Balance Sheet Effects on Household Consumption: Evidence from Micro Data

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Abstract

While considerable evidence has been accumulated for the wealth effect on consumption, much less is known about how changes in household assets and liabilities are related to household consumption. Using micro data for U.S. households, this paper provides evidence on conditions when balance sheet effects have large impact on household consumption. By using a nonparametric regression model, the balance sheet effects are specified as nonlinear functions, and this allows to detect nonlinearities at different net changes of household assets and liabilities. Our major finding is that durable consumption is subject to large balance sheet effects, especially from net additions to household liabilities, and from net reductions in household assets. In contrast, balance sheet effects on nondurable consumption are much smaller.

1 Introduction

Considerable evidence has accumulated on how much household consumption changes after shocks to household wealth. Most studies focused on the consumption behavior of the U.S. households, and there is a broad agreement that one dollar increase in household wealth produces an immediate rise in consumption by 3 to 5 cents, while the accumulated effect over several years is in the range of 4–10 cents (Carroll *et al.*, forthcoming).

Compared with the plethora of studies on the wealth effect on household consumption, there is surprisingly little evidence on how households change their consumption in response to shocks to their balance sheets, especially in the aftermath of credit bubbles. While studies of wealth effect on consumption typically examined the effect from net worth (obtained as the difference between assets and liabilities), balance sheet effects consider how assets and liabilities have separate effects on consumption. The importance of examining the liability side of household balance sheets was demonstrated during the recent housing bubble in the United States, when many households with little assets or income could accumulate substantial debts. Though the recent build-up of household debt in the United States had few historical precedents, there is very little evidence how the increased leverage of households changes their household consumption. Similarly, there is little evidence how net change in the asset size of household balance sheets (rather than *unrealized* capital gains) have substantial effects on household consumption expenditures.

The lack of evidence about balance sheet effects became particularly acute after the U.S. housing bubble burst in 2006. The intensive build-up of household debt during the credit bubble quickly became history, with many households switching instead to repairing their overstretched balance sheets. However, there is little evidence on how exactly household consumption responds to these deleveraging efforts of households.

In this paper we will examine the hypothesis whether the balance sheet effects of households could explain why the 2007-2009 recession turned out so severe, and why the subsequent recovery continues to be weak. Figure 1 illustrates the relative harshness of the 2007-2009 recession by comparing it to a median pattern among post-war recession, as well as to the worst macroeconomic conditions among post-war recessions. Panel (a) shows the accumulated change in output since the peak of business cycles. In the 2007-2009 recession, the output dropped by more that 4 percentage points, and this exceeded the previous worst record among post-war recessions. In addition, the current recovery still remains unusually subdued, with output remaining below its pre-recession level, in sharp contrast with other post-war recoveries. Panels (b) and (c) demonstrate the severity of the latest recession in the labor market. The accumulated job losses remain stuck at minus 6 percentage points compared with the labor force at the recession's start. In contrast, st comparable stages of previous post-war recoveries, the labor force exceeded pre-recession level by 2 percentage points. Panel (c) shows that the large share of long-term unemployment is particularly serious problem. In the latest recession, the share soared by almost 30 percentage points, and greatly exceeds the previous worst record. With labor markets depressed by record unemployment, the real disposable income per capita remains depressed (as shown in Panel (d)), while disposable income in previous post-war recoveries increased by 6 percentage points compared with its level at the start of the recessions.

To identify the most sluggish component of aggregate demand, Figure 2 reports the accumulated contribution of major components of real gross domestic product (GDP) since the beginning of the 2007-2009 recession. To put these changes in perspective, Figure 2 also shows median and worst changes among previous post-war recessions. Panel (a) shows that the accumulated contribution of nondurable consumption and services has already recovered to its original pre-recession level. This is much lower that the increase by 17 percentage points in median post-war recessions, but at least this component of GDP no longer pulls down output below its pre-recession level. Panel (b) shows that the situation is much worse with durable consumption and residential investments. The accumulated contribution of these two components of GDP continue to reduce output by 7 percentage points. The contribution of government expenditures to output growth was positive, and comparable to median changes in post-war recessions (Panel (c)). Finally, Panel (d) shows that the remaining components of GDP kept the output close to its pre-recession level.

A distinctive feature of durable consumption and residential investments is that these expenditures are usually financed by new household debt. If households do not increase their debts, we can expect that both durable consumption and residential investments are likely to remain sluggish. Figure 3 puts recent changes in household debt into historical perspective, comparing them with a long-term trend from 1919 to 2010.

The rapid rise in household debt began in the early 1990s, when the ratio of debt to disposable income was about 80 percent, and this was below its long-term trend. However, during the late 1990s, the debt started to surge, and reached the record level of 130 percent of disposable at the peak of the housing bubble in 2006. The subsequent collapse of housing bubble and the economic recession in 2007-2009 resulted in a rapid reversal in household accumulation of debts, with households reducing their debts. The latest figures indicate that the debt-income ratio dropped below its long term trend by about 10 percent, which the last time happened only in the 1930s.

This depressed level of household borrowing may be either due to restrictions on the supply of new credit to households (*i.e.*, the credit crunch effect), or due to the reduced demand among households for new debt, no matter how easy borrowing terms are[1]. Hall (2010) studied the importance of the supply-side channel during the latest U.S. recession. The study found that restrictions on the supply of bank credit did account for the drop in durable consumption and residential investments (as well as in business investments), but only during the *initial* stage of the recession, from the second quarter of 2008 to the first quarter of 2009. Afterwards,

[1]The effect was described in the 1920s by a British economist R. Hawtry, who named it ‘a credit deadlock’ (Laidler, 1999, p. 123).

financial frictions in the banking sector were greatly reduced, and credit spreads were back to pre-recession levels, so the credit crunch model predicted that output would recover to its potential level. As illustrated by Figure 1, the prediction is not supported by the continuous slow pace of the recovery.

If the supply-side restraints on household borrowing no longer contribute to reduced household borrowing, then the lack of demand among households for new debt may be a important factor why durable consumption and residential investments continue to drag down the economic recovery. To examine this alternative explanation of the continuing slack in durable consumption and residential investments, this paper will study how household balance sheets are related to durable and nondurable consumption expenditures. Using micro data from the Survey of Consumer Expenditures (CEX), we begin with a conventional life-cycle model of consumption that accounts for age, cohort and year effects, and estimate the model separately for durable and nondurable consumption. Then we augment the standard model with balance-sheet effects from changes in household assets and liabilities. These balance sheet effects are specified by smooth nonlinear functions, and are estimated by a non parametric regression. This allows to identify possible nonlinearities in the balance sheet effects at different levels of net changes of assets and liabilities.

