# Shocks and Crashes*

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# Shocks and Crashes

**Abstract**

Three shocks, distinguished by whether their effects are permanent or transitory, are identified to characterize the post-war dynamics of aggregate consumer spending, labor earnings, and household wealth. The first shock accounts for virtually all of the variation in consumption and has effects akin to a permanent total factor productivity shock in canonical frictionless macroeconomic models. The second shock underlies the bulk of fluctuations in labor income, accounting for 76% of its variation. This shock permanently reallocates rewards between shareholders and workers but leaves consumption unaffected. Over the last 25 years, the cumulative effect of this shock has persistently boosted stock market wealth and persistently lowered labor earnings. The third shock is a persistent but transitory innovation that accounts for the vast majority of quarterly fluctuations in asset values but has a negligible impact on consumption and labor earnings at all horizons. We show that the 2000-02 asset market crash was the result of a negative transitory wealth shock, predominantly associated with stock market wealth. By contrast, the 2007-09 crash was accompanied by a string of large negative realizations in both the transitory shock and the permanent productivity shock, with the latter having especially important implications for housing wealth.

JEL: G12, G17, E21, E24, E27

# 1 Introduction

For generations macroeconomic theorists have postulated models of the economy wherein a few primitive shocks drive fluctuations in aggregate variables. A key aspect of theoretical inquiry concerns the extent to which the presumed primitive shocks generate aggregate fluctuations in the model that are consistent with historical dynamics. In this paper, we use the restrictions implied by cointegration to decompose the historical dynamics of aggregate consumer spending, labor earnings, and household wealth into components driven by three structural disturbances. Two of the disturbances we identify have permanent effects on the variables in the system, while the third has persistent but transitory effects.

The shocks we identify are distinguished by their degree of persistence, and so do not in general correspond to the primitive shocks in economic models. Nevertheless we show that identification can be achieved by choosing one of the shocks in a way that associates it with a familiar economic mechanism, namely a factor-neutral productivity shock that raises or lowers the value of all productive capital and labor input. This shock has a long-run effect on consumption, labor earnings and wealth, in a manner akin to a permanent total factor productivity (TFP) shock in canonical frictionless macroeconomic models. A positive value for this shock quickly raises consumption to a new trend level and accounts for the virtually all of its fluctuations. We refer to this shock as a *permanent productivity* shock.

The two remaining shocks we identify are more difficult to reconcile with modern macroeconomic theories, but are nevertheless quantitatively important in the data. Indeed, we find that one or the other of these remaining shocks accounts for the bulk of post-war fluctuations in labor earnings and household wealth. The second shock is a permanent disturbance that moves labor earnings and wealth in opposite directions but leaves consumption unaffected. A positive value for this shock raises stock market wealth and lowers labor income. This shock accounts for 76% of the quarterly fluctuations in labor income in our post-war sample. We refer to this shock as a *permanent reallocation* shock.

The third shock is a persistent but transitory innovation that accounts for the vast majority of short-run fluctuations in asset values but has a negligible impact on consumption and labor earnings, both contemporaneously and at all future horizons. These fluctuations are associated predominantly with the stock market component of wealth and have historically had small effects on other components of wealth, such as non-stock market financial wealth, and housing. The shock has a half life of over three years and explains 89% of the quarterly variation in household net worth. We call this shock a *transitory wealth* shock.

We emphasize two aspects of the results. First, over the last 25 years, the cumulative effect of the second permanent shock has persistently boosted stock market wealth and persistently lowered labor earnings. Moreover, although this disturbance has little impact on the stock market at *quarterly* frequencies, over long-horizons its impact on the level of the stock market is substantial and has contributed to extended periods of relatively high stock market valuation (e.g., the last 25 years) and relatively low stock market valuation (e.g., from the mid-1960s to mid-1980s). This permanent disturbance–which underlies the bulk of quarterly post-war labor income fluctuations–cannot be explained by modern macroeconomic theories in which trend movements in labor income are driven by trend movements in factor-neutral productivity shocks that move the values of labor and productive capital in the same direction.

Second, the transitory wealth shock is difficult to reconcile with modern macroeconomic models because such models typically make no allowance for large transitory fluctuations in wealth. But this finding is also a challenge for consumption-based asset pricing models capable of explaining important features of stock market data. These models are consistent with the existence of a large transitory component in wealth, but they cannot account for our finding that this component is unrelated to consumption.

Of course, some economic models macroeconomists used to interpret aggregate dynamics have fewer than three primitive shocks, the number of empirical disturbances identified here. Canonical real business cycle models, for example, have fluctuations that are driven by a single permanent (or near permanent) productivity shock. Such a shock has effects that are very similar to the first permanent structural disturbance we identify. But the econometric methodology we employ also identifies two additional shocks. In principle, the presence of these additional shocks could be consistent with the model if they represented a negligible fraction of economic fluctuations. We find, however, that their quantitative importance is substantial, suggesting that work-horse macroeconomic models of this type are unlikely to explain important features of the post-war experience.

How does the recent behavior of these shocks relate to the observed volatility in asset values and the real economy in recent business cycle episodes? During the last 20 years, the U.S. economy has experienced two recessions, accompanied by two asset market "crashes." We find that the asset market crashes of 2000-02 and 2007-09 were quite different in terms of the role each shock played in these downturns. The asset market downturn of 2000-02 (and the boom that proceeded it) was almost entirely the result of a string of transitory wealth shocks, the culmination of which ultimately restored wealth to its common trend with consumption and labor income through a downward correction in the stock market. Housing, consumption, and labor earnings were little affected by these transitory shocks, consistent with the historical pattern.

By contrast, the asset market crash of 2007-09 was characterized by large negative roles for both the transitory shock and the permanent productivity shock, with the latter having especially important implications for housing wealth. Moreover, in contrast to the 2000-02 experience, the model forecasts imply persistently low values for home prices going forward from the end of our sample (2010:Q2), the result of a string of negative draws to the permanent productivity shock since 2007. At the same time, the rebound in the stock market since 2009 can be traced to a string of transitory innovations. As of the third quarter of 2010, the cumulative effect of these transitory innovations on stock market wealth has once again driven household net worth to values significantly above its long-run level.

Our paper is broadly related to a series of articles that use cointegration to identify the permanent and transitory components of a system of macroeconomic variables that share at least one common stochastic trend (King, Plover, Stock and Watson, 1991; Cochrane, 1994; Gonzalo and Granger, 1995; Gali, 1999; Francis and Ramey, 2001; Gonzalo and Ng, 2001; and Lettau and Ludvigson, 2004.) Our study is also related to a time-honored literature that studies the sources of business cycle fluctuations as in Sims (1980) and Kydland and Prescott (1982), and more recently, Christiano, Eichenbaum, and Vigusson (2004); Fisher (2006); Smets and Wouters (2007); Justiniano, Primiceri, and Tambalotti (2009, 2010). We discuss how our findings relate to (and differ from) these studies in Section 4. The study that is closest to the present paper is Lettau and Ludvigson (2004) (LL hereafter) who examine the trend and cyclical components of the same system of variables studied here, on earlier data. But the Lettau and Ludvigson (2004) study differs in two key ways from the present one. First, LL did not identify three mutually uncorrelated shocks in this system, instead focusing only on the space spanned by the permanent shocks. We accomplish this here by imposing an additional identifying restriction on the dynamics of consumption, described below. Second, LL did not formally relate fluctuations in the three identified disturbances to the major components of assets (stock market wealth, non-stock financial wealth, and housing) that make up household net worth. We do so here, and provide a decomposition of their effects on the levels of aggregate variables both historically and in the two most recent asset market downturns.

The rest of this paper is organized as follows. Section 2 discusses the data and explains our econometric methodology for identifying the permanent and transitory components of consumption, labor earnings, and wealth. The objective of this methodology is to choose identifying restrictions in such a way that permits one of the three structural disturbances to have effects we would expect of a permanent, factor neutral TFP shock. We may then ask two questions of the remaining non-productivity shocks: first, how quantitatively important are they, and second, what kind of effects do they have? Section 3 presents the main econometric results from applying this methodology to the full post-war sample. Section 4 contrasts the two boom-bust cycles in asset markets that occurred in the last 15 years as they pertain to the role of the economic disturbances we identify. Section 5 concludes with a discussion of how these findings are both related to, and differ from, studies of the stochastic origins of business cycles. It also provides a discussion of the possible economic mechanisms that may underly the quantitatively important post-war behavior of labor income and household net worth that we document here in response to the two non-productivity shocks in our system.

# 2 Econometric Methodology

It is perhaps obvious that consumption, labor income and household wealth should move together over the long-term. This can be motivated more formally by considering the long-run implications of a standard household budget constraint, see Lettau and Ludvigson (2001), LL, and Lettau and Ludvigson (2010). We refer the reader to these papers and simply note here that cointegration among log consumption, $c_t$, log labor income, $y_t$, and log asset wealth, $a_t$, follows from fairly weak theoretical restrictions in a broad class of models for which a household budget constraint must be obeyed.

This section first describes the data and preliminary analysis. It then describes how we isolate the permanent and transitory structural disturbances of a cointegrated vector of variables, $\mathbf{x}_t$, that has $n$ elements. In our application, $\mathbf{x}_t = (c_t,\, a_t, y_t)'$. Throughout this paper we use lower case letters to denote log variables, e.g., $\ln(A_t) \equiv a_t$.

## 2.1 Data and Preliminary Analysis

The Appendix contains a detailed description of the data used in this study. The log of asset wealth, $a_t$, is a measure of real, per capita household net worth, which includes all financial wealth, housing wealth, and consumer durables. Durable goods are accounted for as part of nonhuman wealth, $A_t$, a component of aggregate wealth, $W_t$, and so are not accounted for as part of consumption.[1] Durables expenditures are also excluded in the definition of *flow* consumption, $C_t$, because they represent replacements and additions to a capital stock (investment), rather than a service flow from the existing stock. However, the total flow of consumption is unobservable because we lack observations on the service flow from much of the durables stock. We therefore follow Blinder and Deaton (1985) and Campbell (1987) and use the log of real, per capita, expenditures on nondurables and services (excluding shoes and clothing), as a measure of $c_t$. From the household's budget constraint, an internally consistent cointegrating relation may then be obtained if we assume that the log of (unobservable) real total flow consumption is cointegrated with the log of real nondurables and services expenditures. The log of after-tax labor income, $y_t$, is also measured in real, per capita terms. Our data are quarterly and span the first quarter of 1952 to the second quarter of 2010. Table 1 presents descriptive statistics for the log differences $\Delta c_t$, $\Delta a_t$, $\Delta y_t$. Wealth growth is 4.9 times as volatile as consumption growth and is 2.45 times as volatile as labor income growth in quarterly data.

Let $r < n$ denote the number of cointegrating relationships in a system of $n$ variables. The appendix presents empirical evidence supportive of a single cointegrating relationships between $c_t$, $a_t$, and $y_t$ in quarterly post-war data. Additional tests indicate no evidence of a second cointegrating relationship (see discussion below). Given our system of $n = 3$ variables, this implies the presence of $n - r = 2$ permanent innovations and $r = 1$ transitory innovations (Stock and Watson, 1988). These innovations are the structural disturbances we seek to identify.

Identification of the structural disturbances is achieved in three steps, discussed in detail below. First, cointegrating restricts the long-run multipliers of the structural form shocks; this identifies the space spanned by the permanent shocks. Second, the transitory innovation is assumed to be orthogonal to the permanent innovations, which identifies the transitory shock. Third, the independent effects of the two permanent shocks are distinguished by restricting the contemporaneous responses of $c_t$ to the structural disturbances, in a manner that can be motivated by a canonical frictionless real business cycle model with permanent

[1] Treating durables purchases purely as an expenditure (by, e.g., removing them from $A_t$ and including them in $C_t$) ignores the evolution of the asset over time, which must be accounted for by multiplying the stock by a gross return. (In the case of many durable goods this gross return would be less than one and consist primarily of depreciation.)

shocks to total factor productivity.

Although statistical tests are supportive of a single trivariate cointegrating relation between $c_t$, $a_t$, and $y_t$, the data provide no evidence of a second linearly independent cointegrating relation (there can be at most two). In particular, bivariate log ratios of these variables appear to contain trends in our sample. These ratios may not contain trends in population and economic theory would typically imply that such ratios are stationary, as for example in models with balanced growth (though see Section 4 for a discussion of alternative theories that could imply the existence of trends in the bivariate log ratios). Nevertheless we follow the advice of Campbell and Perron (1991) and empirically model only the single, trivariate cointegrating relation for which we find direct statistical evidence of in our sample. Campbell and Perron argue that treating the data in accordance with the stationarity properties inferred from unit root/cointegration tests results in better finite sample approximations of test statistics than treating the data according to its asymptotic distribution that is true in population. Thus, a near-integrated but stationary data generating process is better modeled in a finite sample as a unit root variable, even though the asymptotically correct distribution is the standard one appropriate for stationary variables.

The procedure for identifying structural disturbances based on cointegration restrictions follows Gonzalo and Ng (2001) and is closely related to that in King, Plosser, Stock, and Watson (1991), Gonzalo and Granger (1995). This procedure has several steps, the first of which require estimation of the cointegrating relationship(s) and the vector-error-correction model (VECM) for the cointegrated system. We present these results next.

We assume all of the series contained in $\mathbf{x}_t$ are first order integrated, or I(1), an assumption confirmed by unit root tests, available upon request. The cointegrating coefficient on consumption is normalized to one, and we denote the single cointegrating vector for $\mathbf{x}_t = [c_t, a_t, y_t]'$ as $\boldsymbol{\alpha} = (1, -\alpha_a, -\alpha_y)'$.

The cointegrating parameters $\alpha_a$ and $\alpha_y$ are estimated using dynamic least squares, which generates "superconsistent" estimates of $\alpha_a$ and $\alpha_y$ (Stock and Watson, 1993).[2] We estimate $\widehat{\boldsymbol{\alpha}} = (1, -0.22, -0.67)'$. The Newey and West (1987) corrected $t$-statistics for these estimates are 20 and 56, respectively.[3]

[2]We use eight leads and lags of the first differences of $\Delta y_t$ and $\Delta a_t$ in the dynamic least squares regression. Monte Carlo simulation evidence in both Ng and Perron (1997) and our own suggested that the DLS procedure can be made more precise with larger lag lengths.

[3]Lettau and Ludvigson (2001) and Lettau and Ludvigson (2010) discuss the magnitude of these coefficients and show that they are roughly in accord with what would be predicted from commonly calibrated production functions with labor and capital shares of approximately one third and two thirds.

The VECM representation of $\mathbf{x}_t$ takes the form

$$\Delta \mathbf{x}_t = \boldsymbol{\upsilon} + \boldsymbol{\gamma}\widehat{\boldsymbol{\alpha}}'\mathbf{x}_{t-1} + \boldsymbol{\Gamma}(L)\boldsymbol{\Delta}\mathbf{x}_{t-1} + \mathbf{e}_t, \tag{1}$$

where $\Delta\mathbf{x}_t$ is the vector of log first differences, $(\Delta c_t, \Delta a_t, \Delta y_t)'$, $\boldsymbol{\upsilon}$, and $\boldsymbol{\gamma} \equiv (\gamma_c, \gamma_a, \gamma_y)'$ are $(3{\times}1)$ vectors, $\boldsymbol{\Gamma}(L)$ is a finite order distributed lag operator, and $\widehat{\boldsymbol{\alpha}} \equiv (1, -\widehat{\alpha}_a, -\widehat{\alpha}_y)'$ is the $(3{\times}1)$ vector of previously estimated cointegrating coefficients.[4] The term $\widehat{\boldsymbol{\alpha}}'\mathbf{x}_{t-1}$ gives last period's equilibrium error, or cointegrating residual; $\boldsymbol{\gamma}$ is the vector of "adjustment" coefficients that tells us which variables subsequently adjust to restore the common trend when a deviation occurs. Throughout this paper, we use "hats" to denote the estimated values of parameters.

The results of estimating a first-order specification of (1) are presented in Table 2.[5] The estimates of the adjustment parameters in $\boldsymbol{\gamma}$ are given in the first row of Table 2. An important result is that consumption and labor income are somewhat predictable by lagged consumption and wealth growth, but not by the cointegrating residual $\widehat{\boldsymbol{\alpha}}'\mathbf{x}_{t-1}$. Estimates of $\gamma_c$ and $\gamma_y$ are economically small and insignificantly different from zero. By contrast, the cointegrating error is an economically large and statistically significant determinant of next quarter's wealth growth: $\gamma_a$ is estimated to be 0.27, with a $t$-statistic equal to 2.7.[6] Although there is some short-run predictability in the growth of consumption and labor income (as exhibited by the dependence of these variables on lagged growth rates), the results imply that only wealth exhibits error-correction behavior. Wealth is mean reverting and adapts over long-horizons to match the smoothness in consumption and labor income.

## 2.2 Identification of Permanent and Transitory Shocks

The general identification problem is described as follows. The individual series are presumed to have a reduced-form multivariate Wold representation:

$$\Delta \mathbf{x}_t = \boldsymbol{\delta} + \mathbf{C}(L)\mathbf{e}_t,$$

[4] Standard errors do not need to be adjusted to account for the use of the "generated regressor," $\boldsymbol{\alpha}'\mathbf{x}_t$ in (1) because estimates of the cointegrating parameters converge to their true values at rate $T$, rather than at the usual rate $\sqrt{T}$ (Stock (1987)) .

[5] This first-order lag length was chosen in accordance with the Akaike and Schwarz criteria.

[6] We also find that the *four*-quarter lagged value of the cointegrating error strongly predicts asset growth. This shows that the forecasting power of the cointegrating residual for future asset growth cannot be attributable to interpolation procedures used to convert annual survey data to a quarterly housing service flow estimate, part of the services component of $c_t$.

where $\mathbf{e}_t$ is an $n \times 1$ vector of innovations, and where $\mathbf{C}(L) \equiv \mathbf{I} + \mathbf{C}_1 L + \mathbf{C}_2 L + \mathbf{C}_3 L + \cdots$. The parameters $\boldsymbol{\alpha}$ and $\boldsymbol{\gamma}$, both of rank $r$, satisfy $\boldsymbol{\alpha}'\mathbf{C}(1) = 0$ and $\mathbf{C}(1)\boldsymbol{\gamma} = 0$ (Engle and Granger, 1987).

We seek to identify $n = 3$ transformed, or structural-form, innovations distinguished by whether they have permanent or transitory effects. Denote these transformed innovations $\boldsymbol{\eta}_t \equiv (\eta_{P1,t}, \eta_{P2,t}, \eta_{T,t})'$, where two are permanent and one is transitory. Without loss of generality, shocks are ordered so that the first two have permanent effects ($\eta_{P1,t}$ and $\eta_{P2,t}$ respectively), and the third transitory effects ($\eta_{T,t}$). We will refer to these shocks interchangeably as $P1$, $P2$, and $T$, respectively.

In the decomposition that follows a shock is defined to be permanent if

$$\lim_{h \to \infty} \partial E_t(\mathbf{x}_{t+h}) / \partial \eta_{Pt} \neq 0. \tag{2}$$

Conversely, a shock is transitory if

$$\lim_{h \to \infty} \partial E_t(\mathbf{x}_{t+h}) / \partial \eta_{Tt} = 0. \tag{3}$$

Notice that a permanent shock under this definition differs from the long-run trend component obtained from a Beveridge-Nelson decomposition, in that here a permanent shock may contain serially correlated noise around the random walk component. Regardless of which way the permanent-transitory decomposition is defined, permanent shocks will have the same long-run effects on the variables. Moreover, once a decomposition based on the above definition is obtained, it is straightforward to decompose movements in each of the variables into components that deviate from their random walk components (see below).

Let

$$\mathbf{G} \equiv \begin{bmatrix} \boldsymbol{\gamma}'_{\perp} \\ \boldsymbol{\alpha}' \end{bmatrix}, \tag{4}$$

where $\boldsymbol{\gamma}'_{\perp}$ is a matrix of rank $n - r$ that satisfies[7]

$$\underbrace{\boldsymbol{\gamma}'_{\perp}}_{(n-r)\times n} \underbrace{\boldsymbol{\gamma}}_{n \times r} = \underbrace{\mathbf{0}}_{(n-r)\times r}. \tag{5}$$

[7] There are many such matrices $\boldsymbol{\gamma}'_{\perp}$ that satisfy (5), but $\boldsymbol{\gamma}'_{\perp}$ is typically normalized so that it contains as elements as many zeros and ones as possible while still satisfying (5).

Define a new distributed lag operator

$$\mathbf{D}(L) = \mathbf{C}(L)\mathbf{G}^{-1}.$$

The structural (permanent and transitory) disturbances are given by $\boldsymbol{\eta}_t = \left(\eta_{P1,t}, \eta_{P2,t}\eta_{T,t}\right)$, where

$$\boldsymbol{\eta}_t = \mathbf{G}\mathbf{e}_t,$$

and their relation to $\mathbf{x}_t$ is given by the Wold representation

$$\begin{aligned} \Delta \mathbf{x}_t &= \boldsymbol{\delta} + \mathbf{C}(L)\mathbf{G}^{-1}\mathbf{G}\mathbf{e}_t \\ &= \boldsymbol{\delta} + \mathbf{D}(L)\boldsymbol{\eta}_t, \end{aligned} \tag{6}$$

where $\boldsymbol{\delta}$ is a constant vector. Let $D_{ij}(L)$ denote the $i, j$th element of $\mathbf{D}(L)$. Through the identification of $\boldsymbol{\gamma}_\perp$, this decomposition imposes the following restriction on the long-run multipliers of the structural-form shocks:

$$D_{13}(1) = D_{23}(1) = D_{33}(1) = 0. \tag{7}$$

The restriction follows because the last $r$ columns of the polynomial matrix $\mathbf{D}(L)$ are responses of $\Delta x_t$ to transitory shocks, and by assumption have no influence on the variables in the long-run.

