberg and Ross (1981)) is substantial. They also show that the bias introduced by this error will be especially problematic in models which have debt variables as regressors (as does Chirinko's). The specific source of measurement error investigated results from rough imputations of the market value of debt being used to proxy for actual market values or detailed imputations. This same critique is applicable to the empirical implementation of Chirinko's model. He estimates the market value of corporate debt by treating it uniformly as a perpetuity discounted at the Aaa rate. In addition, he imputes the market value of equity using an aggregate rate of return. As stated previously, the quality of Chirinko's imputed data casts doubt on the apparent failure of his empirical model. Our approach is simply to reestimate Chirinko's model using disaggregated and more accurately measured estimates of Q. In what follows, Section 2 describes the data utilized for this project. Section 3 presents Chirinko's model and the results obtained from estimating the model with our alternative data.

2. DATA

Rather than the aggregate data utilized by Chirinko and other researchers, we make use of firm-level time series data, which is potentially much less susceptible to errors of measurement and problems of aggregation. As Abel and Blanchard have noted, aggregation problems may be considered first in their "list of potential culprits" for "the relatively poor performance of Q in explaining investment." (1986).[1] As in Klock, Thies, and Baum (1991), we utilize the Panel84 dataset. These are detailed annual data on 100 randomly selected large manufacturing firms for the seven year period 1977-1983. For purposes of Q research, this data is preferable to the alternative Compustat data since it contains market value data on debt. Actual market prices are used for traded debt, and fair-value imputations are made using detailed issue-specific information for nontraded debt. This information includes coupon, term, conversion right, sinking fund, and credit rating. Details of the imputations are contained in Thies and Sturrock (1987, pp. 390-391).[2] Two additional advantages of the data: (1) they include replacement cost data taken from firms' 10-K and annual report disclosures, and (2) they contain less firm selection bias than Compustat.[3]

3. ESTIMATION AND RESULTS

Chirinko's modified Q model is based on a separable production technology. In the general form, the firm optimizes over the factors of production, investment, the stock

[1] Other studies making use of firm-level data to analyze investment--using a reduced-form approach--include Salinger and Summers (1983), Fazzari, Hubbard, and Petersen (1988) and Schaller (1990). The latter study states that "..several variables used in the construction of Q can be more accurately measured at the firm level..." (p.310), but utilizes the book value of debt, as well as rough approximations to generate the market value of preferred equity and the key capital stock series.

[2] Descriptions of the data and approach used in constructing investors' required returns, tax and inflation adjustments are contained in a data appendix, available from the authors on request.

[3] Banz and Breen (1986) have shown that the selection bias inherent in Compustat data is potentially harmful. The bias arises for two reasons: first, only currently viable companies are included, creating a survivorship bias. Second, firms enter the dataset with a full 20-year history, creating a startup bias. Banz and Breen note that the former bias can be reduced by using Compustat's Research database, but assert that "little can be done to correct for" startup bias. Use of the Panel84 data should reduce this bias, since only a seven year history is required.

of debt, and the issuance of new debt. The separable form leads to three terms: one in the factors of production, one in investment and the capital stock, and one in the debt and debt-issuance variables. It is the presence of the latter term that endogenizes financial policy, and leads to the following structural econometric equation:

$$I_{j,t}/K_{j,t} = \delta + (1/\alpha)\, \Omega_{j,t}/K_{j,t} - (\gamma/\alpha)\, [\Delta D_{j,t}/D_{j,t} + \eta]^{(\gamma-1)}\, D_{j,t}^{(\sigma+\gamma)}/K_{j,t} -$$

$$((\sigma+\gamma-1)/\alpha)\, \eta^{\gamma}\, [D_{j,t}^{(\sigma+\gamma)}/\rho_{j,t}]/K_{j,t} + \Psi\, I_{j,t-1}/K_{j,t} + \varepsilon_{j,t} \qquad (1)$$

for j = 1,...,N, the number of firms in the sample,

and t = 1,...,T, the number of time periods (years) of data per firm.

The variables are defined as follows:

$I_{j,t}$ =	gross investment of the j^{th} firm in period t,
$K_{j,t}$ =	capital stock of the j^{th} firm at time t,
$D_{j,t}$ =	stock of outstanding debt of the j^{th} firm at time t,
$\Delta D_{j,t}$ =	first difference of $D_{j,t}$,
$\rho_{j,t}$ =	shareholders' real required return on equity of the j^{th} firm at time t,
δ =	the exponential depreciation rate of physical capital,
α =	a parameter positively related to adjustment costs of the capital stock,
γ =	a parameter positively related to flotation costs of debt,
σ =	a parameter positively related to agency costs of debt,
η =	the rate at which debt is retired,

Ψ = a parameter testing for misspecification via inclusion of lagged investment,

$\varepsilon_{j,t}$ = a normally distributed random variable with zero mean and independently and identically distributed across firms and time,

$\Omega_{j,t}$ = the difference between the market value of all financial claims on firm j and the replacement cost of firm j's assets at time t.

