WILEY

Accounting Research Center, Booth School of Business, University of Chicago

The Effect of Sequential Information Releases on the Variance of Price Changes in an Intertemporal Multi-Asset Market
Author(s): Robert W. Holthausen and Robert E. Verrecchia
Source: *Journal of Accounting Research*, Vol. 26, No. 1 (Spring, 1988), pp. 82-106
Published by: Wiley on behalf of Accounting Research Center, Booth School of Business, University of Chicago
Stable URL: http://www.jstor.org/stable/2491114
Accessed: 11/01/2014 22:44

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at http://www.jstor.org/page/info/about/policies/terms.jsp

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.



Wiley and *Accounting Research Center, Booth School of Business, University of Chicago* are collaborating with JSTOR to digitize, preserve and extend access to *Journal of Accounting Research.*

http://www.jstor.org

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

Journal of Accounting Research
Vol. 26 No. 1 Spring 1988
Printed in U.S.A.

Research Reports

The Effect of Sequential Information Releases on the Variance of Price Changes in an Intertemporal Multi-Asset Market

ROBERT W. HOLTHAUSEN* AND
ROBERT E. VERRECCHIA†

1. Introduction

This paper considers several determinants of the magnitude of price reactions to information releases from a theoretical perspective, and indicates how those factors affect the magnitude of price responses to new information. We model the change in price to a sequence of public information releases about the liquidating dividends of two risky assets. The market possesses prior information about the mean and variance of the liquidating dividends of the two assets, as well as their cross-sectional correlation. There are two information releases about each of the risky assets and each information release is received simultaneously by all

* University of Chicago; †University of Pennsylvania. We wish to thank Joel Demski, Doug Diamond, Nick Dopuch, Jon Ingersoll, Richard Leftwich, Jim Patell, Richard Ruback, Tom Stober, Ross Watts, Jerry Zimmerman, and two anonymous referees for their insightful comments at various stages in the development of this paper. In addition, we benefited from the comments of the participants of workshops at the University of Chicago, M.I.T., the University of Michigan, Stanford University, and Washington University (St. Louis). Any remaining errors or ambiguities are solely the responsibility of the authors. Holthausen was supported by the Institute of Professional Accounting at the University of Chicago, and Verrecchia acknowledges financial assistance from Arthur Young & Company and the Zimmerman Fellowship at the University of Haifa, under whose auspices he presented this paper there, and at Hebrew and Tel-Aviv Universities. [Accepted for publication October 1987.]

Copyright ©, Institute of Professional Accounting 1988

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

market participants. Each of the information releases reveals the true cash distribution perturbed by some noise or error. The model allows for a completely general cross-sectional variance/covariance structure for the returns on the risky assets and for the information releases. In addition, time-series correlation in the information releases is allowed.

The potential usefulness of the information is determined, in part, by the variance of its error term (its "quality"). An infinite variance renders the information useless for valuing the risky asset. The intertemporal correlation in the error terms of the information disclosures on a given asset indicates, in part, the degree to which two information releases are substitutes. The cross-sectional correlation in the error terms between simultaneous information releases on the two risky assets indicates, in part, the extent to which information about one asset provides information about the other.

Our model provides some structure for investigating variation in stock price changes associated with information releases, since it indicates how various factors determine price changes at the time of information releases. We are able to obtain unambiguous comparative statics for most of these factors by placing certain restrictions on either the intertemporal correlation in the error terms of the information disclosures or on the cross-sectional correlation in asset returns and noise terms in information releases.

Our results indicate that while multiple correlated assets introduce some complexities beyond the single risky asset case, the comparative statics are not affected greatly. The advantage of modeling multiple assets is that we can determine how the results change from the single-asset case and we can examine the effects of changes in the cross-sectional correlations of asset returns and the noise in information releases on the variance of price changes.

OUTLINE OF THE PAPER

In section 2, we consider a simple, single risky asset economy and develop comparative statics on the variance of unexpected price changes. In section 3, we introduce a general formulation of the same problem that considers cross-sectional dependence among multiple risky assets. Section 4 presents the expressions for unexpected changes in prices and the variance of unexpected price changes. In section 5, we develop comparative statics on the variance of unexpected price changes. In section 6, the implications of the model are discussed; and in section 7 the results are summarized.

2. *The Variance of Price Changes with a Single Risky Asset*

Consider a market consisting of a single risky asset which pays off in the single consumption good in the economy, two information releases, and a competitive, risk-neutral market maker. The unknown liquidating

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

dividend for the risky asset is represented by the random variable $\tilde{u}$. When the market closes and the asset liquidates, it pays u, where $\tilde{u} = u$ represents the realization of the liquidating value. At the inception of the market, it is known that $\tilde{u}$ has a normal distribution with mean m and variance v, where v represents the true underlying variability of cash flows of the asset.

Twice from the time the market opens until the risky asset liquidates, information about the liquidating dividend is disseminated to all market participants. The first information release is a signal $\tilde{y}^1$, which communicates the true liquidating dividend perturbed by noise $\tilde{\nu}^1$: $\tilde{y}^1 = \tilde{u} + \tilde{\nu}^1$. The random variable $\tilde{\nu}^1$ has a normal distribution with mean zero and variance n^1. The second information release is a signal $\tilde{y}^2$, which communicates the true liquidating dividend perturbed by noise $\tilde{\nu}^2$: $\tilde{y}^2 = \tilde{u} + \tilde{\nu}^2$. The random variable $\tilde{\nu}^2$ has a normal distribution with mean zero and variance n^2. Taken together, these assumptions imply that the vector $(\tilde{u}, \tilde{y}^1, \tilde{y}^2)$ has a trivariate normal distribution with mean (m, m, m) and covariance matrix:

$$\begin{bmatrix} v & v & v \\ v & v + n^1 & v + c \\ v & v + c & v + n^2 \end{bmatrix}$$

where c represents the covariance between the noise in the first and second information releases; i.e., $c = E[\tilde{\nu}^1 \cdot \tilde{\nu}^2]$.

The market price for the risky asset is set by a risk-neutral, competitive market maker. We assume there exists no private information in the market,[1] thus the market maker learns nothing about the asset's value from buying or selling activity. Consequently, there is no bid–ask spread and the price of the risky asset is always set equal to the conditional expectation of the value of the asset given all available information. For example, let p^0, p^1, and p^2 represent the market prices for the risky asset when the market opens, at the first information release, and at the second information release, respectively.[2] Then the market maker sets those prices as follows:

$$p^0 = E[\tilde{u}] = m,$$

$$p^1 = E[\tilde{u} \mid \tilde{y}^1 = y^1] = m + v(v + n^1)^{-1}(y^1 - m)$$

$$p^2 = E[\tilde{u} \mid \tilde{y}^1 = y^1, \tilde{y}^2 = y^2]$$

$$= m + \frac{v(n^2 - c)(y^1 - m) + v(n^1 - c)(y^2 - m)}{(v + n^1)(v + n^2) - (v + c)^2}.$$

[1] A similar model involving homogeneous beliefs is in Stapleton and Subrahmanyam [1978]. Our setting could be extended more generally to one with private information; see, for example, Bagehot [1971], Glosten and Milgrom [1985], and Diamond and Verrecchia [1987].

[2] While we do not explicitly model trade, there is nothing to preclude trading in this market. Presumably, traders exchange shares of the risky asset for the single consumption good on the basis of the prevailing market price for a variety of liquidity/consumption needs that we do not consider.

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

To capture the notion of a price change, let $\tilde{\delta}^1$ and $\tilde{\delta}^2$ represent the (uncertain) change in the price of the risky asset on the basis of the first and second information releases, respectively. For example:

$$\tilde{\delta}^1 = \tilde{p}^1 - p^0 = v(v + n^1)^{-1}(\tilde{y}^1 - m),$$

$$\tilde{\delta}^2 = \tilde{p}^2 - \tilde{p}^1$$

$$= \frac{-v(v + c)(n^1 - c)(\tilde{y}^1 - m) + v(v + n^1)(n^1 - c)(\tilde{y}^2 - m)}{(v + n^1)([v + n^1][v + n^2] - [v + c]^2)}.$$

This implies that the (unconditional) expectation of $\tilde{\delta}^1$ and $\tilde{\delta}^2$ is zero: formally, $E[\tilde{\delta}^1] = E[\tilde{\delta}^2] = 0$. The variance of $\tilde{\delta}^1$ is given by the expression:

$$\text{Var}[\tilde{\delta}^1] = v^2(v + n^1)^{-1}.$$

It can be shown that the variance of the change in price from when the market opens until the first information release, i.e., $\text{Var}[\tilde{\delta}^1]$, increases as v increases and decreases as n^1 increases. This result is very intuitive. First, as the underlying cash flows of the risky asset become more variable (i.e., as v increases), the price change becomes more variable, because increased v implies more diffuse priors about the behavior of $\tilde{u}$. For more diffuse priors, we expect greater changes in prices (hence greater variability in price changes) at the first information release. Second, as less is learned at the first information release vis-à-vis what was known when the market opened (i.e., as n^1 increases, where increases in n^1 are equivalent to knowing less because more noise is introduced into the signal $\tilde{y}^1$), the price change becomes less variable. This is because as less is learned, the price $\tilde{p}^1 = p^1$ at the first information release is less likely to be different from the opening price p^0.

