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Abstract

Qualitative literature on equity price bubbles has often emphasised the effects of mispriced equity on economic decisions. This paper investigates this issue quantitatively using two ideas. The first is that equity mispricing is transitory, and has no long-run effects on economic outcomes. The second is that there exist observables that are correlated with mispricing, but uncorrelated with changes in fundamentals. Estimates of mispricing appear to accord well with periods described as bubble episodes for the US. The effects of these shocks on household decisions are found to be statistically significant.

JEL Classification Numbers: C36, E21, G11, G12

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1. Introduction

The existence of fads or bubbles in equity prices has been a question long debated by economists. Notable historical episodes of mispricing in equity markets that have been identified include the South Sea Bubble, the Great Railway Bubble, and the US Roaring Twenties. More recent examples of apparent bubbles include Japan's equity and property markets in the 1980s, and the US dot-com boom in the late 1990s. In view of these experiences, there has been ongoing interest in the extent to which equity price bubbles distort economic decision-making. However, somewhat surprisingly, there remains only a limited literature that attempts to quantify the effects of mispricing in equity markets on household and firm decisions.[1]

To provide insight into this question, this paper focuses on identifying the quantitative effects of equity market mispricing on household consumption and portfolio allocation decisions, and firm dividend policies. If mispricing in equity markets exists, the distortion of price signals associated with household wealth held in the form of equity can affect household consumption and portfolio allocation decisions. In addition, mispricing can potentially affect corporate dividend policies. For example, if prices reflect that firms have overly optimistic expectations regarding their future profitability and investment opportunities, this optimism can lead firms to alter their dividend payment decisions. I focus on whether these effects are economically significant. That is, do households consume more or less during a bubble, purchase more or less equity, and do firms change their dividend policies?

1 Examples of such literature include Chirinko and Schaller (2001) and Gilchrist, Himmelberg and Huberman (2005), both of which focus on the effects of bubbles on firms' investment decisions.

There is an extensive literature that seeks to test or identify the existence of equity price bubbles.[2] However, rather than focusing on tests of existence, this paper takes the view that mispricing shocks exist, and then explores their effect on economic decision-making. It builds on ideas that have previously been used to identify mispricing shocks, including the idea that these shocks should be viewed as transitory[3] and that there exist observable proxies that are correlated with mispricing, but uncorrelated with changes in fundamentals.[4] The contribution is to show how both of these ideas can be incorporated in a simple estimation framework that permits analysis of the effects of equity market mispricing.

Using data for the United States, I estimate a system that allows identification of the effects of mispricing shocks on household consumption and portfolio allocation decisions, firm dividend decisions, and equity prices. The proxies for mispricing that I consider are a measure of analyst forecast dispersion (see Diether *et al* (2002); Gilchrist *et al* (2005)), a survey measure of perceived misvaluation (see Shiller (2000b)), and a measure of expected short-term volatility in equity prices. Importantly, these proxies provide information for identifying equity mispricing that is useful in the case that they are correlated with mispricing, but uncorrelated with shocks to fundamentals.

The identification approach suggested in this paper is informative for several reasons. The first is that it does not rely on the restriction that mispricing has no effect on economic decisions *a priori*, and is therefore well equipped to identify the effects of bubbles.[5] A second advantage is that the method proposed here does not require a unique model of the fundamental structure of the economy. In econometric terms, identifying the effects of the non-fundamental transitory (mispricing) shock does not require identification of the permanent (fundamental) shocks to the system. From this perspective, the methodology proposed can be

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2 See, for example, Vissing-Jorgensen (2003) and Gürkaynak (2008) for reviews of this literature.

3 For example, this is implicit in the work of Lee (1998). Transitory shocks are defined in this paper as perturbations that can affect short- but not long-run forecasts. In contrast, permanent shocks are innovations that can influence both short- and long-run forecasts.

4 See, for example, Diether, Malloy and Scherbina (2002) and Gilchrist *et al* (2005).

5 This is in contrast to previous literature, such as Lee (1998), which assumes that mispricing has no real effects.

considered consistent within a class of economic models of fundamentals, rather than requiring a unique model of fundamentals to be identified.

Importantly, the restrictions imposed for identification are made explicit. This is in contrast to statistical approaches used to identify bubbles where the restrictions imposed can be opaque, and the ability to identify the effects of bubbles on economic decisions remains unclear.[6]

The next section outlines related empirical literature. Section 3 outlines the estimation methodology and the approach to identification. Sections 4 and 5 are concerned with the empirical application and the main results. Section 6 considers robustness, and some conclusions are drawn in the final section.

2. Related Literature and Approaches

One approach to identifying equity price bubbles and their effects is to take a stand on a specific model that describes the evolution of the economy. This includes a specific model for equity prices, and possibly a model of the process underlying an equity price bubble as well. Once the model has been specified, econometric tests for the presence of bubbles can be undertaken. Reviews that summarise this literature include Gürkaynak (2008), concerning rational bubbles, and Vissing-Jorgensen (2003), covering the literature in behavioural finance.

One advantage of such a structural approach to identification is that the restrictions used are made explicit and can often be tested. However, as noted by Gürkaynak, a common criticism of these hypothesis tests is that they are unable to distinguish between a test for a bubble, and a test of the model assumed as part of the maintained hypothesis. Accordingly, the validity of any results obtained are contingent on the reader accepting the economic model proposed as the correct one. If there was a strong consensus concerning the 'correct' or 'true' model for the economy and equity pricing this would not be too problematic. However, given a lack of consensus over these issues, it has been difficult for any one structural approach to remain convincing in its ability to detect a bubble.

6 Helbling and Terrones (2003) and Detken and Smets (2004) are examples of purely statistical approaches that measure reduced-form correlations between bubbles and economic variables of interest.

An alternative approach to identifying bubbles is to use a purely statistical or atheoretical approach. Examples of this approach include Helbling and Terrones (2003), Detken and Smets (2004), and Machado and Sousa (2006). The advantage of atheoretical approaches is that they may be less subject to model misspecification, since they do not rely on any particular assumed model, and can be useful for summarising correlations in the data. However, there remains much scepticism of their ability to identify the effects of bubbles on economic decisions more precisely. This stems from the property that these procedures do not appear well-equipped to distinguish between different sources of movements in equity prices, and thus a boom or bust in equity prices that is identified as a bubble could just as likely reflect improved or worsening fundamentals.

A third approach in the literature, which is closest to this paper, is to use some mix of the structural and statistical approaches. Rather than specifying a tight or unique economic model for fundamentals or bubbles, a weaker set of economic restrictions, consistent with economic theory, is used. These restrictions still provide sufficiently rich information to enable the researcher to get closer to identifying the effects of an equity price bubble, but help to avoid criticisms associated with model specificity. Previous literature in this vein, though not always concerned with identifying the effects of equity market mispricing, includes Cochrane (1994), Lee (1995, 1998), Gallagher (1999), Gallagher and Taylor (2000), Chirinko and Schaller (2001) and Gilchrist *et al* (2005). This paper contributes to this literature by providing an informative alternative approach to identifying episodes of mispricing in equity markets, and by providing additional evidence on the effects of this mispricing on economic decisions.

3. Estimation Methodology

I use two ideas to identify the effects of equity mispricing. The first is that equity mispricing should only have transitory economic effects (see, for example, Lee (1998)). Such an assumption appears reasonable from a theoretical standpoint, given that many economists have the prior that equity prices are not entirely disconnected from the fundamental processes underpinning the economy. If the converse were true, and mispricing shocks had permanent effects, then equity prices would effectively be indeterminate and have no relationship with the underlying value of the dividend streams they pay.

The second idea is that there is observable information that can be used to distinguish between fundamental and non-fundamental transitory shocks. This reasoning follows a recent literature which argues that there are observables that are correlated with equity market mispricing, and that are uncorrelated with measures of economic fundamentals, see, for example, Diether *et al* (2002) and Gilchrist *et al* (2005).

I use these two ideas, in conjunction with a cointegration framework implied by economic theory, to identify the effects of equity mispricing shocks. More specifically, I use five economic relationships to motivate the empirical work in this paper. The first is an accumulation equation for aggregate household wealth

$$W_{t+1} = \left(1 + R^{w}_{t+1}\right)(W_t - C_t)$$

where W_t is beginning of period wealth, C_t is total flow consumption in the period, and R^{w}_{t+1} is the return to total wealth. This formulation assumes that the market value of human capital is tradeable and included in aggregate wealth. This assumption simplifies exposition, but is an assumption that can be relaxed without substantively affecting any of the analysis that follows (see Lettau and Ludvigson (2004)). The second relationship used is that household wealth can be decomposed into its respective equity, non-equity, and human capital components

$$W_t = E_t + N_t + H_t$$

where E_t is total equity wealth held by households, N_t is total non-equity wealth (such as housing, consumer durables, and other forms of financial non-equity wealth), and H_t is human capital. The third and fourth relationships used are an accumulation equation for tradeable human capital, and the definition of equity wealth

$$\begin{aligned} H_{t+1} &= \left(1 + R^{h}_{t+1}\right)(H_t - Yt) \\ E_t &= Q_t (P_t + D_t) \end{aligned}$$

where R^{h}_{t+1} is the return to human capital, Y_t is labour income, Q_t is the quantity of equity held, P_t is the ex-dividend price of equity, and D_t is the dividend paid on equity held in period t. The final relationship used is the definition of the return to equity, R^e_{t+1}, where

$$R^e_{t+1} = \frac{P_{t+1} + D_{t+1}}{P_t}$$

Using arguments that are similar to those used by Campbell and Mankiw (1989), Lettau and Ludvigson (2004, 2005) and Kishor (2007), I log-linearise these relationships, assuming a balanced growth path, and obtain the following economic system[7]

$$c_t - w_t \approx \sum_{i=1}^{\infty} \rho_w^i \left(r^w_{t+i} - \Delta c_{t+i}\right) \tag{1}$$

$$w_t \approx \omega_e e_t + \omega_n n_t + \omega_h h_t \tag{2}$$

$$y_t - h_t \approx \sum_{i=1}^{\infty} \rho_h^i \left(r^h_{t+i} - \Delta y_{t+i}\right) \tag{3}$$

$$e_t \approx q_t + \rho_d p_t + (1 - \rho_d) d_t \tag{4}$$

$$d_t - p_t \approx \sum_{i=1}^{\infty} \rho_d^{i-1} \left(r^e_{t+i} - \Delta d_{t+i}\right) \tag{5}$$

where lower case variables denote natural logarithms,[8] ω_e, ω_n and ω_h are the steady state shares of equity, non-equity and human capital wealth in total wealth respectively, ρ_w is the steady state share of savings in total wealth, ρ_h is one minus the share of labour income in steady state human capital, and ρ_d is the steady state ratio of the ex-dividend equity price to the equity price that includes dividends. It should be noted that the system defined by Equations (1) to (5) contains two variables that are not directly observable, human capital wealth and

7 In taking these approximations, I assume that each variable in the system can be normalised by an appropriate trend (for example, the level of productivity or another variable that captures the long-run growth rate of the economy), and that limit terms associated with iterating these relationships forwards are small (of second-order). I omit linearisation constants and growth rates in unobserved trends in the above approximations.

8 Note for returns I use the normalisation $r_{t+i} \equiv \ln(1 + r_{t+i})$.

total household wealth. To account for this, I substitute human capital and total wealth out of the above system to obtain[9]

$$c_t - \omega_e e_t - \omega_n n_t - \omega_h y_t \approx \sum_{i=1}^{\infty} \rho_w^i \left(r_{t+i}^w - \omega_h r_{t+i}^h - \Delta c_{t+i} + \omega_h \Delta y_{t+i} \right) \tag{6}$$

$$e_t \approx q_t + \rho_d p_t + (1 - \rho_d) d_t \tag{7}$$

$$d_t - p_t \approx \sum_{i=1}^{\infty} \rho_d^{i-1} \left(r_{t+i}^e - \Delta d_{t+i} \right) \tag{8}$$

Assuming that consumption, the quantity of equity held, non-equity wealth, equity prices, labour income, and dividends are integrated of order one, and that returns to total financial wealth, human capital wealth and equity wealth are stationary, it follows that Equations (6) to (8) make up a cointegrated system with two cointegrating vectors.

It should be made clear that Equations (6) to (8) make up a partially specified economic system. Additional model structure, for example including an Euler equation for consumption or an equity pricing equation, could potentially imply more restrictions or additional cointegrating relationships in this system. I choose not to include such structure given existing disagreement over the 'correct' model for either consumption or equity prices. Instead, I use the above framework as a motivation for modelling a system consistent with Equations (6) to (8), and use empirical analysis to determine the number of cointegrating relationships. I do not impose any model-specific restrictions that could otherwise be incorporated.

