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Rejoinder

Retaining the Hotelling Valuation Principle

Joseph G. Eisenhauer

Department of Economics and Finance, Canisius College, 2001 Main Street, Buffalo, NY, 14208-1098, USA (e-mail: eisenhauer@canisius.edu)

Abstract. Further testing of the Hotelling Valuation Principle (HVP) corroborates my initial assessment that the HVP cannot be rejected on the basis of the Cairns and Davis (1998) data set. This conclusion is also consistent with a number of previous studies.

Key words: Mining, heteroscedasticity, exhaustible resources, Hotelling Valuation Principle

JEL classification: L72, Q31

In their commentary, Cairns and Davis (2005) have graciously acknowledged the need to correct the econometric weaknesses in their earlier study (Cairns and Davis 1998) of the Hotelling Valuation Principle (HVP), and have at the same time pointed out some limitations of my tests (Eisenhauer 2005). There remain substantive differences, however, between their assessment of the data and my own, especially involving matters of judgement. In particular, Professors Cairns and Davis attempt to reinterpret my results as supporting their rejection of the HVP, whereas my own view is that no such conclusion can be derived from their data. Indeed, some modest improvements to my methodology as suggested by Cairns and Davis leave my findings essentially unchanged and actually strengthen my initial evaluation by demonstrating robustness. In this rejoinder, I briefly address a few of their remarks.

The simple linear regression of goldmine transaction values (V) on the net value of *in situ* reserves is given by $V = \beta_0 + \beta_1(\omega S)$, where S denotes the volume of reserves. Ideally, the net market price (ω) would represent the difference between the current price per ounce of gold and the *marginal* extraction cost, but the available data measure *average* cost. It is also worth emphasizing at the outset that the presumption in this test rests with the HVP, reflected in the null hypothesis $H_0 : \beta_1 = 1$; rejecting the HVP requires

overcoming the burden of proof. In contrast to Cairns and Davis, I do not subscribe to the view that imprecise and thus statistically insignificant parameter estimates obtained from sample data can be taken as evidence against the null hypothesis, especially when the data are mere proxies for the theoretically correct variables.

Given the heteroscedasticity that was present in the regression residuals when Cairns and Davis (1998) first applied ordinary least squares, the central question is whether the Hotelling Principle can be rejected under a weighted least squares estimation in which the weights are given by $(\omega S)^{.5\psi}$. There are, however, several different values of ψ that may serve this purpose, and the optimal choice is not entirely obvious. In selecting $\psi = 1.5$, I sought to balance the need for homoscedasticity against the need to avoid significant serial correlation which, like heteroscedasticity, would distort the efficiency of the parameter estimates. Cairns and Davis rightly point out that when compared to the 5% critical values of 1.328 and 1.476, the Durbin-Watson statistic of DW = 1.33 leaves the test for serial correlation inconclusive. In addition, they note that selecting the level of significance is a matter of discretion, and suggest that a one-tailed test of the regression slope could legitimately be conducted at the ten percent level of significance (although they continue to test their Eq. (6) at the five percent level).

To accommodate these concerns, let us recalibrate the empirical model slightly, by using a weighting factor that will decisively reject serial correlation and simultaneously restore homoscedasticity, and let us then test the slope at the 10% level of significance. For the sample of 28 gold mines studied by Cairns and Davis (1998), setting $\psi = 1.7$ yields the estimation

$$V = 2.3320 + 0.7715\omega S$$
$$\quad (1.5327)(0.1769)$$

where standard errors are given in parentheses, $R^2 = 0.4224$, $\bar{R}^2 = 0.4002$, and $DW = 1.497$.[1] The Durbin-Watson statistic now exceeds the upper critical value, indicating a clear absence of first-order autoregressive serial correlation. Moreover, the point estimate of the regression slope has increased slightly, and its t-statistic is now $t = (0.7715 - 1)/0.1769 = -1.29$. Consequently, with 26 degrees of freedom, *the slope is still not significantly different from its hypothesized value of one, even in a one-tailed test conducted at the ten percent level of significance*. As a result, this alternative weighting system makes rejection of the HVP even more difficult to justify than it appeared from my earlier estimation.[2] Similarly, increasing the ψ weights slightly for the two discounted valuation equations confirms the absence of serial correlation without fundamentally altering my parameter estimates for them.