To preview our major finding, the balance sheet effects were essentially flat for non-durable consumption, but turned noticeably nonlinear for durable consumption. The effect was particularly pronounced at levels of net debt accumulation that was observed among the U.S. households at the peak of the latest credit boom. After the burst of the credit bubble, the households rapidly reduced their net borrowing, and our results show that the corresponding negative effect on durable consumption was very large. This implies that as long as households continue reducing their accumulated debt to more sustainable levels, durable consumption and residential investments will continue to hold back the recovery of the U.S. economy.

We conclude that the balance-sheet position of households may have substantial impact on household consumption, but the effect works through expenditures on durable consumption and residential investments. During credit booms, household debt rapidly increases, but then it slumps abruptly when credit bubbles eventually burst. This wide variation in net debt position of households greatly inflates their expenditures during the credit boom, and also dampens them markedly during the credit bust.

The paper is organized as follows. In section 2 we survey literature on balance sheet effects on household consumption. Section 3 introduces the framework of sectoral financial balances that helps to evaluate changes of balance sheet positions of major institutions sectors, such as households. Using the sectoral financial approach, we examine the recent build-up of household debt in the U.S., and compare it with four representative bubbles in the early 1990s in Japan, U.K., Finland and Sweden. Section 4 introduces life-cycle models of household consumption, and introduces our nonparametric regression model. Section 5 provides information on micro data for U.S. households. Section 6 reports major findings, and section 7 presents major conclusions.

2 Review of related studies.

The possible effect from household balance sheets on consumption expenditures remains little understood. The idea that household debts may worsen economic recession goes back to Fisher (1933), who explained the unusual severity of the Great Depression by the increased real burden of debt after general fall in priced. Minsky (1986) put the accumulation of debt at the center of his 'financial instability hypothesis' by noting that the economic prosperity may lead to a rapid build-up in household and business debts. For a while, unsustainable levels of debt are masked by increasing assets prices, but when they eventually collapse, the debt burden leads to financial crises and protracted economic recessions. More recently, Koo (2008) put forward the concept of 'balance sheet recession' that follows credit bubbles when the private sector optimistically takes on large amounts of debt. When the bubble eventually bursts, the private sector starts to pay back its excessive debts. By saving more, the private sector reduces its expenditures. This deleveraging behavior worsens the overall macroeconomic condition, and makes post-bubble recessions particularly painful. As typical 'balance sheet recessions', Koo identified Japanese economy in the 1990s, and the U.S. economy during the Great Depression.

More recently, Eggertsson and Krugman (2010) summarized the contributions of Fisher, Minsky and Koo in a New Keynesian theoretical model, in which there are two types of households: 'impatient' households that accumulate debts, and 'patient' households that are lenders. When the first group of households faces an exogenous shock that require them to pay back debts, the shock forces these households to reduce their spending. The shock also reduces the interest rate, which should have positive effect on the consumption of net lenders. However, due to the zero lower bound, the interest rate could not be reduced to a sufficiently low level to have a positive effect on net lenders that exceeds the negative effect from the deleveraging behavior among net borrowers. The overall effect of the deleveraging shock is a protracted recession that is made worse by a liquidity trap and deflation.

Apart from the above-mentioned contributions, little theoretical work has been done on how changing balance sheet effects, and in particular, the excessive levels of household debt, may have negative effects on the overall economic situation[2]. In a survey of unexplored topics in macroeconomics, White (2010) acknowledged that we still know little how the state of balance sheets affects households and their consumption expenditures.

The number of empirical studies on balance sheet effects on consumption remains similarly scarce. Mishkin (1978) demonstrated that high levels of household debt worsened the economic conditions during the Great Depression. King (1994) examined how 10 developed countries

[2]Probably, a major explanation why debt is ignored in conventional macro models is because they typically consider only a single 'representative agent', while it takes two to borrow.

recovered from the global recession in the early 1990s, and found that the slowest recoveries occurred in countries where households accumulated substantial debt compared to disposable income. Glick and Lansing (2010) examined whether the heavier household debt increased the severity of economic recession during the 2007-2009 recession. Using data for 16 developed economies, they found that countries with the fastest increase household debt had more severe contractions in real consumption during the global recession.

All these empirical studies explored links between household debt and macroeconomic performance with aggregate data. Such data could not control for specific characteristics of households, and so results from aggregate data may reflect the influence of same omitted variables, which simultaneously affect household debt and household consumption.

The problem of the spurious correlation due to some omitted variable is less serious with disaggregated data that allow controlling for various characteristics of households, but studies that used micro data are particularly scarce. Mian and Sufi (2010) used disaggregated data for the largest 450 counties in the United States. The study found that counties with the fastest increase in debt-income ratios among households had far more severe economic contractions during the 2007-2009 recession. For instance, counties where households had heavy debts had deeper drops in auto sales and in new housing permits during the recession, and experienced larger increases in the unemployment rate. Another recent study was done by Bostic *et al.* (2009), who compiled a composite dataset for U.S. households from the Consumer Expenditure Survey and the Survey of Consumer Finance. The study examined how net worth of households affected consumption expenditures on durable and non-durable goods. Though the study did not separate the impact of assets and liabilities, it found indirect evidence that consumption expenditures are sensitive to debt side of household balance sheets.

3 Financial balances and their impact on balance sheets of households.

3.1 Definitions of financial balances of households.

Changes in the balance sheets of households can be traced through their financial balances, which are defined as the difference between disposable income and total expenditures of households. Other things being equal, positive financial balances indicate that households are increasing their assets over liabilities, allowing households to increase their net worth. Conversely, when households spend more then their current disposable income, this reduces their net worth.

In this section, we consider the definition and historical changes of financial balances of the household sector. In the next section, we examine how financial balances of households are related to other major institutional sectors, with particular focus on the latest credit boom and burst in the United States, and similar credit bubbles in other developed economies in the early 1900s.

A basic accounting identity states that the sources of funds must be equal to the uses of funds. For households, the sources of funds are given by $SF = YD + T + \Delta L$, where YD is disposable income, T is net monetary transfers to households from other sectors, and ΔL is net borrowing from other sectors. On the other hand, the uses of funds are defined as $UF = C + I_h + \Delta A$, where C is total consumption expenditure of households, I_h is net capital formation of households (which is mostly residential investments), and ΔA is the acquisition of financial assets. From the equality of sources and uses of funds, we get two alternative definitions of financial balances of households:

$$(YD + T - C) - I_h = \Delta A - \Delta L \qquad (1)$$

The left-hand side of the identity states that the financial balance can be measured as the difference between a residual measure of household savings S_h (i.e., disposable income and net transfers $YD + T$ less consumption C) and net investment expenditures of households I_h. On the other hand, the right-hand side of the identity measures the financial balance as the change in household's net worth. In other words, household savings in excess of net investments are equal to increased net worth of households $\Delta A - \Delta L > 0$. Conversely, household investments in excess of their savings can be financed only by a net increase in external borrowing, after which the net worth of households is reduced.