This decomposition can be understood intuitively by noting that it gives the $j$th variable a large weight in the permanent innovations and a small weight in the transitory innovations when $\gamma_j$ is small (via computation of $\boldsymbol{\gamma}'_\perp$). In this case, the $j$th variable participates little in the error-correction required to restore the series to their identified common trend, implying that it displays only small deviations from this common trend. Conversely, it gives the $j$th variable a small weight in the permanent innovations and a large weight in the transitory innovations when $\gamma_j$ is large, implying that it plays an important role in the error-correction required to restore the series to their identified common trend. In the application studied here, the elements of the adjustment vector $\boldsymbol{\gamma}$ corresponding to $c_t$ and $y_t$ are statistically indistinguishable from zero (Table 2), implying that these variables have a large weight in the permanent innovations and a small weight in the transitory innovations. By contrast, the element of the adjustment vector $\boldsymbol{\gamma}$ corresponding to $a_t$ is large in absolute value and strongly statistically significant, implying that $a_t$ will have a large weight in the transitory innovations and a small weight in the permanent innovations.

The Gonzalo and Ng (2001) procedure involves restricting the values of the parameters in $\boldsymbol{\gamma}$ to zero where they are statistically insignificant at the five percent level: failure to do so can result in unreliable estimates of the permanent-transitory decomposition. This restriction is also imposed in other applications of this methodology (Cochrane (1994) and Gonzalo and Granger (1995)). In the computations that follow, we set $\gamma_c$ and $\gamma_y$ to zero in order to match the evidence from Table 2 that these variables are small and statistically indistinguishable from zero.

The cointegration restrictions applied so far are enough to identify permanent and transitory innovations, but not enough to identify innovations that are mutually uncorrelated. To identify shocks that are mutually uncorrelated we apply a rotation to the vector of transformed shocks $\boldsymbol{\eta}_t$. Specifically, let $\mathbf{H}$ be a lower triangular matrix that accomplishes the Cholesky decomposition of $\text{Cov}(\boldsymbol{\eta}_t)$, and define a set of orthogonal structural disturbances $\widetilde{\boldsymbol{\eta}}$ such that

$$\widetilde{\boldsymbol{\eta}} \equiv \mathbf{H}^{-1}\boldsymbol{\eta}_t = \mathbf{H}^{-1}\mathbf{G}\mathbf{e}_t.$$

Also define

$$\begin{aligned} \widetilde{\mathbf{D}}(L) &\equiv \mathbf{C}(L)\mathbf{G}^{-1}\mathbf{H} \\ &= \mathbf{D}(L)\mathbf{H}. \end{aligned}$$

Then we may re-write the decomposition of $\Delta\mathbf{x}_t = (\Delta c_t, \Delta a_t, \Delta y_t)'$ as

$$\Delta\mathbf{x}_t = \boldsymbol{\delta} + \widetilde{\mathbf{D}}(L)\widetilde{\boldsymbol{\eta}}_t, \tag{8}$$

which now yields a vector of mutually uncorrelated permanent and transitory innovations $\widetilde{\boldsymbol{\eta}}_t$.

We make two identification assumptions that justify the particular rotation $\mathbf{H}^{-1}$ chosen. First, following King, Plosser, Stock, and Watson (1991), and Gonzalo and Ng (2001), we assume that the space spanned by permanent shocks is uncorrelated with the transitory shock. Second, the independent effects of the two permanent shocks are identified by restricting the contemporaneous response of $c_t$ to the structural disturbances. The assumption is that consumption is forward-looking and responds *only* to innovations in the long-run (trend) component of total (asset and labor) income. Under this assumption, *innovations in the trend component of total income are revealed as innovations in consumption*. Thus, if the first permanent shock $\eta_{P1,t}$ is identified as an innovation in the trend component of total income, it cannot be the case that consumption responds contemporaneously to a second permanent shock in the system that is orthogonal to the first. Nor can it respond contemporaneously to a transitory shock orthogonal to the first. Given the structure of $\widetilde{\mathbf{D}}(L)$ with lower triangular $\mathbf{H}^{-1}$, these assumptions are imposed on the structural disturbances in our system as long as $\Delta c_t$ is ordered first in $\mathbf{x}_t$. The remaining permanent shock, $\eta_{P2t}$, is orthogonal to the first permanent shock, $\eta_{P1,t}$, and by construction has no contemporaneous effect on consumption.

This restriction on the contemporaneous responses of $c_t$ to the structural-form disturbances can be motivated by canonical frictionless real business cycle models in which fluctuations are driven by permanent innovations in total factor productivity (TFP). In such models, consumption adapts immediately to reflect permanent innovations in TFP because such innovations immediately affect the trend level of total income. Thus the restriction imposed enables us to choose the first permanent shock ($P1$) in a way that associates it with a familiar economic mechanism, namely a permanent, factor-neutral productivity shock that raises (or lowers) the value of all productive capital and labor input. The canonical real business cycle model is a general equilibrium version of the permanent income model of Hall (1978) and Flavin (1981) when the intertemporal elasticity of substitution in consumption (EIS) is zero. For this reason we refer to the $\eta_{P1t}$ shock interchangeably as a "permanent productivity" shock, or a "permanent income" shock. Cochrane (1994) uses this same type of restriction to identify permanent and transitory income fluctuations in a bivariate VECM consisting of consumption and GNP. We show below that the dynamic responses of consumption and labor income to an $\eta_{P1t}$ shock are qualitatively the same as the responses of these variables to a permanent TFP shock in a canonical real business cycle model.

## 2.3 Relating Structural Disturbances to Wealth Components

In this paper we also study the dynamic behavior of three major components of household assets: stock market wealth, non-stock market financial wealth, and housing. The category referred to as "non-stock financial" wealth includes all financial wealth outside of the stock market. So that the three components sum up to total assets, we also include non-housing tangible assets in this category, which are a small component comprising only 10% of the category. For brevity, we simply refer to this component as non-stock financial wealth. On average over the period spanning the fourth quarter of 1951 to the second quarter of 2010, assets accounted for of 1.16 of net worth while liabilities accounted for 0.16. Stock market wealth accounted for 22% of net worth, housing wealth 29%, and non-stock financial wealth 68%.

Table 3 summarizes the statistics for these wealth components. Stock market wealth is by far the most volatile component: the annualized standard deviation of the log difference in stock wealth is 8.85%. By contrast, housing wealth growth has a standard deviation of 1.66% and non-stock financial wealth growth just 0.68%. This shows that all the "action" is in stock wealth and housing. Moreover, the correlation of the log difference in net worth, $\Delta a_t$, with the log difference in stock market wealth is 89%. Quarterly changes in net worth are dominated by fluctuations in the stock market.

To relate these wealth components to the disturbances $\eta_{P1,t}$, $\eta_{P2,t}$ and $\eta_{T,t}$, we estimate empirical relationships taking the form

$$\Delta z_{i,t} = A_i(L)\,\eta_{P1,t} + B_i(L)\,\eta_{P2,t} + C_i(L)\,\eta_{T,t} + \epsilon_{i,t}, \tag{9}$$

where $z_{i,t}$ represents the log level of the $i$th component of net worth (e.g., stock market wealth, non-stock market wealth, housing). Since $\eta_{P1,t}$, $\eta_{P2,t}$ and $\eta_{T,t}$ are mutually uncorrelated and i.i.d., we estimate these equations for each component separately by OLS with $L = 16$ quarters.[8] Because the disturbances $\eta_{P1,t}$, $\eta_{P2,t}$ and $\eta_{T,t}$ account for 100 percent of the variation in the log of net worth, $a_t$, the residuals $\epsilon_{i,t}$ are, by construction, shocks to wealth components that are orthogonal to $a_t$. Hence a positive innovation in one component must be met with a negative innovation in another component. Note, however, that the residuals $\epsilon_{i,t}$ also include log/level errors since the logs of the components do not sum up to the log of the sum $a_t$. We discuss this further below.

[8]In principle, one could directly estimate permanent and transitory components of a larger system of variables that would include $c$, $y$, and the various components of wealth separately. We do not pursue this approach here, however, because there is no statistical evidence of cointegration in any of these larger systems where wealth components are included separately.

# 3 Empirical Results

## 3.1 Permanent and Transitory Components of Consumption, Labor Earnings, and Wealth

Using the permanent-transitory decomposition discussed above, we now investigate how each of the variables in our system are related to permanent and transitory shocks. Figure 1 plots the cumulative sum, over time, of each structural disturbance after having removed a deterministic trend. The permanent productivity $P1$ shock was close to average until the mid-1960s, but on average positive from 1965 to 1973. From 1975 to 2005, the shocks were again close to average and then turned negative after that till the end of our sample in 2010:Q2. The permanent reallocative $P2$ shock was close to average from the mid-1950s to mid 1960s, then below average from the mid-1960s to the mid-1980s, and then above average over the last 25 years. We discuss the implications of this for labor income and wealth further below. Finally, the cumulative sum of transitory $T$ shocks over time shows notable above average values leading up to the peak of several asset market booms, also discussed below. This shock appears to have become more volatile since 1998.

To characterize the dynamic impact of the structural disturbances, Figure 2 shows the cumulative impulse responses of $\Delta c_t$, $\Delta a_t$, and $\Delta y_t$, to a one-standard deviation innovation in each structural disturbance $\eta_{P1,t}$, $\eta_{P2,t}$ and $\eta_{T,t}$. Confidence intervals for these responses are presented in Table 7. The top panel shows that a positive innovation in the first permanent shock $\eta_{P1,t}$ leads to an immediate increase in $c_t$, $a_t$, and $y_t$. All three variables reach a new, higher long-run level within a few quarters in response to this shock.

The responses of $c_t$ and $y_t$ to the first permanent shock $\eta_{P1,t}$ are quite similar to what would be obtained in a canonical frictionless real business cycle model as responses to an permanent innovation in total factor productivity. Figure 3 shows the impulse responses from such a model for three different values of the elasticity of intertemporal substitution in consumption (EIS), equal to 0.5, 0.2, and 0.1.[9] As the EIS falls, the response of consumption is less sluggish and for small values of the EIS the consumption is close to what would occur if it were exactly a random walk. It is straightforward to show that, when $\sigma = 0$, log consumption is a random walk and log labor income and log capital follow unit root

[9]For simplicity, the calculations presented in Figure 2 assume that labor input is fixed. The results are unchanged qualitatively if labor supply is instead elastically supplied and leisure appears non-separably in the utility function.

processes cointegrated with consumption. Moreover, when $\sigma = 0$, the model is a general equilibrium version of the permanent income model of Hall (1978) and Flavin (1981) in which log consumption is exactly a random walk and equals "permanent income," given by the annuity value of wealth plus the present discounted value of all future labor income.

The response of $a_t$ to the first permanent shock is also consistent, at least in the long-run, with what we would expect from basic economic theory. The latter is given by the response of the log of the capital stock (which equals the log of wealth in the canonical business cycle model) to a TFP shock (Figure 2). The response is positive as in the data, but is more sluggish than the response of $a_t$ to a $P1$ shock in the data. This sluggishness follows from a well-known limitation of the canonical, frictionless business cycle model for explaining stock market behavior: the consumption-good value of a unit of installed capital is fixed at unity, so the only way wealth can adjust to an innovation in TFP is through a change in the quantity of capital, $K_{t+1}$, which evolves slowly over time according to an accumulation equation $K_{t+1} = (1 - \delta) K_t + I_t$, where $\delta$ is a depreciation rate and $I_t$ is a flow of investment. The adaption of real business cycle models to explain stock market data presents significant challenges and remains an important area of research.[10]

The second panel of Figure 2 displays the empirical responses of $c_t$, $a_t$, and $y_t$ to the second permanent shock, $\eta_{P2,t}$. Consumption is unaffected by this shock, both on impact (by assumption) and in all future period (a result). Instead, this shock drives $a_t$ and $y_t$ in opposite directions. A positive value for this shock raises asset wealth $a_t$ and lowers labor income $y_t$, both of which reach new long-run levels. The effect on labor earnings is large and immediate: labor income jumps to a new lower level within the quarter. Below we present evidence that changes in $a_t$ resulting from this shock are predominantly driven by the stock market. We discuss the importance of this shock further below.

The third panel of Figure 2 shows that a positive transitory shock leads to a sharp increase in asset wealth, but has virtually no impact on consumption and labor earnings at any future horizon. The consumption and labor income responses are economically negligible even though the confidence bands are quite tight implying some tiny positive responses (Table 7). By contrast, the effect of a transitory wealth shock on $a_t$ is strongly significant over periods from a quarter to several years, but is eventually eliminated, as it must be, since the shock is transitory. This shock is quite persistent, however, having a half-life of over 3 years. Despite their persistent effect on asset values, such shocks bear virtually no relation to consumption

[10]See for example, Boldrin, Christiano, and Fisher (2001).

at any future horizon.

How quantitatively important are these shocks? Table 4 displays the fraction of $h$-step ahead forecast error in the log difference of consumption, labor income and wealth that is attributable to the two permanent shocks and to the single transitory shock, $\eta_{P1,t}$, $\eta_{P2,t}$ and $\eta_{T,t}$. For $h = 1$ and $h \to \infty$, the latter giving the portion of the total variance of each variable attributable to each disturbance. To quantify the sampling uncertainty of the variance decompositions, we compute cumulative distribution functions for each variance decomposition using a bootstrapping procedure described in the Appendix.

As Table 4 shows, the first permanent shock $\eta_{P1,t}$ explains 93 percent of the variance in the forecast error of consumption growth at long horizons. Only 6 percent of the variation in consumption growth is attributable to the transitory shock. By contrast, it is the second permanent shock, $\eta_{P2,t}$, that explains almost all of the variance in income growth. This shock explains 76% of the variance of labor income growth in our sample. The first permanent shock, $\eta_{P1,t}$, explains 23%. Together, the two permanent shocks account for 99 percent of the variation in the long-run forecast error of $\Delta y_t$. This shows that consumption growth and labor income growth are dominated by permanent shocks–but they are not dominated by the *same* permanent shock. The only disturbance in this system that can be plausibly interpreted as a conventional permanent productivity shock, $\eta_{P1,t}$, explains a small fraction of quarterly variation in labor earnings. We discuss this finding further below.

The results are quite different for asset wealth. Transitory shocks dominate changes in wealth: the estimates imply that 89 percent of the quarterly variation in the growth of asset wealth is attributable to this shock; only 11 percent is attributable to permanent shocks. Because this shock bears very little association with $\Delta c_t$ and $\Delta y_t$, the transitory shock in this system is essentially a wealth shock. This result can be understood intuitively by observing that, since consumption, wealth and labor income are cointegrated, their annualized growth rates must be tied together in the very long run, and therefore so must their volatilities. Measured over quarterly horizons, however, wealth growth is far more volatile than both consumption and labor income growth (Table 1). The short-run and long-run properties of these variables can only be reconciled if either, (i) the annualized volatility of consumption and/or labor income growth increases with the horizon over which they are measured, or (ii) the annualized volatility of wealth growth decreases with the horizon over which it is measured. The second possibility implies that wealth is not a random walk, but instead displays mean-reversion and adjusts over long horizons to match the smoothness of consumption and labor income. The evidence in Table 4 suggests that the second possibility better describes US data than the first, signaling the existence of a significant transitory component in wealth that is unrelated to consumer spending and labor income. This finding has been previously emphasized in LL using earlier data. Here we show how this shock is related to the major components of household net worth and present evidence that the transitory component is most relevant for stock market wealth. This transitory component is a reflection of the sizable forecastable component in stock market returns that is observed in U.S. data over medium to long horizons.[11]

The permanent-transitory decomposition employed here allows us to identify the random walk component of each variable, given by the multivariate Beveridge-Nelson decomposition for this system. Not surprisingly given the results above, Table 5 shows that consumption and labor income are highly correlated with their random walk components, while wealth is not. Even with the serial correlation in measured spending growth, consumption still displays a correlation of 97 percent with its random walk component. Similarly, labor income growth displays a 99.6 percent correlation with its random walk component. By contrast, asset wealth is far from a random walk, displaying a correlation of just 33 percent with its random walk component.

How do the major components of wealth respond to the structural disturbances? Figure 4 shows the cumulative impulse responses of the three major components of asset wealth (stock market wealth, housing, and non-stock market financial wealth) to a one-standard deviation innovation in each structural disturbance. The responses are constructed using the OLS estimates of (9). The first permanent shock $\eta_{P1,t}$ has an immediate impact on all three components (top panel), though note the scale of these responses is much smaller than that of the transitory shock (bottom panel). For housing, this shock is by far the most important, especially in the long-run, as is evident from a comparison of long-horizon responses of housing to each shock. By contrast, the second permanent shock $\eta_{P2,t}$ and the transitory shock $\eta_{T,t}$ have much smaller effects on home values, over almost every horizon.

For stock market wealth on the other hand, Figure 4 shows that two of the structural disturbances are important: Over short horizons, the transitory shock $\eta_{T,t}$ dominates variability in stock market wealth. A one-standard deviation increase in $\eta_{T,t}$ has a large and persistent effect on equity values. But over long horizons, the second permanent realloca-

[11] Recent summaries of the evidence on stock return predictability are provided in Lettau and Ludvigson (2010) and Koijen and Van Nieuwerburgh (2010).

tion shock $\eta_{P2,t}$ becomes quantitatively important. Indeed, the long-run response of stock market wealth to this shock is as quantitatively important as the short-run response to the transitory shock. It is perhaps puzzling that stock market wealth responds so sluggishly to this second permanent shock, suggesting that the information revealed in the innovation is incorporated only slowly into stock prices. Alternatively, it could be that it is not the price component but rather the quantity component that responds slowly if the shock has a long-run effect on the number of firms going public. Notice that $\eta_{P2,t}$ has almost no effect on housing wealth or non-stock market financial wealth. Thus Figure 4 shows clearly that this reallocation shock is a shock to *shareholder* wealth.

The inverse influence that the reallocation ($P2$) shock has on stock market wealth and labor earnings is highlighted in Figure 5, which puts together the findings from Figures 3 and 4. A one standard deviation increase in $\eta_{P2,t}$ leads to an immediate decline in labor earnings and a long-run increase in stock market wealth. Both stock market wealth and labor income reach new, higher, and lower trend levels, respectively, in response to this shock.

Using (9), we characterize the relative quantitative importance of each structural disturbance (as well as of the residual in (9)) for the major components of wealth by computing a variance decomposition. Table 6 shows that the transitory shock is most closely related to stock market wealth and accounts for 72% of its quarterly volatility. The two permanent shocks account for very small amounts, both around 8%. The transitory shock also accounts for the majority of fluctuations in non-stock financial wealth, but this component is so stable that it plays little role in the volatility of net worth (Table 3). Housing wealth, on the other hand, is more closely related to the two permanent shocks than is stock market wealth, especially the first, which accounts for 15% of its variation. Still, the transitory shock accounts for a non-negligible 29% of the quarterly fluctuations in housing wealth growth in this sample. Sub-sample analysis (not reported) suggest this latter number is in large part attributable to the most recent boom-bust cycle that culminated in the 2007-09 asset market downturn. The remaining percentages for housing are accounted for by P2 (8%) and the residual $\epsilon_{i,t}$ (47%) in (9). The relatively large role for the residual in driving the quarterly dynamics of the log difference of housing wealth is likely to be at least in part attributable to a mechanical log/level error in (9).[12]

[12]Since stock wealth has a much larger transitory component than has housing, most of the quarterly variation in net worth is driven by transitory shocks that change the *share* of stock market wealth in total net worth. Because the log of net worth is only approximately equal to a (constant) share-weighted average of the logs of the components of net worth, shocks that change the wealth shares would show up in the residual of (9), implying (for example) that a large positive transitory shock that increased the share of

Because the permanent $P2$ reallocation shock accounts for 76% of the quarterly variation in labor income, it is especially puzzling for canonical macroeconomic models where *trend* fluctuations in labor earnings are driven by permanent technology shocks that move the value of labor and productive capital in the same direction. Even in models where non-technology shocks (e.g., preference shocks, fiscal shocks, monetary shocks) play a role, they typically have only a temporary impact on the economy and do not permanently reallocate rewards among factors of production. We discuss some possible non-canonical economic theories for this shock below.

The transitory shock is also puzzling from the standpoint of economic theory, even among those theories that resolve important asset pricing puzzles. To illustrate, Figure 6 shows impulse responses of consumption and wealth in the Constantinides (1990) habit-formation model, a framework that can explain the high equity premium in the data without appealing to high risk aversion. The model is an endowment economy, so there is no labor income and therefore only a bivariate cointegrating relation between consumption and asset wealth. The model contains only a single primitive shock, namely the permanent shock to the invested endowment which is a shock to log consumption. Thus there is in fact no transitory shock in the model, but because the model is nonlinear the permanent/transitory decomposition can still be computed using data simulated from the non-linear model. The decomposition therefore produces two shocks, one labeled permanent and one labeled "transitory." The decomposition illustrates the extent to which this non-linear model would produce evidence of quantitatively important transitory shock, if in fact it had generated the historical data.

Perhaps not surprisingly as Figure 6 shows, the quantitative importance of the transitory shock in the model is tiny. Thus, nonlinearities alone are not enough to allow the model to explain the large transitory component in wealth found in post-war data. On the other hand, the consumption innovation in this model has effects that are very similar to the first permanent productivity shock in or data.

The same calculation can be applied to the Campbell and Cochrane (1999) external habit formation model. Campbell and Cochrane (1999), building on work by Abel (1990) and Constantinides (1990), showed that high stock market volatility and predictability could be explained by a small amount of aggregate consumption volatility if it were amplified by

stock market wealth in total net worth would show up as a large negative residual in housing (and a smaller positive residual in stock market wealth). Consistent with this, the residuals in (9) for these two wealth components are highly negatively correlated.

time-varying risk aversion.[13] Figure 7 presents impulse responses for log consumption and log wealth using simulated data from the baseline Campbell-Cochrane model. As for the Constantinides model, this is an endowment economy with a single permanent shock to log consumption, $c_t$. Also as in the Constantinides model, log consumption and wealth are cointegrated, and there is no labor income. This model differs from the Constantinides model in that the habit is external and is a highly non-linear function of current and an infinite number of lags of past (aggregate) consumption. The top panel of Figure 7 shows the responses of $c_t$ and $a_t$ to the one permanent shock in the model. Consumption jumps immediately to its new long-run level while wealth initially over-shoots its long-run level. This temporary but persistent over-shooting implies that wealth in the Campbell-Cochrane model deviates substantially from its random walk component, given by the log level of consumption. The model therefore implies that asset wealth has a quantitatively important transitory component that is *correlated* with the permanent consumption shock, implying that excess returns in the model have a significant forecastable component over longer horizons, as in the data. The bottom panel of this figure shows, however, that although wealth responds some to the orthogonal "transitory" shock, and consumption responds not at all to this shock, the orthogonal transitory shock represents a quantitatively small fraction of the variation in wealth, accounting for only 16% of its fluctuations. Yet we have seen above that the orthogonal transitory shock accounts for the vast majority of fluctuations in wealth. As emphasized by Lettau and Ludvigson (2001), Lettau and Ludvigson (2005), and LL, much of the short to medium-run forecastability of excess stock market returns is driven by this *orthogonal* transitory component of wealth, rather than by deviations from the random walk in wealth that are perfectly correlated with consumption innovations. In summary, unlike the Constantinides model, the Campbell-Cochrane habit model is consistent with the finding that wealth deviates substantially from its random walk component, but it cannot account for the finding here that such deviations are uncorrelated with consumption.