This latter variable, Ω, is the analogue of Tobin's Q in Chirinko's specification. Rather than the ratio of financial value to replacement cost of standard q, Ω is essentially the difference between the numerator and denominator of Tobin's Q.

As in Chirinko's specification, all variables are scaled by $K_{j,t}$ to avoid the spurious correlation possible in variables trending upward over time. Lagged investment, although not analytically justified, was added "to capture any dynamic effects not fully accounted for by the adjustment cost technology." (1987, p.78). A significant value of Ψ could be interpreted as a sign of misspecification of the model. As Chirinko notes, adding lagged investment to the model compromises the structural interpretation of the investment function. The model was estimated via nonlinear least squares algorithms in the Shazam and RATS packages.

One additional feature of the data affecting the sample for estimation must be discussed. The model requires that $(\Delta D_{j,t}/D_{j,t} + \eta)$ be strictly positive for each observation. For Chirinko's aggregate data, this translates into a requirement that η must exceed 0.15: that is, firms must not retire more than 15 per cent of their outstanding debt in the aggregate. Chirinko found that his data were not rich enough to estimate η while allowing all parameters to vary freely; however, using a grid search, Chirinko found the likelihood function to be slightly increasing in η. This notwithstanding, he constrained η to be 0.15 on *a priori* grounds. If we were to constrain η to exceed the absolute value of the largest negative value of $\Delta D_{j,t}/D_{j,t}$, we would require an η greater than unity.[4] Instead, we delete observations for which $(\Delta D_{j,t}/D_{j,t} + \eta)$ is nonpositive. As a consequence, we had to delete nine per cent of our observations: those for which firms' debt retirement exceeded 15 per cent of their outstanding debt in particular years.

Our firm-level data are sufficiently rich to estimate η directly; we obtained an estimate of 0.189 with a t-statistic of 5.8. However, using a likelihood ratio test, we were unable to reject the null hypothesis that η equals 0.15 at the ten per cent level of significance. Therefore, in order to facilitate comparison of our results with Chirinko's, we report results from estimation in which η is constrained to 0.15. Note that by making use of these pooled cross-section/time series data we were able to directly estimate δ, α, γ, σ, and Ψ.

Table 1 presents our results contrasted with Chirinko's. Column 1 presents Chirinko's results in the "conventional" form of the model, in which terms involving debt are suppressed–i.e. agency and flotation costs are ignored. Column 3 presents our estimates for the equivalent model. The column 3 results show a marked improvement over those of column 1. In an effort to determine whether this improvement can be attributed to the use of firm-level data or the use of a more refined estimate of Q, we calculated the results of column 2 by estimating the model with firm-level data using a

[4] The percentage decrease in debt can be greater than -100 per cent since the current value of debt is used in the denominator of $\Delta D_{j,t}/D_{j,t}$ (rather than the previous value). Thus a reduction in the stock of debt by more than half of its current value will cause this fraction to be less than -1.0.

"poor" estimate of Q.[5] Column 4 presents Chirinko's estimates of the general form of the model, in which both agency and debt flotation costs are taken into account. Column 5 reports our estimates of this model using the "poor" Q series, while column 6 reports our estimates using the refined Q. The differences between columns 2 and 3, and columns 5 and 6 are small, suggesting that the improvements are attributable to the use of firm-level data.

Our results for both forms of the model are definitely improved over Chirinko's aggregate estimates. As noted earlier, we enjoyed greater computational success in estimating the model. All of our coefficients are significant at the one per cent level in both the general and conventional models. The estimates of α, which govern the speed of adjustment of the capital stock, are much smaller, implying a more rapid adjustment.[6] Whereas Chirinko's data were unable to deliver significant estimates of γ and σ, we are able to estimate both parameters with considerable precision. The parameter γ–reflecting the flotation costs of debt–is positive but less than unity, implying that costs of issuance rise less than proportionally to the volume of new debt issued. Likewise, for σ–which theory posits to be non-negative–we find a point estimate of 0.42, suggesting that agency costs of debt are a sharply declining function of the total stock of debt outstanding.

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[5] Conceptually, this issue could be addressed by aggregating the panel data. As a practical matter, this is unworkable given the short time series we have on each firm. Thus, we attempt to address this issue by examining firm-level results from a "poor" Q measure (recognizing that the choice of such a measure is arbitrary). The "poor" measure utilised here makes use of the book value of debt as a proxy for the market value of debt.

[6] We also estimated the model after adjusting the replacement cost of capital for tax effects. Interestingly, the only marked change in the estimates occurs in the value of α, which roughly doubles (but is still only half of Chirinko's estimated value). The relationship between the estimated speed of adjustment of the capital stock and tax parameters would be an interesting area for further research.