A general econometric representation that is consistent with Equations (6) to (8) is the structural vector error correction model (SVECM)

$$\mathbf{A}_0 \Delta \mathbf{y}_t = -\alpha^* \beta' \mathbf{y}_{t-1} - \mathbf{A}(L) \Delta \mathbf{y}_t + \varepsilon_t \tag{9}$$

where $\mathbf{y}_t$ is an $n \times 1$ vector of observables, $\mathbf{y}_t = \begin{bmatrix} c_t & d_t & n_t & y_t & q_t & p_t \end{bmatrix}'$, $\mathbf{A}(L)$ is a lag polynomial of order l, β' is the matrix of cointegrating vectors, and α^* the matrix of loading coefficients on the cointegrating vectors.[10] I assume $\mathbf{A}_0$ is non-singular and that $\alpha^* \beta'$ has rank $r < n$ so that at least one cointegrating

9 Without loss of generality, I assume when making these substitutions that $\rho_w = \rho_h$.

10 Note I substitute e_t out of the system in Equations (6) to (8) in the analysis that follows.

vector exists. The ε_t are the primitive structural shocks. I assume these shocks are independently identically distributed, with $E(\varepsilon_t) = 0$ and

$$E\left(\varepsilon_t \varepsilon_\tau'\right) = \begin{cases} \Omega \text{ if } \tau = t \\ 0 \text{ otherwise} \end{cases} \tag{10}$$

where Ω is a diagonal matrix (with elements that are not necessarily equal).[11] The ε_t are the underlying structural shocks that I am in interested in identifying. Specifically, I wish to identify the elements of ε_t that only have transitory effects, and in particular, non-fundamental transitory effects.

It should be noted that the structural shocks being serially uncorrelated is not necessarily a restrictive assumption in the current context. In particular, Equation (9) can be viewed as a finite-order approximation of a model in which the structural shocks are serially correlated (see, for example, Lütkepohl (2006)). That is, Equation (9) can be viewed as an approximation of a SVECM with moving average errors,

$$\begin{aligned} \mathbf{A}_0 \Delta \mathbf{y}_t &= -\alpha^* \beta' \mathbf{y}_{t-1} + v_t \\ v_t &= \Psi(L) v_{t-1} + \varepsilon_t \end{aligned} \tag{11}$$

where $\Psi(L)$ is an infinite-order lag polynomial. In this model, transitory mispricing disturbances in v_t can be serially correlated with permanent shocks to fundamentals, an assumption that is consistent with the idea that permanent shocks to fundamentals, such as permanent changes in technology, can precede mispricing in the equity market. In the analysis that follows, I focus on estimating Equation (9), which can be interpreted as a finite-order approximation of Equation (11).[12]

3.1 Identification of Reduced-form Shocks

To distinguish between the reduced-form transitory and permanent shocks in Equation (9), I follow a re-parameterisation of the approach to identification

11 Rather than assuming $E\left(\varepsilon_t \varepsilon_t'\right) = \mathbf{I}$, I impose normalisation (unity) restrictions on the main diagonal of $\mathbf{A}_0$.

12 Lütkepohl (2006) provides a review of the regularity conditions under which such an approximation will be valid.

suggested by Pagan and Pesaran (2008). Without loss of generality, I order the permanent and transitory shocks according to

$$\varepsilon_t = \begin{bmatrix} \varepsilon_t^P \\ \varepsilon_t^T \end{bmatrix}$$

where ε_t^P is a $(n-r) \times 1$ vector of shocks with permanent effects $\left(\lim_{k\to\infty} \frac{\partial E_t(\mathbf{y}_{t+k})}{\partial(\varepsilon_t^P)'} \neq \mathbf{0}_{n\times n-r}\right)$, and ε_t^T is a $r \times 1$ vector of shocks that have transitory effects $\left(\lim_{k\to\infty} \frac{\partial E_t(\mathbf{y}_{t+k})}{\partial(\varepsilon_t^T)'} = \mathbf{0}_{n\times r}\right)$.[13] Since I assume that mispricing shocks have only transitory effects on the system, a mispricing shock must be an element of ε_t^T.

I proceed by estimating Equation (9) using limited information methods. The first step is to obtain a consistent estimate of the cointegrating matrix, β (or use the known cointegration matrix in the case that β is known). Importantly, as emphasised by Pagan and Pesaran, only a consistent estimate of the cointegration space – the column space of β, $\{\beta Q : Q'\beta'\mathbf{y}_t \sim I(0)\text{; given } \mathbf{y}_t \sim I(1) \text{ and } Q \text{ non-singular}\}$ – is required since the instrumental variable (IV) methods described below are invariant to non-singular transformations. A consistent estimate of this space can be obtained, for example, from the Johansen full information maximum likelihood (FIML) estimates of the reduced form of Equation (9) or using alternative system methods discussed by Lütkepohl (2006).

Assuming a consistent estimate of β is available, I partition Equation (9) into a system of $n-r$ equations with permanent shocks, ε_t^P, and r remaining equations with transitory shocks ε_t^T

$$\begin{bmatrix} A_{11}^0 & A_{12}^0 \\ A_{21}^0 & A_{22}^0 \end{bmatrix} \begin{bmatrix} \Delta\mathbf{y}_{1t} \\ \Delta\mathbf{y}_{2t} \end{bmatrix} = -\alpha^*\beta' \begin{bmatrix} \mathbf{y}_{1t-1} \\ \mathbf{y}_{2t-1} \end{bmatrix} - \begin{bmatrix} A_{11}^2 & A_{12}^2 \\ A_{21}^2 & A_{22}^2 \end{bmatrix} \begin{bmatrix} \Delta\mathbf{y}_{1t-1} \\ \Delta\mathbf{y}_{2t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_t^P \\ \varepsilon_t^T \end{bmatrix} \tag{12}$$

13 The fact that the number of transitory shocks is equal to the number of cointegrating vectors is an implication of the Granger representation theorem. Lütkepohl (2006) provides a useful review.

and I assume, without loss of generality, that $\mathbf{A}(L) = A_2 L$. This assumption abstracts from lag dynamics that do not affect the generality of the identification approach proposed.

Since I previously assumed $E\left(\varepsilon_t \varepsilon_t'\right) = \Omega$, where Ω is a diagonal matrix, I impose n normalisation restrictions on the main diagonals of A_{11}^0 and A_{22}^0. I further assume that A_{11}^0 is non-singular. With these assumptions, a simple matrix premultiplication yields

$$\begin{bmatrix} I & \widetilde{A}_{12}^0 \\ A_{21}^0 & A_{22}^0 \end{bmatrix} \begin{bmatrix} \Delta \mathbf{y}_{1t} \\ \Delta \mathbf{y}_{2t} \end{bmatrix} = -\begin{bmatrix} \widetilde{\alpha}_1^* \\ \alpha_2^* \end{bmatrix} \beta' \begin{bmatrix} \mathbf{y}_{1t-1} \\ \mathbf{y}_{2t-1} \end{bmatrix} - \begin{bmatrix} \widetilde{A}_{11}^2 & \widetilde{A}_{12}^2 \\ A_{21}^2 & A_{22}^2 \end{bmatrix} \begin{bmatrix} \Delta \mathbf{y}_{1t-1} \\ \Delta \mathbf{y}_{2t-1} \end{bmatrix} + \begin{bmatrix} u_t^P \\ \varepsilon_t^T \end{bmatrix} \tag{13}$$

where

$$u_t^P = \left(A_{11}^0\right)^{-1} \varepsilon_t^P, \qquad \widetilde{A}_{12}^0 = \left(A_{11}^0\right)^{-1} A_{12}^0$$
$$\widetilde{\alpha}_1^* = \left(A_{11}^0\right)^{-1} \alpha_1^*, \qquad \widetilde{A}_{1j}^2 = \left(A_{11}^0\right)^{-1} A_{1j}^2 \quad \text{for } j = 1,2$$

The above premultiplication is useful because it allows identification of transitory shocks, without requiring identification of the permanent shocks to the system. That is, I only identify linear combinations of the permanent shocks, u_t^P, and not the underlying permanent structural shocks, ε_t^P.

Using the result that lagged error correction terms should not be present in the structural permanent equations, $\alpha_1^* = 0$,[14] one can use these restrictions to estimate the first $n-r$ permanent equations in Equation (13). Specifically, this set of restrictions implies that the $r \times 1$ vector $\xi_{t-1} = \beta' \mathbf{y}_{t-1}$ can be used as instruments for the vector $\Delta \mathbf{y}_{2t}$. And so, the first $n-r$ permanent equations

$$\Delta \mathbf{y}_{1t} = -\widetilde{A}_{12}^0 \Delta \mathbf{y}_{2t} - \widetilde{A}_{11}^2 \Delta \mathbf{y}_{1t-1} - \widetilde{A}_{12}^2 \Delta \mathbf{y}_{2t-1} + u_t^P \tag{14}$$

14 This result is derived in Pagan and Pesaran (2008) with respect to Equation (12), and is consistent with the ordering of permanent and transitory shocks.

can be estimated using standard IV methods. This provides consistent estimates of the reduced-form matrices $\widetilde{A}_{12}^{0}, \widetilde{A}_{11}^{2}$ and $\widetilde{A}_{12}^{2}$, and the reduced-form permanent shocks, u_t^P.

To estimate the remaining r transitory equations

$$A_{22}^{0}\Delta\mathbf{y}_{2t} = -A_{21}^{0}\Delta\mathbf{y}_{1t} - \alpha_2^{*}\xi_{t-1} - A_{21}^{2}\Delta\mathbf{y}_{1t-1} - A_{22}^{2}\Delta\mathbf{y}_{2t-1} + \varepsilon_t^{T} \tag{15}$$

I can now use the consistent estimates, $\widehat{u_t^P}$, as instruments for the endogenous variables in $\Delta\mathbf{y}_{1t}$ (see Pagan and Pesaran (2008)). This would enable identification of the reduced-form transitory shocks, $\left(A_{22}^{0}\right)^{-1}\varepsilon_t^{T}$, but to identify the structural transitory shocks, ε_t^{T}, it is clear that additional restrictions are required.

3.2 Identification of Structural Transitory Shocks

Focusing on the transitory equations in Equation (15), recall that I have already imposed r normalisation (unity) restrictions on the main diagonal of A_{22}^{0}. Since I have previously assumed that transitory shocks are uncorrelated (see Equation 10), this implies that an additional $r(r-1)/2$ additional restrictions are required to be able to identify the structural shocks, ε_t^{T}. Although one could proceed by imposing additional restrictions on the elements of A_{22}^{0}, or using restrictions on any of A_{21}^{0}, α_2^{*}, A_{21}^{2} or A_{22}^{2},[15] in some applications such restrictions may not be appealing on theoretical grounds. This is the case, for example, when attempting to distinguish between fundamental and non-fundamental transitory shocks as considered in the empirical application below.

Instead, I assume there exists additional observable information available to the researcher that allows identification of ε_t^{T}, or at least some of the elements in this transitory shock vector. Specifically, I assume that Equation (15) can be partitioned in a form that is consistent with the presence of an $(r-1)\times 1$ vector

15 This is the approach followed by Pagan and Pesaran (2008) after fully identifying the effects of permanent shocks.

of fundamental transitory shocks, $\varepsilon_t^{f,T}$, and a single non-fundamental transitory shock, $\varepsilon_t^{b,T}$,[16]

$$\begin{bmatrix} A_{11}^{0,22} & a_{12}^{0,22} \\ a_{21}^{0,22} & 1 \end{bmatrix} \begin{bmatrix} \Delta\mathbf{y}_{21t} \\ \Delta\mathbf{y}_{22t} \end{bmatrix} = - \begin{bmatrix} \left[A_{21}^{0}\right]_1 \\ \left[A_{21}^{0}\right]_2 \end{bmatrix} \Delta\mathbf{y}_{1t} - \begin{bmatrix} \left[A_{22}^{2}\right]_1 \\ \left[A_{22}^{2}\right]_2 \end{bmatrix} \begin{bmatrix} \Delta\mathbf{y}_{21t-1} \\ \Delta\mathbf{y}_{22t-1} \end{bmatrix}$$
$$- \begin{bmatrix} \left[A_{21}^{2}\right]_1 \\ \left[A_{21}^{2}\right]_2 \end{bmatrix} \Delta\mathbf{y}_{1t-1} - \begin{bmatrix} \left[\alpha_2^{*}\right]_1 \\ \left[\alpha_2^{*}\right]_2 \end{bmatrix} \xi_{t-1} + \begin{bmatrix} \varepsilon_t^{f,T} \\ \varepsilon_t^{b,T} \end{bmatrix} \tag{16}$$

I further assume there exists an observable instrument (or set of instruments) $\mathbf{Z}_t = \left[z_{1t}', ..., z_{kt}'\right]'$, a $k \times 1$ vector ($k \geq 1$), with the properties that,

$$\begin{aligned} E\left(z_{it}\varepsilon_t^{b,T}\right) &\neq 0 \\ E\left(z_{it}\varepsilon_t^{f,T}\right) &= 0 \\ E\left(z_{it}\varepsilon_t^{P}\right) &= \mathbf{0}_{n-r\times 1} \\ \text{for } i &= 1, ..., k \end{aligned} \tag{17}$$

That is, there exists one or more instruments for equity prices growth that are correlated with mispricing shocks, and contemporaneously uncorrelated with either fundamental transitory or permanent shocks.[17] Assuming $A_{11}^{0,22}$ is non-singular, again using a simple premultiplication of Equation (16) yields

16 I use the notation that $\underset{r\times r}{A_{ij}^{x}} = \begin{bmatrix} \underset{r-1\times r}{\left[A_{ij}^{x}\right]_1} \\ \underset{1\times r}{\left[A_{ij}^{x}\right]_2} \end{bmatrix}$. A similar partition is used with respect to α^*.