## 3.2 Trend and Cyclical Components of $c$, $a$, and $y$

The empirical procedure employed here can be used to decompose any of the variables in our system into a "trend" and "cyclical" components. A natural definition of trend component in each variable is the long-run forecast of the variable, given by the trend component from

[13] Recent surveys of evidence on stock market predictability and volatility are included in Cochrane (2005), Lettau and Ludvigson (2010), and Koijen and Van Nieuwerburgh (2010).

the multivariate Beveridge-Nelson decomposition for the cointegrated system $(c_t, a_t, y_t)'$. We define the *cyclical component* to be the difference between the actual series and the long-run trend (random walk) component. Note that this definition for the cyclical component differs from the *transitory component*. The transitory component is the difference between the actual series and the permanent component of each variable, where the latter is driven by the two permanent shocks in our system defined by (2).

The three panels of Figure 8 plot the resulting trend components of consumption, asset wealth and labor earnings over time, along with the actual series for each variable. The plot spans the length of our sample, from the second quarter of 1952 to the second quarter of 2010. Consumption and labor earnings are visually indistinguishable from their long-run trends. This is not surprising because we already know that they are highly correlated with these trends (Table 5). For asset wealth, by contrast, there are many times in the post-war period when asset wealth has diverged substantially from its estimated trend.

A clearer picture of the extent to which this is true is given in Figure 9, which shows the difference between the trend and actual value of asset wealth (the cyclical component of wealth), in percent of the trend component. The series displayed in the figure has been normalized so that when it is above zero, wealth is estimated to be above its long-term trend; when it is below zero, wealth is estimated to be below its long-term trend.

The figure shows clearly that transitory swings in wealth are both quantitatively large and persistent. The two recent boom-bust episodes in asset markets stand out. In the period just before the 2000-02 crash, the transitory component reached as high as 18.9 percent of the permanent component of wealth. Translated into dollar amounts, this implies that wealth exceeded its long-run level by as much \$28,138 per capita in 2005 dollars. The subsequent decline in stock market wealth that was predicted by this large deviation restored net worth to its long-run trend with consumption and labor earnings. Similarly, in the period just before the 2007-09 crash, the transitory component reached as high as 28.1 percent of the permanent component of wealth. Translated into dollar amounts, this implies that wealth exceeded its long-run trend by as much \$45,294 per capita in 2005 dollars. We discuss these subperiods further below.

## 3.3 Decomposition of Levels

To shed light on the role that each shock has played on the evolution of the variables over time, we decompose the log levels of the variables into components driven by each structural disturbance. To do so, consider the decomposition of growth rates of wealth components in (9), reproduced here for convenience:

$$\begin{aligned}\Delta z_{i,t} &= A_i(L)\,\eta_{P1,t} + B_i(L)\,\eta_{P2,t} + C_i(L)\,\eta_{T,t} + \epsilon_{i,t} \\ &\equiv \Delta z_{i,t}^{P1} + \Delta z_{i,t}^{P2} + \Delta z_{i,t}^{T} + \epsilon_{i,t}.\end{aligned}$$

The effect on the log levels of the variables of each disturbance is obtained by summing up the effects on the log differences (where below we drop the $i$ subscript to denote the generic approach):[14]

$$\begin{aligned}z_t &= z_0 + \sum_{s=1}^{T} \Delta z_s \\ &= z_0 + \sum_{s=1}^{T} \Delta z_s^{P1} + \sum_{s=1}^{T} \Delta z_s^{P2} + \sum_{s=1}^{T} \Delta z_s^{T} + \epsilon_t \\ &= z_0 + z_t^{P1} + z_t^{P2} + z_t^{T} + \epsilon_t, \end{aligned} \tag{10}$$

where $T$ is the sample size. A similar decomposition of levels can be obtained for $c_t$, $a_t$, and $y_t$ by referring to the relevant sub-matrices of (8):

$$\begin{aligned}\Delta x_{i,t} &= \widetilde{D}_{i,1}(L)\,\eta_{P1,t} + \widetilde{D}_{i,2}(L)\,\eta_{P2,t} + \widetilde{D}_{i,3}(L)\,\eta_{T,t} \\ &\equiv \Delta x_{i,t}^{P1} + \Delta x_{i,t}^{P2} + \Delta x_{i,t}^{T},\end{aligned}$$

where $x_{i,t}$ is the $i$the element of $\mathbf{x}_t = (c_t, a_t, y_t)'$ and where $\widetilde{D}_{i,j}(L)$ denotes the scalar polynomial lag operator that is the $i,j$th element of $\widetilde{\mathbf{D}}(L)$. Summing the first differences we again obtain the effect of each shock on the log levels:

$$\begin{aligned}x_{i,t} &= x_{i,0} + \sum_{s=1}^{T} \Delta x_{i,s} \\ &= x_{i,0} + \sum_{s=1}^{T} \Delta x_{i,s}^{P1} + \sum_{s=1}^{T} \Delta x_{i,s}^{P2} + \sum_{s=1}^{T} \Delta x_{i,s}^{T} \\ &= x_{i,0} + x_{i,t}^{P1} + x_{i,t}^{P2} + x_{i,t}^{T}.\end{aligned} \tag{11}$$

Figures 10, 11, and 12, plot the levels decompositions over time for $c_t$, $y_t$, and net worth $a_t$, respectively using (11). The top panels of each figure shows the sum of each component,

[14] We remove the deterministic trend from the log level prior to summing over each component.

or the total level of the variable. The bottom panels show the decomposition in the total level attributable to the level components of each structural disturbance. We have removed the deterministic trend from the levels of each variable so that each component and its sum have a well defined mean.

Figure 10 shows that the movement in the log-level of consumption over time is dominated by the movement in the level of the $P1$ shock. The other two shocks play virtually no role in the determination changes in the level of consumption. By contrast, shorter-term fluctuations in net worth (Figure 11) are dominated by the pattern in the $T$ shock, but these short-run tendencies are shifted up or down by the cumulative effect of two permanent shocks. For labor earnings (Figure 12), both the first and second permanent shocks have influenced its level over low frequencies while the $T$ shock plays no role. In particular, the cumulation of $P2$ shocks has been a persistent drag on labor earnings since the mid 1980s, while it was a persistent boon from the mid 1960s to the mid 1980s.

Figure 13 shows how these shocks have affected the levels of the three major wealth components, obtained using the OLS estimates and (10). It is clear from the top panel that all three major asset classes (stock wealth, housing, and non-stock financial wealth) are affected by about the same magnitude by the $P1$ shock over time. There are significant differences among these components in the roles the other two shocks play, however. For example, low frequency movements in the level of stock market wealth are dominated by the cumulative swings in the $P2$ component, whereas shorter-lived peaks and troughs in the stock market have coincided with spikes up or down in the transitory component. For example, the asset market booms from 1994 to late 2000 and from the third quarter of 2002 to the third quarter of 2007 coincided with upward spikes in the $T$ component. But the figure also shows that the stock market experience over long periods is driven in great part by the $P2$ shock, discussed below. Both the reallocation $P2$ shock and the transitory $T$ shock are much more important, quantitatively, for stock market wealth than is the productivity $P1$ shock (note the left-hand scales). Finally, note that housing and non-financial stock market wealth are little effected by both the $P2$ shock and the $T$ shock. For these components, the quantitatively important innovation over long and short horizons is the permanent productivity shock $P1$.

An important aspect of these results, noted above, is that the low frequency movements in the stock market are the inverse image of those in labor earnings. The importance of this is further illustrated by Figure 14, which shows the stark inverse relationship over time between labor earnings and the stock market that is the result of the cumulative reallocative outcomes of the second permanent shock. For the last 25 years, the cumulative effect of the $P2$ shock has persistently lowered the level of labor earnings and boosted stock market wealth. By contrast, for 20 years prior to that (from the mid 1960s to the mid 1980s), the cumulative effect of the $P2$ shock persistently boosted labor earnings and lowered stock market wealth.

Another way to examine how the behavior of the *level* of the variables is affected over time by the three shocks is to decompose the variance of the log level by frequency, using a spectral decomposition. To do so, we estimate the spectrum for the log difference in each variable and then apply a filter to infer the level spectrum, allowing us to compute the fraction of the variance in the log level of each variable that is attributable to cycles of different lengths, in quarters. Figure 15 shows this decomposition for $c_t$, $a_t$, and $y_t$; Figure 16 exhibits the same decomposition for the major components of wealth.

Figure 15 shows that the variance in the level of consumption is dominated at all frequencies by the first permanent shock (Figure 15, top panel). The variance of labor income, on the other hand, is dominated by $P2$ for cycles of one quarter to 16 quarters, where the latter roughly corresponds to the length of a typical (median) NBER business cycle as measured from cycle peak to cycle peak. For cycles between 6 and 32 quarters, $P1$ and $P2$ explain about the same amount of the variance in the level of labor earnings; for very long cycles, $P1$ explains a little more than 60%, while $P2$ explains a little less than 40%. The transitory $T$ shock plays no role in the variance of labor income at any horizon. This shock is the most important contributor to the volatility of total net worth at all frequencies, a fact that reflects the persistent nature of the transitory wealth shock.

The large role for the transitory component in the variance of $a_t$ is reflected in all the major components of $a_t$, especially at frequencies corresponding to cycles between 2 and 40 quarters. For stock market wealth, however, the second permanent $P2$ disturbance plays an increasingly important role as the length of the cycle increases, eventually explaining about the same fraction of variance as the $T$ shock at very low frequencies. For housing wealth, the transitory shock and the $P1$ shock play important roles over cycles of most lengths.

## 3.4 A Comparison of Two Asset Market Cycles

How does the recent behavior of these shocks relate to the observed volatility in asset values and the real economy in recent business and asset market cycle episodes? During the last 20 years, the U.S. economy has experienced two recessions, accompanied by two asset market "crashes." From March 2000 to September 2002, the S&P 500 index declined 39%, accompanied by only a modest drop in real activity during the 2001 recession. In fact, real, per capita consumption and housing wealth rose from the first quarter of 2000 through third quarter of 2002, increasing 3.6 and 23 percent, respectively. During the boom years leading up to this contraction, the S&P 500 index rose 221% (March 1994 to March 2000) while real, per capita housing wealth rose a more modest 22%. By contrast, the 2007-09 recession was associated with a decline in stock market wealth of similar magnitude (the S&P 500 fell 44% from September 2007 to March 2009), but a much larger decline in real activity and housing wealth. From the third quarter of 2007 through the first quarter of 2009, consumption fell 1.67 percent and housing wealth declined 26 percent on a real, per capita basis. Prior to this crash, the S&P 500 rose 75% (September 2002 to September 2007), while housing wealth rose 38% (third quarter 2002 to first quarter 2006).

The next figures explore the role of each structural disturbance in the driving household net worth and its major asset components over these two boom/bust cycles. Figures 17-20 show the same level decompositions described above, but focused on the time period of these two episodes. The three vertical lines in each plot divide the episodes into four sub-panels, two boom and two bust periods, with the first boom period measured from 1994:Q1-2000:Q1, followed by a bust from 2000:Q1 to 2002:Q3, followed by a boom from 2002:Q3-2007:Q3, followed by a bust from 2007:Q3 to the end of our sample, 2010:Q2.

Figure 17 exhibits the role each shock played in driving the level of total net worth during these episodes. The figure shows that the asset market downturn of 2000-02 (and the boom that proceeded it) was almost entirely the result of a string of transitory wealth shocks. The boom in net worth in the first sub-panel on the left and the decline in the second sub-panel mirror closely the boom-bust pattern in the cumulative effects of the transitory $T$ shock. Indeed, the other two permanent shocks had little effect on the level of net worth: the cumulative effect of these shocks was relatively flat over these two subperiods. Figure 18 shows that this same pattern is evident in stock market wealth but there is no similar boom-bust pattern in housing wealth (Figure 19), or in non-stock financial wealth (Figure 20). This shows that the asset market downturn of 2000-02 and the boom that proceeded it was almost entirely the result of a string of transitory wealth shocks to the stock market component of wealth.

By comparison, the asset market boom from 2002:Q2-2007:Q3 (third sub-panel from the left) was the result of a culmination of transitory shocks that affected all three major wealth components. This boom therefore represents a departure from the usual historical pattern for housing wealth, which has historically shown only weak correlation with the transitory $T$ shock. The asset market *crash* of 2007-09, on the other hand, was characterized by large negative roles for *both* the transitory shock and the permanent productivity shock $P1$, with the latter having especially important effects on housing wealth. These patterns are similar in spirit to findings in Campbell, Giglio, and Polk (2010) who argue that, in 2000-02, stock prices fell primarily because discount rates increased (implying a transitory decline in stock wealth), while the 2007-2009 crash was attributable to both worsening cash flow prospects (implying a permanent decline in stock wealth) and to higher discount rates.

The last sub-panel of each plot includes the level forecasts for each component, extended out past the end of our sample (2010:Q2). The forecasts are computed from (9) by assuming all future innovations (past the end of our sample) are equal to their population means of zero, and then rolling the computation for the levels forward (see (10)). Since the distributed lag operators in (9) use 16 quarterly lags, the model produces forecasts for 16 quarters past the end of our sample. In contrast to the 2000-02 experience, the model forecasts imply persistently low home values going forward from the end of our sample, the result of a string of negative draws to the permanent productivity shock since 2007 (Figure 19, second panel). The cumulative effects of the other two shocks play no role in this gloomy forecast. At the same time, the rebound in the stock market since 2009 can be traced to a string of transitory innovations (Figure 18, third panel): the only component of stock market wealth moving up during the period since 2009Q1 is the transitory component, a movement that is echoed in the plots for total household net worth (Figure 17). Figure 9 shows that, as of the third quarter of 2010, the cumulative effect of these innovations on stock market wealth has once again driven household net worth to values significantly above its long-run level.

# 4 Discussion

What are the predominant sources of post-war fluctuations in labor markets and household wealth? We find here that the prime movers are a permanent shock that reallocates rewards between workers and shareholders and a transitory shock that effects only wealth. To draw these conclusions we have identified three shocks, distinguished by whether their effects are permanent or transitory, and used them to characterize the post-war dynamics of aggregate consumer spending, labor earnings, and household wealth. The first shock does indeed look like a standard factor-neutral technology shock that drives (stochastic) trend movements in productivity, the returns to labor and capital, and consumption, all in the same direction. Panel A of Figure 21 shows that the low frequency variation in the cumulative sum of this shock over time closely mirrors the utilization-adjusted TFP series compiled by Fernald (2009). This $P1$ shock accounts for virtually of the variation in consumption growth in our post-war sample.

But there are two other shocks that are mutually uncorrelated with this permanent productivity shock, and they are dominant forces in the post-war behavior of labor earnings and household wealth. The second of these shocks is a permanent disturbance that sends net worth (in particular stock market wealth) in one direction and labor income in the other. This shock underlies the bulk of post-war fluctuations in labor earnings, accounting for 76% of its quarterly variation; it also plays a quantitatively large role in labor income volatility over business cycles and at low frequencies, reflecting an important "Wall Street versus Main Street" tradeoff in the data. The third shock is a persistent but transitory innovation that accounts for the vast majority of quarterly fluctuations in asset values but has a negligible impact on consumption and labor earnings, both contemporaneously and at any future horizon. We show that transitory innovations played a dominant role in the 2000-02 stock market crash and the run-up that preceded it. By contrast, the 2007-09 asset market crash was accompanied by a string of large negative realizations in both the transitory shock and the permanent productivity shock, with the latter having especially bearish implications for housing wealth for the three years past the end of our sample in 2010:Q2.

The role of two of these shocks in driving the post-war experience appears especially puzzling from the perspective of modern dynamic macroeconomic theory, for two reasons. First, the large transitory component in wealth is impossible to reconcile with any model that is inconsistent with a significant forecastable component in stock market returns over medium to long horizons. But this finding also presents a challenge for leading consumption-based asset pricing theories that are capable of explaining such forecastability: these models are consistent with the existence of a large transitory component in wealth, but they do not account for the finding that this component is unrelated to consumption.

Second, economic theory also teaches us that trend movements in the rewards to labor input typically rise and fall with movements in long-run labor productivity, driven (for example) by a permanent technology shock. Yet the only shock that can plausibly be interpreted as a permanent factor-neutral productivity shock in our data explains just 23 percent of post-war labor income fluctuations. Instead, what explains the variability in labor income is a reallocation shock that shifts rewards between equity shareholders and workers, a finding similar in spirit to estimates of asset pricing models that suggest the return to human capital is negatively correlated with stock market returns (Chen, Favilukis, and Ludvigson (2007), Lustig and Van Nieuwerburgh (2008)). Although this reallocation shock has only a small impact on the level of stock market wealth at quarterly horizons, it is an important force in its low frequency variation around a deterministic trend. Over the last 25 years, the cumulative effect of this reallocative shock has persistently boosted stock market wealth and persistently lowered labor earnings. The disturbance helps explain why the stock market, which rebounded quickly from losses in 2008 and early 2009, has remained buoyed even in the face of an initial subsequent "jobless recovery" that kept labor earnings growth low for many quarters heading out of the recession.

We are not the first to conclude that factor-neutral technology shocks are unlikely to be the most important source of variation in economic aggregates (see for example, King, Plosser, Stock, and Watson (1991); Galí (1999); Christiano, Eichenbaum, and Vigusson (2004); Fisher (2006); Smets and Wouters (2007); Justiniano, Primiceri, and Tambalotti (2009, 2010)). So it is important to note the ways in which our approach, data, and findings, differ from other work that has studied the sources of business cycle fluctuations.

First, other researchers have focused primarily on output, investment and hours, and on their variability at business cycle frequencies. By contrast, we have focused on economic aggregates motivated by the household budget constraint, namely consumption, asset wealth and labor earnings, and have scrutinized both long and short-run tendencies in these variables. In doing so, we provide a new characterization of the non-technology sources of variation in an alternative set of macroeconomic and financial market indicators, finding not only that these sources are quantitatively important but also that their dynamics contain a stark reallocative component that operates between workers and shareholders. Second, in terms of labor market dynamics, most of the macroeconomic literature has focused on hours worked. For example, Galí (1999) argued that non-stationary hours worked do not respond empirically to his identified productivity shocks. We instead focus on the total reward to worker input, or labor earnings (roughly average after-tax wage times hours). Third, the assumptions under which we identify a permanent productivity shock differ from the extant literature. For example, Gali identified technology innovations under the assumption that only technology shocks could have permanent effects on average labor productivity. Our empirical system, on the contrary, contains two permanent shocks with only one of them plausibly interpreted as a conventional factor-neutral productivity shock. Thus, unlike the extant literature, we explicitly allow for the presence of a second non-productivity permanent shock, the nature and quantitative importance of which we investigate.

It is important to emphasize that the first permanent "productivity" shock in our system is interpreted as a permanent total income shock, and is obtained by restricting the contemporaneous response of *consumption* to permanent and transitory innovations. This identifying restriction rules out any role for a second mutually uncorrelated permanent shock to contemporaneously affect consumption. It also rules out a contemporaneous role for transitory shocks (driven by e.g., monetary or fiscal shocks) that could temporarily affect consumption growth through a change in the expected real interest rate if the EIS is non-zero. While such additional sources of variation might be possible and even plausible, the evidence above suggests that, if they are present, they are not quantitatively important for consumption: both the second permanent shock and the transitory shock in our system explain a negligible fraction of the variance of consumption growth at *all* horizons, not just in the zero-th horizon in which the restriction is imposed. This result is consistent with Justiniano, Primiceri, and Tambalotti (2009) who find that the comovement of consumption with the rest of the economy is driven mainly by factor-neutral technology shocks.

Finally, in contrast to approaches that identify shocks by estimating structural dynamic stochastic general equilibrium models (e.g., Smets and Wouters (2007); Justiniano, Primiceri, and Tambalotti (2009, 2010)), our econometric approach uses only an unrestricted VECM and a single contemporaneous restriction on the behavior of consumption to identify three mutually uncorrelated structural disturbances distinguished by their degree of persistence. We view the two approaches as complementary, with each subject to its own strengths and weaknesses that reflect the usual trade-off between efficiency and robustness to model misspecification.

## What is the Transitory Wealth Shock?

We have shown above that the transitory wealth shock is closely related to short- and intermediate-term fluctuations in household net worth and the stock market in particular, but is unrelated to consumption and labor income. How should we interpret these fluctuations in wealth? Variation in stock prices relative to measures of fundamental value can be attributable to one of two factors: changes in expected future cash-flow fundamentals, or changes in the discount rates applied to these cash-flows.[15] Even if expected future cash-flows remain unchanged, wealth can fluctuate considerably if there are large changes in the discount rates that rational investors apply to corporate cash-flows. If the transitory shock represents a pure discount rate shock (orthogonal to expected future cash-flows), it may not have important affects on consumption or labor income, but a simple $Q$-theory of investment would imply that it should have affects on investment. Cochrane (1991) shows that, if managers have access to complete financial markets and if aggregate stock prices represent a claim to the capital stock corresponding to investment, the the discount rates applied to optimal investment decisions will coincide with the discount rates applied to the stock market. Thus, when stock prices rise on the expectation of lower future returns, discount rates fall, raising the expected present discounted value of marginal profits and therefore the optimal rate of investment (Abel, 1983; Abel and Blanchard, 1986). If there are short-term lags between investment decisions and investment expenditures (Lamont, 2000), the expenditures themselves may not rise contemporaneously with a negative discount rate shock that raises stock prices, but investment expenditures should rise after a few quarters and then eventually fall along with the forecastably lower future stock returns that accompanies a decline in discount rates, as emphasized in Lettau and Ludvigson (2002). In summary, if the transitory wealth shock is a discount rate shock rather than a cash-flow shock, it should eventually affect investment even if it does not affect consumption and labor earnings.