To consider the variance of the price change from the first to the second information release, we examine the behavior of the variance of $\tilde{\delta}^2$ conditional on observing the price at $\tilde{p}^1 = p^1$; formally, $\text{Var}[\tilde{\delta}^2 \mid \tilde{p}^1 = p^1]$. We condition on $\tilde{p}^1 = p^1$ to ensure that our results involving the variance of *price* changes are equivalent to those involving the variance of *returns* from the first to the second information release, since in this circumstance p^1 is held fixed.

We first consider the variance of price changes for two special cases of the relation between $\tilde{y}^1$ and $\tilde{y}^2$. The first case, *intertemporal sufficiency*, is one in which the signal $\tilde{y}^2$ is sufficient for describing the behavior of $\tilde{u}$ without making reference to the first information release $\tilde{y}^1$: formally, $E[\tilde{u} \mid \tilde{y}^1 = y^1, \tilde{y}^2 = y^2] = E[\tilde{u} \mid \tilde{y}^2 = y^2]$. It can be shown that $\tilde{y}^2$ is sufficient for describing $\tilde{u}$ without $\tilde{y}^1$ whenever $c = n^2$ and $n^1 > n^2$. An example of intertemporal sufficiency occurs when an earnings forecast is released prior to the release of actual earnings. The second information release contains all of the information in the first release (and possibly more) for purposes of determining the true liquidating dividend. When $\tilde{y}^2$ is

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

sufficient for $\tilde{y}^1$, it can be shown that:

$$\tilde{\delta}^2 = \tilde{p}^2 - \tilde{p}^1 = -\frac{v}{(v + n^1)}(\tilde{y}^1 - m) + \frac{v}{(v + n^2)}(\tilde{y}^2 - m)$$

and:

$$\mathrm{Var}[\tilde{\delta}^2 \mid \tilde{p}^1 = p^1] = v^2(v + n^2)^{-1} - v^2(v + n^1)^{-1}.$$

Assuming intertemporal sufficiency, it can be shown that the variance of the change in price from the first to the second information release, conditional on the price at the first information release, i.e., $\mathrm{Var}[\tilde{\delta}^2 \mid \tilde{p}^1 = p^1]$, increases as v increases, increases as n^1 increases, and decreases as n^2 increases. Here, v and n^1 represent the prior information about the behavior of future prices at the time of the first information release. Consequently, as prior information deteriorates (i.e., as v and n^1 increase), less is known about the liquidating value of the risky asset a priori, and so one expects to learn more at the second information release, ceteris paribus. Therefore, the price at the second information release, $\tilde{p}^2 = p^2$, is expected to be less similar to the price at the first release, $\tilde{p}^1 = p^1$, leading to more variable price changes. Alternatively, as n^2 increases, less is learned about the risky asset at the second information release vis-à-vis what was already known a priori (i.e., at the first information release). Therefore, as less is learned (i.e., as n^2 increases), the price $\tilde{p}^2 = p^2$ at the second information release is less likely to be different from the price $\tilde{p}^1 = p^1$ at the first information release and price changes are less variable.

In the second special case, assume that the signals $\tilde{y}^1$ and $\tilde{y}^2$ are conditionally independent, or, equivalently, their respective noise terms are independent; formally, this requires either that $E[\tilde{y}^1 \cdot \tilde{y}^2 \mid \tilde{u} = u] = 0$ or that $c = E[\tilde{\nu}^1 \cdot \tilde{\nu}^2] = 0$. We refer to this case as *intertemporal independence*, a situation in which, say, two earnings forecasts, at two different dates, have uncorrelated errors. In this case, it can be shown that:

$$\tilde{\delta}^2 = \tilde{p}^2 - \tilde{p}^1 = \frac{-v^2 n^1(\tilde{y}^1 - m) + v n^1(v + n^1)(\tilde{y}^2 - m)}{(v + n^1)(v n^1 + v n^2 + n^1 n^2)}$$

and:

$$\mathrm{Var}[\tilde{\delta}^2 \mid \tilde{p}^1 = p^1] = v^2(n^1)^2(v + n^1)^{-1}(v n^1 + v n^2 + n^1 n^2)^{-1}.$$

Assuming intertemporal independence, it can again be shown that the variance of the price change from the first to the second information release, conditional on observing the price at the first release, i.e., $\mathrm{Var}[\tilde{\delta}^2 \mid \tilde{p}^1 = p^1]$, increases as v and n^1 increase, and decreases as n^2 increases. The intuition is the same as in the sufficiency result described above. The question raised in the subsequent discussion is the extent to which this intuition is appropriate for a market containing many (cross-

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

sectionally dependent) assets and many (cross-sectionally dependent) signals or for cases other than intertemporal sufficiency and intertemporal independence.

3. *General Formulation Involving Cross-Sectionally Dependent Assets*

In this section we extend our discussion from the previous section to the case of two cross-sectionally independent risky assets.[3] All other features of the economy remain unchanged. Table 1 contains the time line of events and summarizes the notation which is described next.[4]

The liquidating dividends of the risky assets are unknown until the end of the period and are represented by a 1×2 vector of random variables $\tilde{\mathbf{U}} = (\tilde{u}_1, \tilde{u}_2)$, where $\tilde{u}_1$ is the unknown liquidating dividend of the first risky asset and $\tilde{u}_2$ is the unknown liquidating dividend of the second. Let the 1×2 vector $\mathbf{U} = (u_1, u_2)$ denote the realization of this random variable. Prior beliefs about $\tilde{\mathbf{U}}$ are that it has a bivariate normal distribution with mean $\mathbf{M} = (m_1, m_2)$ and a 2×2 covariance matrix $\mathbf{V}$, where:

$$\mathbf{V} = \begin{bmatrix} v_{11} & v_{12} \\ v_{21} & v_{22} \end{bmatrix}.$$

Here, and throughout the analysis, we assume that covariance matrices are positive definite.[5] Note also that $\mathbf{V}$ is a symmetric matrix, since $v_{12} = v_{21} = E[(\tilde{u}_1 - m_1) \cdot (\tilde{u}_2 - m_2)]$.

At the first information release, the market maker observes a 1×2 vector of random variables $\tilde{\mathbf{Y}}^1 = (\tilde{y}_1^1, \tilde{y}_2^1)$, which communicates the true liquidating dividends $\tilde{\mathbf{U}}$ perturbed by a 1×2 vector of noise $\tilde{\boldsymbol{\eta}}^1 = (\tilde{\nu}_1^1, \tilde{\nu}_2^1)$; thus, $\tilde{\mathbf{Y}}^1 = \tilde{\mathbf{U}} + \tilde{\boldsymbol{\eta}}^1$. (We use subscripts to reference the two risky assets, and superscripts to reference the two information releases.) The signal $\tilde{y}_1^1$ can be thought of as the first information release, or report, about asset 1 and, similarly, $\tilde{y}_2^1$ the first report about asset 2. The random variable $\tilde{\boldsymbol{\eta}}^1$ has a bivariate normal distribution with mean zero and a 2×2 covariance matrix $\mathbf{N}^1$, where:

$$\mathbf{N}^1 = \begin{bmatrix} n_{11}^1 & n_{12}^1 \\ n_{21}^1 & n_{22}^1 \end{bmatrix}.$$

$\mathbf{N}^1$ is symmetric and assumed to be positive definite.

[3] It can be shown that all the results of our analysis hold for an arbitrary number of both (cross-sectionally dependent) risky assets and information releases.

[4] In this section, we use the same notation as in section 2 but adopt the convention of using uppercase letters to represent vectors and matrices. Single-valued parameters continue to be represented by lowercase letters.

[5] It should be emphasized that $\mathbf{V}$ represents the true underlying variability of cash flows of the assets. Specifically, the diagonal terms of $\mathbf{V}$ represent the variability of the cash flows of the two assets, and the off-diagonal terms of $\mathbf{V}$ represent the covariance between the cash flows of the two assets.

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

TABLE 1

Table of Symbols and Sequence of Events

Event	Market Opens	At First Information Release	At Second Information Release	Consumption
Description	Prices are determined on the basis of prior beliefs.	First information release causes change in beliefs and prices of risky assets change accordingly.	Second information release causes change in beliefs and prices of risky assets change accordingly.	Liquidating dividends paid.
Existing Beliefs of Market Maker	$\tilde{\mathbf{U}}$ has a normal distribution with mean $\mathbf{M}$ and covariance matrix $\mathbf{V}$.	$\tilde{\mathbf{U}}$ has a normal distribution with mean $\mathbf{M} + \mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}(\mathbf{Y}^1 - \mathbf{M})'$ and covariance matrix $\mathbf{V} - \mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}\mathbf{V}$.	$\tilde{\mathbf{U}}$ has a normal distribution with mean $\mathbf{M} + (\mathbf{V}, \mathbf{V})\mathbf{H}^{-1}(\mathbf{Y}^1 - \mathbf{M}, \mathbf{Y}^2 - \mathbf{M})'$ and covariance matrix $\mathbf{V} - (\mathbf{V}, \mathbf{V})\mathbf{H}^{-1}(\mathbf{V}, \mathbf{V})'$.	$\tilde{\mathbf{U}} = \mathbf{U}$
Price	$\mathbf{P}^0$	$\mathbf{P}^1$	$\mathbf{P}^2$	$\mathbf{U}$
Change in Price	NA[1]	$\mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}(\mathbf{Y}^1 - \mathbf{M})'$	(see equation (1))	$\mathbf{U} - \mathbf{P}^2$

[1] NA means not applicable.