Financial balances of households and other major institutional sectors are measured in the *System of National Account* (hereafter, SNA), and two alternative estimates of financial balances are available. The financial balance is calculated by capital accounts as the difference of net savings and investments of households (as measured by the left side of identity (1)), while financial accounts report the financial balance as net change in assets minus net change in liabilities (as measured by the right side of identity (1)). In both cases, the financial balance of households is called 'net lending (+)/net borrowing (-)'. Both definitions of financial balances should in principle be identical, but they rarely match, since different data sources are used in capital and financial accounts of the SNA (Lequiller and Blades, 2006). In this paper, we will use financial balances that are reported by capital accounts.

Figure 4 illustrates how the financial balance of U.S. households is obtained from the difference between net savings and net investments. Up to the mid-1980s, American households saved around 8 percent of disposable income. These savings were always larger than household investments, which stayed close to 4 percent of disposable income. Then the saving rate started to decline, and reached 3 percent of disposable income in 2005. On the other hand, the rate of household investments initially changed little, but then increased in mid-1990s.

Then a remarkable change occurred in the late 1990s, when American households started to invest more than they saved, so that households no longer played their traditional role of net lenders, and became net borrowers. The largest amount of net borrowing was in 2005, right before the peak of the housing bubble, when the financial balance of households reached almost -5 percent of disposable income. When the housing bubble burst, the financial balance quickly became positive, as households saved a larger portion of their disposable income, while household investments collapsed to almost zero.

The saving-investment balance of households is related to financial flows to other major institutional sectors by a useful accounting identity. Let saving-investment balance of households be denoted by $S_h - I_h$. For the business sector, the corresponding balance is given by $I_b - PR$, where I_b is business investments, and PR are retained earnings. For the government sector, the saving-investment balance is GB, which is the opposite of the budget deficit. Finally, the saving-investment balance of the foreign sector is BP, which is the balance of payments on current account. In Appendix A, we derive the following accounting identity that relates saving-investment balances of households, private business, government and foreign sector:

$$(S_h - I_h) - (PR - I_b) + GB - BP = 0 \quad (2)$$

For each sector, the identity shows the excess of disposable income over current expenditures, or the excess of savings over investments. Positive values show which sectors are increasing their lending to other sectors, while negative values indicate sectors that are net borrowers.

The adding-up restriction (2) has a useful interpretation after reversing the order of saving-investment balances:

$$(I_h - S_h) - (I_b - PR) + GD + BP = 0 \quad (3)$$

This modified version shows sectoral injections of funds (*i.e.*, investments by households and domestic business, expenditures by the government and expenditures by the foreign sector in domestic economy) versus corresponding leakages of funds (*i.e.*, savings by households and the business sector, taxes paid to the government, , and the income of the foreign sector from domestic economy).

3.2 Historical changes in financial balances

Figure 5 illustrates historical changes in investment-saving balances of major sectors of the U.S. economy. The balances are derived from the adding-up restriction (3), and are normalized by the nominal GDP. In this representation of financial balances, sectors with upward movement in financial balances have positive contribution to effective demand (Barbosa-Filho *et al.*, 2008). Shaded areas in the figure indicate time periods between recession peaks and troughs, as defined by the National Bureau of Economic Research (NBER).

Panel (a) of Figure 5 shows that since the early 1990s, the U.S. households had increasingly larger investment-saving balances, moving from deficit of -3 percent of GDP in 1992 to 3 percent surplus in 2005. The change in financial position of households required increased net borrowing that mostly came from foreign creditors (as shown by increasing negative balance for the foreign sector). When the financial balance of households declined during the 2007-2009 recession, the investment-saving balance of households dropped by about 8 percent of GDP. This shortage of expenditures was compensated by the government sector that increased its investment-saving balance from 2 to 11 percent of GDP, with the government becoming a major borrower in the U.S. economy.

In panel (b) of Figure 5 we show that investment-saving balances of households and non-financial corporations were closely related to changing macroeconomic conditions in the U.S. economy, which are expressed by changes in unemployment rate. The Figure indicates a particularly close negative correlation between the unemployment rate and the financial balance of households. When investment-saving balance of households was above its historical norm of -2 percent of GDP, the economic conditions were relatively benign, as reflected in historically low unemployment rates.

Conversely, when private sector was reducing its investment-saving balance by cutting investments and rising savings, the economic conditions worsened rapidly, and unemployment rates surged to high levels, with notable episodes in the early 1980s and 1990s. The negative correlation was particularly strong during the 2007-2009 recession, when the decrease in investment-saving balance of households occurred simultaneously with the surge in unemployment rate from 4.6 in 2006 to almost 10 percent in 2010.

Was the negative correlation between investment-saving balance of households and the unemployment rate a just coincidence, or it reflects a general pattern that is not specific to the United States? In Figure 6, we look at four representative credit bubbles and busts from the early 1990s that occurred in Japan, the United Kingdom, Finland and Sweden.[3]

Figure 6 shows how financial balances of households and nonfinancial corporations in Japan, the United Kingdom, Finland and Sweden were related to changes in the unemployment rate. Periods of credit bubbles are shaded. With a notable exception of Japan, households in other countries had positive investment-saving balances, requiring households to finance the excess of investment over savings by net borrowing from other sectors. As for Japan, the excessive growth of investment-saving balance occurred primarily in the non-financial corporate sector, while households continued to run negative investment-saving balances close to 10 percent of GDP until the burst of the Japan's bubble economy.

Thus, Figure 6 demonstrates two types of credit bubbles that are fueled by the excessive debt in the private sector. Japan is an example of credit bubble that originated in the corporate sector, while credit bubbles in the United Kingdom, Finland, are Sweden were mainly driven

[3]These countries were previously examined by Bank of International Settlements (2001) and International Monetary Fund (2000, 2008) to illustrate that changes of private financial balances during credit bubbles and busts have substantial macroeconomic consequences. Reinhart and Reinhart (2010) also included credit bubbles in Japan, Finland and Sweden during the early 1990s among five case cases of 'the most severe financial disruptions in advanced economies'.

by the excess of investments above savings among households. Each of these household-driven bubbles show that at the top of credit bubble, investments of households exceeded their savings by about 2-4 percent of GDP. This proved remarkably close to the financial balance among the U.S. households at the peak of American housing bubble in 2005, as shown in Figure 5. Similarly, when the bubble economies collapsed, households quickly switched to negative investment-saving balances of 4-6 percent of GDP, once again showing a surprising similar pattern to the current deleveraging among households in the United States.