Figure 22 shows the dynamic response of various measures of investment expenditure to the three structural disturbances in our system. The responses are computed in the same way that the responses for the wealth components are computed, by summing the growth rates implied by an OLS regression of investment on distributed lags of $\eta_{P1,t}$, $\eta_{P2,t}$, and $\eta_{T,t}$, as in (10). An increase in the transitory shock raises all four types of investment (private investment, nonresidential investment, structures, and equipment) within a few quarters time and then eventually lowers investment, consistent with the interpretation of the transitory shock as a discount rate shock. Since the transitory shock is unrelated to consumption, however, the source of this discount rate shock cannot be a consumption innovation, as in many consumption-based asset pricing models.

An increase in the permanent productivity ($P1$) shock has a positive effect on all investment categories. This is not surprising since a positive productivity shock increases the expected value of marginal profits (cash-flows), and therefore optimal investment in a

[15] This decomposition rules out rational bubbles.

$Q$ model with adjustment costs. Finally, the figure shows that a positive value for the reallocative ($P2$) shock leads to a decrease in investment. This could occur if $P2$ is driven by a persistent shock to uncertainty about firm-level growth rates or by price markups, as discussed in the next section.

## What is the Permanent Reallocation Shock?

How can we interpret the post-war behavior of labor income and household net worth that we have documented here in response to the second permanent shock in our system? What economic mechanisms might be consistent with these findings? We conclude by conjecturing a few possibilities.

First, search models with shocks to the bargaining power of firms are an intuitively appealing possibility. It is important to remember, however, that the reallocation shock we identify explains the bulk of *quarterly* labor income fluctuations, so low frequency shifts in bargaining power alone (designed to explain e.g., the secular decline in union membership over the post-war period) are unlikely to explain these higher frequency movements in the labor market.

A second possible explanation could involve "uncertainty" shocks driven by fluctuations in the dispersion of firm-level growth rates. A (positive) uncertainty shock makes the distribution of future dividends right-skewed and raises the price-dividend ratio (Pastor and Veronesi, 2006). At the same time, macroeconomic researchers have explored the interactions of financial frictions with increases in uncertainty about firm level growth rates and have found that increases in uncertainty generate a fall in both output and labor income and a rise in interest rates (e.g., Arellano, Bai, and Keno, 2010). Similarly, Schaal (2010) studies a dynamic search model of heterogeneous firms with both TFP shocks and uncertainty shocks but without financial frictions. A positive uncertainty shock in his model increases both average productivity and the real wage but also significantly raises unemployment, implying that total labor income could fall under the right calibration.

These models also often imply that positive uncertainty shocks interacting with financial frictions lead to a reduction in investment, as in Gilchrist, Sim, and Zakrajsek (2010), consistent with the effect of $P2$ on investment discussed above. Justiniano, Primiceri, and Tambalotti (2009) find that an investment shock that determines the efficiency of newly produced investment goods explains most of the variation in output at business cycle frequencies while Justiniano, Primiceri, and Tambalotti (2010) argue that this shock is closely related to financial intermediation frictions, consistent with the interpretation of Gilchrist, Sim, and Zakrajsek (2010). Panel B of Figure 21 shows that the low frequency variation in the cumulative sum the investment-efficiency shock estimated in Justiniano, Primiceri, and Tambalotti (2009) is closely related over time to that of the $P2$ shock.[16] Taken together, these results are suggestive of a possible role for uncertainty shocks (and a lesser role for productivity shocks) in explaining both the post-war behavior of labor earnings and the low frequency behavior of the stock market. To provide more than suggestive evidence, however, future research must formally investigate the simultaneous effects of such shocks on stock market wealth and labor income in a unified general equilibrium model.

Other researchers have examined the role of shocks to labor's share in the production process, both in the data and in a standard real business cycle model, as for example in Ríos-Rull and Santaeulalia-Llopis (2009). Some have argued that variation in the labor share explains an important fraction of inflation variation, as in Galí and Gertler (1999). Ríos-Rull and Santaeulalia-Llopis (2009) find empirically, however, that shocks to labor's share tend to be negatively correlated with measures of productivity, whereas the $\eta_{P2,t}$ shock we identify is orthogonal to the permanent productivity shock in our decomposition. In addition, Ríos-Rull and Santaeulalia-Llopis (2009) find that shocks to labor's share display an overshooting pattern that is not immediately evident in the response of labor income to a $\eta_{P2,t}$ shock.

A fourth possible explanation for our findings is *directed* technological change. Researchers have postulated models of directed technological change to explain why the returns to some factors deviate persistently from others (e.g., Acemoglu, 2002). This suggests that, in principle, a model of technological change biased *in favor* of capital and *against* labor might explain the simultaneous high rewards to the stock market and low rewards to labor effort resulting from the cumulative effect of the $\eta_{P2,t}$ shock over the last 25 years, while technological change biased *in favor* of labor and *against* capital might explain the converse over the 20 years prior to that. More work is needed to determine whether a reasonable model of directed technological change can explain the findings here, especially given the role skill-biased technological change is thought to have played in the returns to highly educated workers over the last 20 years.

A final possible explanation for these findings could involve price mark-up shocks. A price mark-up creates a wedge between prices and marginal cost, so an increase in the mark-up increases profits and decreases the real wage. Justiniano, Primiceri, and Tambalotti (2009)

[16]We are grateful to Giorgio Primiceri for providing us with the investment shock data.

find that price mark-up shocks explain 31 percent of the variance of wages at business cycle frequencies, while factor-neutral productivity shocks explain 40 percent. Unreported results in Justiniano, Primiceri, and Tambalotti (2009) also imply that a positive price markup shock lowers investment, as in the response of investment to a P2 shock. Given the cumulative values of $P2$ displayed in Figure 1, this interpretation implies that the economy has become much less competitive in the last 25 years. Rigorous evaluation of these and other possible contending explanations awaits future research.

# Appendix

## Data Description

CONSUMPTION

Consumption is measured as either total personal consumption expenditure or expenditure on nondurables and services, excluding shoes and clothing. The quarterly data are seasonally adjusted at annual rates, in billions of chain-weighted 2005 dollars. The components are chain-weighted together, and this series is scaled up so that the sample mean matches the sample mean of total personal consumption expenditures. Our source is the U.S. Department of Commerce, Bureau of Economic Analysis.

AFTER-TAX LABOR INCOME

After-tax labor income is defined as wages and salaries + transfer payments + employer contributions for employee pensions and insurance - employee contributions for social insurance - taxes. Taxes are defined as [ wages and salaries/(wages and salaries + proprietors' income with IVA and Ccadj + rental income + personal dividends + personal interest income)] times personal current taxes, where IVA is inventory valuation and Ccadj is capital consumption adjustments. The quarterly data are in current dollars. Our source is the Bureau of Economic Analysis.

POPULATION

A measure of population is created by dividing real total disposable income by real per capita disposable income. Our source is the Bureau of Economic Analysis.

WEALTH

Total wealth is household net worth in billions of current dollars, measured at the end of the period. A break down of net worth into its major components is given in the table below. Stock market wealth includes direct household holdings, mutual fund holdings, holdings of private and public pension plans, personal trusts, and insurance companies. Nonstock wealth includes tangible/real estate wealth, nonstock financial assets (all deposits, open market paper, U.S. Treasuries and Agency securities, municipal securities, corporate and foreign bonds and mortgages), and also includes ownership of privately traded companies in noncorporate equity, and other. Subtracted off are liabilities, including mortgage loans and loans made under home equity lines of credit and secured by junior liens, installment consumer debt and other. Wealth is measured at the end of the period. A timing convention for wealth is needed because the level of consumption is a flow during the quarter rather than a point-in-time estimate as is wealth (consumption data are time-averaged). If we think of a given quarter's consumption data as measuring spending at the beginning of the quarter, then wealth for the quarter should be measured at the beginning of the period. If we think of the consumption data as measuring spending at the end of the quarter, then wealth for the quarter should be measured at the end of the period. None of our main findings discussed below (estimates of the cointegrating parameters, error-correction specification, or permanent-transitory decomposition) are sensitive to this timing convention. Given our finding that most of the variation in wealth is not associated with consumption, this timing convention is conservative in that the use of end-of-period wealth produces a higher contemporaneous correlation between consumption growth and wealth growth. Our source is the Board of Governors of the Federal Reserve System. A complete description of these data may be found at http://www.federalreserve.gov/releases/Z1/Current/.

PRICE DEFLATOR

The nominal after-tax labor income and wealth data are deflated by the personal consumption expenditure chain-type deflator (2005=100), seasonally adjusted. In principle, one would like a measure of the price deflator for total flow consumption here. Since this variable is unobservable, we use the total expenditure deflator as a proxy. Our source is the Bureau of Economic Analysis.

INVESTMENT

Investment is fixed private investment, seasonally adjusted in chain-weighted 2005 dollars. Our source is the Bureau of Economic Analysis.

INVESTMENT - NONRESIDENTIAL

Nonresidential investment is fixed private non-residential investment, seasonally adjusted in chain-weighted 2005 dollars. Our source is the Bureau of Economic Analysis.

INVESTMENT - EQUIPMENT AND SOFTWARE

Investment in equipment and software is fixed private non-residential investment in equipment and software, seasonally adjusted in chain-weighted 2005 dollars. Our source is the Bureau of Economic Analysis.

INVESTMENT - STRUCTURES

Investment in structures is fixed private non-residential investment in structures, seasonally adjusted in chain-weighted 2005 dollars. Our source is the Bureau of Economic Analysis.

**Table A.1: Flow of Funds Balance Sheet**

| | | | |
|---|---|---|---|
| Assets | \$200,619 | Liabilities | \$41,709 |
| Tangible Assets | | Mortgages | \$30,551 |
| Real Estate | \$49,175 | Consumer Credit | \$7,447 |
| Other | \$19,389 | Other | \$3,860 |
| Financial Assets | | | |
| Corporate Equity | \$46,289 | | |
| Deposits | \$23,207 | | |
| Credit Market Instruments | \$12,865 | | |
| Other (incl. pension funds) | \$49,691 | *Net Worth* | \$158,909 |

Notes: Data for the year 2010:Q2. Source: Flow of Funds, Board of Governors of the Federal Reserve. "Other" includes all types of assets (held in or out of pension funds) that are not corporate equity (held directly or indirectly) or credit market instruments. Of these, assets other than corporate equity held indirectly in pension funds and other funds (eg mutual funds) is the largest component. Equity in noncorporate businesses is another large component which includes also the net value of rented homes (tenant occupied housing.).

## Cointegration Tests

This appendix presents the results of cointegration tests. Tests for the presence of a unit root in $c$, $a$, and $y$ (not reported) are consistent with the hypothesis of a unit root in those series and are available upon request.

We report results below for tests of the null of deterministic cointegration (estimated cointegrating vector eliminates both the deterministic and stochastic trends). The methodology follows Park (1990), Park (1992), Han and Ogaki (1997), and Ogaki and Park (1997). The cointegrating regression is the form: $c_t = cons + \beta_a a_t + \beta_y y_t + \varepsilon_t$. The $H(0,1)$ test statistic tests the hypothesis $\gamma_1 = 0$ in the regression:

$$c_t^* = c + \gamma_1 t + \beta_y y_t^* + \beta_a a_t^* + \varepsilon_t^*, \tag{12}$$

where variables with a "*" denote their transformed values based on the "canonical cointegrating regressions," e.g.,

$$c_t^* = c_t + d_c \varepsilon_t,$$

and similarly for $y_t^*$ and $a_t^*$. The parameters $d_c$, etc., are real numbers. Since the cointegrating residual $\varepsilon_t$ is stationary, $c_t^*$, $a_t^*$ and $y_t^*$ are cointegrated with the same cointegrating vector as $c_t$, $a_t$ and $y_t$. The parameters $d_c$ etc., are selected so that $c_t$, etc., are uncorrelated with disturbances of the regression in the long-run, implemented by using the "variable additive method" of Park (1990). These parameters depend on the OLS estimate of the cointegrating vector and the long-run autocovariance function of $\varepsilon_t$, $\Omega = \sum_{i=-\infty}^{\infty} E\left[\varepsilon_t \varepsilon_{t-i}'\right]$. The null hypothesis of deterministic cointegration is a test of the hypothesis $\gamma_1 = 0$; hence a rejection of $\gamma_1 = 0$ is a rejection of this null. Table A.2 below provides test results for the sample 1952:Q1-2010:Q2. The $H(0,1)$ test statistic provides no evidence against the null of deterministic cointegration.

**Table A.2: Canonical cointegrating regression results**

| $\widehat{\beta}_a$[a] | $\widehat{\beta}_y$[a] | $H(0,1)$[b] |
|---|---|---|
| 0.2186 | 0.6700 | 0.0013 |
| (0.0412) | (0.0461) | (0.9717) |

Park and Ogaki's (1991) VAR prewhitening method with Andrew's (1991) automatic bandwidth parameter estimator was used to estimate long-run covariance parameters. The parameters $\widehat{\beta}_a$ and $\widehat{\beta}_y$are estimated cointegrating parameters on $a$ and $y$, respectively.

[a]Standard errors are in parentheses.

[b]$\chi^2$ test statistic with one degree of freedom for the deterministic cointegration restriction. P-values are in parentheses.

## Standard Errors for Impulse Response Functions and Variance Decompositions

This appendix explains the computation of 95% confidence intervals for the impulse response functions and variance decompositions given in the text in response to the structural disturbances. The confidence intervals are generated from a bootstrap as described in Gonzalo and Ng (2001). The procedure is as follows. First, the cointegrating vector is estimated, and conditional on this estimate, the remaining parameters of the VECM are estimated. The fitted residuals from this VECM, $\widehat{e}_t$, are obtained and a new sample of data is constructed using the initial VECM parameter estimates by random sampling of $\widehat{e}_t$ with replacement. Given this new sample of data, all the parameters are reestimated, holding fixed the number of cointegrating vectors, and the impulse responses and variance decompositions stored. This is repeated 5,000 times. The empirical 95% confidence intervals are evaluated from these 5,000 samples of the bootstrapped impulse response functions and variance decompositions are presented in the text.

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Table 1: Growth Rates

| | Consumption | Labor Income | Financial Net Worth |
|---|---|---|---|
| Std. Dev. | 0.46% | 0.92% | 2.26% |
| Correlations | | | |
| Consumption | 1.00 | 0.30 | 0.46 |
| Labor Income | 0.30 | 1.00 | 0.18 |
| Net Worth | 0.46 | 0.18 | 1.00 |

Notes: The table reports descriptive statistics of log first differences of consumption, labor income and financial net worth. The sample spans the fourth quarter of 1951 to the second quarter quarter of 2010.

Table 2: VECM

| Dependent variable | Equation | | |
|---|---|---|---|
| | $\Delta c_t$ | $\Delta a_t$ | $\Delta y_t$ |
| $cay_{t-1}$ | -0.01 | **0.27** | 0.06 |
| | (-0.26) | (2.72) | (1.58) |
| $\Delta c_{t-1}$ | **0.27** | 0.32 | **0.58** |
| | (4.07) | (1.15) | (3.94) |
| $\Delta a_{t-1}$ | 0.06 | **0.25** | -0.13 |
| | (1.66) | (3.62) | (-1.18) |
| $\Delta y_{t-1}$ | 0.06 | -0.08 | -0.14 |
| | (1.67) | (-0.45) | (-1.72) |
| $\bar{R}^2$ | 0.21 | 0.07 | 0.08 |

Notes: The table reports the estimated coefficients from cointegrated vector autoregressions (VECM) of the column variable on the row variable; $t$-statistics are in parentheses. Estimated coefficients that are significant at the 5% level are highlighted in bold face. The term $c_t - \widehat{\alpha}_a a_t - \widehat{\alpha}_y y_t = \widehat{\boldsymbol{\alpha}}' \mathbf{x}_t$ is the estimated cointegrating residual. The sample spans the fourth quarter of 1951 to the second quarter quarter of 2010.

Table 3: Wealth Components

| | Net Worth | Assets | Liabilities | Stock Wealth | Housing | Non-stock Fin. |
|---|---|---|---|---|---|---|
| *Share in Net Worth* | | | | | | |
| 1951Q4–2010Q2 | 1.00 | 1.16 | 0.16 | 0.22 | 0.29 | 0.65 |
| 1951Q4–1961Q4 | 1.00 | 1.10 | 0.10 | 0.18 | 0.26 | 0.67 |
| 1999Q3–2010Q2 | 1.00 | 1.22 | 0.22 | 0.30 | 0.34 | 0.58 |
| *Std. Dev.* | 2.23 | 1.90 | 1.05 | 8.85 | 1.66 | 0.68 |
| *Correlations of log growth rates* | | | | | | |
| Net Worth | 1.00 | 0.99 | 0.31 | 0.89 | 0.47 | 0.38 |
| Assets | 0.99 | 1.00 | 0.38 | 0.89 | 0.50 | 0.42 |
| Liabilities | 0.31 | 0.38 | 1.00 | 0.18 | 0.50 | 0.51 |
| Stock Mkt. Wealth | 0.89 | 0.89 | 0.18 | 1.00 | 0.19 | 0.10 |
| Housing | 0.47 | 0.50 | 0.50 | 0.19 | 1.00 | 0.56 |
| Non stock Financial | 0.38 | 0.42 | 0.51 | 0.10 | 0.56 | 1.00 |

Notes: The table reports descriptive statistics of wealth components from the Flow of Funds. The sample spans the fourth quarter of 1951 to the second quarter quarter of 2010.

Table 4: Variance Decomposition

| Variable | P1 | P2 | T |
|---|---|---|---|
| $\Delta c_{t+1} - E_t \Delta c_{t+1}$ | 100% (100%, 100%) | 0% (0%, 0%) | 0% (0%, 0%) |
| $\Delta y_{t+1} - E_t \Delta y_{t+1}$ | 17% (13%, 27%) | 83% (73%, 87%) | 0% (0%, 0%) |
| $\Delta a_{t+1} - E_t \Delta a_{t+1}$ | 7% (5%, 14%) | 0% (0%, 2%) | 93% (85%, 95%) |
| $\Delta c_{t+\infty} - E_t \Delta c_{t+\infty}$ | 93% (88%, 97%) | 1% (0%, 6%) | 6% (1%, 8%) |
| $\Delta y_{t+\infty} - E_t \Delta y_{t+\infty}$ | 23% (19%, 33%) | 76% (65%, 78%) | 1% (0%, 5%) |
| $\Delta a_{t+\infty} - E_t \Delta a_{t+\infty}$ | 8% (6%, 14%) | 3% (1%, 7%) | 89% (81%, 91%) |

Notes: The table report results from a variance decomposition of orthogonal permanent shocks (P1, P2) shocks and a transitory shock (T). Bootstrapped 90% confidence intervals are in parentheses. The sample spans the fourth quarter of 1951 to the second quarter quarter of 2010.

Table 5: Correlation with Random Walk Component

| Consumption | Labor Income | Financial Net Worth |
|---|---|---|
| 0.970 | 0.996 | 0.331 |

Notes: This table reports the correlations with the nonstationary random walk components constructed from the permanent/transitory identification of shocks. The sample spans the fourth quarter of 1951 to the second quarter quarter of 2010.

Table 6: Wealth Components: Variance Decomposition

| Wealth Component | P1 | P2 | T | Residual |
|---|---|---|---|---|
| Net Worth | 8% | 4% | 88% | 0% |
| Stock Mkt. Wealth | 7% | 8% | 72% | 13% |
| Housing | 15% | 8% | 29% | 48% |
| Non-Stock Fin. Wealth | 20% | 9% | 29% | 42% |

Notes: This table reports the variance decomposition of wealth components based on OLS regressions on contemporaneous and lagged P1, P2 and T shocks. The last column reports that share of the variance that is due to the residual of the regressions. The sample spans the fourth quarter of 1951 to the second quarter quarter of 2010.