At the second information release the market maker observes a 1×2 vector of random variables $\tilde{\mathbf{Y}}^2 = (\tilde{y}_1^2, \tilde{y}_2^2)$, which communicates the true liquidating dividends $\tilde{\mathbf{U}}$ perturbed by a 1×2 vector of noise $\tilde{\boldsymbol{\eta}}^2 = (\tilde{\nu}_1^2, \tilde{\nu}_2^2)$; thus, $\tilde{\mathbf{Y}}^2 = \tilde{\mathbf{U}} + \tilde{\boldsymbol{\eta}}^2$. The signal $\tilde{y}_1^2$ is the second information release about asset 1, and, similarly, $\tilde{y}_2^2$ is the second report about asset 2. The random variable $\tilde{\boldsymbol{\eta}}^2$ has a bivariate normal distribution with mean zero and a 2×2 covariance matrix $\mathbf{N}^2$, where:

$$\mathbf{N}^2 = \begin{bmatrix} n_{11}^2 & n_{12}^2 \\ n_{21}^2 & n_{22}^2 \end{bmatrix}.$$

$\mathbf{N}^2$ is symmetric and assumed to be positive definite.[6]

Taken together, these assumptions imply that the 1×6 vector $(\tilde{\mathbf{U}}, \tilde{\mathbf{Y}}^1, \tilde{\mathbf{Y}}^2)$ has a joint hex-variate (unconditional) distribution which is normal with mean $(\mathbf{M}, \mathbf{M}, \mathbf{M},)$, where each $\mathbf{M}$ is the 1×2 vector determined by (m_1, m_2), and a 6×6 covariance matrix:

$$\begin{bmatrix} \mathbf{V} & \mathbf{V} & \mathbf{V} \\ \mathbf{V} & \mathbf{V} + \mathbf{N}^1 & \mathbf{V} + \mathbf{C} \\ \mathbf{V} & \mathbf{V} + \mathbf{C}' & \mathbf{V} + \mathbf{N}^2 \end{bmatrix}$$

where $\mathbf{C}$ is a 2×2 matrix which represents the covariance of the vectors of noise between the first and second information releases:

$$\mathbf{C} = \begin{bmatrix} c_{11} & c_{21} \\ c_{21} & c_{22} \end{bmatrix} = \begin{bmatrix} E[\tilde{\nu}_1^1 \cdot \tilde{\nu}_1^2] & E[\tilde{\nu}_1^1 \cdot \tilde{\nu}_2^2] \\ E[\tilde{\nu}_2^1 \cdot \tilde{\nu}_1^2] & E[\tilde{\nu}_2^1 \cdot \tilde{\nu}_2^2] \end{bmatrix}$$

and $\mathbf{C}'$ is the transpose of $\mathbf{C}$. Note $\mathbf{C}$ is the only matrix, among $\mathbf{V}$, $\mathbf{N}^1$, and $\mathbf{N}^2$, that is not symmetric and is not required to be positive definite for the subsequent analysis. For convenience, we define the 4×4 submatrix $\mathbf{H}$ by:

$$\mathbf{H} = \begin{bmatrix} \mathbf{V} + \mathbf{N}^1 & \mathbf{V} + \mathbf{C} \\ \mathbf{V} + \mathbf{C}' & \mathbf{V} + \mathbf{N}^2 \end{bmatrix}.$$

Note that $\mathbf{H}$ is symmetric and assumed to be positive definite.

Although we begin the analysis without restricting the matrix $\mathbf{C}$, eventually, we consider the same two special cases of the relation between $\tilde{\mathbf{Y}}^1$ and $\tilde{\mathbf{Y}}^2$, as in section 2. Let the notation $\mathbf{A} > \mathbf{B}$ indicate that all ith row, jth column elements of the 2×2 matrix $\mathbf{A}$ are greater than or equal to the equivalent ith row, jth column elements of the 2×2 matrix $\mathbf{B}$ and at least one element is strictly greater. First, the information releases $\tilde{\mathbf{Y}}^1$ and $\tilde{\mathbf{Y}}^2$ are said to be *intertemporally sufficient* if the second information release $\tilde{\mathbf{Y}}^2$ is sufficient for describing the behavior of $\tilde{\mathbf{U}}$ without making reference to the first information release $\tilde{\mathbf{Y}}^1$; that is, $E[\tilde{\mathbf{U}} \mid \tilde{\mathbf{Y}}^1 =$

[6] The first information release can be interpreted as two simultaneous public announcements about the two risky assets, or one public announcement which has implications for both risky assets. This interpretation is appropriate for the second information release as well.

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

$\mathbf{Y}^1$, $\tilde{\mathbf{Y}}^2 = \mathbf{Y}^2] = E[\tilde{\mathbf{U}} \mid \tilde{\mathbf{Y}}^2 = \mathbf{Y}^2]$. Intertemporal sufficiency requires that the matrix $\mathbf{C}$ be identical to the matrix $\mathbf{N}^2$ and $\mathbf{N}^1 > \mathbf{N}^2$.

Second, the information releases $\tilde{\mathbf{Y}}^1$ and $\tilde{\mathbf{Y}}^2$ are said to be *intertemporally independent* if the perturbations of noise in the first and second information releases are independent: that is, $[\tilde{\boldsymbol{\eta}}^1 \cdot \tilde{\boldsymbol{\eta}}^2] = \mathbf{0}$, where $\mathbf{0}$ is a 2×2 matrix of zeroes. Intertemporal independence requires that the matrix $\mathbf{C}$ be identically equal to a 2×2 matrix of zeroes.

Consideration of the general covariance matrix $\mathbf{C}$, and the two special cases of intertemporal sufficiency and independence, provide the basis for examining how the change in the terms of the matrices, $\mathbf{V}$, $\mathbf{N}^1$, and $\mathbf{N}^2$ affects the variance of the price changes at the time of the second information release.

4. *The Change of Prices to Information Releases*

Let $\mathbf{P}^0$, $\mathbf{P}^1$, and $\mathbf{P}^2$ represent the 1×2 vectors of equilibrium prices of the two risky assets when the market opens, at the first information release, and at the second information release, respectively. These prices are set by the competitive, risk-neutral market maker to be equal to the expectation of $\tilde{\mathbf{U}}$ conditional on what is commonly known at the time; that is:

$$\begin{aligned}
\mathbf{P}^0 &= E[\tilde{\mathbf{U}}] = \mathbf{M}, \\
\mathbf{P}^1 &= E[\tilde{\mathbf{U}} \mid \tilde{\mathbf{Y}}^1 = \mathbf{Y}^1] = \mathbf{M} + \mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}(\mathbf{Y}^1 - \mathbf{M})', \\
\mathbf{P}^2 &= E[\tilde{\mathbf{U}} \mid \tilde{\mathbf{Y}}^1 = \mathbf{Y}^1, \tilde{\mathbf{Y}}^2 = \mathbf{Y}^2] \\
&= \mathbf{M} + (\mathbf{V}, \mathbf{V})\mathbf{H}^{-1}(\mathbf{Y}^1 - \mathbf{M}, \mathbf{Y}^2 - \mathbf{M})'.
\end{aligned}$$

Let the 1×2 vector of random variables $\tilde{\boldsymbol{\Delta}}$ define the change in the prices of the two risky assets from the first information release to the second information release; that is:

$$\begin{aligned}
\tilde{\boldsymbol{\Delta}} &= \tilde{\mathbf{P}}^2 - \tilde{\mathbf{P}}^1 \\
&= (\mathbf{V}, \mathbf{V})\mathbf{H}^{-1}(\tilde{\mathbf{Y}}^1 - \mathbf{M}, \tilde{\mathbf{Y}}^2 - \mathbf{M})' - \mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}(\tilde{\mathbf{Y}}^1 - \mathbf{M})' \\
&= ((\mathbf{N}^2(\mathbf{V} + \mathbf{N}^2)^{-1}\mathbf{V} - \mathbf{V}(\mathbf{V} + \mathbf{N}^2)^{-1}\mathbf{C}')\mathbf{Q} \\
&\quad - \mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1})(\tilde{\mathbf{Y}}^1 - \mathbf{M})' \\
&\quad + (\mathbf{V}(\mathbf{V} + \mathbf{N}^2)^{-1} - (\mathbf{N}^2(\mathbf{V} + \mathbf{N}^2)^{-1}\mathbf{V} \\
&\quad - \mathbf{V}(\mathbf{V} + \mathbf{N}^2)^{-1}\mathbf{C}')\mathbf{Q}(\mathbf{V} + \mathbf{C})(\mathbf{V} + \mathbf{N}^2)^{-1})(\tilde{\mathbf{Y}}^2 - \mathbf{M})',
\end{aligned} \tag{1}$$

where:

$$\mathbf{Q} = (\mathbf{V} + \mathbf{N}^1 - (\mathbf{V} + \mathbf{C})(\mathbf{V} + \mathbf{N}^2)^{-1}(\mathbf{V} + \mathbf{C}'))^{-1}.$$

As before, we are concerned with the behavior of $\tilde{\boldsymbol{\Delta}}$ conditional upon observing prices at the first information release, i.e., $\tilde{\mathbf{P}}^1 = \mathbf{P}^1$.