Indeed, Cairns and Davis (2004, p. 11) are justly concerned with providing a simple, serviceable valuation equation for practitioners; but their argument that "if practitioners evaluate properties using the formula $V = \lambda S$ then the

[1] These statistics, as well as the R-squared statistics that Cairns and Davis were unable to replicate from Eisenhauer (2004), were generated with the statistical software SPSS, version 12.

[2] If constant returns to scale are assumed, the regression can be run through the origin. In that case, the least squares regression with a weight of 1.7 yields a slope of .914 (with a standard error of .1536)—a more precise estimate that is even closer to one.

Table 1. Z-scores and Two-tailed Prob-values for Wilcoxon Signed-Rank Tests Comparing Prediction Errors from the HVP with Those of Alternative Models

HVP model versus:	Discounted model without inflation	Discounted model with inflation	Ad hoc valuation model $V = 100S$
Absolute errors	−1.252 (0.210)	−1.344 (0.179)	−0.387 (0.699)
Squared errors	−0.911 (0.362)	−1.207 (0.227)	−0.296 (0.767)

factor λ should not be equal to net price but a fraction of it'' begs the question of precisely what fraction to use. Not only is the HVP more convenient in this respect, in practical applications it appears to perform as well as the suggested alternatives. Cairns and Davis object to the use of matched-pairs t-tests to compare predictions across the valuation equations on the grounds that the prediction errors are not normally distributed, [3] so let us instead apply the nonparametric Wilcoxon signed-rank test, which does not require normality. The Z-statistics and two-tailed prob-values for these comparisons are given in Table 1.[4] Regardless of whether the prediction errors are squared or taken in absolute value, *there is still no significant difference in prediction accuracy between the HVP and any one of the three alternatives* that were considered by Cairns and Davis (1998) — the discounted model without inflation, the discounted model with inflation, or the *ad hoc* valuation model $V = 100S$.[5]On both statistical and practical grounds, then, it appears that retention of the HVP is preferable to its rejection.

It is therefore puzzling that Cairns and Davis (2004, p. 7) would conclude, ''Our interpretation is that Eisenhauer's replication … has added to a long series of empirical studies that question the validity of the Hotelling Valuation Principle.'' That assessment is rather misleading in two respects. First, while there are studies whose findings are inconsistent with the HVP, many others endorse the Hotelling Principle. For example, the influential study by Miller and Upton (1985) strongly supports the HVP, as does the work of Stollery (1983), Crain (1988), Crain and Jamal (1991, 1996), Bell et al. (2000), and Chermak and Patrick (2001). Several authors, including Magliolo (1986), Johnson et al. (1995, 1996) and Chermak and Patrick (2002), obtain mixed results, while Heal and Barrow (1980), Agbeyegbe (1989), Young and Ryan (1996), and Slade and Thille (1997) demonstrate that incorporating uncertainty and expectations while attributing risk aversion rather than risk neutrality to mine owners can enhance the predictive accuracy of the basic HVP model. Thus, there is in fact no clear consensus in the literature at large.[6]

At the same time, it seems rather disingenuous to construe my test results as being among those in opposition to the HVP. On the contrary, I find that the HVP cannot be rejected at any reasonable level of significance, and that

[3] They did not, however, raise this objection in their capacity as referees on the first draft of my manuscript.

[4] Kenkel (1989) notes that a sample with more than 15 observations is sufficient for computing Z in Wilcoxon's test.

[5] Similar results are obtained in other nonparametric tests, including Kendall's test, which compares the prediction errors from all four equations simultaneously.

[6] Chermak and Patrick (2002) attempt unsuccessfully to reconcile the differences among several conflicting studies.

its accuracy in predicting gold mine values is not significantly different from the accuracy of any one of the proposed alternatives. Indeed, though I appreciate the authors' efforts to model inflation and discount rates separately, it rather appears that the Cairns and Davis (1998) data have contributed to the body of research that preserves the presumption in favor of Hotelling's rule.

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