17 To be clear, only the first two conditions are required for identification. I use the stronger requirement $E\left(z_{it}\varepsilon_t^{P}\right) = \mathbf{0}_{n-r\times 1}$ since the proxies for mispricing have desirable properties when used as instruments in estimating the permanent equations.

$$\begin{bmatrix} \mathbf{I}_{r-1} & \widetilde{a}_{12}^{0,22} \\ a_{21}^{0,22} & 1 \end{bmatrix} \begin{bmatrix} \Delta\mathbf{y}_{21t} \\ \Delta\mathbf{y}_{22t} \end{bmatrix} = -\begin{bmatrix} \left[\widetilde{A}_{21}^{0}\right]_1 \\ \left[A_{21}^{0}\right]_2 \end{bmatrix} \Delta\mathbf{y}_{1t} - \begin{bmatrix} \left[\widetilde{A}_{22}^{2}\right]_1 \\ \left[A_{22}^{2}\right]_2 \end{bmatrix} \begin{bmatrix} \Delta\mathbf{y}_{21t-1} \\ \Delta\mathbf{y}_{22t-1} \end{bmatrix}$$
$$-\begin{bmatrix} \left[\widetilde{A}_{21}^{2}\right]_1 \\ \left[A_{21}^{2}\right]_2 \end{bmatrix} \Delta\mathbf{y}_{1t-1} - \begin{bmatrix} \left[\widetilde{\alpha}_{2}^{*}\right]_1 \\ \left[\alpha_{2}^{*}\right]_2 \end{bmatrix} \xi_{t-1} + \begin{bmatrix} u_t^{f,T} \\ \varepsilon_t^{b,T} \end{bmatrix} \tag{18}$$

where

$$\begin{aligned} \left[\widetilde{A}_{21}^{0}\right]_1 &= \left(A_{11}^{0,22}\right)^{-1}\left[A_{21}^{0}\right]_1 & \left[\widetilde{\alpha}_{2}^{*}\right]_1 &= \left(A_{11}^{0,22}\right)^{-1}\left[\alpha_{2}^{*}\right]_1 \\ \left[\widetilde{A}_{21}^{2}\right]_1 &= \left(A_{11}^{0,22}\right)^{-1}\left[A_{21}^{2}\right]_1 & \left[\widetilde{A}_{22}^{2}\right]_1 &= \left(A_{11}^{0,22}\right)^{-1}\left[A_{22}^{2}\right]_1 \\ \widetilde{a}_{12}^{0,22} &= \left(A_{11}^{0,22}\right)^{-1} a_{12}^{0,22} & u_t^{f,T} &= \left(A_{11}^{0,22}\right)^{-1}\varepsilon_t^{f,T} \end{aligned}$$

This system can be estimated using a method analogous to that used for the permanent equations. Specifically, one can estimate the first $r-1$ transitory equations using $\widehat{u}_t^P$ and $\mathbf{Z}_t$ as instruments for $\Delta\mathbf{y}_{1t}$ and $\Delta\mathbf{y}_{22t}$ respectively. The residuals $\widehat{u}_t^{f,T}$ and $\widehat{u}_t^P$ can then be used as instruments for $\Delta\mathbf{y}_{21t}$ and $\Delta\mathbf{y}_{1t}$ when estimating the final transitory equation.

In sum, this procedure enables identification of the structural mispricing shock, $\varepsilon_t^{b,T}$, including associated impulse response functions and forecast error variance decompositions that identify the effects of this shock. If alternative instruments, or valid restrictions can be imposed to identify the effects of fundamental transitory shocks, then these too can be used. However, such restrictions are not required to identity the effects of the mispricing shock.

In the empirical application that follows I eliminate Equation (7) from Equations (6) to (8) and order the vector of observables such that $\mathbf{y}_t = \begin{bmatrix} c_t & d_t & n_t & y_t & q_t & p_t \end{bmatrix}'$, and so $\mathbf{y}_{1t} = \begin{bmatrix} c_t & d_t & n_t & y_t \end{bmatrix}'$ and $\mathbf{y}_{2t} = \begin{bmatrix} q_t & p_t \end{bmatrix}'$. That is, there are two cointegrating vectors (transitory shocks) in the system

$(n = 6, r = 2)$,[18] and I assume that these shocks have direct effects on the quantity and price of equity held by households, and indirect effects on consumption, dividends, non-equity worth and labour income. The latter variables are also those directly perturbed by permanent fundamental shocks.

4. Empirical Application

4.1 Data and Preliminary Analysis

For estimation I use quarterly data for the United States, covering the sample period from June 1986 to December 2006 when either forecast dispersion or option-implied equity volatility are used as instruments for mispricing (the $\mathbf{Z}_t$ in the methodology described above), or from December 1988 to June 2010 when using the direct survey measure of overvaluation as an instrument. The starting points of these samples reflect data availability on the instruments used for mispricing. The different end points of these samples allow for a comparison of the results with and without the effects of the financial crisis that emerged in 2007.

Following Lettau and Ludvigson (2004), I use household flow consumption of non-durables (excluding clothing and footwear) as a measure of household consumption, and real household after-tax labour income as the measure of income obtained from human capital.[19] Although it would be ideal to use a measure of the total flow services from consumption, excluding durable expenditures, this measure is not directly observed.[20] To measure the cost of purchasing a unit of US equity (equity prices) I use the share price of Vanguard's S&P 500 ETF measured at the end of the quarter.[21] This measure provides a good proxy for the cost of purchasing a diversified equity portfolio that replicates the US S&P 500. I use a seasonally adjusted quarterly dividend measure, also measured with respect to the US S&P 500.

18 This is confirmed by cointegration matrix rank tests (see Appendix B).

19 For a more detailed description of the data, see Appendix A.

20 See Lettau and Ludvigson (2004) for further discussion.

21 The results are very similar if the US S&P 500 index is used.

US Flow of Funds Accounts data are used to separate US household net financial wealth into its domestic equity and non-domestic-equity components. I focus on domestic equity because I am interested in studying the effects of mispricing in the US equity market.[22] To construct a measure of household wealth held in US equity, I multiply total household equity holdings (which includes both domestic and foreign components) by the proportion of equity held by all sectors (households and corporate) in US equity. This assumes that the household portfolio share allocations to domestic and foreign equity are similar to the allocations held across the total US private sector.[23] Household non-US-equity net wealth (hereafter non-equity net wealth) is a residual defined as total household net financial wealth less holdings of domestic equity. To construct an internally consistent measure of the quantity of equity held by US households (equity quantities), I divide the domestic equity holdings measure by the share price measure defined above.[24]

In terms of observable information used to distinguish between fundamental and non-fundamental transitory shocks, I consider three measures. The first is a measure of analyst forecast dispersion with respect to the US S&P 500, obtained from the Institutional Brokers' Estimate System (I/B/E/S). Specifically, I use the weighted average standard deviation of analysts long-term average growth in earning per share forecasts for the US S&P 500.[25] The second instrument considered is a measure of option-implied equity volatility. In particular, I use implied 30-day volatility for the US S&P 100 as traded on the Chicago Board Options Exchange (with ticker VXO). I use this measure because longer time series are available than for implied 30-day volatility for the US S&P 500 (the VIX), but both measures are highly correlated and the results obtained are not sensitive to this choice over a common sample. The third measure I use is a direct

22 The preceding theoretical discussion can be appropriately modified to account for the fact that US households own both domestic and foreign equity.

23 This assumption is required since data on domestic and foreign equity portfolio allocations are only reported for all US sectors, and not specifically for households.

24 Both the non-equity net wealth and equity quantities measures are lagged one quarter to be consistent with their beginning of period values used in the theory previously discussed.

25 This index is constructed by weighting the standard deviation of analyst forecasts (of long-term average growth in earnings per share) for each firm in the US S&P 500. The weights used reflect the market capitalisation of each firm in the total index.

survey measure of perceived over-valuation in the US equity market obtained from surveys of US institutional investors and sourced from the Yale School of Management (see also Shiller (2000b)).[26] The rationale for using each of these measures as instruments for equity prices growth is discussed further below.

Consumption, non-equity net wealth, equity quantities and real after-tax labour income are all in per capita log terms, and data on equity prices and dividends are in log terms. All data, with the exception of equity quantities, consumption and the instruments for mispricing, are deflated by the US personal consumption expenditure deflator.[27] All data used in estimation are measured at a quarterly frequency.

Before proceeding with the proposed identification methodology, it is important to establish that a cointegration framework is in fact a suitable representation of the data. For pre-testing I use all available data on the endogenous variables $(\mathbf{y}_t)$ from March 1953 to June 2010, to ensure accurate inference. Unit root tests are consistent with each of the data series being $I(1)$, and standard information criteria are consistent with two lags in a levels VAR (a VECM with a single lag). Tests of whether the data are cointegrated (the rank of the cointegration matrix) suggest two cointegrating vectors in the data.[28] All pre-testing results are reported in Appendix B.

Turning to estimation of the cointegration matrix, $\beta' = \left[\beta_1' : \beta_2'\right]$, I restrict attention to the main samples used for estimation, from June 1986 to December 2006 and December 1988 to June 2010. Since it is well known that cointegration estimates are more precise if all known information is used by the researcher in estimation, I restrict the second cointegrating vector to have one and minus one coefficients on dividends and equity prices respectively, $\beta_2' = [\ 0 \ \ 1 \ \ 0 \ \ 0 \ \ 0 \ \ -1\ ]$. This implies that the log dividend to equity price ratio is stationary, which is consistent with

26 I am most grateful to Robert Shiller and the Yale School of Management for making these data available.

27 Consumption of non-durables (excluding clothing and footwear) is deflated by its own implicit price deflator. See Lettau and Ludvigson (2004) for further detail.

28 Rank tests yield similar results if performed on the main estimation sample, from June 1986 to December 2006. All tests allow for an unrestricted constant in the cointegration model.

the theory described above and is a common assumption that has been used in previous empirical research.[29]

Estimating the cointegration matrix, subject to the above restriction, the first cointegrating vector has coefficients $\widehat{\beta}_1'^{1986-2006} = [\ 1\ \ -0.03\ \ -0.08\ \ -0.51\ \ -0.12\ \ -0.08\ ]$ in the sample from June 1986 to December 2006, and $\widehat{\beta}_1'^{1988-2010} = [\ 1\ \ -0.03\ \ -0.04\ \ -0.54\ \ -0.13\ \ -0.07\ ]$ in the sample from December 1988 to June 2010.[30] These coefficients are consistent with economic theory, with human capital estimated to be the largest share of wealth, and the sum of the coefficients on equity prices and dividends being almost identical to the coefficient on equity quantities (as implied by the previous theoretical motivation). These estimates are also comparable to estimates of the same cointegrating relationship – that do not distinguish between the US equity and non-US equity components of wealth – using single-equation methods, see, for example, Lettau and Ludvigson (2004). In the analysis that follows, I use $\widehat{\beta}'^x = \left[\ \widehat{\beta}_1'^x\ \ \beta_2'\ \right]$ for $x = \{1986-2006, 1988-2010\}$ as a consistent estimate of the true cointegration space of the data in each sample, identified up to a non-singular transformation.

4.2 Identification

In view of the fact that the estimation methodology in Section 3 relies on IV techniques, it is important to establish that the instruments used are both relevant and valid.[31] This is especially so for the instruments used for equity prices growth, that enable identification of fundamental and non-fundamental transitory shocks. I first address the question of instrument relevance, before turning to the issue of validity, for each of the instruments in turn.

The rationale for forecast dispersion being correlated with bubbles is that greater heterogeneity in analysts expectations could be consistent with mispricing in equity markets if some analysts are unable (or unwilling) to execute trades

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29 See, for example, Campbell and Shiller (1987), Cochrane (1994) and Lee (1998) amongst others.

30 Specifically, I use FIML (Johansen's approach), subject to the restrictions that the rank of β is two and that β_2' is known. The coefficients in β_1 are identified up to a linear scaling factor.

31 Sarte (1997) provides a useful discussion in the context of structural vector autoregressions.

that reflect this greater divergence of opinion. For example, a constraint on short-selling is one frequently cited market or institutional constraint that would be consistent with greater heterogeneity implying equity mispricing (see, for example, Diether *et al* (2002) and the references cited therein). However, other explanations such as the existence of heterogenous investors, including rational and non-rational investors, and the inability of rational investors to co-ordinate their actions could also imply a correlation between forecast dispersion and mispricing (see, for example, Shleifer and Vishny (1997); Abreu and Brunnermeier (2003)). Furthermore, heterogenous optimism (Brunnermeier and Parker 2005), and the incentive for informed advisors to inflate their forecasts of fundamentals (Hong, Scheinkman and Xiong 2008), are also economic environments that can support a correlation between forecast dispersion and mispricing in the equity market.

In terms of exogeneity, Diether *et al* (2002) and Gilchrist *et al* (2005) argue that forecast dispersion is unlikely to be correlated with the fundamental investment opportunities available to firms. The underlying assumption is that shocks that affect mean forecasts for earnings and equity prices are not systematically correlated with shocks to the variance of these forecasts. For example, Diether *et al* (2002) provide evidence supporting the view that forecast dispersion in earnings per share is a useful instrument for equity prices growth in the US context. These authors highlight that on average companies with higher forecast dispersion for their earnings tend to have low future returns. According to the authors, this pattern is consistent with an interpretation where over-confidence or over-optimism on the part of some investors can lead to overpricing when combined with market, institutional or information constraints on non-optimistic investors. Alternatively, such a correlation is inconsistent with an interpretation where fundamental shocks to uncertainty are driving the correlation between equity prices growth and forecast dispersion.