LEMMA 1. Conditional upon observing $\tilde{\mathbf{P}}^1 = \mathbf{P}^1$, $\tilde{\boldsymbol{\Delta}}$ has a bivariate normal distribution with mean (0, 0) and a 2×2 covariance matrix $\mathrm{Var}[\tilde{\boldsymbol{\Delta}}]$, where:

$$\mathrm{Var}[\tilde{\boldsymbol{\Delta}}] = (\mathbf{V}, \mathbf{V})\mathbf{H}^{-1}(\mathbf{V}, \mathbf{V})' - \mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}\mathbf{V}. \tag{2}$$

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

Proof. Equation (2) results from the fact that the vectors of random variables $\tilde{\mathbf{P}}^1$ and $\tilde{\mathbf{P}}^2$ have a joint (unconditional) distribution which is normal with mean $(\mathbf{M}, \mathbf{M})$ and a 4×4 covariance matrix:

$$\begin{bmatrix} \mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}\mathbf{V} & \mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}\mathbf{V} \\ \mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}\mathbf{V} & (\mathbf{V}, \mathbf{V})\mathbf{H}^{-1}(\mathbf{V}, \mathbf{V})' \end{bmatrix}$$

Therefore, the variance of $\tilde{\Delta}$ conditional on $\tilde{\mathbf{P}}^1 = \mathbf{P}^1$ is identical to the variance of $\tilde{\mathbf{P}}^2$ conditional on $\tilde{\mathbf{P}}^1 = \mathbf{P}^1$. The expression for the variance of $\tilde{\Delta}$ is the one given in equation (2) above, using standard formulas for computing the conditional variance of a multivariate normal. The expectation of $\tilde{\Delta}$ is computed similarly, using standard conditional expectation formulas. *Q.E.D.*

Lemma 1 states that the conditional variance of the change in prices is simply the difference between the unconditional variance of $\tilde{\mathbf{P}}^2$, which is $(\mathbf{V}, \mathbf{V})\mathbf{H}^{-1}(\mathbf{V}, \mathbf{V})'$, and the unconditional variance of $\tilde{\mathbf{P}}^1$, which is $\mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}\mathbf{V}$. Intuitively, this occurs because $\tilde{\mathbf{P}}^2$ contains all of the information in $\tilde{\mathbf{P}}^1$ through the signal $\tilde{\mathbf{Y}}^1$, and perhaps more through the signal $\tilde{\mathbf{Y}}^2$. Thus, $\tilde{\mathbf{P}}^2$ is sufficient for describing the behavior of $\tilde{\mathbf{U}}$ without reference to $\tilde{\mathbf{P}}^1$: formally, $E[\tilde{\mathbf{U}} \mid \tilde{\mathbf{P}}^1 = \mathbf{P}^1, \tilde{\mathbf{P}}^2 = \mathbf{P}^2] = E[\tilde{\mathbf{U}} \mid \tilde{\mathbf{P}}^2 = \mathbf{P}^2]$. Consequently, the covariance between $\tilde{\mathbf{P}}^1$ and $\tilde{\mathbf{P}}^2$ is equal to the variance of $\tilde{\mathbf{P}}^1$ alone, which, in turn, implies that the conditional variance is the difference between the unconditional variances.

5. *The Behavior of the Conditional Variance of the Change in Prices*

In this section we derive some results concerning the variance of the change in prices from the first information release to the second information release conditional upon observing $\tilde{\mathbf{P}}^1 = \mathbf{P}^1$.[7] This conditional variance is represented by a 2×2 matrix $\mathrm{Var}[\tilde{\Delta}]$ defined in equation (2) above, whose diagonal terms represent the (conditional) variances of the change in prices of the first and second risky assets, respectively. The off-diagonal terms of the matrix $\mathrm{Var}[\tilde{\Delta}]$ represent the covariance of the

[7] We do not examine in detail the comparative statics for the variance of the change in prices from when the market opens to the first information release with multiple assets because this case is largely subsumed in the more general case of the change between information releases. The expression for the variance of this change is $\mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}\mathbf{V}$. It can be shown that as the quality of the first information release increases, the variance of the change in prices at the first information release increases. However, an increase in the variance of the liquidating dividends can increase or decrease the variance of the change in prices at the first information release, depending on assumptions about the cross-sectional correlations in asset returns and in the noise terms of the first information release. For example, if asset returns and noise terms in the first information release are cross-sectionally independent, an increase in the variance of the liquidating dividends leads to an increase in the variance of price changes at the first information release, ceteris paribus.

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

change in prices of the first and second risky assets. Recall that the diagonal terms of the matrices:

$$\mathbf{V} = \begin{bmatrix} v_{11} & v_{12} \\ v_{21} & v_{22} \end{bmatrix}, \quad \mathbf{N}^1 = \begin{bmatrix} n^1_{11} & n^1_{12} \\ n^1_{21} & n^1_{22} \end{bmatrix}, \quad \text{and} \quad \mathbf{N}^2 = \begin{bmatrix} n^2_{11} & n^2_{12} \\ n^2_{21} & n^2_{22} \end{bmatrix}$$

represent the variances of the liquidating dividends of the first and second risky assets, the variances of the noise perturbations associated with information about the first and second risky assets at the first information release, and the variances of the noise perturbations associated with information about the first and second risky assets at the second information release, respectively. We refer to the diagonal terms in the matrices $\mathbf{N}^1$ and $\mathbf{N}^2$ as measures of the "quality of information" of the information releases $\tilde{\mathbf{Y}}^1$ and $\tilde{\mathbf{Y}}^2$, respectively. Specifically, the quality of the information about asset i at information release t increases (decreases) as n^t_{ii} decreases (increases) $i = 1, 2$, $t = 1, 2$.

In the remainder of section 5, we develop comparative statics on the conditional variance in the change in prices at the time of the second information release with respect to (1) the quality of the second-period information release, (2) the quality of the first-period information release, (3) the variance of the liquidating dividends, and (4) the covariance of the liquidating dividends and the covariances of the noise in the information releases. Table 2 summarizes the comparative static relations involving the conditional variance of the change in prices at the time of the second information release which we develop in the remainder of this section.[8]

5.1 QUALITY OF THE SECOND INFORMATION RELEASE

Our first result, on the quality of the second information release, concerns the general case of no restrictions on either the cross-sectional correlation among assets or information releases, or the intertemporal correlation among information releases. Preliminary to this we need to introduce Lemma 2. We define the matrix $\mathbf{0(j)}$ as a 4×4 matrix with zeroes everywhere except the jth diagonal term (i.e., the jth row, jth column term) which is one.

LEMMA 2. Let $\mathbf{A}$ be a 2×4 matrix. Then all the diagonal terms of the 2×2 matrix $\mathbf{A0(j)A}'$ are nonnegative.

Proof. The 2×4 matrix $\mathbf{A0(j)}$ has zeroes everywhere except the jth column, which is identical to the jth column of the matrix $\mathbf{A}$. The kth diagonal term of the matrix $\mathbf{A0(j)A}'$ is determined by multiplying the kth row of the matrix $\mathbf{A0(j)}$ by the kth column of $\mathbf{A}'$. However, the kth row of the matrix $\mathbf{A0(j)}$ has zeroes everywhere except the jth column term, which is the kth row, jth column term of the matrix $\mathbf{A}$. Call this

[8] Note that in table 2, and throughout the paper, when we use the word "ambiguous" we mean that we can find examples where the comparative statics go in either direction depending on the parameter values chosen.

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

TABLE 2

Comparative Statics for the Variances of the Change in Prices of Both Risky Assets Under Various Conditions

Comparative Static	Assumption Regarding Cross-Sectional and Intertemporal Correlation							
	General Case [No Cross-Sectional or Intertemporal Restriction]	Intertemporal Sufficiency and No Cross-Sectional Restriction	Intertemporal Sufficiency and Assets and Information Releases are Cross-Sectionally Independent	Intertemporal Independence and Assets and Information Releases Are Cross-Sectionally Independent	Assets and Information Releases Are Cross-Sectionally Independent [Single Risky Asset Case]	Intertemporal Independence and No Cross-Sectional Restriction	Intertemporal Dependence (Excluding Intertemporal Sufficiency) and No Cross-Sectional Restriction	Assets and Information Releases Are Cross-Sectionally Dependent and No Intertemporal Restriction
As the Variance of the Liquidating Dividends of Either Risky Asset Increases	Ambiguous[1]	Ambiguous	Nondecreasing	Nondecreasing	Ambiguous Without Intertemporal Sufficiency or Intertemporal Independence	Ambiguous Unless Assets and Information Releases Are Cross-Sectionally Independent	Ambiguous	Ambiguous
As the Quality of Information Concerning Either Risky Asset at the First Information Release Decreases	Ambiguous	Nondecreasing	Nondecreasing	Nondecreasing	Ambiguous Without Intertemporal Sufficiency or Intertemporal Independence	Ambiguous Unless Assets and Information Releases Are Cross-Sectionally Independent	Ambiguous	Ambiguous Without Intertemporal Sufficiency
As the Quality of Information Concerning Either Risky Asset at the Second Information Release Decreases	Nonincreasing	Nonincreasing	Nonincreasing	Nonincreasing	Nonincreasing	Nonincreasing	Nonincreasing	Nonincreasing
As the Covariance in the Liquidating Dividends Increases	Ambiguous	Ambiguous	Not Applicable	Not Applicable	Not Applicable	Ambiguous	Ambiguous	Ambiguous
As the Contemporaneous Covariance in the Noise of Either Information Release Increases	Ambiguous	Ambiguous	Not Applicable	Not Applicable	Not Applicable	Ambiguous	Ambiguous	Ambiguous

[1] Ambiguous means that the comparative statics can go in either direction, depending on the parameter values chosen.