Table 7: Impulse Response Function with 90% Confidence Intervals

| Horizon | Consumption | | | | | |
|---|---|---|---|---|---|---|
| $h$ | P1 | | P2 | | T | |
| 1 | 0.407 | (0.374, 0.430) | 0.000 | (0.000, 0.000) | 0.000 | (0.000, 0.000) |
| 2 | 0.685 | (0.590, 0.761) | 0.038 | (-0.016, 0.086) | 0.165 | (0.100, 0.221) |
| 4 | 0.710 | (0.608, 0.816) | 0.003 | (-0.066, 0.062) | 0.143 | (0.079, 0.205) |
| 8 | 0.713 | (0.615, 0.831) | -0.027 | (-0.108, 0.044) | 0.109 | (0.051, 0.177) |
| 16 | 0.715 | (0.620, 0.844) | -0.049 | (-0.141, 0.031) | 0.083 | (0.032, 0.157) |
| $\infty$ | 0.720 | (0.630, 0.922) | -0.120 | (-0.290, -0.016) | 0.000 | (0.000, 0.024) |
| Horizon | Labor Income | | | | | |
| $h$ | P1 | | P2 | | T | |
| 1 | 0.363 | (0.266, 0.446) | 0.799 | (0.722, 0.853) | 0.000 | (0.000, 0.000) |
| 2 | 0.690 | (0.534, 0.823) | 0.717 | (0.608, 0.799) | 0.136 | (0.047, 0.223) |
| 4 | 0.717 | (0.557, 0.876) | 0.689 | (0.571, 0.777) | 0.124 | (0.047, 0.202) |
| 8 | 0.720 | (0.566, 0.886) | 0.663 | (0.536, 0.759) | 0.095 | (0.033, 0.168) |
| 16 | 0.721 | (0.572, 0.894) | 0.644 | (0.510, 0.746) | 0.072 | (0.022, 0.145) |
| $\infty$ | 0.726 | (0.589, 0.950) | 0.582 | (0.393, 0.708) | 0.000 | (0.000, 0.018) |
| Horizon | Net Worth | | | | | |
| $h$ | P1 | | P2 | | T | |
| 1 | 0.564 | (0.395, 0.739) | 0.010 | (-0.197, 0.185) | 2.058 | (1.857, 2.191) |
| 2 | 0.947 | (0.621, 1.382) | -0.452 | (-0.859, -0.149) | 2.309 | (1.853, 2.676) |
| 4 | 1.008 | (0.722, 1.672) | -0.930 | (-1.539, -0.454) | 1.778 | (1.173, 2.392) |
| 8 | 1.035 | (0.765, 1.916) | -1.296 | (-2.051, -0.660) | 1.351 | (0.711, 2.181) |
| 16 | 1.055 | (0.782, 2.128) | -1.574 | (-2.427, -0.826) | 1.026 | (0.427, 1.995) |
| $\infty$ | 1.118 | (0.778, 3.562) | -2.450 | (-4.364, -1.501) | 0.003 | (0.000, 0.332) |

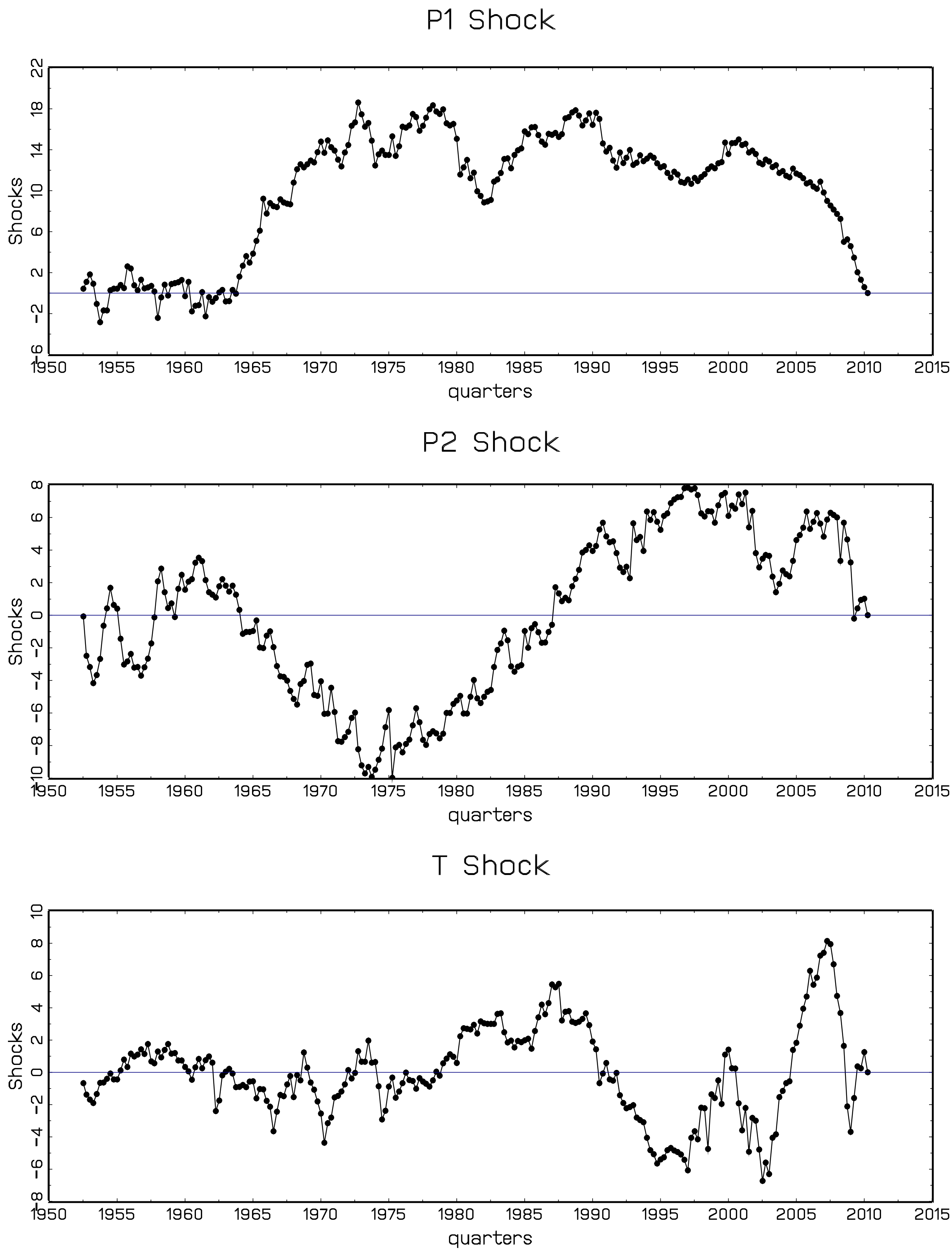
Notes: THis table reports impulse response functions of consumption, labor income and net worth to orthogonal permanent shocks (P1 and P2) and the transitory shock (T). Bootstrapped 90% confidence intervals are in parentheses. The sample spans the fourth quarter of 1951 to the second quarter quarter of 2010.

Table 8: Variance-Covariance Decomposition

| Variable | P1 | P2 | T | (P1,P2) | (P1,T) | (P2,T) |
|---|---|---|---|---|---|---|
| $\Delta c_{t+1} - E_t \Delta c_{t+1}$ | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| $\Delta y_{t+1} - E_t \Delta y_{t+1}$ | 0.000 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| $\Delta a_{t+1} - E_t \Delta a_{t+1}$ | 0.836 | 1.755 | 2.406 | -1.003 | -0.186 | -2.808 |
| $\Delta c_{t+\infty} - E_t \Delta c_{t+\infty}$ | 1.047 | 0.061 | 0.151 | -0.106 | -0.026 | -0.126 |
| $\Delta y_{t+\infty} - E_t \Delta y_{t+\infty}$ | 0.121 | 0.963 | 0.023 | -0.063 | -0.006 | -0.037 |
| $\Delta a_{t+\infty} - E_t \Delta a_{t+\infty}$ | 0.825 | 1.692 | 2.304 | -0.977 | -0.177 | -2.667 |

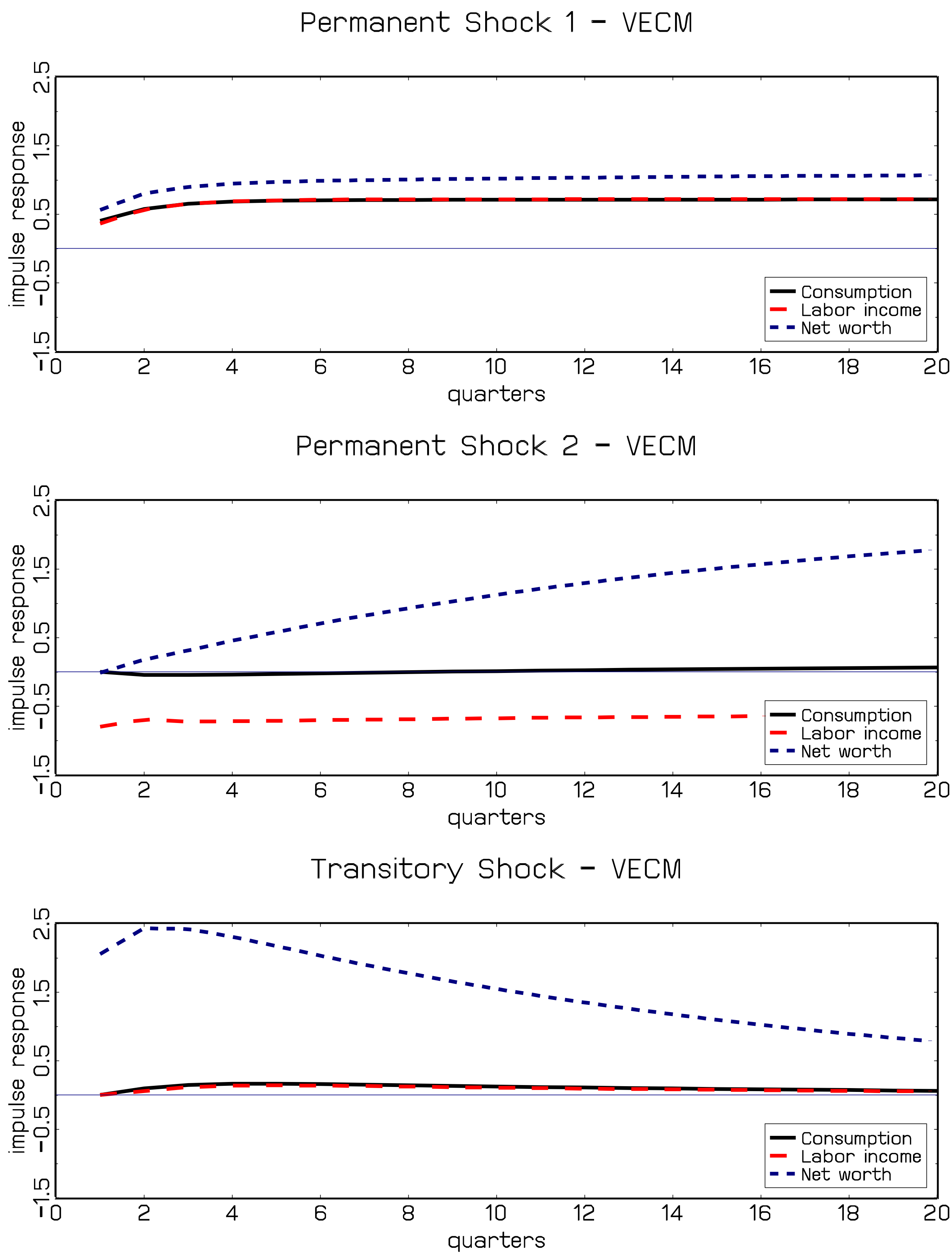
Notes: The table report results from a variance decomposition of unorthogonalized permanent shocks (P1, P2) shocks and a transitory shock (T). The sample spans the fourth quarter of 1951 to the second quarter quarter of 2010.

Figure 1: Cumulative P1, P2 and T Shocks



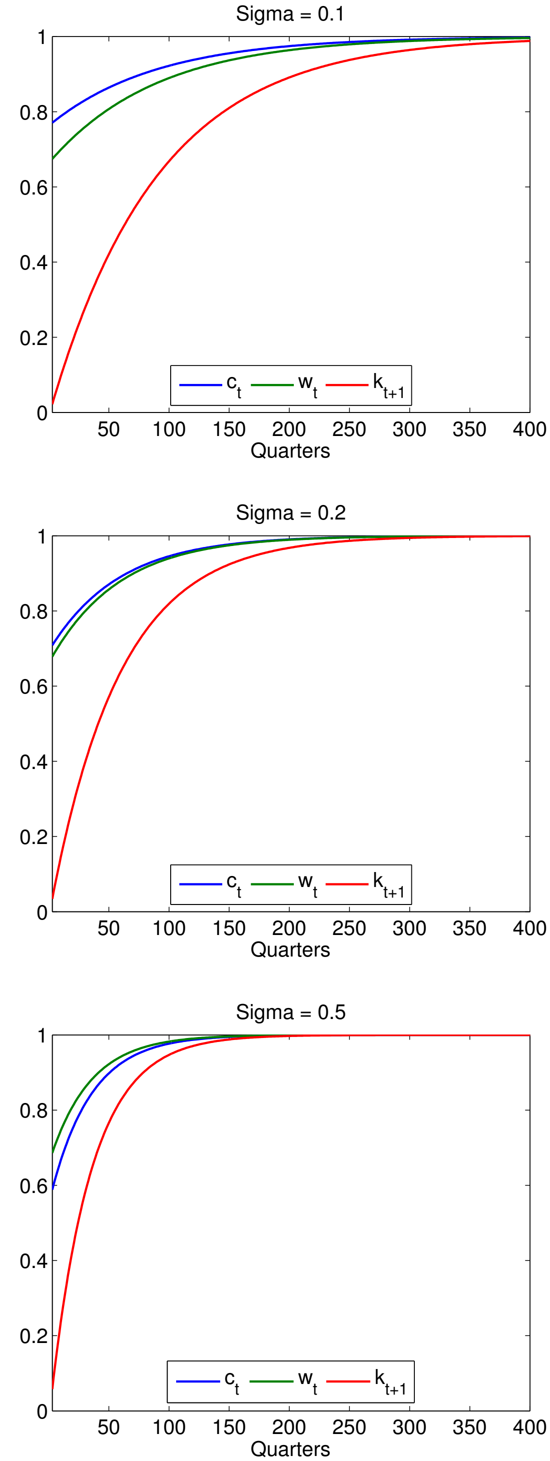

Notes: The figure plots cumulative permanent and transitory shocks identified by Gonzalo and Ng's (2001) methodology.

Figure 2: Impulse Response Functions



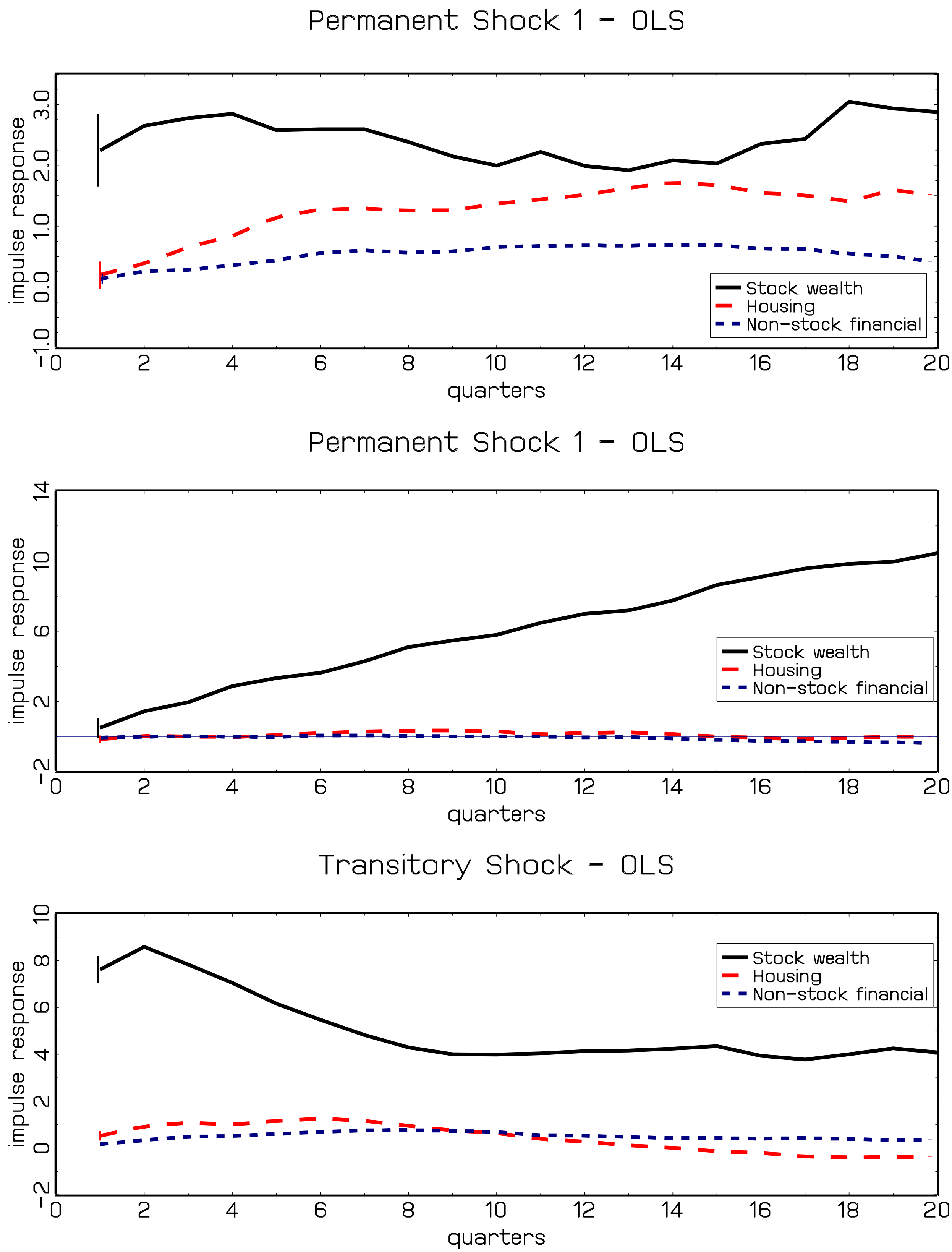

Notes: The figure plots impulse response functions of permanent and transitory shocks by using Gonzalo and Ng's (2001) methodology.

Figure 3: Impulse Response Functions in RBC Model



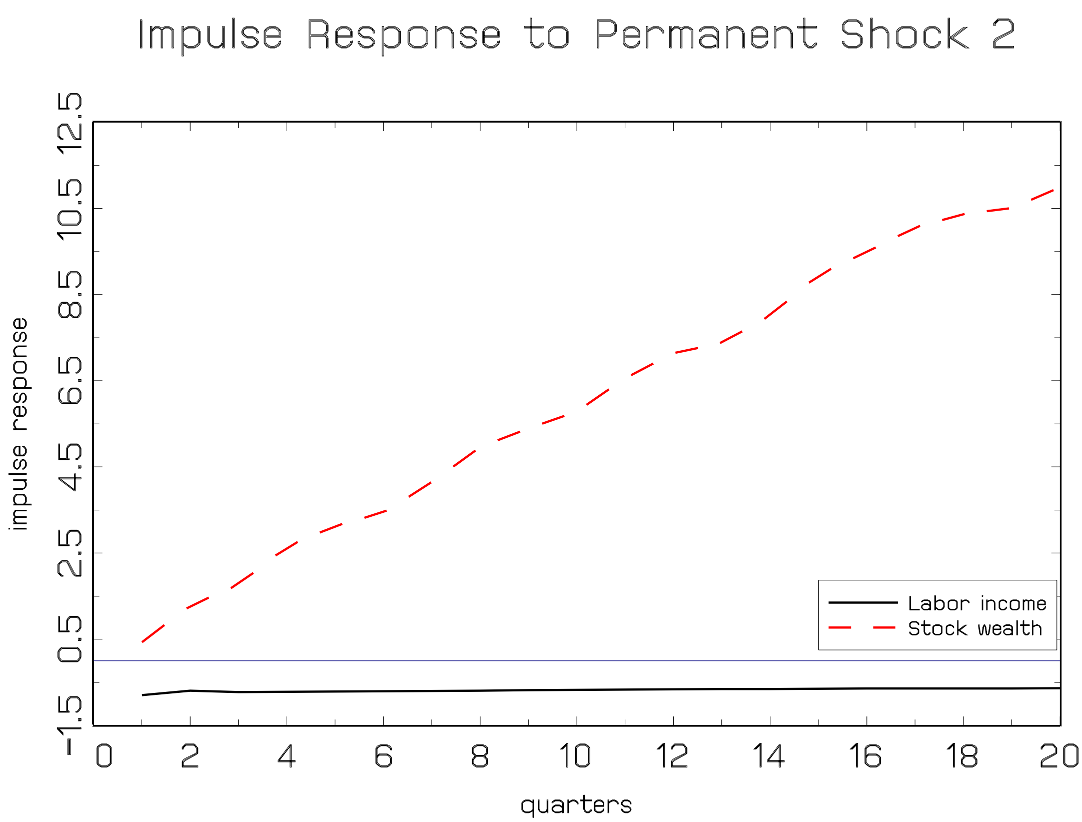

Notes: Percentage response of consumption, capital and labor income, corresponding to a 1% technology shock in a model with fixed labor supply (normalized to one), specified in the following equations: $Y_t = A_t^\alpha K_t^{1-\alpha}$; $K_{t+1} = (1-\delta)K_t + Y_t - C_t$; $C_t^{-\gamma} = \beta E_t\{C_{t+1}^{-\gamma} R_{t+1}\}$; $a_t = \phi a_{t-1} + \epsilon_t$. Lowercase letters denote log levels. $w_t$ is log labor income (equal to real wage since labor supply is fixed at unity), $c_t$ is log real consumption and $k_t$ is log capital. The parameter values are set as follows: $\phi = 1$, $r = 0.015$, $g = 0.005$, $\alpha = 0.667$, $\delta = 0.025$ and $\sigma = 1/\gamma$.

Figure 4: Impulse Response Functions



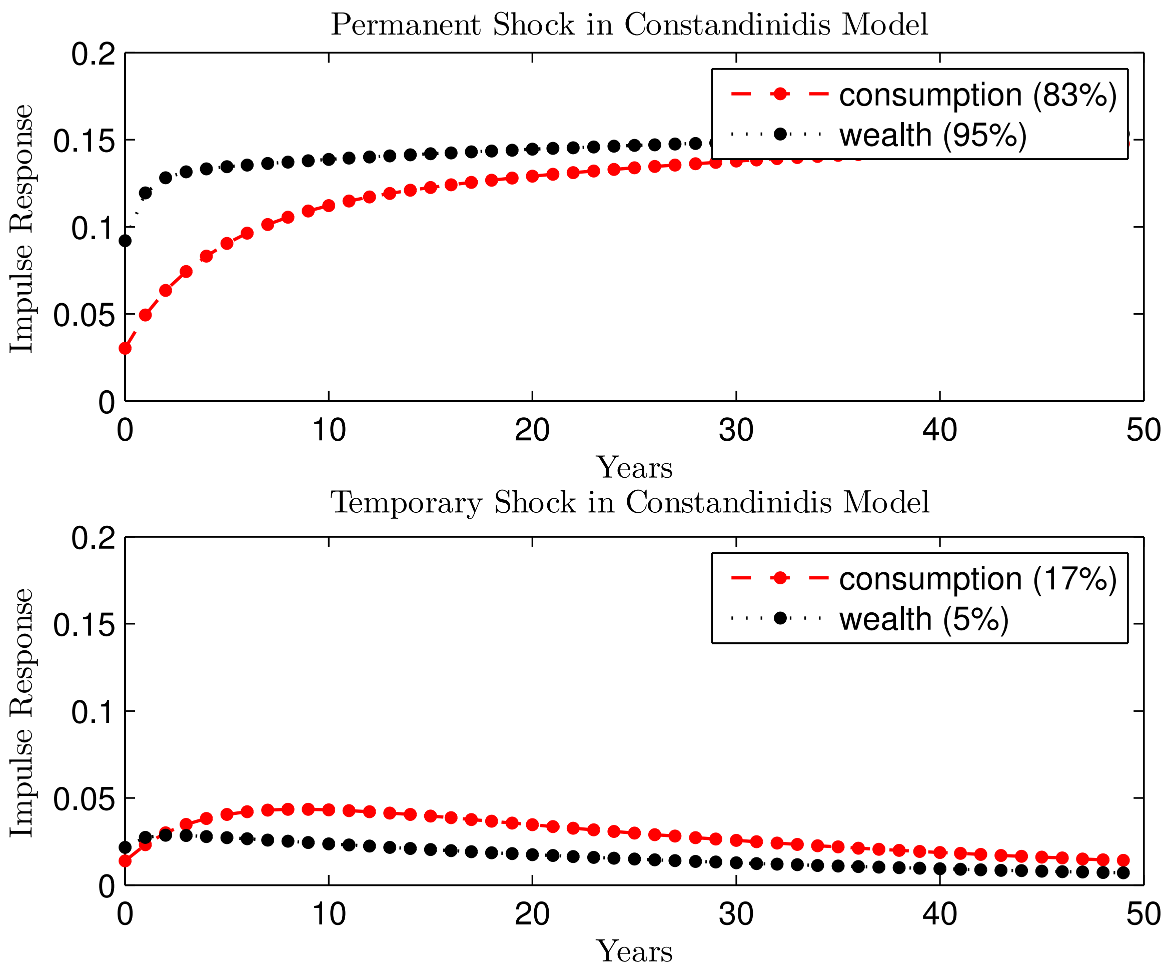

Notes: The figure plots impulse response functions of wealth components to permanent and transitory shocks identified by Gonzalo and Ng's (2001) methodology.