Finally, household-based bubbles in Figure 6 provide additional evidence about the negative correlation between investment-saving balances of households and the unemployment rate. The figure shows that at the peak of credit bubbles, the unemployment rate was unusually low, reaching as low as only 2 percent in Finland and Sweden before their credit bubbles collapsed. Conversely, the burst of credit bubbles led to the surging unemployment rates, once again mimicking the latest experience in the United States.

How it was possible for households to finance the excess of investments over savings at the peak of credit bubbles? Three financing options are available: households may run down their financial assets, or use proceeds from selling off their assets, or increase their net debts to other sectors (Godley, 1999) . The first two sources of funds are limited by the amount of available financial and non-financial assets, while the additional borrowing does not have these limitations.

Figure 7 illustrates how households financed their investments by increasingly heavy borrowing during credit bubbles in the U.S., Japan, the U.K., and Finland[4] The debt burden is measured by net flow of household liabilities, divided by disposable income. Panel (a) reports historical changes for U.S. households. Note that until the late 1990s, the net addition of household debt usually stayed close to a historical norm of about 5-7 percent of disposable income, and household investments never exceeded their savings. When the credit boom in the late 1990s led to the positive investment-saving balance, the shortfall of savings was financed by increased net borrowing. The peak was reached in 2006, when net borrowing was almost 15 percent of disposable income. Household-centered credit bubbles in the United Kingdom and Finland had even more excessive levels of net borrowing by households. At bubble peaks in these countries, new borrowing by households was about 20 percent of disposable income. In sum, at the peak of credit bubbles, households were able to supplement their disposable income by net borrowing of 15-20 percent of disposable income.

Figure 7 also shows what happened to household borrowing after the credit bubbles collapsed. Households rapidly started to rebuild their balance sheets, and their net borrowing dropped to as low as -5 percent of disposable income (the most extreme drops occurred in Finland in the early 1990s, and in the United States and the United Kingdom in recent years). The episodes when households had negative net borrowing indicates that debt no longer supplemented the disposable income of households. Instead, a part of disposable income was used

[4]For Sweden, data for household debts was missing for the early 1990s

for paying back previously accumulated debts. In section 6, we will use these two extreme levels of debt accumulation and debt reduction (namely, plus 20 percent and minus 5 percent of disposable income, respectively) to interpret the likely range of balance sheet effects on consumption expenditures.

4 Model specification and estimation method

4.1 Specification of standard life-cycle model of household consumption

Our initial model is based on the standard life-cycle model of household consumption, which previously was estimated by Fernández-Villaverde and Krueger (2007) and Attanasio *et al.* (2009). The model assumes that households are consuming a fraction of their lifetime wealth, and the fraction depends on the age of household head:

$$Y_{i,t} = \delta\left(age_i\right) W_i \exp\left(\varepsilon_{i,t}\right) \tag{4}$$

where $Y_{i,t}$ is consumption expenditures of household i at time t, W_i is lifetime wealth of household, and $\varepsilon_{i,t}$ is the regression disturbance. The term $\delta\left(age_i\right)$ defines the age effect on consumption, which reflects changes in the composition of households, different needs of household members, and other factors that change with age.

Taking logs of (4), we obtain

$$\log\left(Y_{i,t}\right) = \log\left(\delta\left(age_i\right)\right) + \log\left(W_i\right) + \varepsilon_{i,t}$$

This specification is extended by adding to the model a vector of observable variables $z_{i,t}$ that may have effect on the level of household consumption:

$$\log\left(Y_{i,t}\right) = \log\left(\delta\left(age_i\right)\right) + \beta' z_{i,t} + \log\left(W_i\right) + \varepsilon_{i,t} \tag{5}$$

These observable variables in $z_{i,t}$ include the number of adults and children in household, various characteristics of the household head, such as occupation, education, race, marital status, gender, and similar control variables.

One problem in estimating specification (5) is that it is very difficult to collect panel datasets that trace households over sufficiently long period of time. The problem is usually solved by creating pseudo-panels of household cohorts that differ by the year of birth of the household head. Let these birth cohorts be denoted by c. After averaging the specification (5) across birth cohorts c, we get

$$\log\left(Y_{c,t}\right) = \log\left(\delta\left(age_c\right)\right) + \beta' z_{c,t} + \alpha_c + \varepsilon_{c,t} \tag{6}$$

where index c identifies a particular birth cohort, and α_c is the average logarithm of lifetime wealth of households belonging to cohort c.

To account for the cyclical variation in household consumption, specification (6) is augmented by a set of year dummies D_t that differentiate among different years t. In additional, the age effect $\log(\delta(age_c))$ is approximated by a flexible function of age, such as a set of dummy variables D_a. Similarly, cohort effect is estimated by a set of cohort dummies D_c:

$$\log(Y_{c,t}) = \alpha_a D_a + \alpha_c D_c + \alpha_t D_t + \beta' z_{c,t} + \varepsilon_c \tag{7}$$

The specification, however, could not be estimated by linear regression models because there is exact linear relationship between age, cohort, and year effects (i.e., current year minus age produces the birth cohort). Fernández-Villaverde and Krueger (2007) solved the identification problem by assuming that the age effect can be approximated by a smooth function of age, which is estimated by a semiparametric regression. As a regression estimator, they choose the partially linear model of Speckman (1988), but the estimator has a serious limitation that it can contain only a single nonparametric term.

In this paper, we solve the identification problem among age, cohort and year effects by using the generalized additive model (GAM) of Hastie and Tibshirani (1990). In contrast to the Speckman estimator, the GAM does not have a limit on the number of nonlinear terms. Initially, nonlinear effects are assumed only in the cohort effect on consumption. This implies that the impact of different age cohort is a smooth function $f(c)$ of cohort year c. Apart from this assumption, the shape of $f(c)$ is left unspecified. After introducing the nonparametric cohort effect in specification (7, we get the following semiparametric model:

$$\log(Y_{c,t}) = \alpha_a D_a + f(c) + \alpha_t D_t + \beta' z_{c,t} + \varepsilon_c \tag{8}$$

Specification (8) can be estimated not only with cohort averages, but also with raw data, as suggested by Attanasio *et al.* (2009). We assume a special term $u_{i \to c,t}$ that denotes deviations of household i from the corresponding cohort average. With this modification, we get the final specification of the standard life-cycle model of household consumption:

$$\log(Y_{i \to c,t}) = \alpha_a D_a + f(c) + \alpha_t D_t + \beta' z_{i \to c,t} + u_{i \to c,t} + \varepsilon_{c,t} \tag{9}$$

where subscript $h \to c$ denotes household i belonging to cohort c.