Gilchrist *et al* (2005) also use forecast dispersion as an instrument for mispricing in the US equity market. They argue that forecast dispersion is a better measure of mispricing than other proxies for bubbles that have been suggested in previous literature, such as lagged prices or market to book valuations. The latter measures are thought more likely to be affected by the investment opportunities available to firms, and thus are more likely to be correlated with fundamental shocks.[32]

Turning to the survey measure of valuation confidence compiled by the Yale School of Management, and discussed in Shiller (2000b), this measure is also likely to be correlated with mispricing in the US equity market. This measure reflects a survey of US institutional investors undertaken biannually until July 2001, and at a monthly frequency thereafter.[33] Institutional investors are asked the following question:

> 'Stock prices in the United States, when compared with measures of true fundamental value or sensible investment value, are: [CIRCLE ONE NUMBER]
> 1. Too low. 2. Too high. 3. About right. 4. Do not know.'

The responses are designed to provide a direct gauge on whether institutional investors perceive US equity markets as being priced correctly, or whether they are undervalued or overvalued.[34] The exogeneity of this measure is largely assured due to survey design. Shiller (2000b) argues that the wording of this question is informative about potential mispricing in the market, because it explicitly asks survey respondents on their views of valuation controlling for their own knowledge or assessment of market fundamentals.[35] Rather than asking institutional investors whether they expected prices to rise or fall, as some other survey measures that would be correlated with fundamentals do, the survey asks

32 For additional surety, I use a measure of forecast dispersion with regard to average long-term growth in earnings per share. This should help to ensure that dispersion is not being driven by fundamental shocks relating to near-term uncertainty.

33 When used in estimation, quarterly data are interpolated from the biannual data prior to July 2001.

34 The Yale School of Management measure reports the Valuation Confidence Index as the number of respondents who choose 1 or 3 as a percentage of those who chose 1, 2 or 3. I use one minus this percentage in subsequent empirical analysis.

35 There is an extensive literature in behavioural finance documenting potential market, institutional or information impediments that can sustain such mispricing, even when certain classes of investors feel confident that current market conditions are consistent with a bubble. See, for example, Shiller (2000a).

respondents directly about valuation in relation to fundamentals, and whether they perceive the current market as being ‘too low’ (undervalued), ‘too high’ (overvalued) or ‘about right’ (fair value).

The third instrument considered is option-implied equity volatility. Conceptually, this derivative is a measure of market expectations concerning future short-term volatility in a share market index. One might expect that during bubble episodes mispricing in equity markets could be correlated with expected volatility in the index. This could occur if some investors use trading strategies that are based on volatility to profit from bubbles. For example, if informed investors consider the market to be over-valued, but are unable to time exactly when a price correction is likely, then a trading strategy that pays high when markets are expected to move strongly in either direction may be a more profitable risk-adjusted strategy than taking short or long positions on a bubble directly.

Nonetheless, whether short-term option-implied volatility is uncorrelated with fundamental shocks is less clear on theoretical grounds. Although implied volatility may be uncorrelated with conventional fundamental shocks, such as shocks to firm productivity or household preferences, it could be argued that movements in short-term volatility could be correlated with short-term uncertainty that is fundamental in nature. For example, shocks such as terrorism attacks, wars, or uncertainty about major policy changes that affect US corporate profitability could be regarded as fundamental short-term volatility shocks that affect option-implied volatility, and potentially other economic variables of interest (see, for example, Bloom (2009)). This suggests that using this third instrument, in conjunction with the identification strategy proposed, may result in inference that is not able to distinguish between the effects of fundamental uncertainty shocks that have transitory effects, and mispricing.

With this caveat in mind, I test whether this third instrument is valid, conditional on either forecast dispersion, or valuation confidence being valid instruments. If it is true that fundamental uncertainty shocks are important in the sample under consideration, and these are correlated with the other permanent or transitory shocks in this system, one would expect option-implied volatility to fail instrument orthogonality tests. Table 1 reports the results of Hausman tests that are robust to the presence of weak instruments.[36] The null hypotheses considered are that each

36 See Hahn, Ham and Moon (2011).

of the permanent shocks are individually uncorrelated with option volatility, and that a linear combination of the permanent shocks and the fundamental transitory shock is also uncorrelated with option volatility.[37] The results in Table 1 highlight that these null hypotheses cannot be rejected at standard significance levels, and so they are consistent with option volatility being a valid instrument for equity prices growth.[38]

Table 1: **Instrument Validity Tests for Option-implied Equity Volatility**

Equation	Hausman test statistic	Hausman test statistic
Consumption[(a)]	0.05	0.04
Dividends[(a)]	0.04	0.01
Non-equity net wealth[(a)]	1.62	0.85
Labour income[(a)]	0.01	0.06
Equity quantities[(b)]	0.04	0.40
Critical value[(c)]	3.84	3.84
Exogenous instruments	$\beta_1 \mathbf{y}_{t-1}$[(a)] Forecast dispersion[(a), (b)]	$\beta_1 \mathbf{y}_{t-1}$[(a)] Valuation confidence[(a), (b)]
Sample	Jun 1986 to Dec 2006	Dec 1989 to Jun 2010

Notes: (a) The null hypothesis is $H_0 : E(z_t u^P_{i,t}) = 0$ vs the alternative $H_1 : E(z_t u^P_{i,t}) \neq 0$

(b) The null hypothesis is $H_0 : E(z_t \tilde{\varepsilon}^{P,T}_t) = 0$ vs the alternative $H_1 : E(z_t \tilde{\varepsilon}^{P,T}_t) \neq 0$

(c) Obtained from a Chi-squared distribution with one degree of freedom, and at the 5 per cent level of significance

An additional reason to think that option volatility is a valid instrument in the current context is due to the sample under consideration. Although fundamental uncertainty shocks are likely to be relevant in the period following the financial crisis that began in 2007–2008, the importance of these shocks is less clear in the sample from June 1986 to December 2006. In particular, one would have to justify why option-implied volatility drifted upwards from June 1995 to March 2000 (see Figure 1), at the same time that equity prices in the United States grew substantially. Such a result is inconsistent with typical fundamental explanations of volatility, which usually suggest that higher volatility should be associated with greater fundamental uncertainty, lower investment and lower equity prices.

37 Refer to Appendix D for the appropriate regression specification in the latter case.

38 Additional tests for conditional validity, for example of forecast dispersion being valid conditional on valuation confidence being valid, also fail to reject the hypothesis that both instruments are valid. Results are available on request.

I now address whether these instruments are relevant from an empirical perspective. Figure 1 reports a graph of equity prices growth compared with each of the three candidate instruments – the second lag of detrended forecast dispersion, contemporaneous option-implied equity volatility, and the first lead of the second difference of the valuation confidence index. These instruments are selected because they have the highest reduced-form correlations with equity prices growth. I use detrended forecast dispersion to account for the upwards drift in earnings per share over time. The second difference, or change in momentum, of valuation confidence is used because it ensures that only information at a biannual frequency is actually used in estimation.[39]

Figure 1 highlights that all three variables appear to exhibit some correlation with equity prices growth, a result that is investigated more formally below. Forecast dispersion and option volatility appear to be most highly correlated with equity prices growth, although all three measures are consistent with an increase in forecast dispersion, uncertainty and concerns of overvaluation in the late 1990s. This preceded the sharp deceleration in prices growth observed in 2000.

Table 2 reports the results from first-stage regressions, and formal tests for instrument relevance, with respect to the permanent equations in Equation (14). To be clear, the two relevant first-stage regressions are of the form

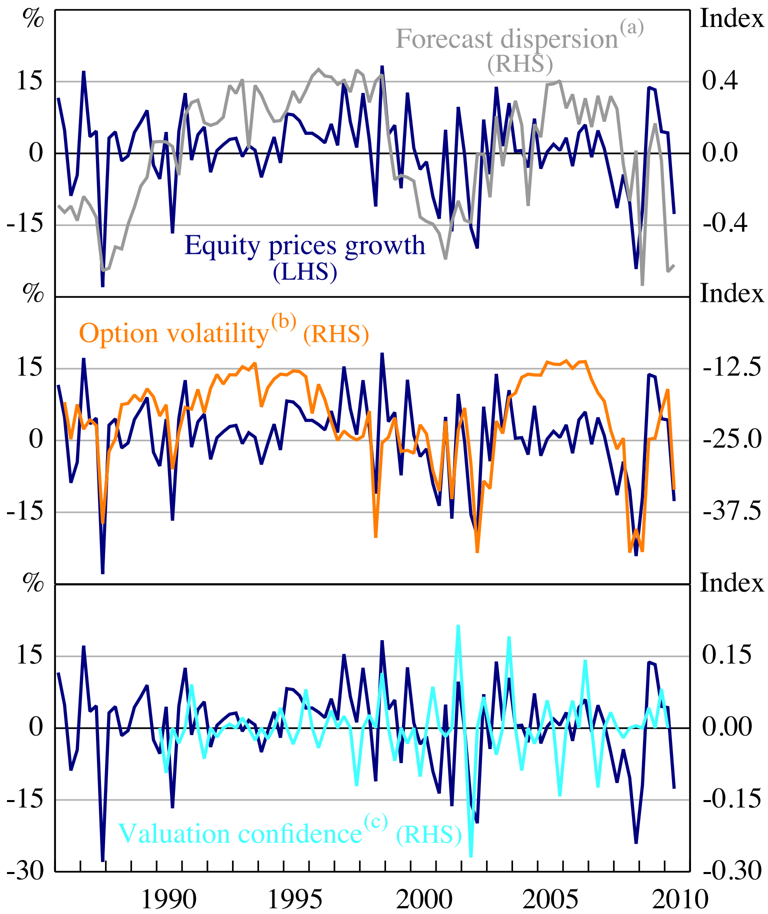
$$\Delta y_{2j,t} = \phi_{1j}' \Delta \mathbf{y}_{1t-1} + \phi_{2j}' \xi_{1t-1} + \phi_{3j}' z_t + \varphi_{2j,t} \tag{19}$$

for $j = 1,2$, where $\xi_{1t-1} = \beta_1 \mathbf{y}_{t-1}$, and z_t is one of the candidate instruments.

The results are highlighted when using each candidate instrument in turn. The first test for relevance considered is that the instruments are under-identified. Essentially, it is a test of whether the excluded instruments, ξ_{1t-1} and z_t, are sufficiently correlated with the endogenous regressors, $\Delta y_{21,t}$ and $\Delta y_{22,t}$, for meaningful IV inference to be undertaken. Using the Cragg-Donaldson Wald statistic (rows 5 and 6),

39 Recall that valuation confidence prior to July 2001 is only measured at a biannual frequency. Using the second difference, on a quarterly linear interpolation, in effect implies that only the change in momentum measured at six-monthly intervals is used. Under relatively weak assumptions, this measure will provide consistent IV estimates.

Figure 1: **Equity Prices Growth and the Instruments for Mispricing**



Notes: (a) Negative of the second lag of detrended forecast dispersion
(b) Negative of VXO stock market volatility index
(c) First lead of the second difference in the Valuation Confidence Index

Sources: Bloomberg; Thomson Reuters; Yale School of Management

the null that the instruments are under-identified can be rejected at conventional significance levels.[40]

Although tests for the null of under-identification can be rejected, tests of the null that the instruments are only weakly correlated with the endogenous regressors cannot be rejected at conventional significance levels. In particular, using the test for weak instruments proposed by Stock and Yogo (2005), the critical values published by Stock and Yogo are greater than the relevant Cragg-Donaldson Wald F-statistics (rows 7 to 9). Moreover, F-statistics associated with the first-stage

40 Although the lagged dividend to equity price ratio, $\beta_2'\mathbf{y}_{t-1}$, is also a valid instrument in the first stage, this instrument was found only to be weakly correlated with equity prices growth and is not therefore used when applying IV.

regressions for each of the instruments suggest that weak instruments could be a concern, especially with respect to the equity quantities measure (rows 1 to 2).

Table 2: Instrument Relevance Statistics – Permanent Equations

	Forecast dispersion	Option volatility	Valuation confidence
Equity quantities F-stat	2.76	2.77	1.71
	3.32	*3.26*	*2.09*
Equity prices F-stat	5.41	11.09	2.10
	3.60	*7.66*	*2.28*
CD Wald stat[(a)(b)]	*4.67*	*5.50*	*3.28*
	(*0.03*)	(*0.02*)	(*0.07*)
CD Wald F-stat[(a)]	2.11	2.37	1.47
	2.08	*2.45*	*1.46*
Critical value[(c)]	3.63	3.63	3.63

Notes: Statistics in italics are computed with robust standard errors
(a) Cragg-Donaldson test statistic
(b) P-values are in parentheses
(c) Based on 25 per cent maximal LIML size and assuming homoskedastic errors

In view of the concern associated with weak instruments for these first-stage regressions, I use two strategies in the analysis that follows. The first is to use just-identified IV estimators, using each of the candidate instruments in turn. There is research suggesting that just-identified estimators can be viewed as approximately median-value unbiased with weak, though identified, instruments.[41] The second strategy, followed in Section 6, is to consider an alternative approach to estimation of the system in Equation (12) that requires fewer instruments in the procedure used to identify the mispricing shock. By reducing the number of endogenous variables, specifically eliminating the need to instrument for the measure of equity quantities, tests of the null that the instruments are weak can be rejected at conventional significance levels. As discussed in Section 6, the results using either strategy are comparable at short- to medium-term horizons.