Figure 5: Impulse Response Functions to P2 Shock



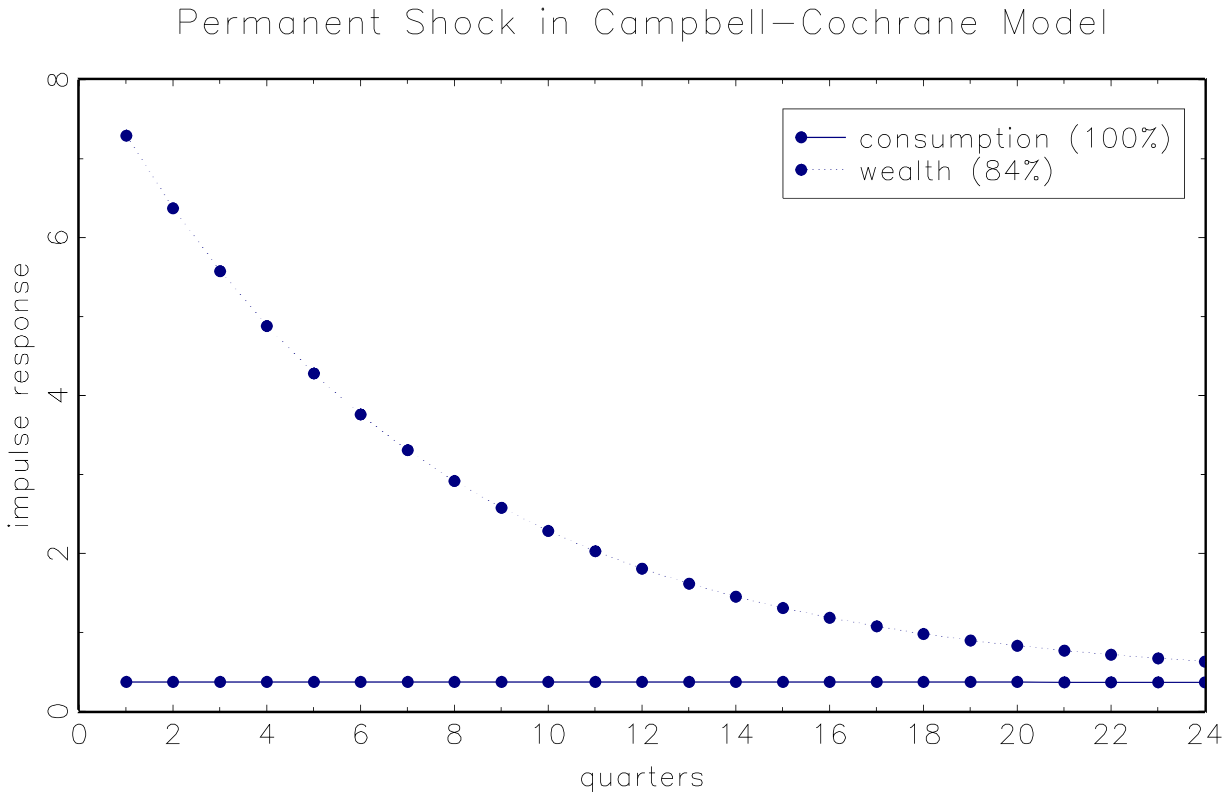

Notes: The figure plots impulse response functions of stock market wealth and labor income to a P2 shock.

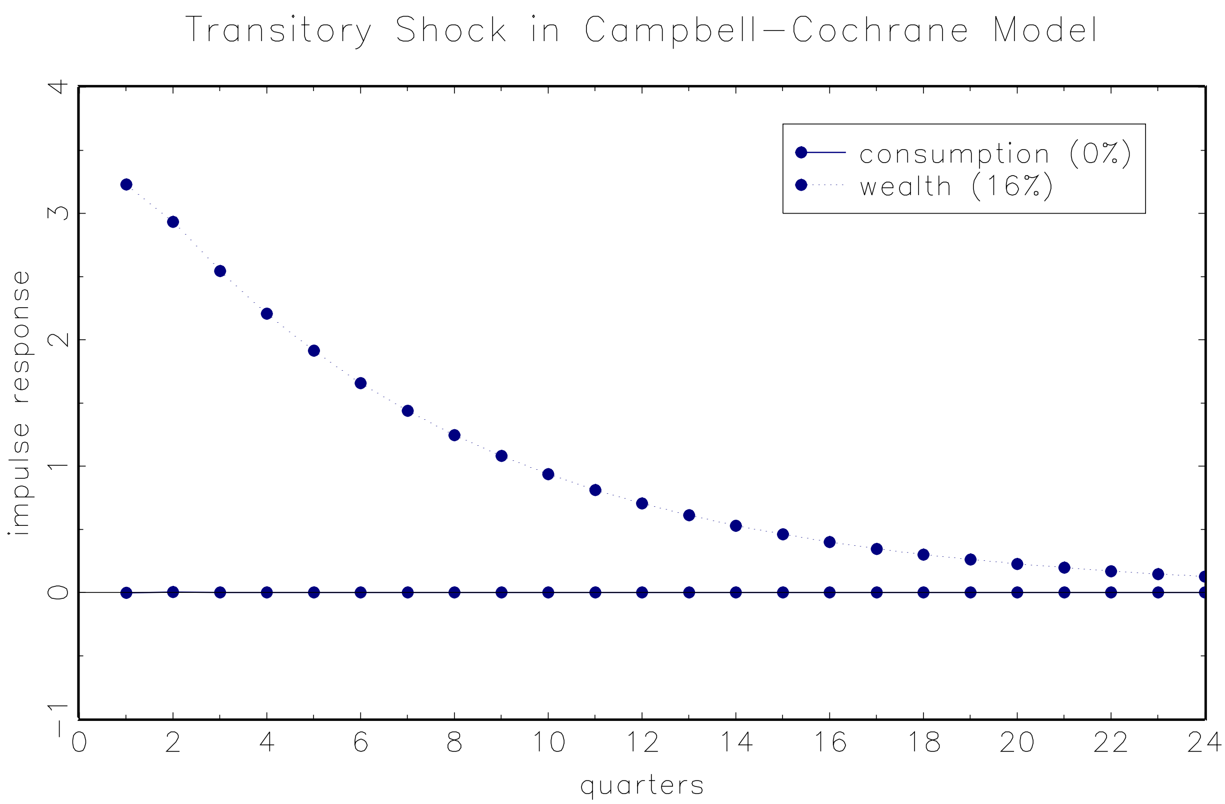
Figure 6: PT Decomposition of Constantinides Habit Model




Notes: The figure plots impulse response functions of consumption and wealth to permanent and transitory shocks in simulated data from Constantinides' (1990) habit model.

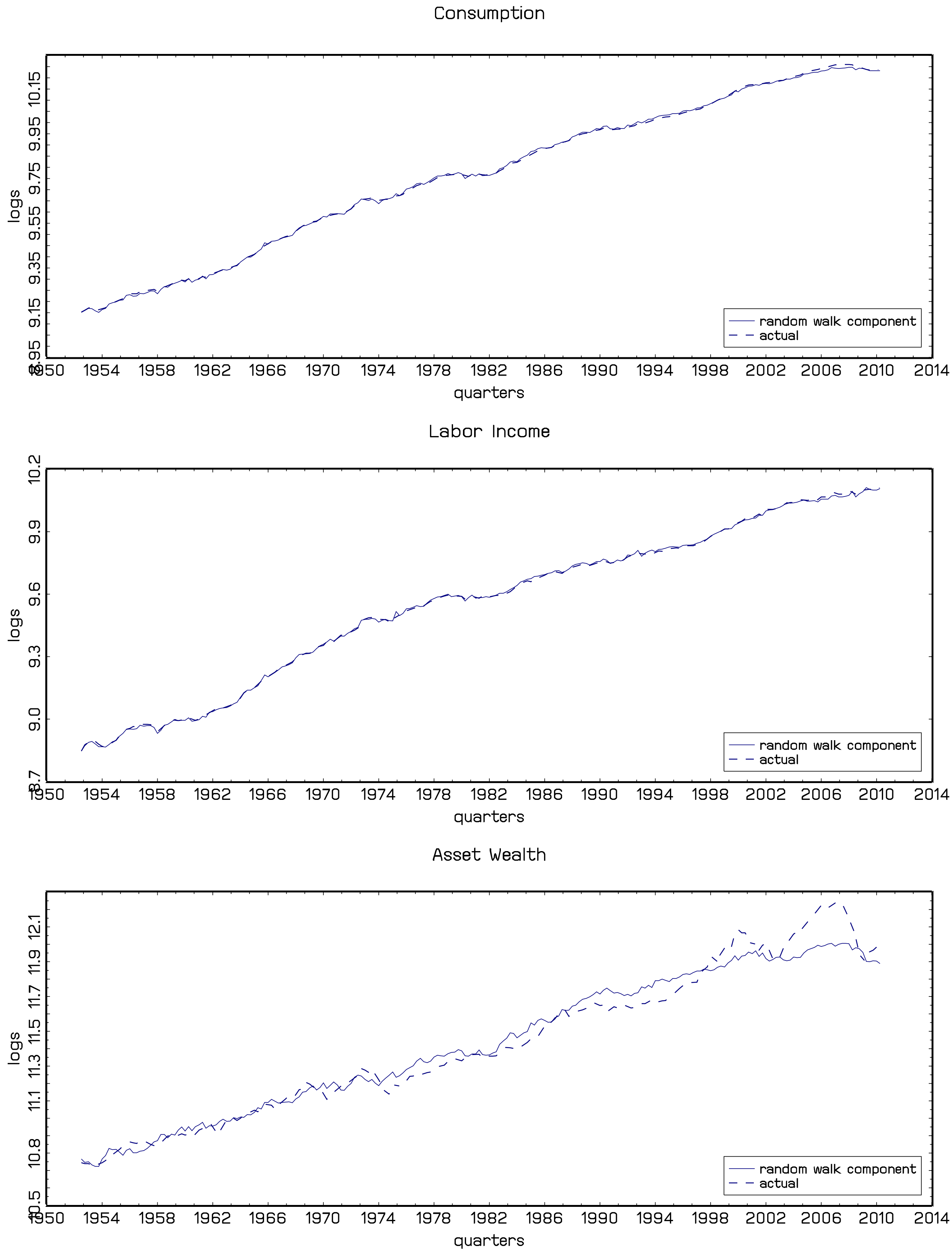
Figure 7: PT Decomposition of Campbell Cochrane Habit Model



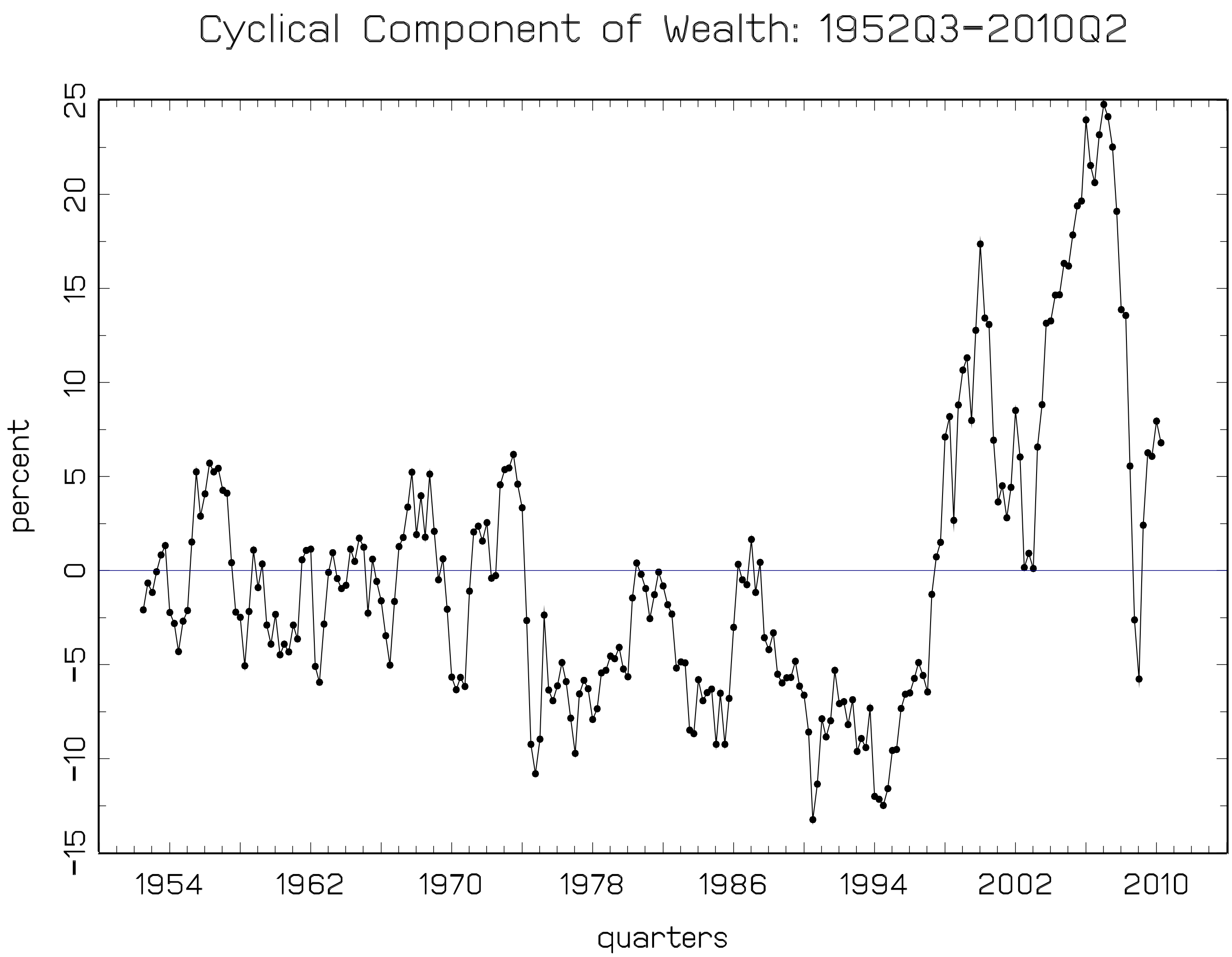

Notes: The figure plots impulse response functions of consumption and wealth to permanent and transitory shocks in simulated data from Campbell and Cochrane's (1999) habit model.

Figure 8: Random Walk Components



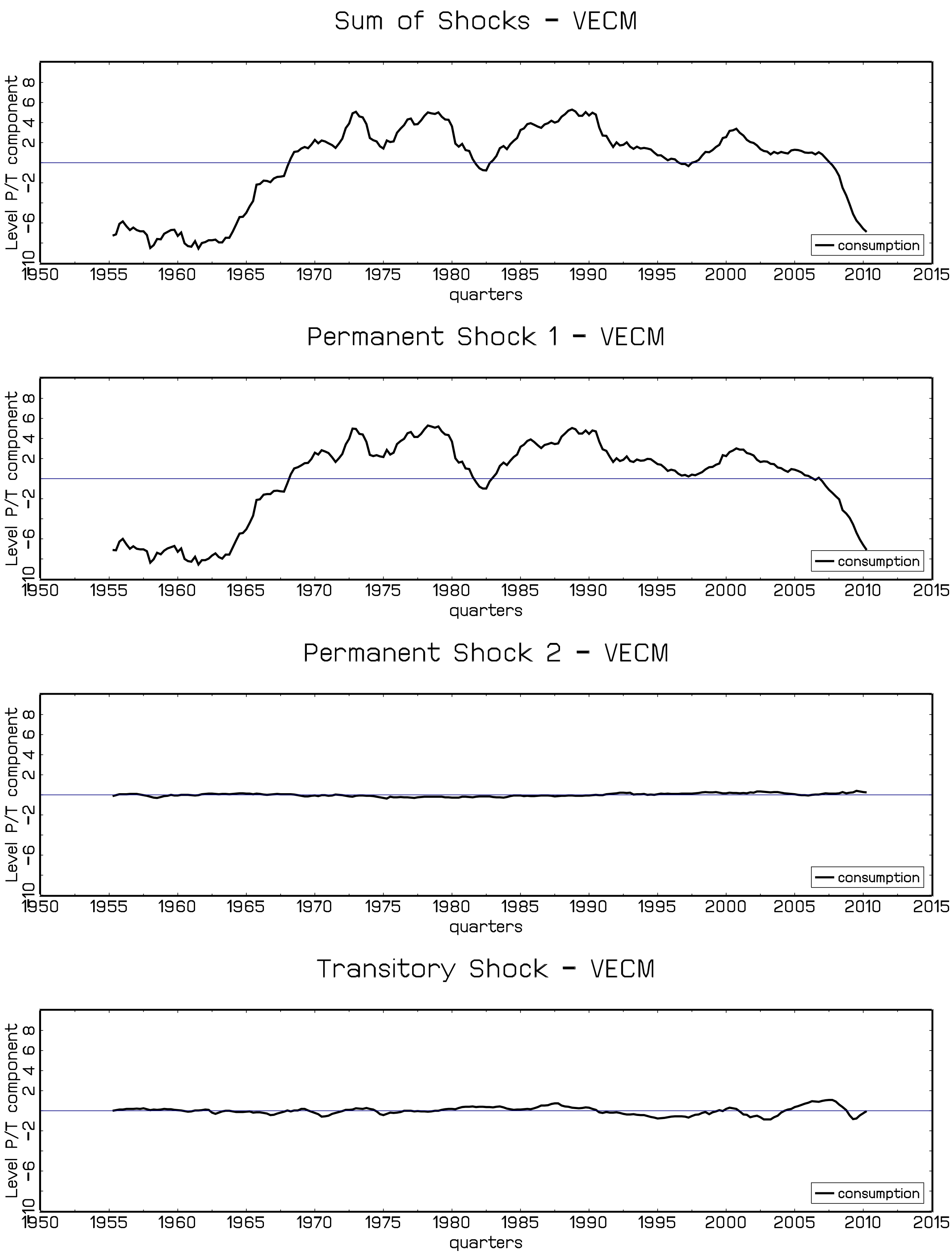

Notes: The figure plots the random walk components of consumption, labor income and asset wealth.

Figure 9: Cyclical Component of Net Worth



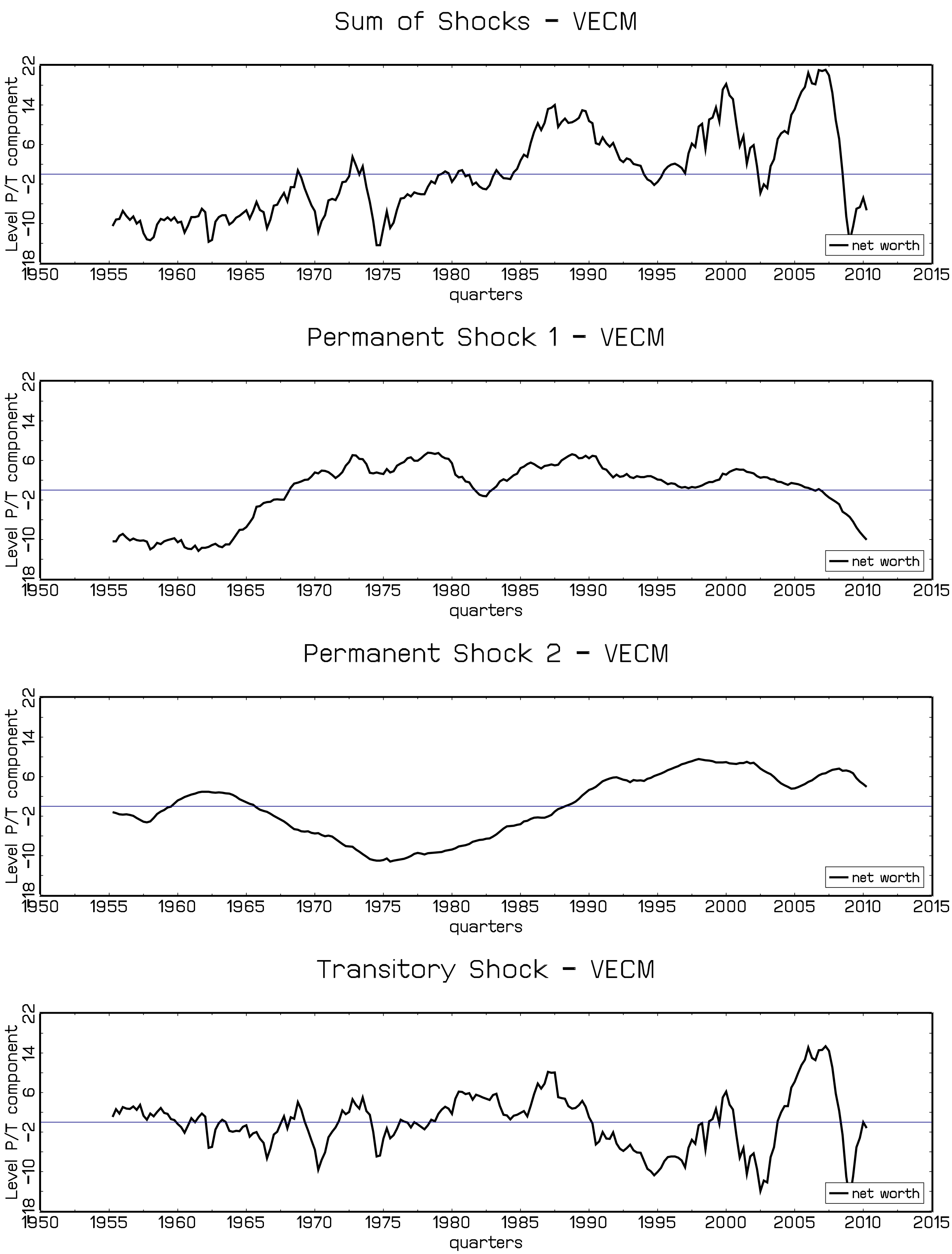

Notes: The figure plots the cyclical component of asset wealth defined as the difference between the trend and actual value of asset wealth in percent of the trend component.