The model has several distinctive features. First, it contains two components: a nonparametric part with cohort effect, and parametric part with sets of age and year dummies, as well as other control variables (such as marital status, race, etc.). Second, the model does not include household income as an explanatory variable, because the *expected* levels of income are already accounted by the deterministic part of specification (9), while *unexpected* shifts in income is attributed to the regression disturbance $\varepsilon_{c,t}$.

4.2 Addition of balance sheet effects on consumption

In subsection 3.2, we found that during credit bubbles, it was common for households to increase their purchasing power by new debts that could be as much as 20 percent of disposable income. To account for the increased purchasing power on households, we add to the standard specification (9) two balance-sheet variables that measure net changes in assets and liabilities, and normalize these changes by current disposable income of households, and obtained the following model:

$$\begin{aligned}\log\left(Y_{i\to c,t}\right) &= \alpha_a D_a + s(c) + \alpha_t D_t + \beta' z_{i\to c,t} \\ &+ s\left(\Delta A_{i,t}/YD_{i,t}\right) + s\left(\Delta L_{i,t}/YD_{i,t}\right) + u_{i\to c,t} + \varepsilon_{c,t} \end{aligned} \tag{10}$$

where $\Delta A_{i,t}/YD_{i,t}$ and $\Delta L_{i,t}/YD_{i,t}$ denote net change in assets and liabilities of household i at time t, respectively, and YD is disposable income. To allow for possible nonlinearity from assets and liabilities, these effects are estimated similarly to the cohort effects, by specifying smooth functions $s\left(\Delta A_{i,t}/YD_{i,t}\right)$ and $s\left(\Delta L_{i,t}/YD_{i,t}\right)$ that may have nonlinear effects on household consumption.

What effects on consumption can be expected from different configurations of household balance sheets? Table 1 lists six possible combinations of changes in assets, liabilities, and net worth. The table also provides illustrative examples for each of these combinations. Since we include separate effects of net assets and liabilities, we will consider only cases, when assets change with liabilities fixed, and conversely, when liabilities change with assets fixed.[5]

In Case 1 and 2 of Table1, we have an increase and decrease in assets with fixed liabilities. Case 1 corresponds to simple accumulation of financial assets, financed from saved, rather than spend, disposable income, so in this case we expect no impact on consumption. Case 2 is related to consumption, financed from running down the financial assets, when, for instance, consumption expenditure is financed by decreased bank deposit, with no new debts. In this case, we expect a negative correlation between consumption expenditures and reduced financial assets.

In Cases 3 and 4, we fix the asset side of balance sheets, and change liabilities. In Case 3, consumption expenditure is financed by incurring new debt. With the extra purchasing power, households could increase their current consumption, so we expect a positive correlation between debt and consumption. On the other hand, households reduce debt in Case 4 by saving extra disposable income. Once households start channeling their income to reduce debts, no consumption expenditure is taking place, so we expect a flat effect on consumption as long as net flow of debt remains negative.

[5]The restriction that the other side of balance sheets is kept fixed corresponds to the conventional, ‘other things being equal’, interpretation of regression parameters.

4.3 Estimation method

In this section we discuss details of semiparametric estimation of regression models (9) and (10). These generalized additive models (GAM) can be estimated in several ways. The most traditional approach uses the backfitting algorithm of Hastie and Tibshirani (1990). However, the backfitting algorithm requires that smoothing parameters for each non-parametric part are specified prior to estimation. These smoothing parameters are given by the number of degrees of freedom v that are used to approximate nonparametric terms. For example, when $v = 1$, this implies that a single variable is used, which is the case of a linear regression model. On the other hand, semiparametric effects are obtained with $v > 1$, with larger values of v indicating increasingly nonlinear effects.

There is usually no prior information about relative linearity of nonparametric effects. So instead of essentially *ad hoc* selection of v, we use the automatic selection of the smoothing parameter that is provided in the modified generalized cross validation (*MGCV*) algorithm of Wood (2004). The algorithm selects an optimal degree of smoothness of nonparametric terms by minimizing the cross-validation (GCV) criteria of Wahba (1990).

Appendix C provides more details on how *MGCV* algorithm estimates the GAM. Essentially, the *MGCV* algorithm searches for an optimal degree of smoothness by evaluating the cross-validation criteria with different values of v. In practice, the algorithm can select as optimal any degree of smoothing, including the special case of linear age effect, when $v = 1$. Specifically, we used *MGCV* library (Wood, 2010), which is a part of *R* statistical package (R Development Core Team, 2010).

5 Data.

Household data were taken from the Consumption Expenditure Survey (CEX), which is an annual survey of U.S. households conducted by the Bureau of Labor Statistics (BLS). The primary purpose of CEX is collect information on expenditure weights in calculating consumer price index, so the survey contains detailed information of current consumption expenditures. In addition, the survey collects data on sources of household income and changes in household assets and liabilities, which are sub-divided into housing and financial assets and liabilities.

The survey is a rotating panel, with households participating in five quarterly interviews. During the first interview, households provide information on their socio-economic status (such the number of household members, their age, marital status, education and similar information). In the remaining four interviews, households report their consumption expenditures. Data on current income and changes in household balance sheets are collected in the second and fifth interviews. In practice, the survey has high attrition rate, with only half of households completing all five interviews. However, the BLS provides special weights that take into account the high attrition rate, making the CEX data a representative sample of the U.S. population.

Household surveys often contain a large number of incomplete or unreliable household data, and the CEX is not exception. When cleaning-up the dataset, we omitted households that met the following criteria:

1. households with top-coded expenditures or income;

2. households with incomplete income or expenditure data (*i.e.*, households that did not participate in all five interviews);

3. households that had a large absolute discrepancy between uses and sources of funds, with the cut-off value 33.3%. For each household, we calculated the source of funds SF and use of funds UF, as defined on page 6. Then we calculated a discrepancy measure $\frac{|SF-UF|}{0.5\times(SF+UF)}\times 100\%$, and dropped households with the discrepancy measure exceeding 33.3 percent.[6]

We used the CEX data that are provided at the NBER homepage. The full dataset is available between 1980 and 2004, but we omitted the CEX data for 1980-1981 because these early surveys are not strictly comparable to subsequent CEX surveys. The CEX provides data for nominal expenditures, and we converted them into real expenditures by consumer expenditure indices for major expenditure categories from the Bureau of Labor Statistics.

The original sample of included 127495 households. After applying the three selection criteria, the sample size decreased to 116254, 48451 and 30516 households, respectively, with the largest reduction in the sample size due to households with incomplete income and expenditure records.