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

term a_{kj}. When the kth row of the matrix $\mathbf{A0(j)}$ is multiplied by the kth column of the matrix $\mathbf{A}'$, the resulting kth diagonal term of the matrix $\mathbf{AO(j)A}'$is a_{kj}^2, since the jth row, kth column term of the matrix $\mathbf{A}'$ is a_{kj}. Thus, regardless of the sign of a_{kj}, the square of this number must be nonnegative. *Q.E.D.*

PROPOSITION 1. As the quality of information concerning either risky asset at the second information release decreases (i.e., as n_{11}^2 or n_{22}^2 increases), the variances of the change in price of both risky assets are nonincreasing (i.e., both diagonal terms of the matrix Var$[\tilde{\mathbf{\Delta}}]$ are nonincreasing), conditional on observing prices at the first information release.

Proof. Mathematically, this proposition requires demonstrating that as either n_{11}^2 or n_{22}^2 increases, all other things held constant, the diagonal terms of the matrix Var$[\tilde{\mathbf{\Delta}}]$ do not increase, and generally decrease. Recall that the matrix $\mathbf{H}$ is defined by:

$$\mathbf{H} = \begin{bmatrix} \mathbf{V} + \mathbf{N}^1 & \mathbf{V} + \mathbf{C} \\ \mathbf{V} + \mathbf{C}' & \mathbf{V} + \mathbf{N}^2 \end{bmatrix}.$$

Using standard results of matrix differentiation (see, e.g., Theil [1971]):

$$\frac{\partial \text{Var}[\tilde{\mathbf{\Delta}}]}{\partial n_{11}^2} = \frac{\partial}{\partial n_{11}^2} ((\mathbf{V}, \mathbf{V})\mathbf{H}^{-1}(\mathbf{V}, \mathbf{V})' - \mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}\mathbf{V})$$

$$= -(\mathbf{V}, \mathbf{V})\mathbf{H}^{-1}\mathbf{0(3)}\mathbf{H}^{-1}(\mathbf{V}, \mathbf{V})'.$$

Note also that:

$$((\mathbf{V}, \mathbf{V})\mathbf{H}^{-1})' = (\mathbf{H}^{-1})'(\mathbf{V}, \mathbf{V})' = \mathbf{H}^{-1}(\mathbf{V}, \mathbf{V})',$$

since $\mathbf{H}$ is a symmetric matrix and hence its inverse is symmetric, thereby justifying $(\mathbf{H}^{-1})' = \mathbf{H}^{-1}$. Thus, letting $\mathbf{A}$ be represented by $(\mathbf{V}, \mathbf{V})\mathbf{H}^{-1}$, Lemma 2 establishes that all the diagonal terms of the 2×2 matrix $\frac{\partial \text{Var}[\tilde{\mathbf{\Delta}}]}{\partial n_{11}^2}$ are nonpositive. This shows that the diagonal terms of the matrix Var$[\tilde{\mathbf{\Delta}}]$ are nonincreasing as n_{11}^2 increases. A similar argument holds for n_{22}^2. *Q.E.D.*

This result is the only unambiguous comparative static result we can achieve for a general setting.[9] The intuition underlying this result was developed in section 2 of a single risky asset.

[9] This result is not limited to the case of two information releases. It indicates that, given our assumptions, the variance of the change in prices at the time of any information release, ceteris paribus, is increasing in the quality of *that information release*. It should be noted, however, that our model ignores the effect of private information, among other factors, and it is possible that the unambiguous prediction obtained on the quality of the second information release becomes ambiguous when private information is considered. That question is beyond the scope of this paper.

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

5.2 QUALITY OF THE FIRST INFORMATION RELEASE

In this section, we show that the result obtained in section 2, concerning the quality of the first information release, is robust with multiple cross-sectionally correlated assets and information releases assuming intertemporal sufficiency. To obtain the same comparative static with intertemporal independence, we must assume either a single risky asset or, equivalently, cross-sectionally independent asset returns and information releases. Moreover, even in the case of a single risky asset, the comparative static result obtained with intertemporal sufficiency or intertemporal independence is not a general result across all possible assumptions about intertemporal correlation.

5.2.1. Intertemporal Sufficiency. Intertemporal sufficiency characterizes a situation in which the price vector at the second information release, $\tilde{\mathbf{P}}^2$, is not directly affected by a change in the information at the first information release, $\tilde{\mathbf{Y}}^1$, since $\tilde{\mathbf{Y}}^2$ contains all the information released by $\tilde{\mathbf{Y}}^1 = \mathbf{Y}^1$ (and, perhaps, more). This can be seen from the fact that the unconditional variance of $\tilde{\mathbf{P}}^2$ is $\mathbf{V}(\mathbf{V} + \mathbf{N}^2)^{-1}\mathbf{V}$ when $\mathbf{C} = \mathbf{N}^2$. Furthermore, the variance of $\tilde{\mathbf{\Delta}}$ conditional upon $\tilde{\mathbf{P}}^1 = \mathbf{P}^1$ also reduces to a simpler form.

LEMMA 3. When the information releases $\tilde{\mathbf{Y}}^1$ and $\tilde{\mathbf{Y}}^2$ are intertemporally sufficient, the variance of $\tilde{\mathbf{\Delta}}$ conditional on observing prices at the first information release reduces to:

$$\mathrm{Var}[\tilde{\mathbf{\Delta}}] = \mathbf{V}(\mathbf{V} + \mathbf{N}^2)^{-1}\mathbf{V} - \mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}\mathbf{V}.$$

Proof. From equation (2) in Lemma 1, when $\mathbf{C} = \mathbf{N}^2$ the matrix $\mathbf{H}^{-1}$ becomes:

$$\mathbf{H}^{-1} = \begin{bmatrix} \mathbf{V} + \mathbf{N}^1 & \mathbf{V} + \mathbf{N}^2 \\ \mathbf{V} + \mathbf{N}^2 & \mathbf{V} + \mathbf{N}^2 \end{bmatrix}^{-1}$$

$$= \begin{bmatrix} (\mathbf{N}^1 - \mathbf{N}^2)^{-1} & -(\mathbf{N}^1 - \mathbf{N}^2)^{-1} \\ -(\mathbf{N}^1 - \mathbf{N}^2)^{-1} & (\mathbf{V} + \mathbf{N}^2)^{-1} + (\mathbf{N}^1 - \mathbf{N}^2)^{-1} \end{bmatrix}.$$

Note that $\mathbf{H}$ is a positive definite matrix since intertemporal sufficiency also requires that $\mathbf{N}^1 > \mathbf{N}^2$. Thus:

$$\mathrm{Var}[\tilde{\mathbf{\Delta}}] = (\mathbf{V}, \mathbf{V})\mathbf{H}^{-1}(\mathbf{V}, \mathbf{V})' - \mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}\mathbf{V}$$

$$= \mathbf{V}(\mathbf{V} + \mathbf{N}^2)^{-1}\mathbf{V} - \mathbf{V}(\mathbf{V} + \mathbf{N}^1)^{-1}\mathbf{V}. \quad \textit{Q.E.D.}$$

The following comparative static follows almost immediately from Lemma 3.

PROPOSITION 2. As the quality of information concerning either risky asset at the first information release decreases (i.e., as n_{11}^1 or n_{22}^1 increases), the variances of the change in price of both risky assets at the second information release are nondecreasing (i.e., both diagonal terms of the matrix $\mathrm{Var}[\tilde{\mathbf{\Delta}}]$ are nondecreasing), conditional on observing prices

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

at the first information release if the information releases are intertemporally sufficient.

Proof. Using an argument similar to that employed in Proposition 1, here we show that as n_{11}^1 increases, the diagonal terms of the matrix $\mathrm{Var}[\tilde{\Delta}]$ do not decrease, and generally increase. Standard matrix differentiation yields:

$$\frac{\partial \mathrm{Var}[\tilde{\Delta}]}{\partial n_{11}^1} = \frac{\partial}{\partial n_{11}^1}\left(\mathbf{V}(\mathbf{V}+\mathbf{N}^2)^{-1}\mathbf{V} - \mathbf{V}(\mathbf{V}+\mathbf{N}^1)^{-1}\mathbf{V}\right)$$

$$= +\mathbf{V}(\mathbf{V}+\mathbf{N}^1)^{-1}\mathbf{0}(\mathbf{1})(\mathbf{V}+\mathbf{N}^1)^{-1}\mathbf{V}.$$

Note also that:

$$(\mathbf{V}(\mathbf{V}+\mathbf{N}^1)^{-1})' = (\mathbf{V}+\mathbf{N}^1)^{-1}\mathbf{V},$$

which allows us to invoke Lemma 2. This, in turn, establishes that all the diagonal terms of the 2×2 matrix $\dfrac{\partial \mathrm{Var}[\tilde{\Delta}]}{\partial n_{11}^1}$ are nonnegative. Finally, this demonstrates that all the diagonal terms of the matrix $\mathrm{Var}[\tilde{\Delta}]$ are nondecreasing as n_{11}^1 increases. A similar argument holds for n_{22}^1. *Q.E.D.*

The result obtained in Proposition 2 depends on intertemporal sufficiency and, hence, is not a general result across all intertemporal correlation structures. The intuition underlying Proposition 2 is that the conditional variance of the change in prices is the difference between the unconditional variance of $\tilde{\mathbf{P}}^2$ and the unconditional variance of $\tilde{\mathbf{P}}^1$. With intertemporal sufficiency, the former is not directly affected by the quality of information at the first information release. Therefore, as the quality of information at the first information release decreases, the market learns less when $\tilde{\mathbf{Y}}^1 = \mathbf{Y}^1$ is disseminated, thus learning increases at the second information release relative to the first. Hence, the variability of the change in prices increases.