Figure 10: VECM Level Decomposition - Consumption



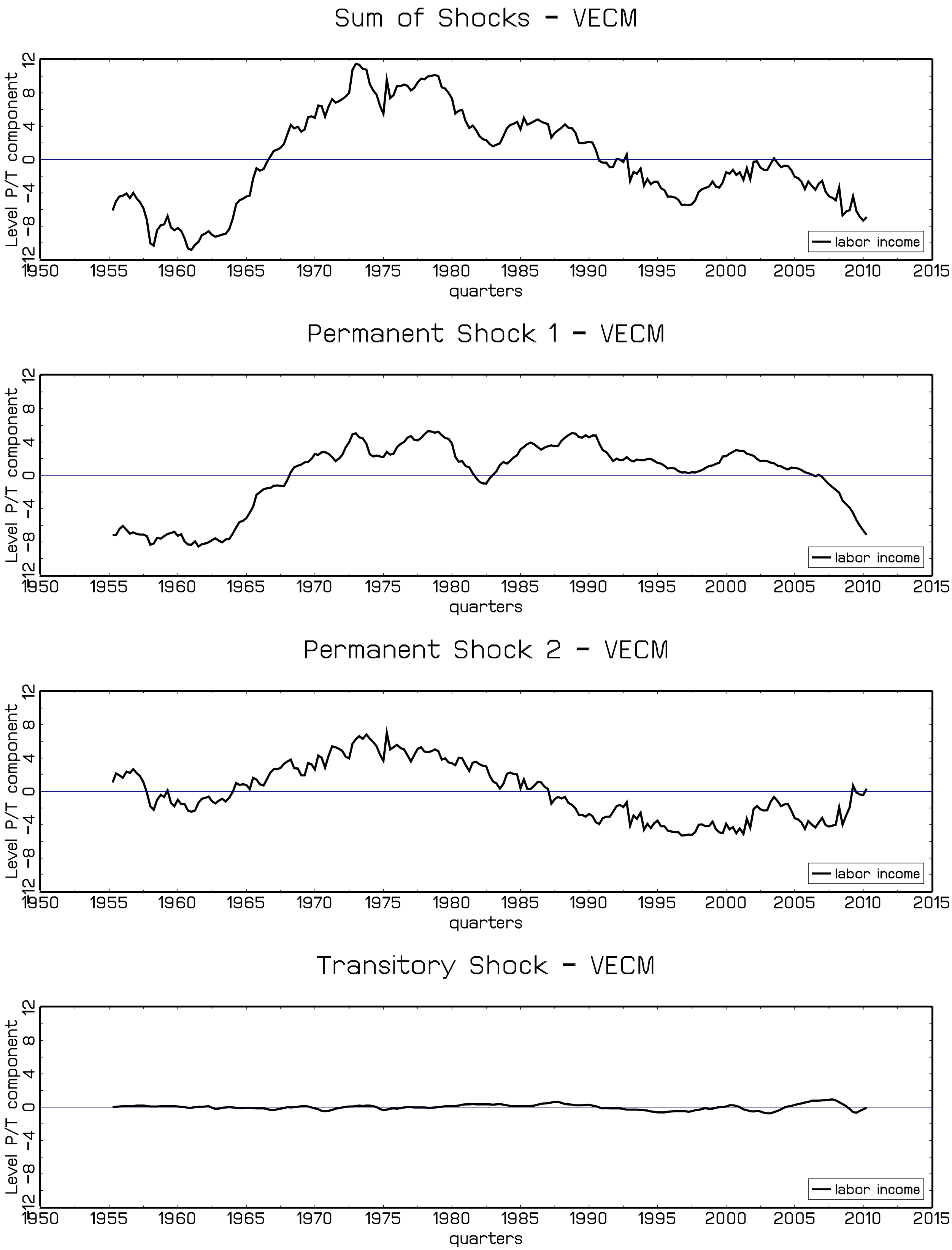

Notes: The figure shows the decomposition of the detrended log level of consumption over time as defined in section 3.3. A linear time time trend is removed.

Figure 11: VECM Level Decomposition - Net Worth



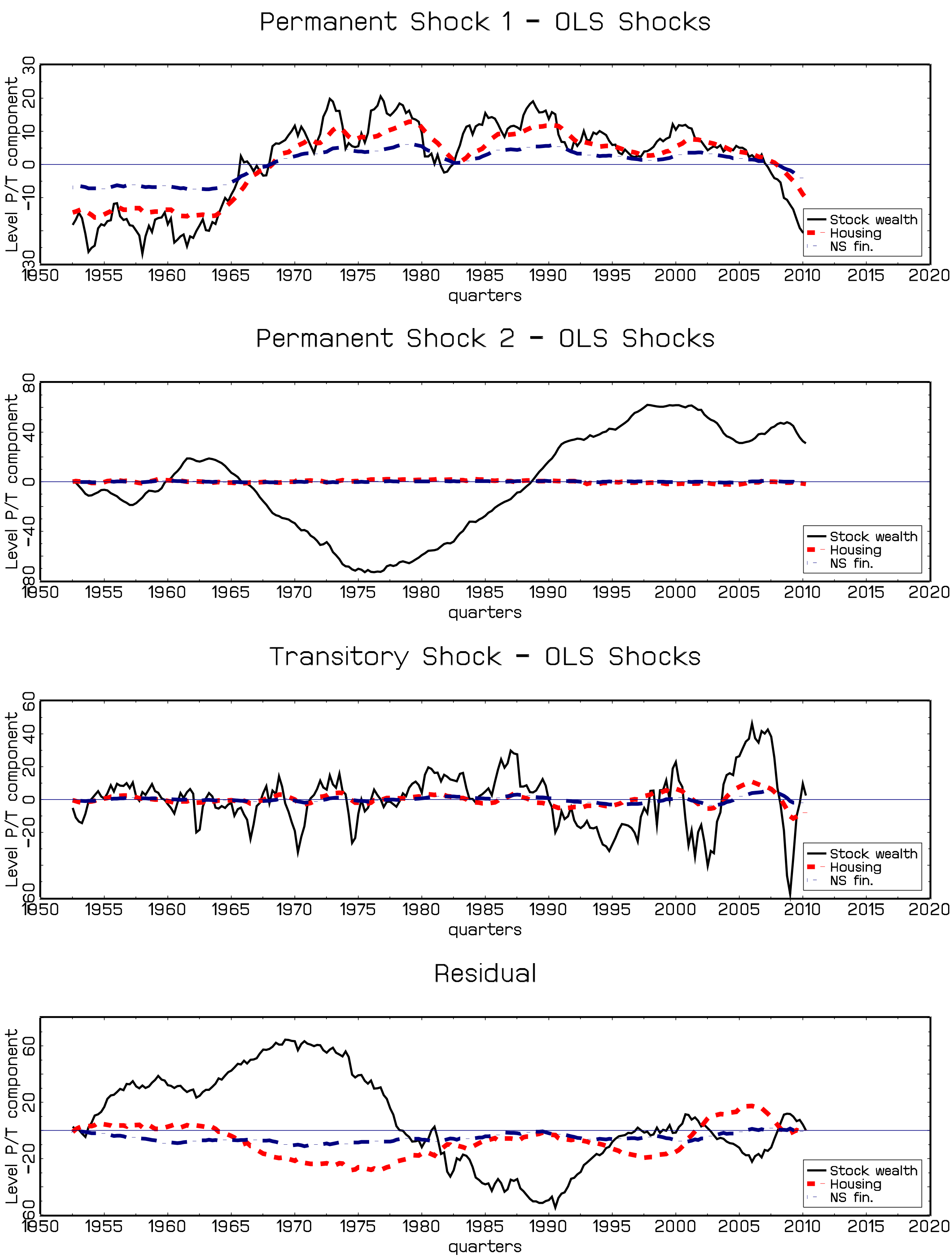

Notes: The figure shows the decomposition of the detrended log level of net worth as defined in section 3.3. A linear time time trend is removed.

Figure 12: VECM Level Decomposition - Labor Income



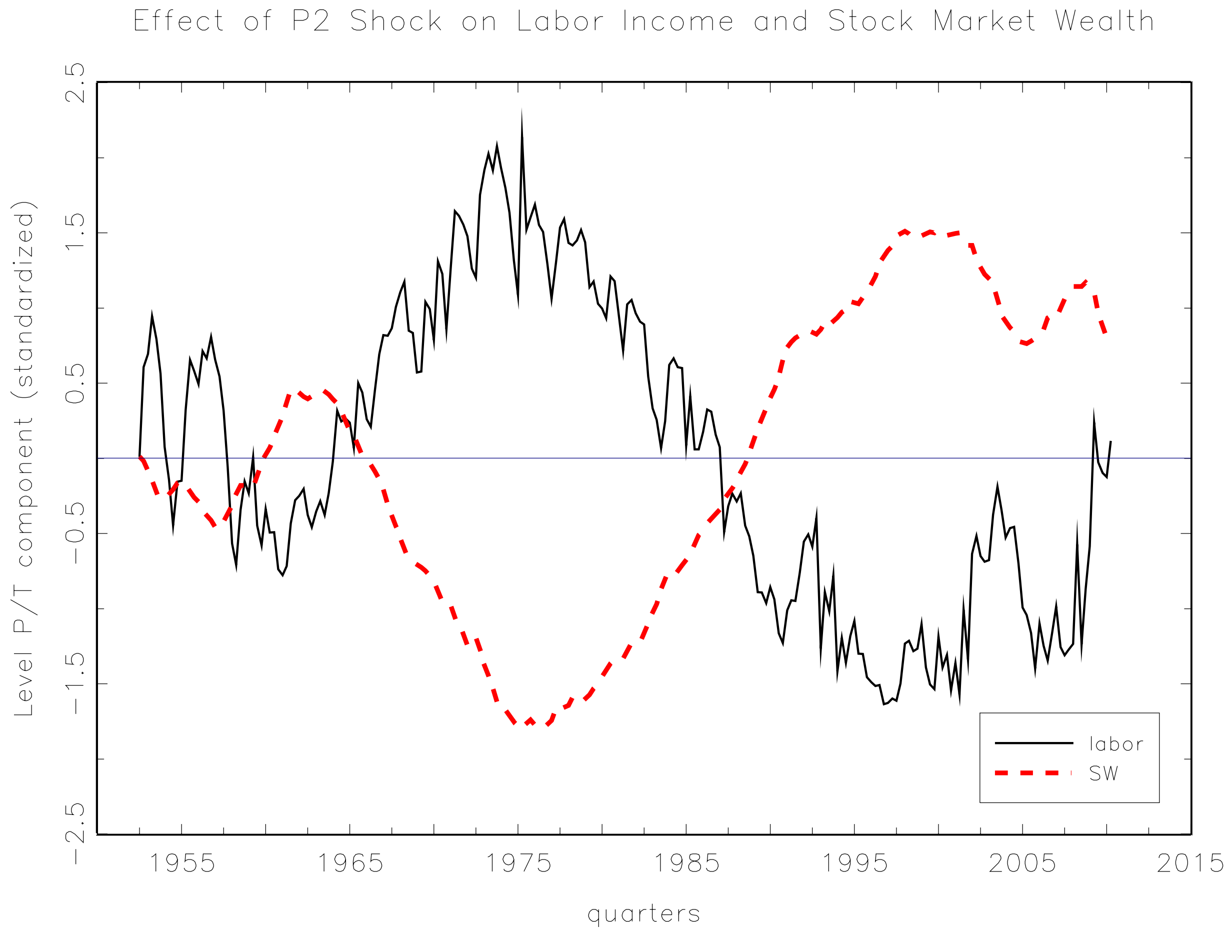

Notes: The figure shows the decomposition of the detrended log level of labor income as defined in section 3.3. A linear time time trend is removed.

Figure 13: Level Decomposition - joint



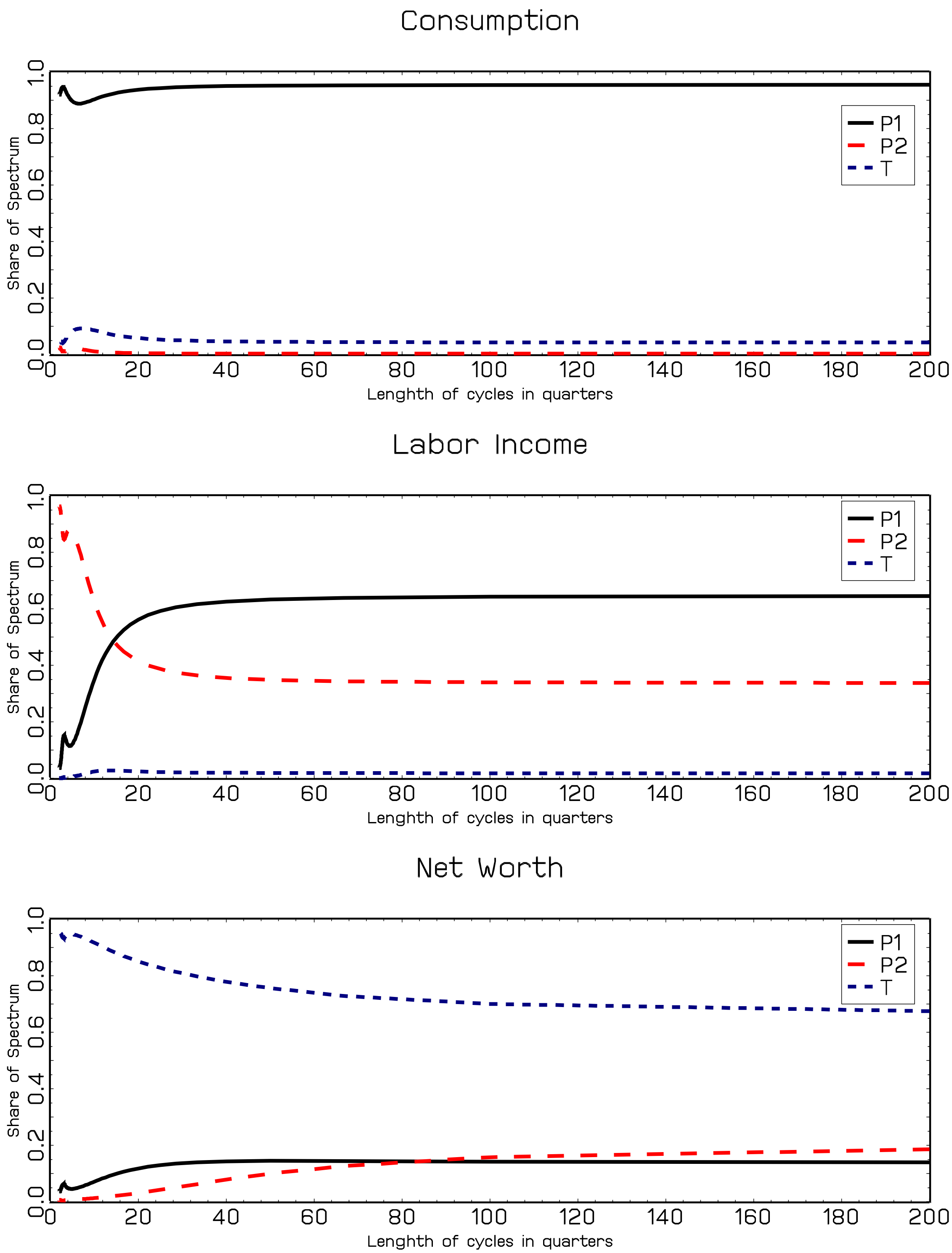

Notes: The figure shows the decomposition of the detrended log level of stock wealth, housing wealth and non-stock financial wealth as defined in section 3.3. A linear time time trend is removed.

Figure 14: Decomposition of Labor Income and Stock Market Wealth



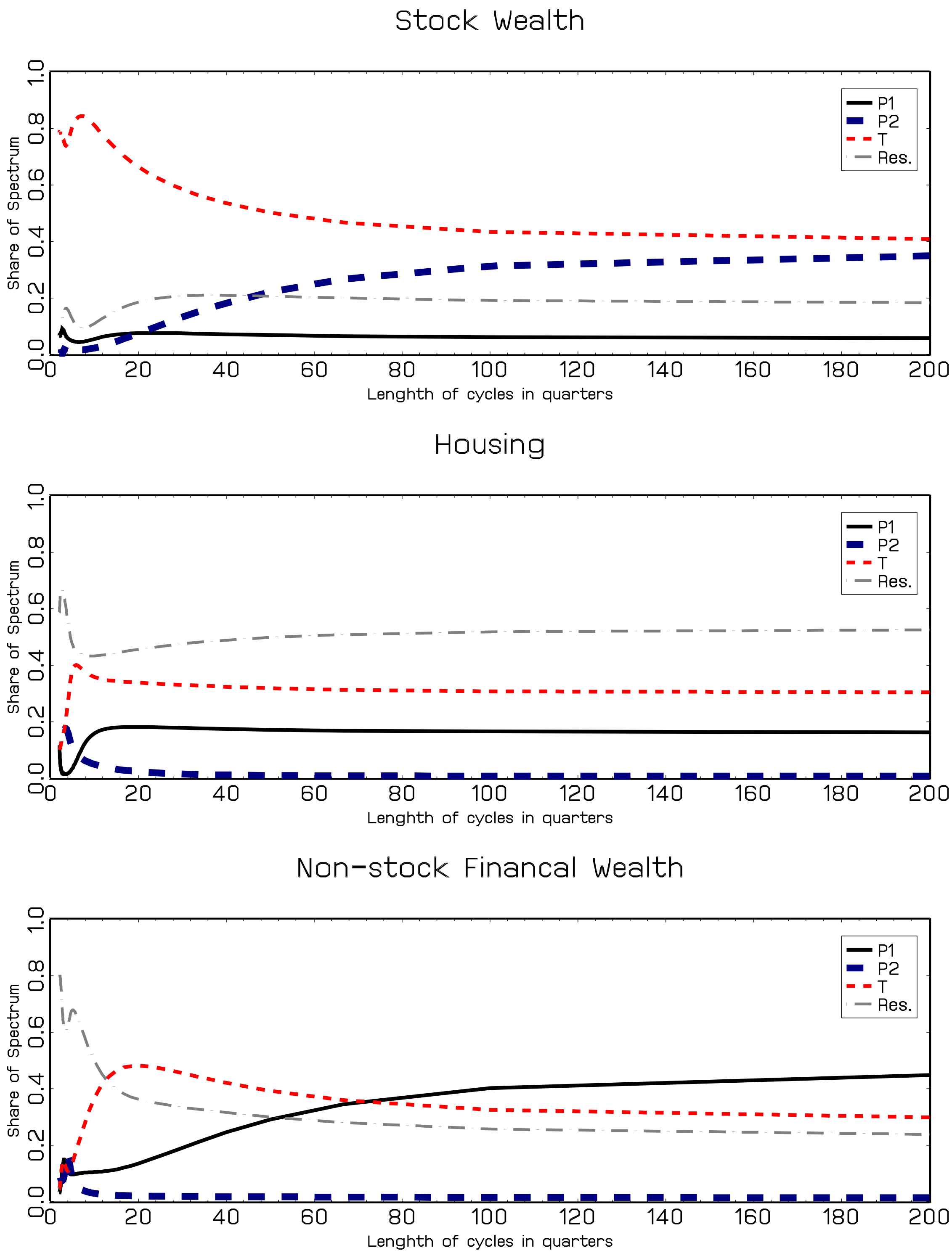

Notes: The figure shows the effect of the P2 shock on the levels of labor income and stock market wealth. Both series are divided by their standard deviations.

Figure 15: Decomposition of Spectra




Notes: The figure shows the decomposition of spectra at different frequencies. Spectra are estimated in first differences and converted into spectra for levels: $S_x(\omega) = (1 - \exp(-i\omega))^{-1}(1 - \exp(i\omega))^{-1} S_{\Delta x}$.

Figure 16: Decomposition of Spectrum




Notes: The figure shows the decomposition of spectra at different frequencies. Spectra are estimated in first differences and converted into spectra for levels: $S_x(\omega) = (1 - \exp(-i\omega))^{-1}(1 - \exp(i\omega))^{-1}S_{\Delta x}$.