Proceeding using the just-identified IV estimators, first-stage tests for instrument relevance in the transitory equation for equity quantities are obtained from the following first-stage regressions

$$\Delta \mathbf{y}_{1t} = \Theta_{11}\Delta \mathbf{y}_{t-1} + \theta_{12}\xi_{t-1} + \Theta_{13}\widehat{u}_t^{P,T} + \theta_{14}z_t + \eta_{1t} \tag{20}$$

$$\Delta y_{22t} = \Theta_{21}\Delta \mathbf{y}_{t-1} + \theta_{22}\xi_{t-1} + \Theta_{23}\widehat{u}_t^{P,T} + \theta_{24}z_t + \eta_{22t} \tag{21}$$

41 See, for example, Angrist, Imbens and Krueger (1999) and Angrist and Pischke (2009).

where $\widehat{u}_t^{P,T}$ are the residuals obtained from IV estimates of the permanent equations. Table 3 highlights that when using these residuals and each of the proxies for mispricing shocks as instruments (in turn), first-stage F-statistics are large and the null that these instruments are under-identified can be rejected at conventional significance levels.[42] Nonetheless, it should be noted that the F-statistics that provide a measure of the correlation between the excluded instruments and equity prices growth, rows 9 and 10, remain in a range where weak instruments could be a concern. I next present point estimates based on the just-identified IV estimators, before turning to the question of whether concerns associated with weak instruments are likely to be biasing these point estimates.

Table 3: Instrument Relevance Statistics – Transitory Equation for Equity Quantities

	Forecast dispersion	Option volatility	Valuation confidence
Consumption F-stat	17.85	13.23	16.45
	11.40	*12.98*	*15.11*
Dividends F-stat	55.77	51.82	231.32
	54.24	*47.59*	*209.17*
Non-equity net worth F-stat	108.70	7.5×10^4	33.54
	60.00	1.6×10^5	*36.09*
Labour income F-stat	142.88	145.73	210.13
	160.69	*168.64*	*295.70*
Equity prices F-stat	7.14	7.48	4.89
	4.54	*4.88*	*3.86*
CD Wald stat[(a)(b)]	*8.90*	*16.90*	*4.62*
	(0.00)	*(0.00)*	*(0.03)*

Notes: Statistics in italics are computed with robust standard errors
(a) Cragg-Donaldson test statistic
(b) P-values are in parentheses

42 Results are qualitatively similar for the transitory equation for equity prices, and are available on request.

5. Results

5.1 Response Functions and Variance Decompositions

Figure 2 reports the impulse response functions associated with an exogenous 1 per cent increase in mispricing that is transitory, when using forecast dispersion, option volatility, and valuation confidence in turn as instruments.[43] The results highlight that the mispricing shock has a persistent effect on equity prices, with more than one quarter of its initial effect still being observed after five years. In addition, prices do not appear to over-correct in response to a positive mispricing shock, suggesting that both positive and negative mispricing shocks are required to generate the boom and bust patterns often referred to in qualitative accounts of equity market bubbles.

In terms of the effects on other economic variables in the system, there is a persistent increase in consumption in response to a positive innovation in mispricing. Consumption exhibits a hump-shaped response with the maximum effect being in the order of 0.05 percentage points, which occurs around three years after the initial shock. This effect increases to around 0.5 percentage points in response to a one standard deviation mispricing shock.[44]

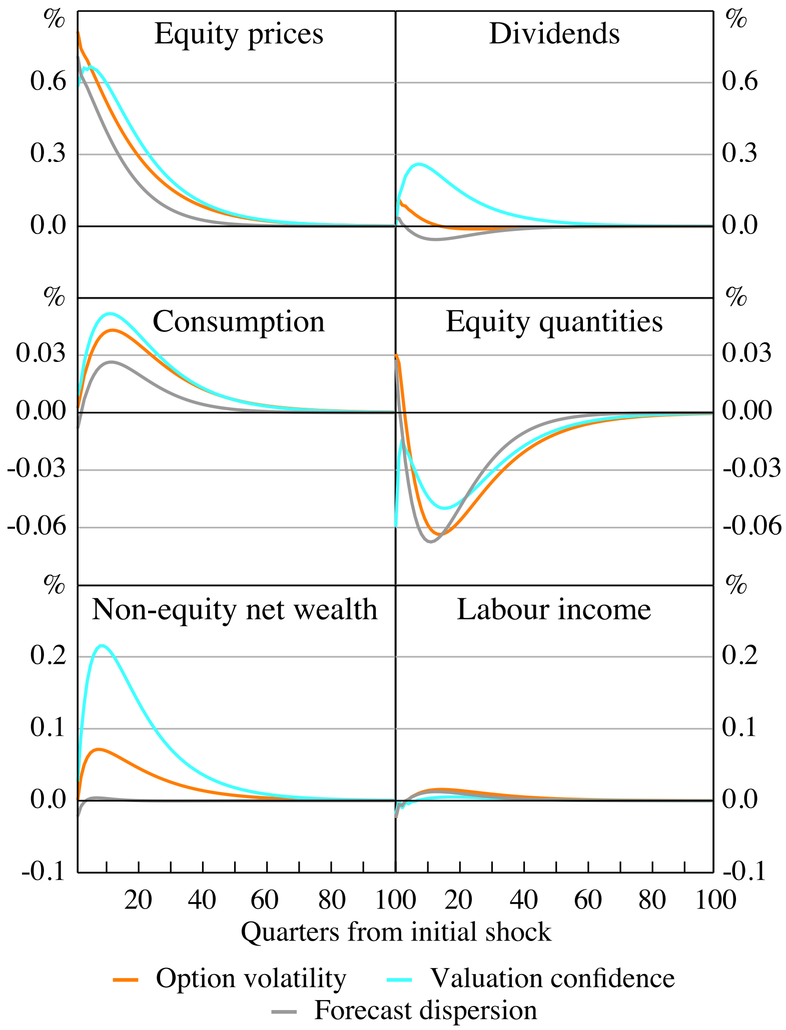
An interesting pattern can be observed in the impulse response function for the quantity of equity held by households (equity quantities). Initially, households increase their equity holdings, when using either forecast dispersion or option volatility as instruments, and then subsequently reduce these holdings as the effects of the mispricing shock begin to dissipate. One interpretation consistent with this result is that households are able to perceive misvaluation in equity markets following a mispricing shock. This could help to explain why households reduce their equity holdings before prices have fully reverted to their fundamental value. The reduction in equity holdings is also consistent with households using the proceeds of equity sales to increase their level of consumption.

Nevertheless, it should be noted that the reduction in equity quantities is smaller than the increase in prices, and so the value of households' equity holdings

43 Confidence intervals for these estimates are analysed in Section 6.1.

44 A one standard deviation mispricing shock increases equity prices in the order of 9 to 10 per cent depending on the instrument used.

Figure 2: **Impulse Response Functions to a Positive 1 Per Cent Mispricing Shock**



increases in response to the mispricing shock. In this light, an alternative interpretation of the reduction in equity holdings is that it represents portfolio rebalancing given US households' increased exposure to domestic equities.

Turning to corporate dividend policies, the estimated results are less precise with the magnitude of the impulse response functions sensitive to the choice of instrument used. However, there is evidence to suggest that firms may bring forward the timing of their dividend payments in response to a positive mispricing shock. This could reflect firms using dividends as a signal of their more favourable expectations concerning their future profitability. Interestingly, only when using forecast dispersion as an instrument are dividends subsequently underpaid relative to their value without mispricing.

For the non-equity net wealth measure, the impulse response function is close to zero when using forecast dispersion as an instrument, but positive when using either option volatility of valuation confidence. Thus, whether positive mispricing in equity markets affects other components of household net worth remains an open questions based on these estimates. With regard to labour income, all three measures suggest that positive mispricing shocks have little effect on the after-tax income earned by households.

Table 4 reports a forecast error variance decomposition of equity prices and quantities, with the contributions of fundamental shocks and mispricing shocks separately identified at short- to medium-term forecast horizons.[45] The results highlight that transitory mispricing shocks explain the majority of variation in equity prices growth at these forecast horizons. For example, when using forecast dispersion as an instrument, around two-thirds of the forecast error variance in prices growth can be explained by mispricing. In contrast, fundamental shocks are only able to explain between 16 and 40 per cent of the variation in equity prices growth at short to medium forecast horizons, depending on the instrument used. These results suggest that fundamental shocks to two of the most important variables emphasised by economic theory for equity pricing, consumption and dividends, explain some of the variation in equity prices. However, a larger part of this variation remains unexplained.

For equity quantities the proportion of the forecast error that can be explained by permanent and transitory fundamental shocks is much larger, in excess of 90 per cent according to these estimates. This suggests that changing fundamentals, as measured here, are much more able to explain variation in the quantity of domestic equity held by households, rather than the price of domestic equity.

Table 5 reports a similar forecast error variance decomposition for consumption and dividends. In this case fundamental shocks explain much of the short term variation in consumption. However, there is evidence to suggest that at medium horizons, from one to four years, a non-trivial fraction of the variation in consumption can be explained by mispricing shocks. These estimates suggest that although fundamental shocks are most important, non-fundamental transitory

45 Note that fundamental shocks include both the reduced-form permanent and transitory fundamental shocks identified.

shocks do not necessarily have trivial effects on the consumption decisions of households.

Table 4: Forecast Error Variance Decomposition

	Equity prices		Equity quantities	
	Fundamental[(a)]	Mispricing	Fundamental[(a)]	Mispricing
Forecast dispersion				
2-quarter	0.33	0.67	0.99	0.01
1-year	0.34	0.66	0.99	0.01
4-year	0.40	0.60	0.95	0.05
Option volatility				
2-quarter	0.17	0.83	0.99	0.01
1-year	0.16	0.84	0.99	0.01
4-year	0.16	0.84	0.97	0.03
Valuation confidence				
2-quarter	0.40	0.60	0.95	0.05
1-year	0.16	0.84	0.97	0.03
4-year	0.17	0.83	0.96	0.04

Notes: (a) Fundamental includes both permanent and transitory fundamental shocks

Table 5: Forecast Error Variance Decomposition

	Consumption		Dividends	
	Fundamental[(a)]	Mispricing	Fundamental[(a)]	Mispricing
Forecast dispersion				
2-quarter	0.96	0.04	0.98	0.02
1-year	0.95	0.05	0.99	0.01
4-year	0.86	0.14	0.98	0.02
Option volatility				
2-quarter	0.94	0.06	0.86	0.14
1-year	0.80	0.20	0.88	0.12
4-year	0.64	0.36	0.96	0.04
Valuation confidence				
2-quarter	0.78	0.22	0.88	0.12
1-year	0.66	0.34	0.74	0.26
4-year	0.64	0.36	0.71	0.29

Notes: (a) Fundamental includes both permanent and transitory fundamental shocks

For dividends, fundamental permanent and transitory shocks again explain the majority of the forecast error variation at all horizons. However, in line with the estimated impulse responses, there is mixed evidence on the importance of mispricing shocks for variation in dividends, with estimates ranging from close to zero to as much as 29 per cent of the variation in dividends at a medium-term horizon, depending on the instrument used.

5.2 Analysis of Historical Episodes

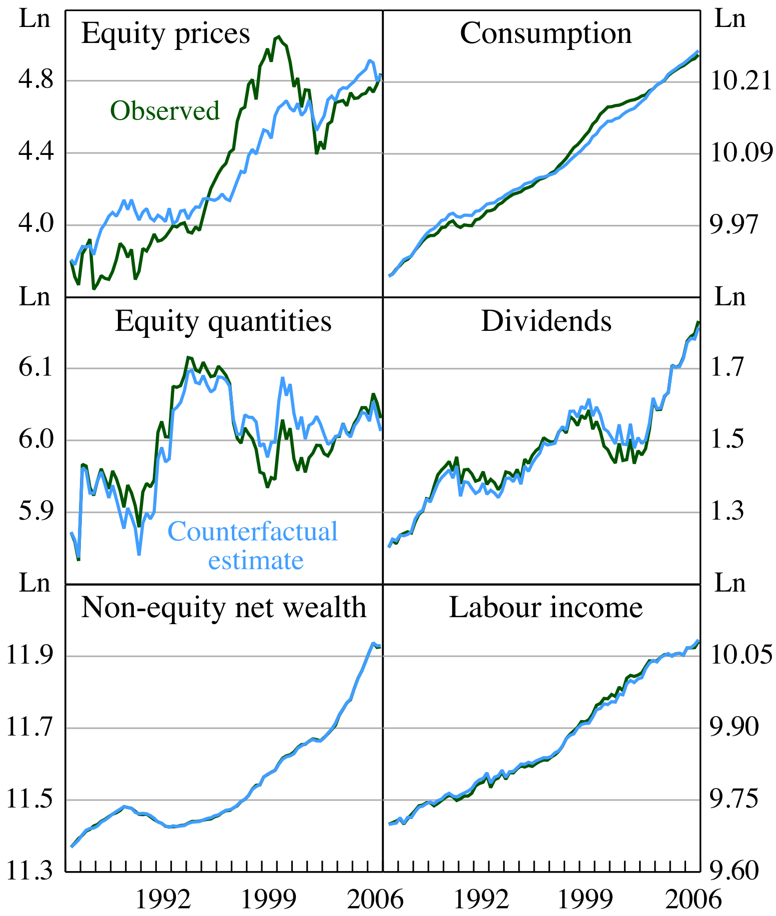
The previous forecast error variance decompositions compute the relative importance of alternative shocks over the full estimation sample. To provide additional insight into the importance of mispricing shocks in various historical episodes, Figure 3 compares each observed variable with a counterfactual estimate that assumes that all mispricing shocks are zero in the estimation sample from June 1986 to December 2006, and when using forecast dispersion as the relevant instrument. Estimates of the counterfactuals are conditioned taking the December 1985 and March 1986 observations as initial values.[46] The equity prices panel in Figure 3 identifies two notable episodes of mispricing in the data. The first is under-valuation of US equity from 1987 to around 1995, which appears to be at least partly associated with the October 1987 stock market crash. After this time the equity market remains undervalued during the 1990–1991 recession. Prices then start to correct as the US economy recovers from this recession with prices being closer to their fundamental value from around 1992.