5.2.2. Intertemporal Independence and Cross-Sectional Dependence. To appreciate the significance of intertemporal sufficiency when discussing changes in the quality of information at the first information release, consider the following example when we assume that the information releases at the first and second periods are intertemporally independent instead of intertemporally sufficient.

Let:

$$\mathbf{V} = \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix}, \quad \mathbf{N}^1 = \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}, \quad \mathbf{N}^2 = \begin{bmatrix} 50 & 0 \\ 0 & 1 \end{bmatrix}$$

and $\mathbf{C} = \mathbf{0}$. This implies that $\tilde{\mathbf{Y}}^1$ and $\tilde{\mathbf{Y}}^2$ are intertemporally independent but not intertemporally sufficient. Here, the first diagonal term in the matrix $\mathrm{Var}[\tilde{\Delta}]$ is 0.0526. If, however, n_{11}^1 is increased to 3 and everything else is held constant, the first diagonal term in the matrix $\mathrm{Var}[\tilde{\Delta}]$ decreases to 0.0481. This implies that as the quality of information

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

concerning the first risky asset at the first information release decreases, the conditional variance of the change in price of the first risky asset at the time of the second information release decreases. This result seems counterintuitive, in that it would seem that the lower the quality of the information at the first information release concerning the first risky asset, the greater the variability of the change in the price of the first risky asset when $\tilde{\mathbf{Y}}^2 = \mathbf{Y}^2$ is revealed.

We are able to construct the example detailed above because the two information releases are intertemporally independent but not intertemporally sufficient; and the first information release is cross-sectionally dependent. This means that information about the second risky asset at the first information release provides information about the first risky asset because we learn something about the noise associated with the signal about the first risky asset. This, in turn, makes it possible for the conditional variance of the price change of the first risky asset actually to decrease even though less is learned directly about the first risky asset through $\tilde{y}_1^1 = y_1^1$, that part of the signal $\tilde{\mathbf{Y}}^1$ related specifically to the first risky asset.

5.2.3. Intertemporal and Cross-Sectional Independence. As we show in Proposition 3 below, cross-sectional and intertemporal independence are strong assumptions which eliminate some counterintuituve examples like the one constructed in section 5.2.2. Assets and information releases are said to be *cross-sectionally independent*, if the off-diagonal terms of the matrices $\mathbf{V}$, $\mathbf{N}^1$, $\mathbf{N}^2$, and $\mathbf{C}$ are all zero. This implies that the two risky assets, as well as their respective information releases, are wholly independent. Assuming cross-sectional independence, the conditional variances of the change in prices of the two risky assets can be computed as follows.

LEMMA 4. When assets and information releases are cross-sectionally independent:

$$\text{Var}[\tilde{\Delta}] = \begin{bmatrix} \Delta_1 & 0 \\ 0 & \Delta_2 \end{bmatrix}$$

where:

$$\Delta_1 = (v_{11}, v_{11})\mathbf{H}_1^{-1}(v_{11}, v_{11})' - v_{11}(v_{11} + n_{11}^1)^{-1}v_{11}$$

and:

$$\Delta_2 = (v_{22}, v_{22})\mathbf{H}_2^{-1}(v_{22}, v_{22})' - v_{22}(v_{22} + n_{22}^2)^{-1}v_{22}$$

and $\mathbf{H}_i$ is a 2×2 matrix defined by:

$$\mathbf{H}_i = \begin{bmatrix} v_{ii} + n_{ii}^1 & v_{ii} + c_{ii} \\ v_{ii} + c_{ii} & v_{ii} + n_{ii}^2 \end{bmatrix},$$

$i = 1, 2$.

Proof. This result follows from equation (2) in Lemma 1 and setting

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

all the off-diagonal terms of the matrices $\mathbf{V}$, $\mathbf{N}^1$, $\mathbf{N}^2$, and $\mathbf{C}$ equal to zero. *Q.E.D.*

PROPOSITION 3. Suppose that assets and information releases are cross-sectionally independent and information releases are intertemporally independent. Then as the quality of information concerning either risky asset at the first information releases decreases (i.e., as n^1_{11} or n^1_{22} increases), the variances of the change in price of both risky assets at the time of the second information release are nondecreasing (i.e., both Δ_1 and Δ_2 are nondecreasing), conditional on observing prices at the first information release.

Proof. Trivially, as n^1_{ii} increases Δ_j is nondecreasing $i \neq j$, $i = 1, 2, j = 1, 2$, because Δ_j does not change at all whenever assets and information releases are cross-sectionally independent. To examine the relation between n^1_{ii} and Δ_i first note that since information releases are intertemporally independent $c_{11} = c_{22} = 0$. Thus $\mathbf{H}_i^{-1}$ reduces to:

$$\mathbf{H}_i^{-1} = \frac{1}{v_{ii}n^1_{ii} + v_{ii}n^2_{ii} + n^1_{ii}n^2_{ii}} \begin{bmatrix} v_{ii} + n^2_{ii} & -v_{ii} \\ -v_{ii} & v_{ii} + n^1_{ii} \end{bmatrix},$$

and thus Δ_i yields:

$$\Delta_i = \frac{v^2_{ii}(n^1_{ii} + n^2_{ii})}{v_{ii}n^1_{ii} + v_{ii}n^2_{ii} + n^1_{ii}n^2_{ii}} - \frac{v^2_{ii}}{v_{ii} + n^1_{ii}}.$$

Taking the derivative of Δ_i with respect to n^1_{ii} implies:

$$\frac{\partial \Delta_i}{\partial n^1_{ii}} = \frac{v^2_{ii}(v^2_{ii}(n^1_{ii})^2 + 2v^2_{ii}n^1_{ii}n^2_{ii} + 2v_{ii}(n^1_{ii})^2n^2_{ii})}{(v_{ii} + n^1_{ii} + n^2_{ii})^2(v_{ii} + n^1_{ii})^2},$$

which is clearly nonnegative. *Q.E.D.*

Proposition 3 yields the intuitive result that decreasing the quality of information at the first information release results in greater variability in the change in prices. Taken together, Propositions 2 and 3 indicate that we obtain the intuitive comparative static when we assume either intertemporal sufficiency or cross-sectional and intertemporal independence. For some intertemporal correlation structures, however, examples contrary to the implied direction of the comparative statics in Propositions 2 and 3 can be constructed, even in the presence of assets and information releases that are *cross-sectionally independent.* Of course, the lack of an unambiguous comparative static for the most general setting does not indicate that the assumptions of Propositions 2 and 3 are necessary conditions to obtain the intuitive comparative static. They are, however, sufficient conditions.

5.3 VARIANCES OF THE LIQUIDATING DIVIDENDS

In this section, we consider the relation between the underlying variances of the liquidating dividends and the conditional variances of the change in prices at the time of the second information release. Prima

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

facie, it would appear that as v_{11} and v_{22}, the variances of the liquidating dividends of the first and second risky assets, increase, the diagonal terms of the matrix $\mathrm{Var}[\tilde{\Delta}]$ should also increase (or, at least, be nondecreasing). This is because as the liquidating dividends become more variable, expectations, prices, and, presumably, the changes in prices also become more variable. This is the result obtained in section 2 with a single risky asset (or equivalently with cross-sectionally independent assets and information releases) when information releases are either intertemporally independent or intertemporally sufficient. While this result is obtained in those two cases, it is not a general result.

PROPOSITION 4. Suppose that assets and information releases are cross-sectionally independent. Then, as the liquidating dividend of either risky asset becomes more variable (i.e., as v_{11} or v_{22} increases), the variances of the change in price of both risky assets at the time of the second information releases are nondecreasing (i.e., both Δ_1 and Δ_2 are nondecreasing), conditional on observing prices at the first information release whenever information releases are either intertemporally independent or intertemporally sufficient.