Finally, while Chirinko found that the restrictions characterizing the "conventional" model could not be rejected by the data, and therefore concluded that the weaknesses of empirical Q models could not be overcome by incorporating financial policy, we find the opposite. Using a likelihood ratio test (Harvey, 1981, pp. 164-165) we are able to reject the "conventional" Q model in favor of Chirinko's general Q model at the one per cent level of significance.

We also investigated several alternative specifications. We constrained the agency cost technology to be linear homogeneous ($\gamma + \sigma = 1$), and were unable to reject the null hypothesis of linear homogeneity at any conventional level of significance. Additionally, we introduced fixed effects for each year. While the set of fixed effects is statistically significant, their inclusion does not appreciably alter the value or significance of any of the parameter estimates; for instance, the resulting year-specific estimates of δ range between 6.6 per cent and 10.7 per cent. Finally, we estimated the models without lagged investment. While there is a significant loss of explanatory power, the qualitative results did not change: the values and significance of the remaining parameter estimates varied little, and the general Q model remained a significant improvement over the conventional specification.

Where the use of aggregate data led Chirinko to conclude that "the source of misspecification in Q models is not related to the treatment of financial policy." (1987, p.82), disaggregated data lead us to conclude that the inclusion of financial policy contributes meaningfully to these models. We would agree that the continuing significance of lagged investment is an unresolved issue. Additional theoretical and empirical research is required to determine whether this enigma can be reconciled with Q theory.

Table 1

Estimates of the Q model with and without endogenous financial policy

Model	Without financial policy			With financial policy		
Dataset: *Q estimate:*	Aggregate *Aggregate*	Firm-level *Book Value Debt*	Firm-level *Market Value Debt*	Aggregate *Aggregate*	Firm-level *Book Value Debt*	Firm-level *Market Value Debt*
Parameter	(1)	(2)	(3)	(4)	(5)	(6)
δ	0.028 (3.89)	0.078 (13.90)	0.075 (14.09)	0.031 (1.03)	0.090 (11.62)	0.086 (12.13)
α	195.909 (2.39)	40.747 (4.33)	42.005 (4.37)	209.608 (2.30)	42.008 (4.22)	42.558 (4.39)
γ				17.668 (0.11)	0.741 (10.66)	0.569 (4.50)
σ				-13.818 (-0.11)	0.292 (4.80)	0.423 (3.78)
Ψ	0.781 (3.53)	0.238 (4.72)	0.258 (5.38)	0.757 (3.50)	0.230 (4.64)	0.253 (5.32)
S.E.R.		0.0687	0.0672		0.0682	0.0665

Notes: Asymptotic t-statistics in parentheses. S.E.R. is the standard error of the regression.
Columns 1 and 4: estimated from annual data for the U.S. nonfinancial corporate sector 1950-1981, capital stock of equipment and structures. Taken from columns 1 and 3 of Table 1, Chirinko (1987, p.80).
Columns 2 and 5: estimated from Panel84, 100 large manufacturing firms, annual data for 1978-1983, using book value of debt and market value of equity to construct Tobin's Q. A total of 546 usable observations.
Columns 3 and 6: same as columns 2 and 5, but using imputed market value of debt and market value of equity to construct Tobin's Q.

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DATA APPENDIX

Five variables are taken from Panel84: book value of debt, market value of debt, market value of equity, net replacement cost of assets, and investment in equipment and structures. We also require data on investors' required rate of return. This is calculated using the capital asset pricing model (CAPM) as developed by Lintner (1965) and Sharpe (1964). We take the market risk premium to be 4.5%, as estimated by Sharpe and Alexander (1990, p. 719) and use Moody's long-term government bond yield as the riskless rate of return.[7] Thus, the slope of the security market line is constant over the seven year period, but the intercept is permitted to change annually. Beta values are taken from Value Line where available. Value Line estimates of beta were available for 85 per cent of the observations. Where Value Line estimates were not available, betas were estimated using daily return data from the CRSP tapes. This method accounts for ten per cent of the observations. All 100 firms had either Value Line data or the necessary CRSP data available for at least part of the seven year period. For the remaining five per cent of the observations, the beta for the closest available year was used.

There are two final data requirements. One is the measure of inflation required to deflate nominal values. For this we used the GNP implicit price deflator for nonresidential fixed investment. We also needed tax parameters to construct the tax-adjusted replacement cost of assets. We assumed that firms' marginal federal plus state tax rate was 50% and that incremental investment qualified for the 10% investment tax credit. To calculate the present value of tax deductions received for depreciation we used Ciccolo's (1979) estimates of the present value of $1 in depreciation deductions for structures and for equipment, and took a weighted average of the two estimates, assuming that the mix of investment in structures and equipment is the same for all firms as in the aggregate. Data to calculate the aggregate mix of investment in equipment and structures were obtained from *Historical Statistics of the United States* for each year. Discussion of tax adjustments to replacement costs can be found in Ciccolo (1979) or Downs and Tehranian (1988).

[7] Brigham and Gapenski (1991, p.279) provide a justification for using a long-term rate rather than a short-term rate.