The second notable episode of mispricing is the familiar US dot-com bubble. From March 1995 to the height of the bubble in March 2000, the US equity market appears substantially overvalued. In March 2000, these estimates suggest that the US S&P 500 equity index was overvalued by around 45 per cent, before the subsequent collapse in equity prices was observed. Interestingly, equity was only slightly undervalued following the bursting of the dot-com bubble, and there was no clear evidence that equity markets were substantially mispriced in the lead-up to the financial crisis that began to emerge in September 2007.

Turning to consumption, it is clear that the level of consumption and the sign of mispricing shocks are positively correlated. In particular, observed per capita consumption appears lower than its counterfactual estimate during the late 1980s

46 To ensure that these results are not sensitive to initial conditions, I also compute the observed and counterfactual paths for longer time series of historical data. Under the assumption that the structural model is stable over a period prior to the sample used in estimation, the results are qualitatively similar.

Figure 3: Observed and Counterfactual Comparison



and early 1990s, and is above its counterfactual estimate during the dot-com boom. Between March 1997 and December 2000, consumption grew on average 0.6 per cent per annum faster than in the absence of mispricing associated with the dot-com bubble. This suggests that mispricing did have an effect on the consumption decisions made by households.

Again, an interesting pattern emerges with respect to household equity holdings. During the early stages of the dot-com boom, between 1995 and 1997, the counterfactual estimate of the quantity of equity held lies below its corresponding observed value. However, during the latter stages of the bubble, from 1997 onwards, households actually reduce their exposure to US equity. This finding is somewhat surprising given that many qualitative accounts of bubbles do not contend that households reduce their equity holdings when concerns surrounding a bubble are raised. Nonetheless, these results suggest that households may either be selling equity, in part to fund higher consumption, or are consciously reducing their equity exposure due to concerns about mispricing.

For dividends, labour income, and non-equity net worth, the observed and counterfactual estimates are much more closely aligned. This suggests that mispricing shocks had much less effect on the observed variation in these variables, when using forecast dispersion as an instrument.

Another approach for obtaining insight into the relative contributions of alternative shocks is to use a historical forecast error decomposition. Figures 4 and 5 report the relative contributions to the two-year-ahead forecast errors of transitory mispricing shocks, transitory fundamental shocks, and the reduced-form permanent shocks, again when using forecast dispersion as an instrument. Consistent with the counterfactual analysis discussed previously, it is clear that transitory mispricing shocks explain a non-trivial fraction of the forecast errors in equity prices and consumption. But they explain only a relatively small fraction of the errors for equity quantities, dividends, labour income and non-equity net worth. For these latter variables, reduced-form permanent shocks provide the largest contribution to the forecast errors observed.

Figure 4: Two-year Horizon Forecast Error Contributions

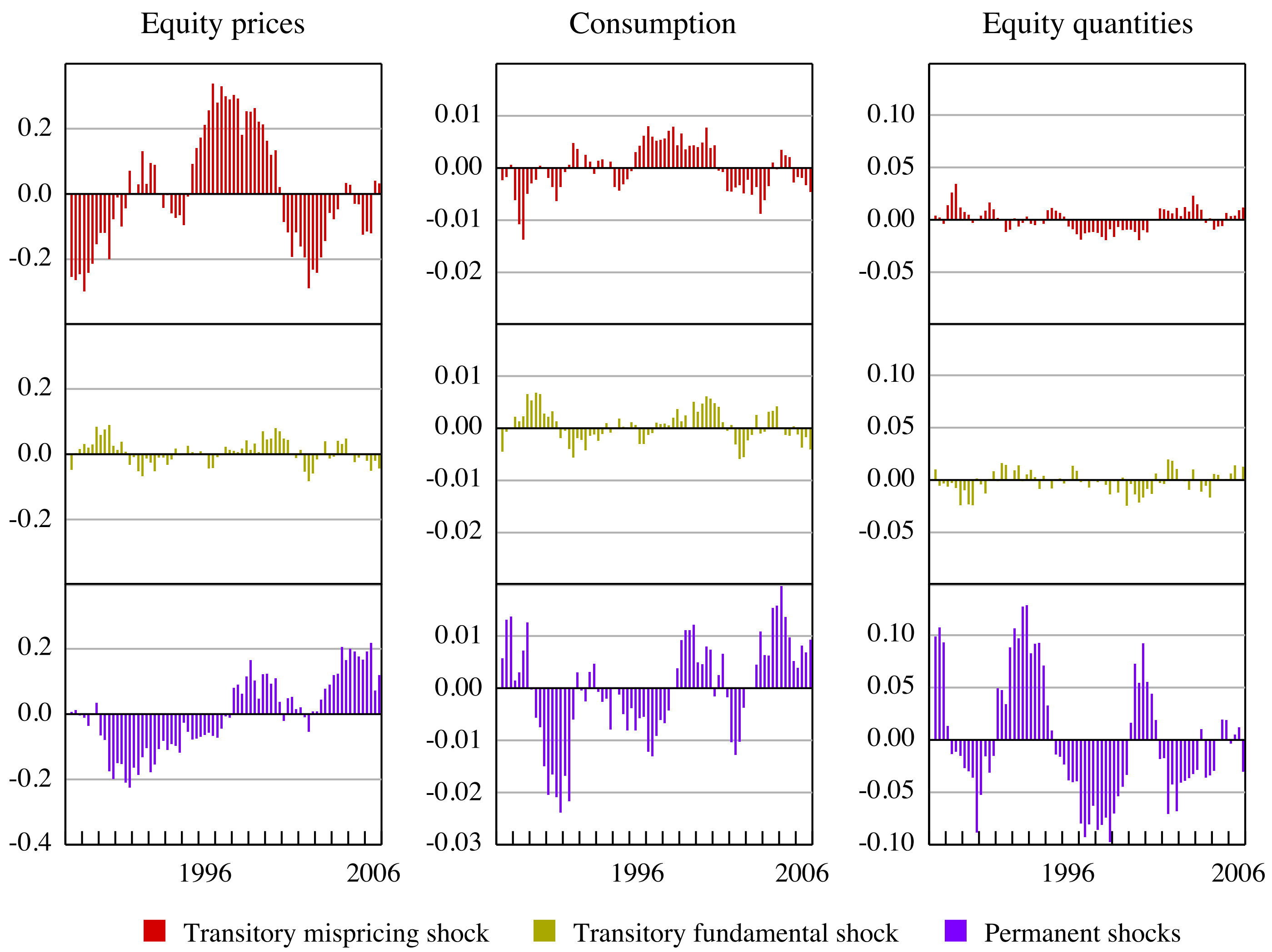
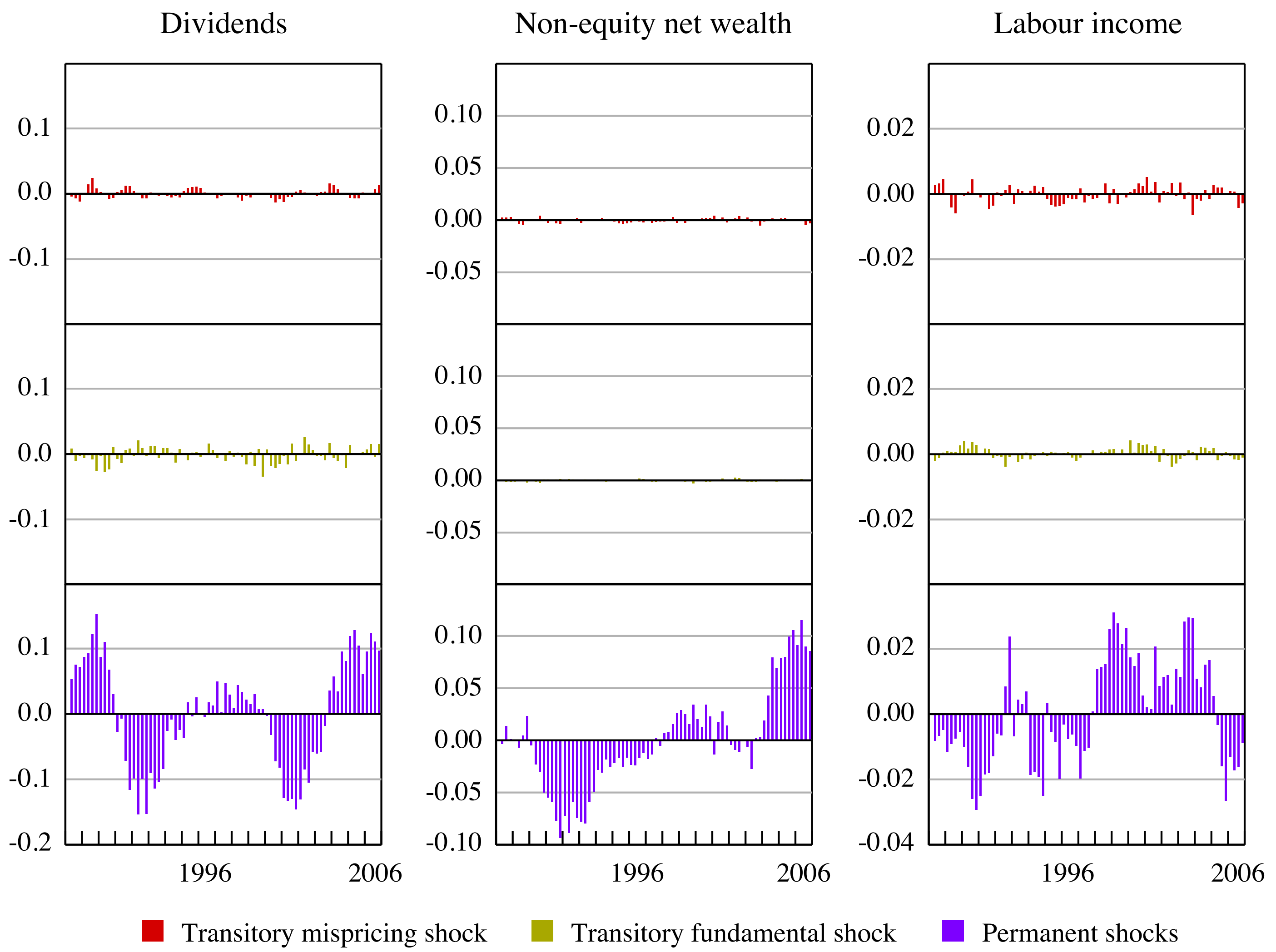


Figure 5: **Two-year Horizon Forecast Error Contributions**



5.3 Comparison with Existing Literature

The findings reported here are broadly similar to those obtained from related empirical literature. Focusing first on the effects of mispricing on consumption, Helbling and Terrones (2003) and Detken and Smets (2004) find a higher reduced-form correlation between consumption growth and equity prices growth during periods identified as equity market bubbles, and a weaker correlation during non-bubble periods, when using atheoretical procedures. The semi-structural approach to identification taken in this paper confirms these findings. A rule of thumb obtained from the estimates presented here would suggest that a one time over-valuation shock in equity markets, in the order of 10 per cent, results in the level of consumption being about 0.5 percentage points higher around three years after the initial shock, all else constant.

Turning to equity prices, the response of equity prices to a non-fundamental transitory shock estimated here is similar to estimates obtained from Lee (1998), who focuses solely on the identification of non-transitory shocks by assuming that such shocks have no real effects (on either dividends or corporate earnings). According to Lee's estimates, a one standard deviation mispricing shock increases equity prices in the order of 4–6 per cent at the end of the first year, with the full effect of the shock dissipating after about 12 years. The estimates presented in this paper are similar, with a one standard deviation mispricing shock increasing prices in the order of 5–7 per cent at the end of the first year, with the full effects dissipating in about 10 to 12 years. The estimated effects of mispricing on equity prices are very similar, notwithstanding different samples and data frequencies for estimation, and that Lee uses a different identification methodology for identifying non-fundamental transitory shocks.