Proof. Trivially, as v_{ii} increases Δ_j is nondecreasing $i \neq j$, $i = 1, 2, j = 1, 2$, because Δ_j does not change at all whenever assets and information releases are cross-sectionally independent. To examine the relation between v_{ii} and Δ_i first consider the case in which information releases are intertemporally independent; this requires $c_{11} = c_{22} = 0$. From Proposition 3, the expression for Δ_i is:

$$\Delta_i = \frac{v_{ii}^2(n_{ii}^1 + n_{ii}^2)}{v_{ii}n_{ii}^1 + v_{ii}n_{ii}^2 + n_{ii}^1 n_{ii}^2} - \frac{v_{ii}^2}{v_{ii} + n_{ii}^1},$$

which implies:

$$\frac{\partial \Delta_i}{\partial v_{ii}} = \frac{(n_{ii}^1)^2((v_{ii}n_{ii}^1)^2 + 2(v_{ii})^2 n_{ii}^1 n_{ii}^2 + 2v_{ii}(n_{ii}^1)^2 n_{ii}^2)}{(v_{ii}n_{ii}^1 + v_{ii}n_{ii}^2 + n_{ii}^1 n_{ii}^2)^2 (v_{ii} + n_{ii}^1)^2},$$

which is clearly nonnegative. When information releases are intertemporally sufficient, from Lemmas 3 and 4, Δ_i reduces to:

$$\Delta_i = v_{ii}^2(v_{ii} + n_{ii}^2)^{-1} - v_{ii}^2(v_{ii} + n_{ii}^1)^{-1},$$

which implies:

$$\frac{\partial \Delta_i}{\partial v_{ii}} = \frac{v_{ii}^2 + 2v_{ii}n_{ii}^2}{(v_{ii} + n_{ii}^2)^2} - \frac{v_{ii}^2 + 2v_{ii}n_{ii}^1}{(v_{ii} + n_{ii}^1)^2}.$$

This expression is clearly nonnegative from the fact that $n_{ii}^2 \leq n_{ii}^1$, $i = 1, 2$, whenever information releases are intertemporally sufficient. *Q.E.D.*

While an increase in the variance of the liquidating dividend of asset i results in an increase in the conditional variance of the change in price of asset i under the conditions of Proposition 4, it also relies on the assumed conditions. Hence, this is not a general result across all inter-

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

temporal correlation structures. The reason for this is that from Lemma 1, the conditional variance of the change in prices can be characterized as the difference between the unconditional variance of $\tilde{\mathbf{P}}^1$ and the unconditional variance of $\tilde{\mathbf{P}}^2$. Although increases in the variances of the liquidating dividends may work to increase the unconditional variances of $\tilde{\mathbf{P}}^1$ and $\tilde{\mathbf{P}}^2$, the sign of the *difference* of the unconditional variances is generally ambiguous (in the absence of the requirements specified in Proposition 4).

For example, consider a case in which information releases are intertemporally sufficient, but not cross-sectionally independent, nor are assets cross-sectionally independent. Specifically:

$$\mathbf{V} = \begin{bmatrix} 1 & .9 \\ .9 & 1 \end{bmatrix}, \quad \mathbf{N}^1 = \begin{bmatrix} 3 & 1 \\ 1 & 2 \end{bmatrix}, \text{ and } \mathbf{N}^2 = \begin{bmatrix} 2 & 1 \\ 1 & 1 \end{bmatrix}.$$

Here, the first diagonal term in the matrix $\mathrm{Var}[\tilde{\Delta}]$ is 0.08647. If, however, v_{11} is increased to 1.09 and everything else is held constant, the first diagonal term in the matrix $\mathrm{Var}[\tilde{\Delta}]$ decreases to 0.08430. This occurs because while v_{11} increases the unconditional variances of both $\tilde{\mathbf{P}}^1$ and $\tilde{\mathbf{P}}^2$, it does so for the former more than for the latter, so the difference between the unconditional variances decreases. Other examples can be constructed whereby the first diagonal term of the matrix $\mathrm{Var}[\tilde{\Delta}]$ decreases as v_{11} increases when information releases are intertemporally independent while assets and information releases are cross-sectionally dependent, and when assets and information releases are cross-sectionally independent while information releases are intertemporally neither independent nor sufficient.[10]

5.4 COVARIANCE OF THE LIQUIDATING DIVIDENDS AND COVARIANCES OF THE NOISE IN THE INFORMATION RELEASES

We first consider the covariance of the underlying liquidating dividends, assuming intertemporal sufficiency. Let:

$$\mathbf{V} = \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}, \quad \mathbf{N}^1 = \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}, \quad \mathbf{N}^2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}.$$

Here the first diagonal term in the matrix $\mathrm{Var}[\tilde{\Delta}]$ is 0.375. If the off-diagonal elements of the matrix $\mathbf{V}$ increase to 2 and everything else remains constant, the first diagonal term in the matrix $\mathrm{Var}[\tilde{\Delta}]$ increases to 0.4535. However, if we change the example slightly by setting the off-diagonal terms of $\mathbf{N}^2$ to 1 (i.e., $n_{12}^2 = n_{21}^2 = 1$) and set n_{22}^2 equal to 2, the first diagonal term in the matrix $\mathrm{Var}[\tilde{\Delta}]$ decreases from 0.3750 to 0.2099 as the off-diagonal terms of $\mathbf{V}$ increase from 1 to 2, holding everything

[10] Although we cannot obtain the intuitive comparative static of Proposition 4 in a more general setting, it can be obtained for parameter values of the correlation structures beyond that considered in Proposition 4. Thus, the assumptions of Proposition 4 are sufficient but not necessary conditions to obtain the intuitive comparative statics.

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

else constant. Thus, unambiguous comparative statics on the effect of changes in the covariance of liquidating dividends on the variance of the change in price at the second information release do not exist. The ambiguous result is not caused by assuming intertemporal sufficiency.

Consider now the effect of an increase in the contemporaneous covariance of the noise terms in the second information releases on the variance of the conditional price change at that release. One might anticipate that such an increase in covariance would increase the variance of the price changes at the second information release because more is learned about the noise terms. Intertemporal sufficiency is assumed in the following example. Let:

$$\mathbf{V} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \quad \mathbf{N}^1 = \begin{bmatrix} 3 & 1 \\ 1 & 2 \end{bmatrix}, \quad \mathbf{N}^2 = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix}.$$

Here the first diagonal element in the matrix $\mathrm{Var}[\tilde{\Delta}]$ is 0.3272. If you increase the off-diagonal elements of the matrix $\mathbf{N}^2$ to 1.40, the first diagonal element of the matrix $\mathrm{Var}[\tilde{\Delta}]$ increases to 0.4698, holding everything else constant. If the example is changed slightly by setting the off-diagonal elements of the matrix $\mathbf{V}$ to 1 (i.e., $v_{12} = v_{21} = 1$) and setting v_{22} equal to 2, then the first diagonal element in the matrix $\mathrm{Var}[\tilde{\Delta}]$ decreases from 0.0417 to 0.0192 as the off-diagonal elements of the matrix $\mathbf{N}^2$ increase from 1.0 to 1.4, holding everything else constant. Thus, comparative statics on the cross-sectional correlation of the noise terms in the second information releases are ambiguous. The ambiguity here is not caused by assuming intertemporal sufficiency.

6. *Implications of the Model*

In this section, we discuss the interpretation and the implications of the model more informally and relate them to recent empirical work. Interpretation is aided by examining the assumed nature of the information releases in the model and considering the extent to which we are likely to observe various intertemporal correlation structures in an institutional setting.

6.1 THE NATURE AND REPRESENTATION OF INFORMATION RELEASES

The results obtained in the model depend on assumptions about cross-sectional correlation in asset returns and cross-sectional and intertemporal correlation in the noise in information releases. The assumption of a single risky asset case in section 2 is equivalent to the assumption of cross-sectional independence of both asset returns and the noise in information releases. Empirically, asset returns tend to be positively cross-sectionally correlated; so one cannot rely on these comparative statics. While one might assume that the single risky asset case applies

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

whenever there are not simultaneous information releases on each risky asset, this logic is not correct if the release of information by one firm provides information about the other.[11]

Comparative statics also depend on the intertemporal correlation in the noise of the information releases. In the case of intertemporal independence, the noise terms from the two public information releases are assumed to be intertemporally independent for each firm. The noise relates to the error associated with the signal in an information release about the firm's cash flows. For example, suppose the first announcement is the period's planned capital expenditures and the second announcement concerns a lawsuit. Both announcements are useful for forming expectations about the firm's cash flows, but it does not seem likely that there would be any correlation in their noise terms.

On the other hand, intertemporal independence is not likely if the first announcement is an analyst's forecast of earnings and the second release is the earnings announcement itself. If the analyst's forecast is an attempt to forecast the reported earnings, not the firm's cash flows, the assumption of intertemporal sufficiency seems appropriate. Since the market is interested in inferring the firm's true cash flows from the two announcements, and since both announcements relate to the firm's accounting earnings, not cash flows, it is highly likely that the errors associated with the two information releases regarding the value of the liquidating dividend will be correlated. Further, the second announcement subsumes (is sufficient for) the first.[12] This example can be changed to make the assumption of intertemporal sufficiency less tenable. For example, if both the analyst and the manager attempt to predict true cash flows, the errors associated with their information releases may be correlated but there is now less reason to expect that the manager's earnings number is a sufficient statistic for the analyst's forecast.

In attempting to make empirical predictions from the model concerning the effect of the quality of the first-period information releases or the variance of the underlying cash flows on the variance in price changes at the second information release, one must consider the setting to determine if the assumption of intertemporal sufficiency or intertemporal independence is likely. Of course, there are other correlation structures for which the intuitive predictions will hold, but determining whether a given situation is likely to lead to those predictions would require estimating the parameters of the model. As a practical matter, we can provide

[11] We have interpreted the model as one where both firms release information simultaneously. Another interpretation is to consider a case where only one firm releases information. Within the context of our model, both firms have had an information release if the announcement by firm 1 provides information about firm 2. Thus, the model can be used to consider cases where a release of information by one firm affects the other firm (e.g., Foster [1981]).