In subsequent cleaning, we dropped households that met the following minor selection criteria:

1. households with implausible values of stock holding (such as 1 dollar);

2. student households;

3. households with negative values of income or total consumption.

After dropping household data that met these minor criteria, the sample size decreased only slightly, to 30188 households.

In the final data cleaning step, we omitted households that had extreme values of net debt to income ratio $\Delta L/YD$. Specifically, we omitted households below 5 percentile and above 95 percentile of the distribution of $\Delta L/YD$. In practice, this meant that we kept households with $-0.23 \leq \Delta L/YD \leq 0.46$. As can be seen in Panel (a) of Figure 7, the historical variation of $\Delta L/YD$ ratio always stayed inside this cut-off band in every case study of credit bubbles. After

[6]More information about the consistency check with the CEX data is available in Sabelhaus (1993).

we dropped households with unusually large changes in debt, our final sample contained 26463 households.

In total consumption expenditures, we differentiated between non-durable and durable consumption. Nondurable consumption included expenditures on food, tobacco, alcohol, clothing, personal care, utilities, services, personal transportation, readings, household supplies, and communication. Durable consumption contained expenditures on jewelry, rent (including imputed rent for home-owners), furniture, vehicles, recording equipment, health care and education

6 Estimation results

Results of estimated semiparametric models (9) and (10) for durable consumption is reported in Table 2, while Table 3 provides estimates for nondurable consumption. Estimation results for the linear parametric part were broadly similar for durable and nondurable consumption. To avoid repetitions, we will focus on estimation results for durable consumption in Table 2.

The goodness-of-fit of the semiparametric models is measured by the explained deviance, which is a similar to its counterpart in linear regression models, the R-squared statistic. As shown at the bottom of Table 2, the explained deviance was 0.583 for the standard life-cycle model (9), while the addition of balance-sheet effect in model (10) increased the explained deviance to 0.628.

Estimates of linear regression parameters broadly agreed with prior expectations. Consumption expenditures were higher for households with more advanced education levels. When households were differentiated by the type of employment of the heads of households, the highest consumption was for the 'full time–full year' category of households. Compared with married heads of households, other categories of marital status had lower consumption expenditures. Finally, the number of adults in households increased consumption expenditures, while the number of children had the negative effect on consumption. In relative terms, the effect of children was about one-third of the effect of adults for durable consumption, while for nondurable consumption, the relative effect of children was about one-fifth compared with the effect from adults.

Table 2 also reports estimated degrees of freedom v for nonparametric terms. For example, the parameter v for cohort effect in model (9) was 8.710, indicating a moderate nonlinearity in the shape of cohort effect.

Figure 8 plots parameter estimates of age, cohort, and year effects in the standard model of household consumption (9). The life-cycle theory postulates that households smooth their consumption over the life cycle, so the expected age profile of consumption is flat. However, Panel (a) of Figure 8 shows little smoothing, with a particular upward trend before the age of 30. There is also a divergence in age profiles of durable and nondurable consumption, with durable consumption starting to increase after age 60, while nondurable consumption was trending back to its level in the early part of the life cycle. Panel (b) shows that the cohort effect on durable consumption was basically flat, but for cohorts born after the late 1970, the cohort effect showed a significant drop by about 30 percentage points.[7] Finally, Panel (c) reports that year effects on consumption were steadily increasing, with a particularly significant upward trend for durable consumption since the mid-1990s.

Figures 9 and 10 report estimates of balance sheet effects $\Delta A/YD$ and $\Delta L/YD$ on durable and non-durable consumption, respectively. In addition, the figures contain 95% confidence bands for estimated effects on consumption. Though the confidence intervals get wider for the most extreme values of net changes in assets and liabilities, several important patterns can be distinguished.

We begin with estimated balance-sheet effects on durable consumption in Figure 9. As we discussed in connection to the Case 2 in Table 1, the negative values of $\Delta A/YD$ are expected to increase household consumption (in other words, households run down their assets to increase consumption). On the other hand, positive values of the ratio are neutral with respect to consumption expenditures, as we discussed in relation to Case 1 in Table 1. Both these predicted patterns are supported by estimated effects in Panel (a) of Figure 9.

As for net changes in debt, Panel (b) of Figure 9 shows no impact on durable consumption for $\Delta L/YD < 0$. However, positive values of $\Delta L/YD$ are associated with a considerable rise in durable consumption expenditures. For example, the increased borrowing of households from zero to 20 percent of disposable income increases the expenditures on durables by about 30 percentage points.

In Figure 10, we report nonparametric estimates of balance sheet effects for non-durable consumption expenditures. In sharp contrast to estimates in Figure 9, changes in both net assets and net liabilities have no significant effect on non-durable consumption. Estimated balance sheet effects turned out essentially flat, especially in Panel (b), indicating that net accumulation of debt has no effect on nondurable consumption.

7 Conclusion.

Our results suggest that changes in balance sheet of households may have an important role in macroeconomic fluctuations, and the major effect operates through variation in the household expenditures on durables. It is instructive to put our estimates of balance sheet effects on consumption in the context of credit bubbles and busts that we discussed in this paper.

For example, during the latest credit circle in the United States, the net debt to income ratio increased from 6 to 13 percent from 1995 to 2005 (as reported in Panel (a) of Figure 7). The estimated debt–consumption profile in Panel (b) of Figure 9 predicts that at this scale of

[7] Cohort effect for nondurable consumption was very similar, and is omitted to avoid repetitions.

additional borrowing, households increased their durable consumption by about 20 percentage points.

Our analysis of representative credit bubbles also showed that when the credit bubbles burst, households rapidly curtailed their net borrowing. For example, in the aftermath of 2007-2009 recession, the net borrowing of U.S. households collapsed to -1 percent of disposable income (as reported in Panel (a) of Figure 7). Using the estimated debt–consumption profile of Figure 9, this abrupt shift in net borrowing reduced the durable consumption of U.S. households by about 30 percentage points.

In summary, our results demonstrate a possible mechanism how changes in balance sheets of households may amplify, and then rapidly reduce the consumption of durables during the boom and bust phases of credit bubbles. We also found that nondurable consumption was little affected by balance sheet effects.