One interesting difference with the previous literature on bubbles concerns the response of household equity holdings. Although this effect has received limited attention in previous empirical literature, it is interesting to note that the decline in household equity holdings in response to a positive mispricing shock is in contrast to qualitative accounts of bubbles. It is also in contrast to research by Gilchrist *et al* (2005) who find that firms tend to issue a small positive amount of stock in response to a mispricing shock. The results here suggest that households do not appear to be purchasing additional equity during the latter stages of a bubble episode. If correct, this would imply that either foreign residents or US corporates would need to be purchasing any additional equity issued.

A second remaining question is on the effects of mispricing on dividends. Previous literature has assumed *a priori* that bubbles do not affect corporate dividend policies.[47] The results here suggest that bubbles can potentially influence corporate dividend policies, although the magnitude of this response is sensitive to the instrument used in identification.

6. Robustness

6.1 Hall Percentile Confidence Intervals

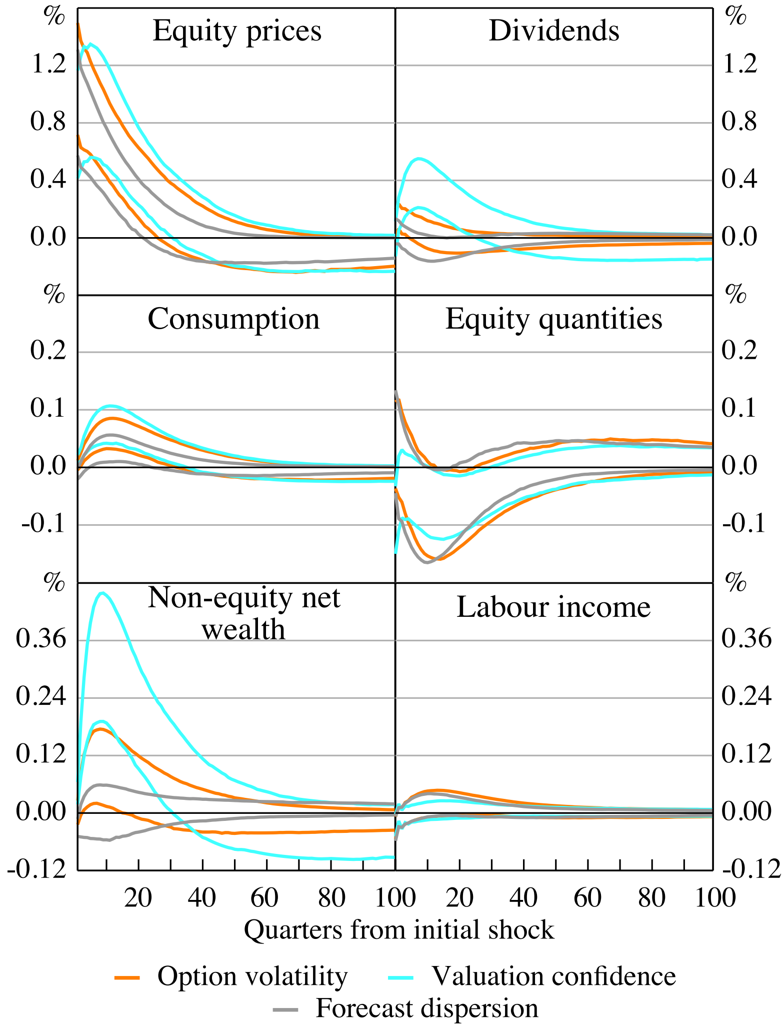
To provide a gauge of the estimation uncertainty surrounding the previous point estimates, I construct 90 per cent confidence intervals for the estimated impulse response functions using a semi-parametric bootstrap (for further detail see Appendix C). Figure 6 reports the bootstrapped confidence intervals using Hall's percentile method, and when each instrument is used in turn as a proxy for mispricing. Two results are noteworthy. First, allowing for estimation uncertainty in this way does not have a substantial effect on the results previously discussed. Mispricing shocks have positive and statistically significant effects on equity prices and consumption, and a negative and significant effect on the quantity of equity held by households irrespective of the instrument used. There is also little evidence of a statistically significant effect of mispricing shocks on household labour income. Again, the results concerning the response of dividends and net worth depend on the instrument used as a proxy for mispricing shocks.

The second point to note is how estimation uncertainty changes when an instrument that is more weakly correlated with equity prices growth is used as a proxy for mispricing shocks. Comparing the width of the confidence intervals produced when valuation confidence, the weakest instrument, is used and the alternative instruments, it is clear that the confidence bands associated with valuation confidence are often wider. Thus, as one would expect, using weaker instruments in the identification procedure does result in greater uncertainty about the estimated impulse response functions.

47 See, for example, Lee (1998).

Figure 6: Hall Confidence Intervals

5th and 95th percentiles



6.2 Are Weak Instruments a Problem?

As mentioned previously, weak instruments are potentially of concern given the instrument relevance statistics highlighted in Tables 2 and 3. To explore whether weak instruments may be resulting in large finite sample biases, I also use an alternative identification procedure that requires fewer instruments when estimating the system in Equation (9).[48] In particular, by relaxing the restriction that mispricing shocks have only transitory effects, one can estimate the system in such a way that growth in equity prices is the only endogenous variable requiring a valid instrument. This is in contrast to the previous identification

48 See Appendix D for further detail.

method that required valid instruments for both equity prices and equity quantities growth (the two variables directly perturbed by transitory innovations). I refer to the alternative identification procedure that requires fewer instruments as the 'alternative' strategy, and that previously used as the 'benchmark' strategy.

The advantage of the alternative strategy is that the concern with weak instruments can be mitigated, since only an instrument that is sufficiently correlated with equity prices growth is required. The disadvantage is that this approach is potentially inefficient, since it no longer uses the restriction that mispricing shocks are assumed to have only transitory effects.

Table 6 reports the first-stage results when using the alternative identification strategy. Tests of instrument relevance in this case are able to reject both null hypotheses that the instruments are under-identified and weakly identified when using forecast dispersion and option volatility as instruments, or if both of these measures and valuation confidence are all used collectively. The difference with regard to the previous results, where the null of weak instruments could not be rejected, is that only instruments that are sufficiently correlated with equity prices growth are required when applying the alternative strategy.[49] In contrast, the benchmark method required instruments that are sufficiently correlated with both equity prices and equity quantities growth.

Table 6: **Instrument Relevance Statistics under Alternative Strategy**

	Forecast dispersion	Option volatility	Valuation confidence	All instruments
CD Wald stat[(a)(b)]	11.19	23.78	5.40	47.61
	(0.00)	(0.00)	(0.02)	(0.00)
CD Wald F-stat[(a)]	9.84	20.91	4.73	13.07
Critical value[(c)]	8.96	8.96	8.96	4.36

Notes: All statistics are calculated assuming homoskedastic standard errors
(a) Cragg-Donaldson test statistic
(b) P-values are in parentheses
(c) Based on 15 per cent maximal LIML size

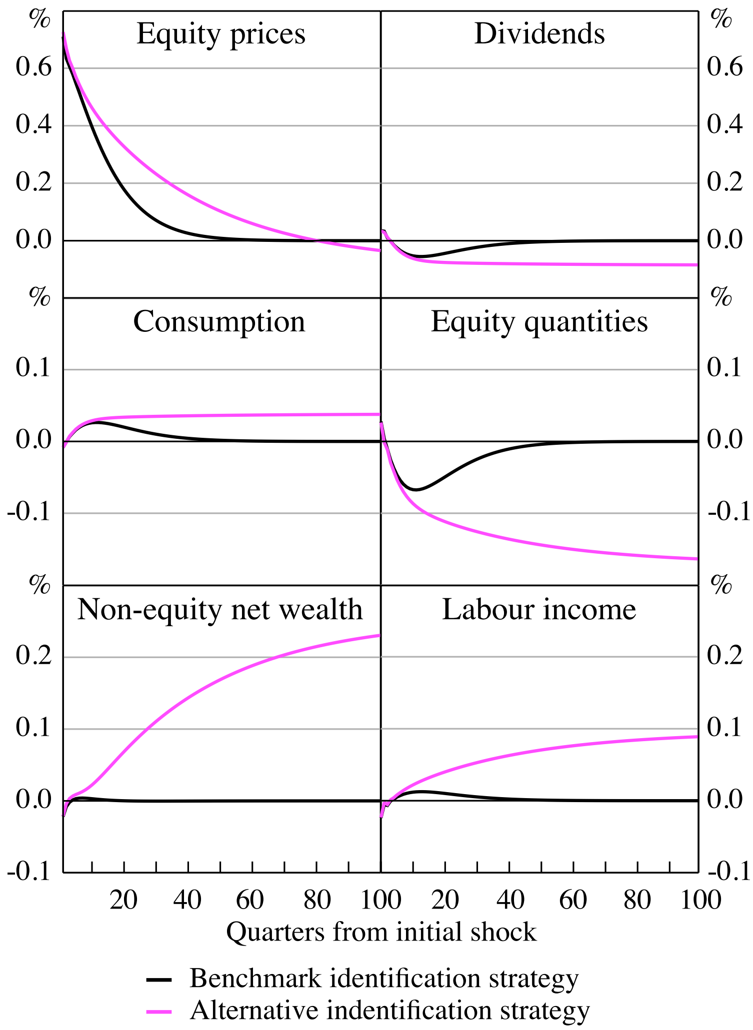
49 More specifically, lags of the cointegrating vectors, $\beta \mathbf{y}_t$, are no longer required as instruments.

Figure 7 compares the estimated impulse response functions using the benchmark and alternative identification strategies when using forecast dispersion as the instrument for equity prices growth.[50] Although it can be observed that estimates using the alternative strategy now permit long-run effects in response to mispricing shocks, it is clear that the sign and magnitude of the responses estimated are very similar to those previously identified, and especially so at horizons of less than four years. This similarity suggests that, at least for short-term horizons, the presence of weak instruments under the benchmark strategy is unlikely to be distorting the sign or magnitude of the responses estimated. At longer horizons, the notable differences in the responses estimated suggests that imposing the restriction that mispricing shocks have only transitory effects is important. Without this restriction, estimates of the response to mispricing shocks under the alternative strategy remain noticeably different from zero.

Overall, the similarity of the results obtained when using just-identified IV estimators with different instruments, the relative widths of the bootstrapped confidence intervals, and the similarity in the short-term point estimates under the benchmark and alternative identification strategies, all suggest that weak instruments are unlikely to be resulting in highly misleading inference. Although valid instruments that are more highly correlated with both equity prices and quantities growth would of course be desirable, there does appear to be sufficient information in the instruments proposed for identifying the sign and magnitude of the effects of transitory mispricing shocks.

50 Results are similar if the other instruments are used.

Figure 7: Impulse Response Functions under Benchmark and Alternative Identification Strategies



7. Conclusion

This paper proposes a new method for identifying the effects of equity market mispricing on household and firm decisions. The key assumptions used are that mispricing shocks only have transitory effects on the economy, and that there exist observable data that are correlated with these shocks, but are not correlated with perturbations to fundamentals.

The results highlighted in this paper are qualitatively consistent with the idea that equity price bubbles have the potential to distort household and firm decisions. Consumption does appear to increase with a lag in response to a positive mispricing shock, and there is evidence to suggest that firms may change the timing of dividend payments as a signal of their optimism concerning future investment opportunities. However, quantitatively, the results estimated here are not consistent with the idea that mispricing has highly distortionary effects on household and firm decisions. Overall, the effects estimated are statistically significant and modest. There is also evidence to suggest that households reduce their exposure to equity in the latter stages of an equity price bubble.

Taken together, these results suggest that the effects of equity market mispricing are neither trivial, nor as large as has sometimes been claimed in qualitative accounts of bubbles. On balance, they suggest that periods identified as bubbles should be taken into consideration by policy-makers to the extent that variables such as consumption may be growing at a rate which differs to that justified by fundamentals. However, they do not imply that policy-makers should necessarily seek to address distorted equity price signals. This is a broader question which requires consideration of the various costs and benefits associated with using different policy tools to address particular episodes of equity market mispricing.

Appendix A: Data

Equity prices

I use the Vanguard S&P 500 ETF price measured at the close of trading of each quarter from September 1976 to June 2010. These data are used in all estimation samples and are sourced from Thomson Reuters. For the pre-estimation specification tests that use a sample from March 1952 to June 2010, I backcast (splice) the Vanguard S&P 500 ETF price index using the price changes history for the US S&P 500 (again sourced from Thomson Reuters).

Consumption and labour income

These data are obtained from Martin Lettau's website (available from March 1952 to June 2010 at the time of writing), and are reported in log real per capita terms.[51] For a full description of these data see Lettau and Ludvigson (2004).

Dividends

Dividends per share are measured as the sum of gross dividends paid in the quarter, with respect to the US S&P 500 index (SPX). Non-seasonally adjusted data are sourced from Bloomberg. Seasonally adjusted estimates are calculated by the author using the US Census Bureau X12 method applied at a quarterly frequency.