[12] With multiple assets, intertemporal sufficiency requires that the second information release is sufficient for the first information release for both firms.

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

no guidance on how that can be done since the noise terms are unobservable. We believe the first step is to consider whether the assumptions of intertemporal sufficiency or intertemporal independence are likely.

If there are more than two information releases on a firm in a given period, determining the intertemporal correlation structure is even more difficult. The previous examples of the likely intertemporal correlation structure of the noise in information releases are relatively simple, because only two information releases are assumed. The greater the number of information releases for a firm, the more difficult it will be to make conjectures about the intertemporal correlation.

If the prediction being made concerns the quality of the second information release, it is not necessary to impose any particular intertemporal correlation structure or to assume cross-sectional independence to obtain an unambiguous prediction given our model. However, to perform an empirical test on whether the variance of price changes increases with the quality of the second information release, a multitude of other factors have to be controlled: in particular, the model indicates that the variance of the underlying cash flows, the quality of the first information release, and the intertemporal and cross-sectional correlation in the noise of the information releases are all important determinants of the variance of the change in prices.[13]

6.2 RELATION OF THE MODEL TO EMPIRICAL RESEARCH

In section 2, we develop a single risky asset model in which we assume either intertemporal independence or intertemporal sufficiency. Section 5 indicates how the intuition developed in section 2 depends on assumptions about intertemporal and cross-sectional correlation. We believe the intuition developed in section 2 is likely to be quite robust in the empirical domain for two reasons. First, some of the counterexamples of section 5 are difficult to find and may perhaps represent perverse cases. Second, the existing empirical work that is related to the model largely supports the intuitive predictions. Despite this, we do expect that some inconsistencies will be observed.

Recent empirical work has examined cross-sectional variation in the common stock return variance at the release of earnings announcements as a function of firm-specific factors such as firm size, predictability of the earnings series, and number of stories in the *Wall Street Journal* prior to the earnings announcement.[14] In general, the results of those papers indicate that the stock return variance at the release of earnings announcements is greater the smaller the firm, the less predictable the earnings series, and the fewer the disclosures in the *Wall Street Journal.*

[13] As indicated by the model, many factors must also be controlled to perform an empirical test on, say, the quality of the first information release or the variance of the asset returns. In these cases, however, we are less likely to have unambiguous comparative statics.

[14] See, for example, Atiase [1985], Freeman [1987], Grant [1980], and Ro [1984].

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

The literature which examines the effect of firm size on the variance of price changes at the time of earnings announcements hypothesizes a negative relation between the two. Firm size is typically used as a proxy for the amount of pre-earnings disclosure or information acquisition. One can think of the first information release in the model as the cumulative effect of the pre-earnings disclosure and the second information release as being the earnings announcement. Since asset returns are empirically cross-sectionally dependent, the prediction being made in this literature is ambiguous within the confines of our model without imposing certain restrictions on the intertemporal correlation structure (e.g., intertemporal sufficiency). In examining the price response to earnings announcements, disclosures which provide information about cash flows beyond the current period's earnings would violate the assumption of intertemporal sufficiency.

Despite the ambiguous comparative static, the literature has consistently found a negative relation between firm size and the variance of returns at the release of earnings announcements. The literature has also found that the number of prior disclosures in the *Wall Street Journal* is negatively related to the variance of stock returns at the time of the earnings announcement. These results suggest that, on average, the intuition developed in section 2 is correct; however, the existence of the counterintuitive results is not precluded.

Pincus [1983] examines whether the variance of stock returns at the time of earnings releases is related to *Value Line*'s measure of the predictability of the earnings, a proxy for the variance of cash flows. He finds evidence consistent with intuition for interim reports; that is, the stock return variance at the release of earnings announcements is greater the less predictable the series. However, he does not obtain that result for annual reports. While our model indicates that the intuition depends on certain restrictions on the cross-sectional and intertemporal correlation structures, we would not have predicted that different results would be obtained for interim and annual reports.

7. *Summary and Conclusions*

The model considers several factors which determine the magnitude of unexpected price reactions to information releases. A sequence of two public information releases on two risky assets is considered. Each information release reveals the true cash distribution of the risky asset plus noise. Unexpected price changes at the time of the second information releases are a function of the market's priors about the liquidating dividends of the two risky assets (their expected values and variance/covariance matrix) and the realized signals associated with the information releases in conjunction with the market's information about the noise in the information signals (i.e., the variance/covariance matrix of the noise terms for the contemporaneous information releases as well as

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

the intertemporal correlation between the noise terms on the two information releases for a given risky asset).

Comparative static relations involving the conditional variance of the change in prices at the time of the second information release are developed. For the general model (with no restrictions on intertemporal correlation in information releases or cross-sectional correlation in information releases or asset returns), unambiguous comparative statics exist only for the variance in price changes at the second information release with respect to the quality of the second information release (see Proposition 1). To develop further comparative statics, on the effect of the quality of the first information release or the underlying variance of the liquidating dividends on the variance of price changes at the second information release, we imposed restrictions on the intertemporal correlation (e.g., intertemporal sufficiency or intertemporal independence) and/or cross-sectional independence (see Propositions 2 to 4). Those propositions yield sufficient but not necessary conditions for obtaining unambiguous comparative statics. No unambiguous comparative statics were found for the covariance in liquidating dividends, or for the contemporaneous covariance in noise terms for the first and second information releases.

The comparative static relations involving the conditional variance of the change in prices at the second information release should be interpreted with care. While counterexamples to the statements of Propositions 2, 3, and 4 can be constructed in the absence of the specified requirements for assets and information releases, it is not clear whether those conditions arise empirically. The characteristics of the information releases and asset returns are specified exogenously in the model, not endogenously. Thus, empirically, a particular covariance structure of asset returns may be associated with particular characteristics of the information releases. Since those "restrictions" are not considered, we are unable to infer whether the intuitive predictions developed in section 2 for the single risky asset case with either intertemporal sufficiency or intertemporal independence will be robust in an empirical setting, even in the absence of the specified requirements of the propositions.

An extension of our analysis might be to test the robustness of the intuitive predictions by performing simulations using data for $\mathbf{V}$, $\mathbf{N}^1$, $\mathbf{N}^2$, and $\mathbf{C}$ that approximate an actual market setting. Unfortunately, measurement of $\mathbf{N}^1$, $\mathbf{N}^2$, and $\mathbf{C}$ is a nontrivial issue, since the noise terms associated with information releases are difficult to measure. We conjecture that the intuition developed in section 2 is important for two reasons. First, at least some of the counterexamples are difficult to generate and may represent perverse cases. Second, the results in the empirical literature are largely consistent with the intuitive predictions. However, we do anticipate that counterintuitive results will arise.

The model has implications for researchers interested in examining the price response to information releases since it indicates the large

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions

number of factors which determine the price reaction. Thus, the model may provide a useful structure for those interested in empirically examining the determinants of cross-sectional variation in price changes to information releases. Simultaneously, however, the model indicates the difficulty in formulating empirical tests to analyze that cross-sectional variation, because of the large number of determinants of the price reaction and the difficulty of empirically estimating those factors.

REFERENCES

ATIASE, R. K. "Predisclosure Information, Firm Capitalization, and Security Price Behavior Around Earnings Announcements." *Journal of Accounting Research* 23 (1985): 21–35.

BAGEHOT, WALTER (pseud.). "The Only Game in Town." *Financial Analysts Journal* 22 (1971): 12–14.

DIAMOND, D. W., AND R. E. VERRECCHIA. "Constraints on Short-Selling and Asset Price Adjustment to Private Information." *Journal of Financial Economics* 18 (1987): 277–311.

FOSTER, G. "Intra-Industry Information Transfers Associated with Earnings Releases." *Journal of Accounting and Economics* 3 (1981): 201–32.

FREEMAN, R. N. "The Association Between Accounting Earnings and Security Returns for Large and Small Firms." *Journal of Accounting and Economics* 9 (1987): 195–228.

GLOSTEN, L., AND P. MILGROM. "Bid, Ask and Transaction Prices in a Specialist Market with Heterogeneously Informed Traders." *Journal of Financial Economics* 14 (1985): 71–100.

GRANT, E. "Market Implications of Differential Amounts of Interim Information." *Journal of Accounting Research* 18 (1980): 255–68.

PINCUS, M. "Information Characteristics of Earnings Announcements and Stock Market Behavior." *Journal of Accounting Research* 21 (1983): 155–83.

RO, B. T. "Firm Size and the Information Content of Actual Earnings Announcements." Working paper, Purdue University, 1984.

STAPLETON, R. C., AND M. G. SUBRAHMANYAM. "A Multiperiod Equilibrium Asset Pricing Model." *Econometrica* 46 (1978): 1077–96.

THEIL, H. *Principles of Econometrics*. New York: Wiley, 1971.

This content downloaded from 211.82.114.94 on Sat, 11 Jan 2014 22:44:37 PM
All use subject to JSTOR Terms and Conditions