Appendices

A Accounting identity among sectoral financial balances

Consider the following institutional sectors: households H, private business B, the government G, and the rest of the world W. Let $T_{i \to j}$ denote net financial transfers from sector i to j. We begin from the basic identify for GDP:

$$GDP = C + I + G + N \tag{11}$$

where C define private consumption expenditures, I – business investments (including changes in inventories), G – government expenditures, and N is net exports. We add and subtract to (11) net financial flows between H, B, G, and W, and group terms as follows:

$$\begin{aligned} &GDP - T_{h \to g} - T_{b \to g} + T_{w \to h} + T_{w \to b} \\ &= C + I + \big(G - T_{h \to g} - T_{b \to g} + T_{g \to w}\big) \\ &+ (N + T_{w \to h} + T_{w \to b} - T_{g \to w}) \end{aligned}$$

The identity can be simplified on its right-hand side. Note that terms in the first bracket are equal to the government deficit, while the second bracket equals to the balance of payments on current account. After denoting these two financial balances by GD and BP, respectively, we get:

$$GDP - T_{h \to g} - T_{b \to g} + T_{w \to h} + T_{w \to b} = C + I + GD + BP \tag{12}$$

Further simplification is obtained by splitting GDP in (12) into personal income Y_h and business gross profits Y_b, and by adding and subtracting transfers from business to households $T_{b \to h}$ (which are basically dividends):

$$\big(Y_h - T_{h \to g} + T_{w \to h} + T_{b \to h}\big) - \big(Y_b - T_{b \to g} + T_{w \to b} + T_{b \to h}\big) = C + I + GD + BP \tag{13}$$

Note that the first term in brackets is the disposable income of households YD, while the second term in brackets denotes undistributed profits PR. To get financial balances for households and business sector, we divide gross private investments I into residential investments of households I_h and nonresidential investments of business I_b. After re-arranging terms in (13), we obtain the final identity for financial balances among major institutional sectors:

$$(S_h - I_h) - (PR - I_b) + GB - BP = 0$$

B Data sources and definitions

Figure 1: Data for historical changes in gross domestic product and in real disposable income per capita are from the National Income and Product Accounts (NIPA), compiled by the Bureau of Economic Analysis. Historical changes in employment, and in the share of long-term unemployment are taken from the Bureau of Labor Statistics. The long-term unemployment includes people who are out of work and continue looking for work for more than 27 weeks or more. The peaks of business cycles are defined according to the business cycle chronology by the National Bureau of Economic Research. Post-war recessions omit the short-lived recession in 1980 because it was unusually quickly followed by recession in 1981-1982.

Figure 2: Contributions of GDP components to economic growth are taken from the NIPA, and the peaks of business cycles are the same as in Figure 1.

Figure 3: Household debt contains the following components: (1) nonfarm residential mortgage debt, (2) short-term consumer credit of urban and rural households, (3) debt for security credit, (4) farm mortgage debt. Household debt and personal disposable income for 1945–2010 were taken from the Flow of Funds Accounts, compiled by the Board of Governors of the Federal Reserve System. Household debts and incomes for 1919-1944 were taken from several sources. Goldsmith and Lipsey (1963, table IV-b-11c-5) provided data on urban mortgage debt. Goldsmith (1955) was used to obtain data for short-term consumer debt (table D-1) and farm mortgage debt (table A-61). Nominal disposable income was taken from U.S. Census Bureau (1975, series F 6-9).

Figure 4: Data are taken from the Integrated Macroeconomic Accounts for the United States, compiled by the Bureau of Economic Analysis. The national accounts are essentially a modified version of official NIPA releases to make them more comparable with the 1993 System of National Accounts (SNA 1993).

Figure 5: Data for investment-saving balances are taken from the Integrated Macroeconomic Accounts for the United States. The unemployment rate is obtained from the Bureau of Labor Statistics. Recession dates are from the NBER.

Figure 6: Financial balances are based on SNA 1993, and were taken from homepages of national statistical offices and OECD (various years). Net investment and saving of households and non-financial corporate sector was 'net borrowing/net lending' balance in capital accounts, but with the oppositive sign due to the use of investment-saving balances (while SNA 1993 calculates saving-investment balances). To make unemployment rate comparable, we used a harmonized unemployment rate, calculated by the OECD.

Figure 7: Sources for financial balances are the same as in Figure 6. Net borrowing by households is calculated from the stock of household debt, reported in financial accounts of the Integrated Macroeconomic Accounts for the U.S. and SNA 1993 for the other countries.

C Estimation of the generalized additive model

Consider a reduced specification of the standard life-cycle model (9), which includes only the nonparametric part $f(c)$, with no parametric terms. After explaining how the nonparametric part $f(c)$ is estimated, it will be trivial to extend the reduced form back to its full semiparametric specification (9). In the reduced specification, the dependent variable y_i is explained by a single explanatory variable c_i with a nonlinear effect on y_i:

$$y_i = f(c_i) + \varepsilon_i \tag{14}$$

where $f(\cdot)$ is an arbitrary smooth function and ε_i is the error term with zero mean and variance σ^2.

Let $\kappa_1 < \cdots < \kappa_M$ be a sequence of breakpoints ('knots') that are distinct numbers that span the range of c_i. In the MGCV algorithm, the smooth function $f(c_i)$ is approximated by a sequence of cubic splines. These splines are a sequence of piecewise polynomials that are joined at the knots. Due to special restrictions, the cubic splines are continuous at the knots, and also have continuous first and second derivatives. Let M be the number of knots. Then a cubic spline can be represented by truncated cubic basis functions:

$$f(c_i) = \delta_0 + \delta_1 c_i + \delta_2 c_i^2 + \delta_3 c_i^3 + \sum_{m=1}^{M} \delta_{m+3}(c_i - \kappa_m)_+^3 \tag{15}$$

where

$$(c_i - \kappa_m)_+ = \begin{cases} 0 & c_i \le \kappa_m \\ c_i - \kappa_m & c_i > \kappa_m \end{cases}$$

In this representation, the cubic spline has a simple interpretation of a *global* cubic polynomial $\delta_0 + \delta_1 c_i + \delta_2 c_i^2 + \delta_3 c_i^3$ and M *local* polynomial deviations $\sum_{m=1}^{M} \delta_{m+3}(c_i - \kappa_m)_+^3$. In matrix form, the truncated cubic basis becomes $\boldsymbol{y} = \boldsymbol{C}\boldsymbol{\delta} + \boldsymbol{\epsilon}$, where $\boldsymbol{C}$ is design matrix with ith row vector $\boldsymbol{C}_i = \begin{bmatrix} 1 & c_i & c_i^2 & c_i^3 & (c_i - \kappa_1)_+^3 & \cdots & (c_i - \kappa_M)_+^3 \end{bmatrix}$, $\boldsymbol{\delta}$ is the corresponding vector of regression parameters, and ε is the error term. The smooth function $f(\boldsymbol{C}, \boldsymbol{\delta})$ is linear in $M + 4$ regression parameters, and can be fitted by minimizing the sum of squared residuals $(\boldsymbol{y} - \boldsymbol{C}\boldsymbol{\delta})'(\boldsymbol{y} - \boldsymbol{C}\boldsymbol{\delta}) = \|\boldsymbol{y} - \boldsymbol{C}\boldsymbol{\delta}\|^2$, where $\| \cdots \|$ stands for the Euclidean norm.