Non-equity net wealth

To construct a measure of non-equity net wealth I use:

$$\begin{aligned}\text{Non-Equity Wealth}_t &= \text{Total Household Net Wealth}_t \\ &\quad - \text{Household US Equity Wealth}_t\end{aligned}$$

where:

$$\begin{aligned}\text{Household US Equity Wealth}_t &= \text{Household Total Equity Wealth}_t \\ &\quad \times \left(1 - \frac{\text{All US sector foreign equity}_t}{\text{All US sector domestic and foreign equity}_t}\right)\end{aligned}$$

51 See http://faculty.haas.berkeley.edu/lettau/data/cay_q_10Q2.txt.

Wealth data are obtained from the US Flow of Funds Accounts. Total household net wealth is reported under identifier FL152090005.Q, household total equity wealth under FL153064475.Q, all US sector holdings of foreign equity under FL263164103.Q, and all US sector holdings of domestic and foreign equity under FL893064125.Q. In line with Lettau and Ludvigson (2004), all wealth variables are lagged one quarter to be consistent with their beginning of quarter values.

Equity quantities

I use:

$$\text{Equity Quantities}_t = \frac{\text{Household US Equity Wealth}_t}{\text{Vanguard 500 ETF Price}_t}$$

where the denominator is the equity prices measure previously described. This measure is also lagged one quarter to be consistent with its beginning of quarter value.

Personal consumption expenditure deflator

Equity prices, non-equity wealth, dividends and labour income are deflated using the personal consumption expenditure deflator, Bureau of Economic Analysis NIPA Table 1.1.9 Line 2.

Population

Non-equity wealth and equity quantities are converted to per capita values using US population estimates, Bureau of Economic Analysis NIPA Table 7.1 Line 18.

Details of the instruments used in estimation are now discussed.

Valuation confidence index

These data are obtained from the Yale School of Management website. I use the proportion of respondents who viewed the stock market as overvalued. From October 1989 to April 2001 biannual survey data are available. From September 2001, six-month-ended averages are reported at a monthly frequency. I construct a biannual measure for the full sample, from October 1989 to

April 2010, and then linearly interpolate the data to a quarterly frequency.[52] As noted in the main text, the use of a linear interpolation will have no effect on the validity of this instrument once the second difference of this measure is used in estimation.

Option volatility

This measure is 30-day option-implied equity volatility with respect to the US S&P 100. These data are sourced from Bloomberg (with ticker VXO) and are measured at market close on the last trading day of the relevant quarter. For comparison, estimation on a shorter sample was also undertaken using 30-day option-implied equity volatility with respect to the US S&P 500. These data are also sourced from Bloomberg (with ticker VIX).

Forecast dispersion

This measures the weighted standard deviation in long-term earnings-per-share-growth forecasts for companies in the US S&P 500, using the Institutional Brokers' Estimate System (I/B/E/S). The weights used reflect market capitalisation, with this series sourced from Thomson Reuters. This series is measured at the beginning of the quarter.

52 From September 2001 onwards, the Yale School of Management reports the six-month-ended average percentage responses, $\bar{s}_t = \frac{1}{6}\sum_{k=0}^{5} s_{t-k}$. To adjust for this change in reporting, biannual monthly survey responses are calculated by the author using

$$s_t = 6\left(\bar{s}_t - \bar{s}_{t-1}\right) + s_{t-6}$$

Appendix B: Specification Tests

Table B1 highlights that the null of a unit root cannot be rejected for each of the endogenous regressors using either Augmented Dicky-Fuller or Phillips-Perron tests.

Table B1: **Unit Root Tests**

March 1953–June 2010 sample period

Variable	ADF test statistic[(a)]	PP test statistic[(b)]
Consumption	−1.71	−2.48
Dividends	−1.53	−1.37
Non-US-equity net worth	−0.79	−0.70
Labour income	−1.32	−1.83
Equity quantities	−1.04	−0.93
Equity prices	−1.91	−1.93

Notes: All tests include four lags in their construction; ***,**,* denote test statistics that reject the null of a unit root at the 1, 5 and 10 per cent significance levels
(a) Augmented Dicky-Fuller test statistic
(b) Phillips-Perron test statistic

Table B2 reports results from lag-order selection criteria tests, and Table B3 reports results from Johansen Trace Tests concerning the rank of the cointegration matrix.

Table B2: **Lag-order Selection Criteria**

March 1953–June 2010 sample period

Lags	LR[(a)]	FPE[(b)]	AIC[(c)]	HQIC[(d)]	SBIC[(e)]
0		$3.4 \times e^{-15}$	−33.42	−33.42	−33.42
1	3 651.9	$5.9 \times e^{-22}$	−48.99	−48.77	−48.45
2	197.67	$3.4 \times e^{-22^{*}}$	-49.53^{*}	-49.10^{*}	-48.46^{*}
3	67.15	$3.5 \times e^{-22}$	−49.51	−48.86	−47.90
4	56.61^{*}	$3.8 \times e^{-22}$	−49.45	−48.58	−47.29

Notes: * denotes lag length selected
(a) Likelihood ratio test statistic
(b) Final prediction error
(c) Akaike information criterion
(d) Hannan Quinn information criterion
(e) Schwarz Bayesian information criterion

Table B3: Johansen Trace Tests

Maximum rank	Trace test statistic Mar 1953–Jun 2010	Trace test statistic Jun 1986–Jun 2010	Critical value(a)
0	111.95	110.68	94.15
1	73.74	71.33	68.52
2	41.84*	38.75*	47.21
3	22.92	19.71	29.68
4	10.27	9.76	15.41
5	2.69	3.29	3.76

Notes: * Denotes the implied rank of the cointegration matrix
(a) 5 per cent level of signficance

Table B4 reports results from Lagrange Multiplier tests for up to third-order serial correlation in the VECM residuals (estimated subject to the restrictions that the cointegration rank $r = 2$ and that $\beta_2' = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & -1 \end{bmatrix}$). A check on the stability properties of the eigenvalues for this restricted VECM are consistent with estimated model being stable.

Table B4: Lagrange Multiplier Tests for Residual Serial Correlation
June 1986–June 2010 sample period

Lags	Test statistic	P-value(a)
1	50.40	0.06
2	40.00	0.30
3	43.45	0.18

Note: (a) Obtained from a Chi-squared distribution with 36 degrees of freedom

Appendix C: Bootstrap Methodology

90 per cent confidence intervals are constructed using the following semi-parametric bootstrap procedure:

1. Using the procedure outlined in Section 3, I obtain estimates of the semi-structural residual vector $\widetilde{\varepsilon}_t = \left[\left(u_t^P\right)', \left(\varepsilon_t^T\right)'\right]'$ conditioning on $\widehat{\beta}$ and the instruments $\widehat{\beta}_1 \mathbf{y}_t$ and z_t (recall z_t is the relevant instrument for mispricing shocks, either forecast dispersion, option volatility or valuation confidence).

2. Randomly draw with replacement (by column) from the matrix of estimation residuals and z_t, $\begin{bmatrix} \widetilde{\varepsilon}_1 & ,..., & \widetilde{\varepsilon}_T \\ z_1 & & z_T \end{bmatrix}$, so that in effect a form of 'pairs' bootstrap is used that accounts for the joint empirical distribution of the errors and the instrument used in identification. One thousand random samples of length $T = 83$ are drawn.

3. Simulate data to construct the vector $\begin{bmatrix} \mathbf{y}_t^i \\ z_t^i \end{bmatrix}$ using

$$z_t^i = z_t^i$$
$$\mathbf{y}_t^i = \left(\mathbf{I} - \widehat{\widetilde{\mathbf{A}}}_0^{-1} \widehat{\widetilde{\alpha}}^* \beta' - \widehat{\widetilde{\mathbf{A}}}_0^{-1} \widehat{\widetilde{\mathbf{A}}}_2\right) \mathbf{y}_{t-1}^i + \widehat{\widetilde{\mathbf{A}}}_0^{-1} \widehat{\widetilde{\mathbf{A}}}_2 \mathbf{y}_{t-2}^i + \widetilde{\varepsilon}_t^i$$

   for $t = 1,...,T$ and for $i = 1,...,1\ 000$ where i is an index identifying the relevant draw in Step 2, and where $\widehat{\widetilde{\alpha}}^*, \widehat{\widetilde{\mathbf{A}}}_0, \widehat{\widetilde{\mathbf{A}}}_2, \widehat{\beta}$ are the point estimates used to construct the statistics of interest discussed in the main text.[53]

4. For each artificial sample, i, estimate $\widehat{\widetilde{\alpha}}_i^*, \widehat{\widetilde{\mathbf{A}}}_{0,i}, \widehat{\widetilde{\mathbf{A}}}_{2,i}$ and then construct the estimated impulse response function (moving average) matrices $\left\{\widehat{\Psi}_{j,i}\right\}_{j=1}^{100}$ for $i = 1,...,1\ 000$. Note that $\widehat{\beta}$ is treated as known and is not re-estimated with each sample.

53 For brevity, I abstract from deterministic terms. In implementation I allow for an unrestricted constant in the SVECM.

5. Construct Hall percentile confidence intervals following Lütkepohl (2006). Let $s^*_{j,0.05}$ and $s^*_{j,0.95}$ be the 5 and 95 percentiles of the statistic $s^*_j = \left(\widehat{\boldsymbol{\Psi}}_{j,i} - \widehat{\boldsymbol{\Psi}}_j\right)$ where $\widehat{\boldsymbol{\Psi}}_j$ is the estimated impulse response function based on the observed data, j quarters after the initial shock of interest. The Hall confidence interval is given by

$$CI_H = \left[\widehat{\boldsymbol{\Psi}}_j - s^*_{j,0.95}, \widehat{\boldsymbol{\Psi}}_j - s^*_{j,0.05}\right]$$

Appendix D: Alternative Identification Strategy

Rather than partitioning the system in Equation (9) according to those variables directly influenced by permanent and transitory shocks, I now partition the system into equity prices ($\mathbf{y}_{22t}$) and other variables $\left(\widetilde{\mathbf{y}}_{1t} = \left[\mathbf{y}'_{1t}, \mathbf{y}_{21t}\right]'\right)$. That is,

$$\begin{bmatrix} B^0_{11} & B^0_{12} \\ B^0_{21} & 1 \end{bmatrix} \begin{bmatrix} \Delta\widetilde{\mathbf{y}}_{1t} \\ \Delta\mathbf{y}_{22t} \end{bmatrix} = -\alpha^*\beta' \begin{bmatrix} \widetilde{\mathbf{y}}_{1t-1} \\ \mathbf{y}_{22t-1} \end{bmatrix} - \begin{bmatrix} B^2_{11} & B^2_{12} \\ B^2_{21} & B^2_{22} \end{bmatrix} \begin{bmatrix} \Delta\widetilde{\mathbf{y}}_{1t-1} \\ \Delta\mathbf{y}_{22t-1} \end{bmatrix} + \begin{bmatrix} \widetilde{\varepsilon}^{P,T}_t \\ \varepsilon^{T,b}_t \end{bmatrix}$$

where again I use six normalisation restrictions on the main diagonal of $\mathbf{B}_0$. Using the same methodology as that discussed previously, it is straightforward to verify that provided $\left(B^0_{11}\right)^{-1}$ exists, one can proceed estimating

$$\begin{aligned} \Delta\widetilde{\mathbf{y}}_{1t} = & -\left(B^0_{11}\right)^{-1} B^0_{12}\Delta\mathbf{y}_{22t} - \left(B^0_{11}\right)^{-1}\left[\alpha^*\beta'\right]_{11}\widetilde{\mathbf{y}}_{1t-1} \\ & -\left(B^0_{11}\right)^{-1}\left[\alpha^*\beta'\right]_{12}\mathbf{y}_{22t-1} - \left(B^0_{11}\right)^{-1} B^2_{11}\Delta\widetilde{\mathbf{y}}_{1t-1} \\ & -\left(B^0_{11}\right)^{-1} B^2_{12}\Delta\mathbf{y}_{22t-1} + \left(B^0_{11}\right)^{-1}\widetilde{\varepsilon}^{P,T}_t \end{aligned}$$

using z_t as an instrument for $\Delta\mathbf{y}_{22t}$. The estimated reduced-form residuals, comprising both permanent and transitory shocks $\left(\widehat{\left(B^0_{11}\right)^{-1}\widetilde{\varepsilon}^{P,T}_t}\right)$, can then be used as instruments for $\Delta\widetilde{\mathbf{y}}_{1t}$ in the estimation of

$$\begin{aligned} \Delta\mathbf{y}_{22t} = & -B^0_{21}\Delta\widetilde{\mathbf{y}}_{1t} - \left[\alpha^*\beta'\right]_{21}\widetilde{\mathbf{y}}_{1t-1} \\ & -\left[\alpha^*\beta'\right]_{22}\mathbf{y}_{22t-1} - B^2_{21}\Delta\widetilde{\mathbf{y}}_{1t-1} \\ & -B^2_{22}\Delta\mathbf{y}_{22t-1} + \varepsilon^{T,b}_t \end{aligned}$$

where I have used the conformable partition

$$\alpha^*\beta' = \begin{bmatrix} \left[\alpha^*\beta'\right]_{11} & \left[\alpha^*\beta'\right]_{12} \\ \left[\alpha^*\beta'\right]_{21} & \left[\alpha^*\beta'\right]_{22} \end{bmatrix}$$

The additional restriction that mispricing shocks have only transitory effects, $\left(\lim_{k\to\infty} \frac{\partial E_t(\mathbf{y}_{t+k})}{\partial\left(\varepsilon_t^{T,b}\right)'} = \mathbf{0}_{n\times 1}\right)$, is not imposed.

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