Figure 17: VECM Level Decomposition - Net Worth: Subsample 1994:Q1-2001:Q2

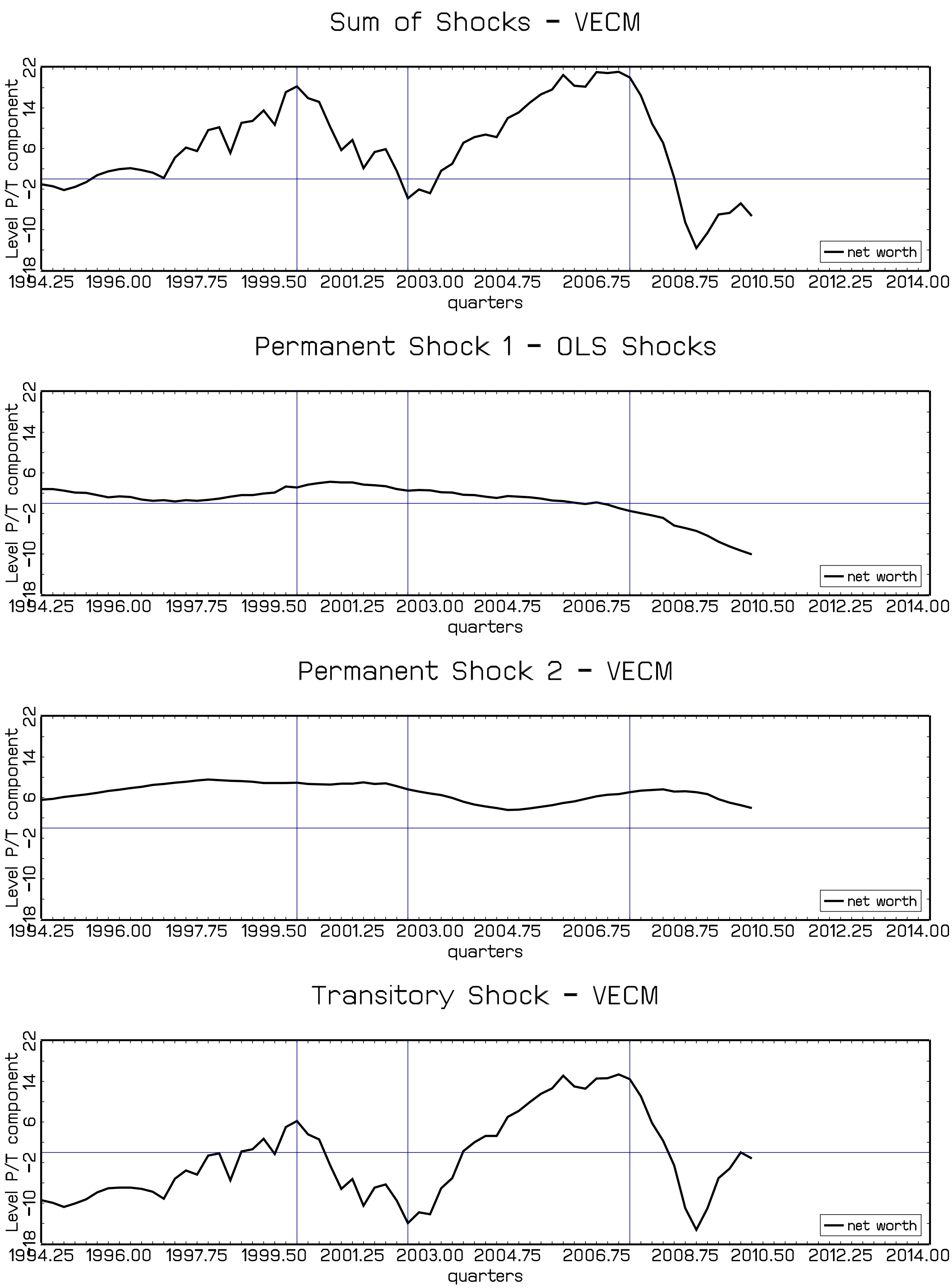


Figure 18: OLS Level Decomposition - Stock Market Wealth: Subsample 1994:Q1-2001:Q2

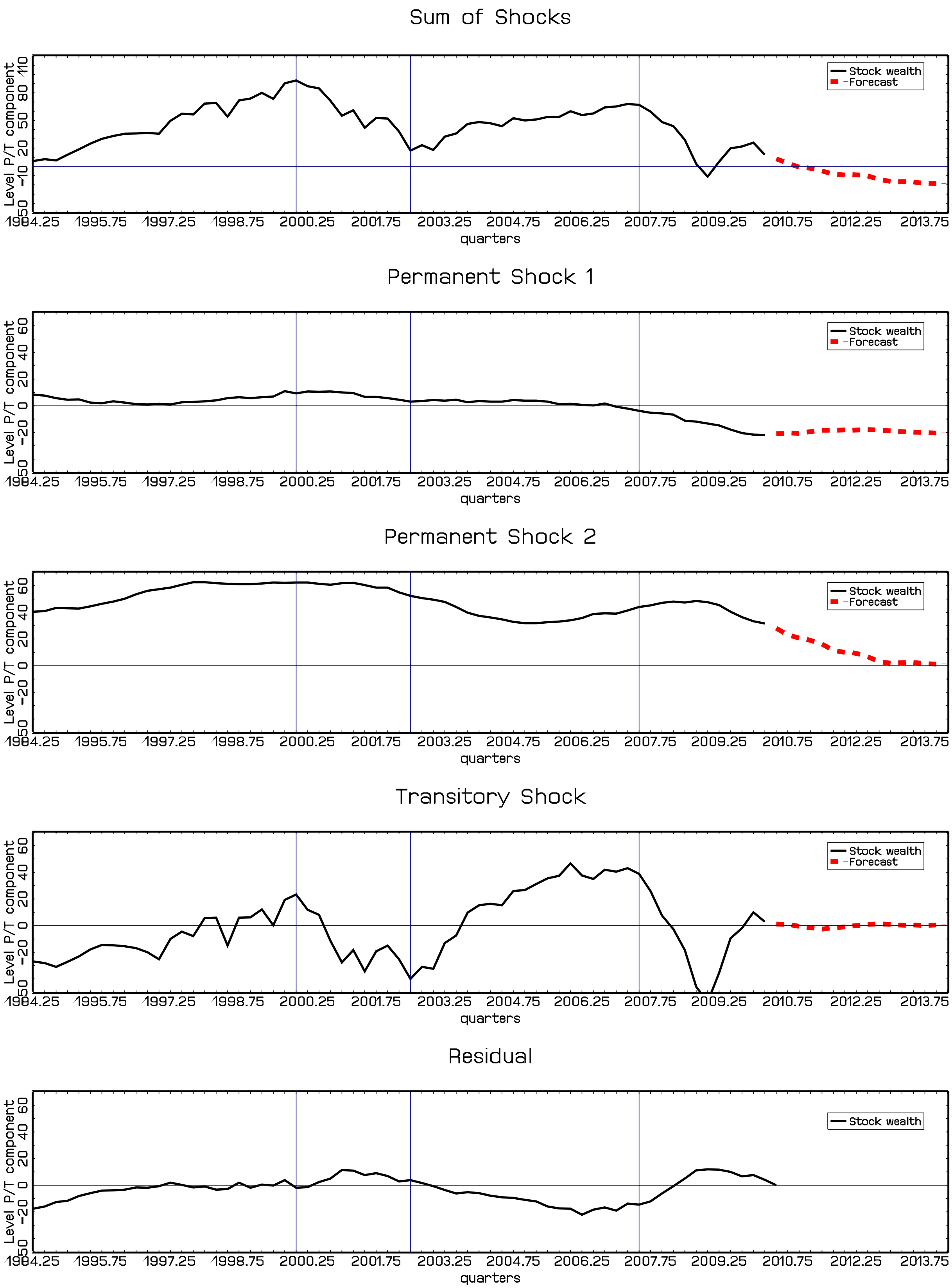


Figure 19: OLS Level Decomposition - Housing Wealth: Subsample 1994:Q1-2001:Q2

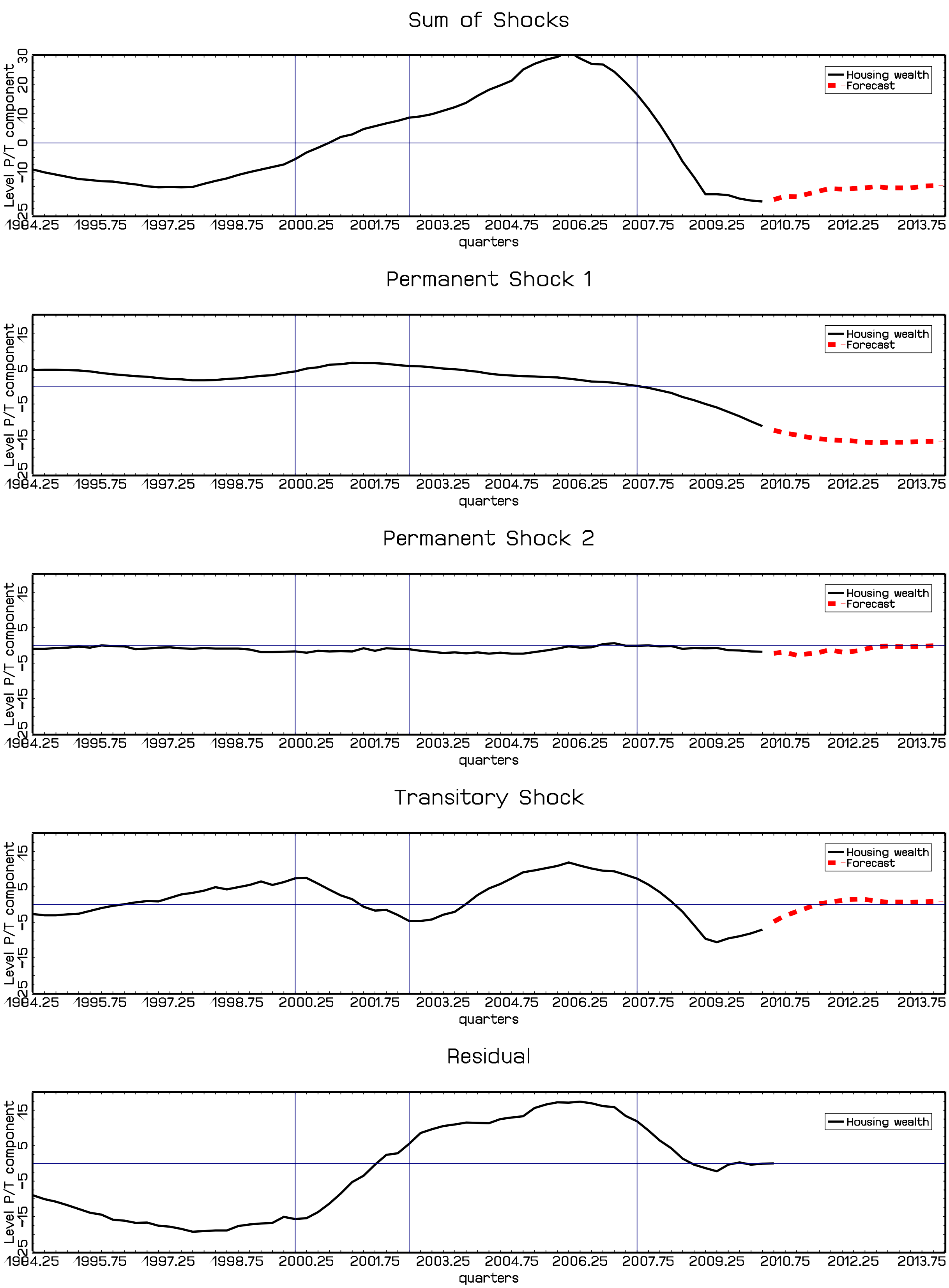


Figure 20: OLS Level Decomposition - Non-Stock Financial Wealth: Subsample 1994:Q1-2001:Q2

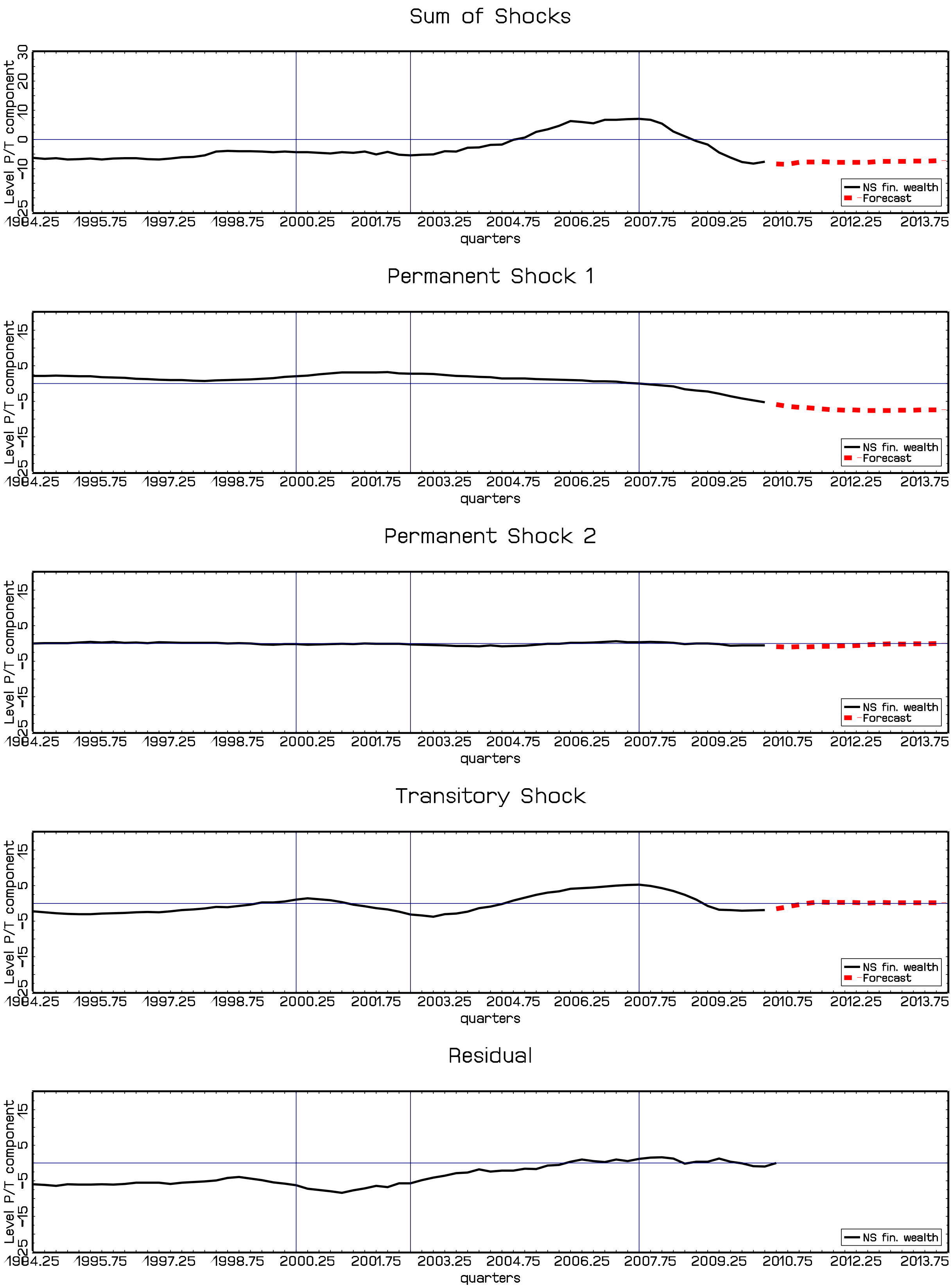
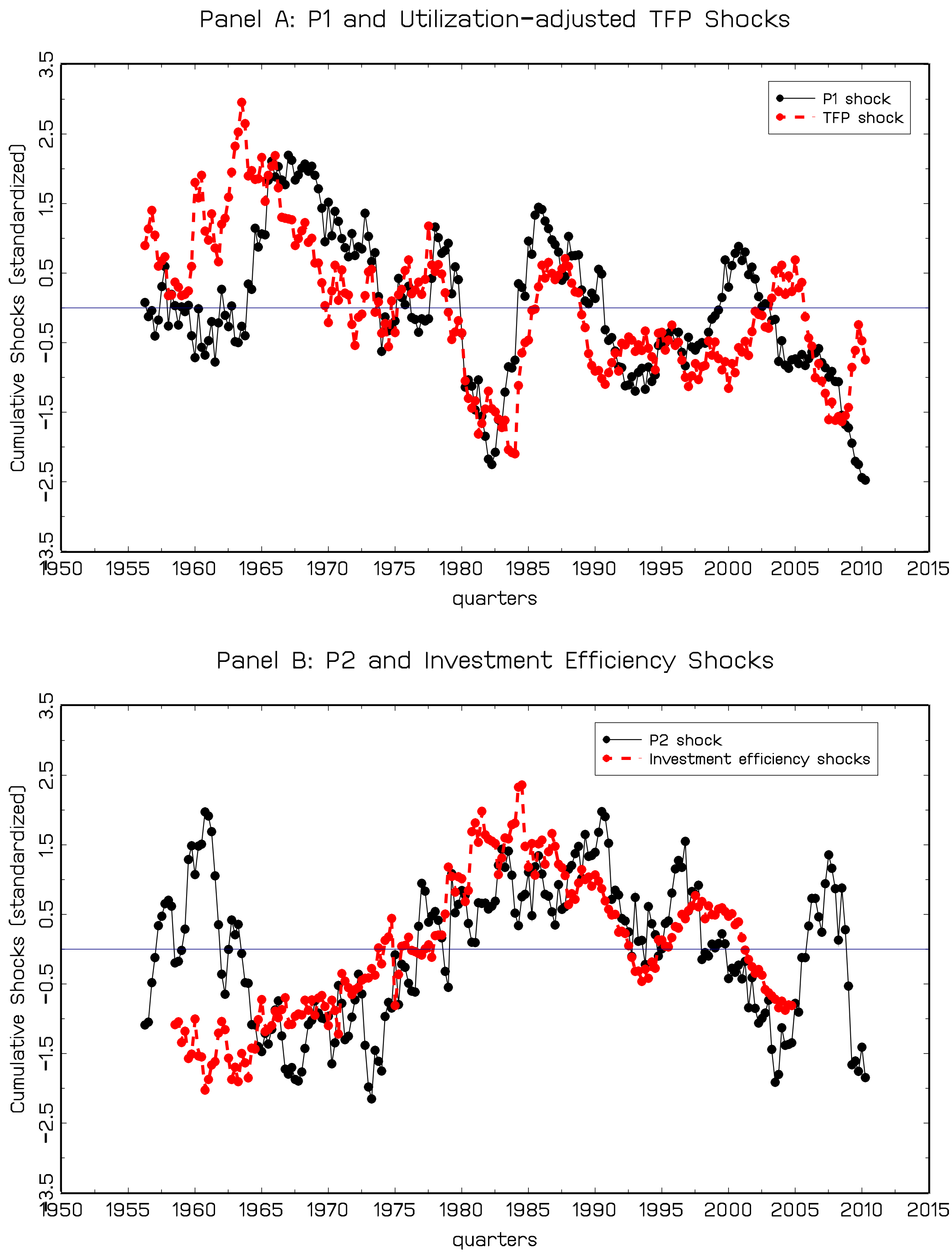
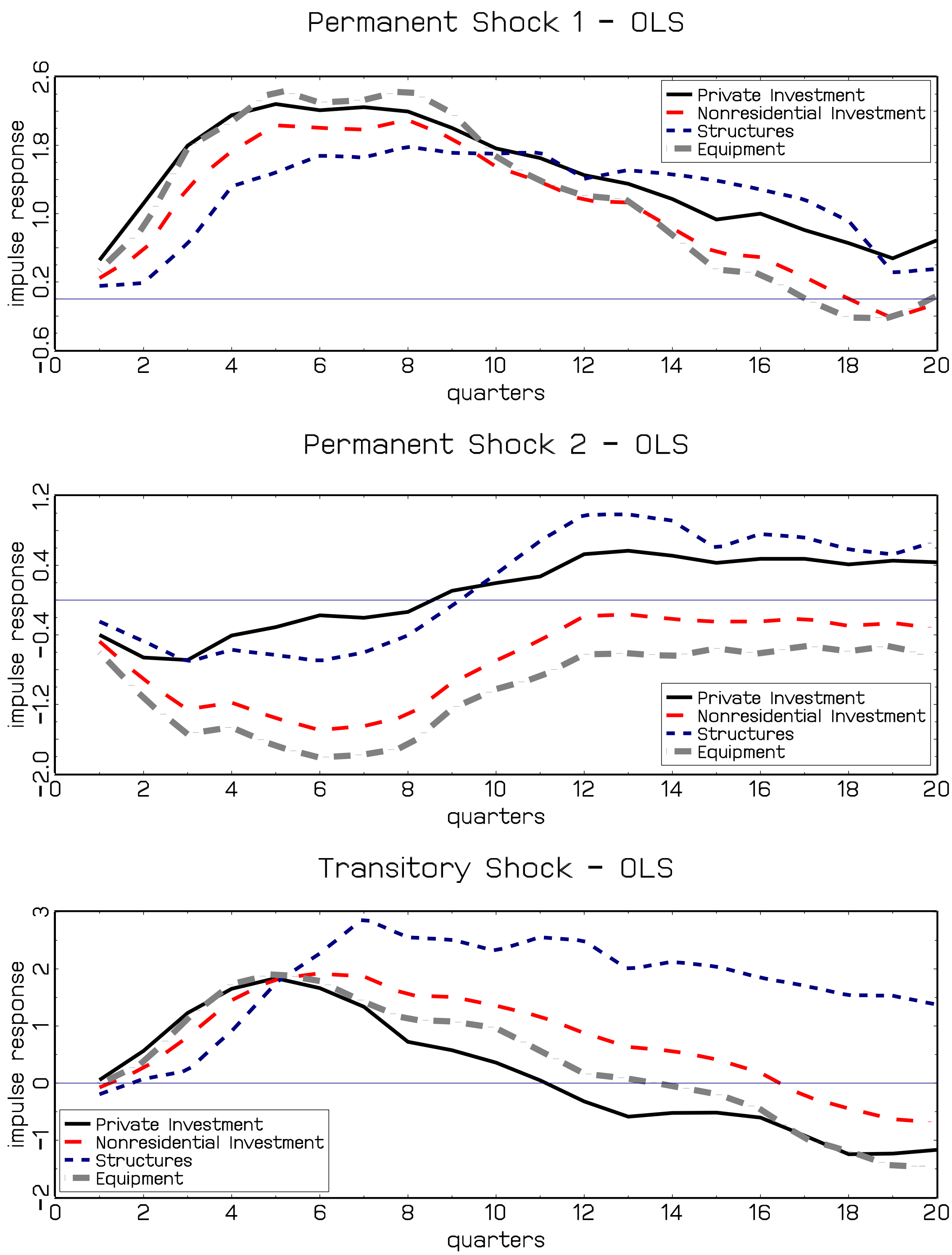


Figure 21: 4-Year Moving Average of Shocks




Notes: The figures shows 4-year moving averages of P1 and utilization-adjusted TFP shocks in the top panel and P2 and investment efficiency shocks in the bottom panel. TFP data is from Fernald (2009) and investment efficiency data is from Justiniano, Primicerai and Tambalotti (2009). TFP and investment efficiency shocks are computed as residuals from an AR(1). Both series are divided by their standard deviations.

Figure 22: IRF of Investment to P1, P2 and T Shocks




Notes: The figure plots impulse response functions of different measures of (log level) investment in response to P1, P2 and T shocks.