By increasing the number of knots M, the model becomes more flexible in approximating y. But if M is too large, the estimates $\hat{f}(c)$ may follow y too closely. In the limit, when

$M = n$, the cubic spline simply interpolates y. To prevent too much wiggliness in the estimated curve, a special term that penalizes rapid changes in $\hat{f}(c)$ is added to the fitting criteria. A common penalty is $\lambda \int [f_{cc}(c)]^2 dx$, which has a smoothing parameter λ and an integrated squared second derivative $f_{cc}(c)$ of $f(c)$. This results in the penalized least-squares criterion

$$Q(f, \lambda) = \|\boldsymbol{y} - \boldsymbol{C\delta}\|^2 + \lambda \int [f_{cc}(c)]^2 dx.$$

If $\hat{f}(c)$ is too rough, this will increase the penalty term $\int [f_{cc}(c)]^2 dx$. The smoothing parameter λ controls the trade-off between the model fit $\|\boldsymbol{y} - \boldsymbol{C\delta}\|$ and *the roughness penalty* $R = \int [f_{cc}(c)]^2 dx$. When $\lambda = 0$, the roughness penalty R has no effect on the minimization criterion $Q(f, \lambda)$, producing unpenalized estimates $\hat{f}(x)$ that just interpolate data. In contrast, when $\lambda = +\infty$, this results in the perfectly smooth line, *i.e.*, in a linear regression line with a constant slope.

The minimization of the penalized criterion $Q(f, \lambda)$ is simplified by noting that derivatives and integrals of $f(c)$ are linear transformations of parameters $d^m(c)$ in the cubic spline basis, with $f_{cc}(c) = \sum_{m=1}^{M} \delta_m d_{cc}^m(c)$ and $\int f(c)dc = \sum_{m=1}^{M} \delta_m \int d^m(c)dc$, where $d^m(c)$ denotes a particular form of basis function (such as the truncated cubic basis function in (15)). Thus, $f_{cc}(c) = \boldsymbol{d}_{cc}(c)'\boldsymbol{\delta}$, from which it follows that $[f_{cc}(c)]^2 = \boldsymbol{\delta}'\boldsymbol{d}_{cc}(c)'\boldsymbol{d}_{cc}(c)\boldsymbol{\delta} = \boldsymbol{\delta}'F(c)\boldsymbol{\delta}$. Finally,

$$R = \int [f_{cc}(c)]^2 dc = \boldsymbol{\delta}' \left(\int F(c)dc \right) \boldsymbol{\delta} = \boldsymbol{\delta}'\boldsymbol{S}\boldsymbol{\delta}.$$

Thus, the roughness penalty R can be represented as a quadratic form in the parameter vector δ and matrix $\boldsymbol{S}$ of known coefficients that are derived from the basis function $d^m(c)$.

Substituting the roughness penalty R with $\boldsymbol{\delta}'\boldsymbol{S}\boldsymbol{\delta}$, the penalized least-squares criterion becomes

$$Q(f, \lambda) = \|\boldsymbol{y} - \boldsymbol{C\delta}\|^2 + \lambda \boldsymbol{\delta}'\boldsymbol{S}\boldsymbol{\delta}.$$

Differentiating $Q(f, \lambda)$ with respect to $\boldsymbol{\delta}$ and setting the derivative to zero produces an estimate of $\boldsymbol{\delta}$:

$$\hat{\boldsymbol{\delta}} = \left(\boldsymbol{C}'\boldsymbol{C} + \lambda \boldsymbol{S}\right)^{-1} \boldsymbol{C}'\boldsymbol{y}. \quad (16)$$

The estimate of δ depends on the value of unknown smoothing parameter λ. The MGCV algorithm selects an appropriate value of λ by using the concept of hat matrix from the ordinary least-squares model. In the linear model, the hat matrix $\boldsymbol{H}$ projects the vector of dependent variable $\boldsymbol{y}$ into the vector of predicted values $\hat{\boldsymbol{y}} = \boldsymbol{H}\boldsymbol{y}$, with $\boldsymbol{H} = \boldsymbol{C}\left(\boldsymbol{C}'\boldsymbol{C}\right)^{-1}\boldsymbol{C}'$. Using the estimate of $\hat{\delta}$ from (16), the hat matrix of the penalized spline model can be similarly defined as $\boldsymbol{H}_S = \boldsymbol{C}\left(\boldsymbol{C}'\boldsymbol{C} + \lambda \boldsymbol{S}\right)^{-1}\boldsymbol{C}'$. Since the matrix $\boldsymbol{H}_S$ transforms the vector of $\boldsymbol{y}$ into the vector of its smoothed values, the matrix $\boldsymbol{H}_S$ is commonly called a smoother matrix. In the MGCV algorithm, the optimal value of λ is found by minimizing the GCV criteria $V_g(\lambda)$ that depends on the sum of squared residuals $\|\boldsymbol{y} - \boldsymbol{C}\hat{\boldsymbol{\delta}}\|^2$ and the trace of smoother matrix $\boldsymbol{H}_S$:

$$V_g(\lambda) = \frac{n\|\boldsymbol{y} - \boldsymbol{C}\hat{\boldsymbol{\delta}}\|^2}{[n - \text{tr}(\boldsymbol{H}_S)]^2} \tag{17}$$

where n is the number of observations, and $\text{tr}(\boldsymbol{H}_S)$ is the trace of $\boldsymbol{H}_S$.

Though the MGCV algorithm selects an appropriate degree of smoothness with respect to parameter λ, this parameter is not very useful in evaluating the estimated degree of smoothness. It is much easier to interpret the trace of the smoother matrix $\text{tr}(\boldsymbol{H}_S)$, since it is equal to the number of degrees of freedom, needed to approximate the smoothed function $f(c)$ (Ruppert *et al.*, 2003). Let $\nu = \text{tr}(\boldsymbol{H}_S)$. Since the smoothing parameter λ is a part of $\boldsymbol{H}_S$, λ and ν are correlated. In particular, a small degree of smoothing is indicated by $\lambda \to 0$ and $\nu \to \infty$. Conversely, a high degree of smoothing corresponds to $\lambda \to \infty$ and $\nu \to 0$. An important special case is when $\nu = 1$. This range of ν indicates a parametric effect, when a single variable is sufficient to approximate the smoothed function $f(c)$, which is the original vector of cohort effects c.

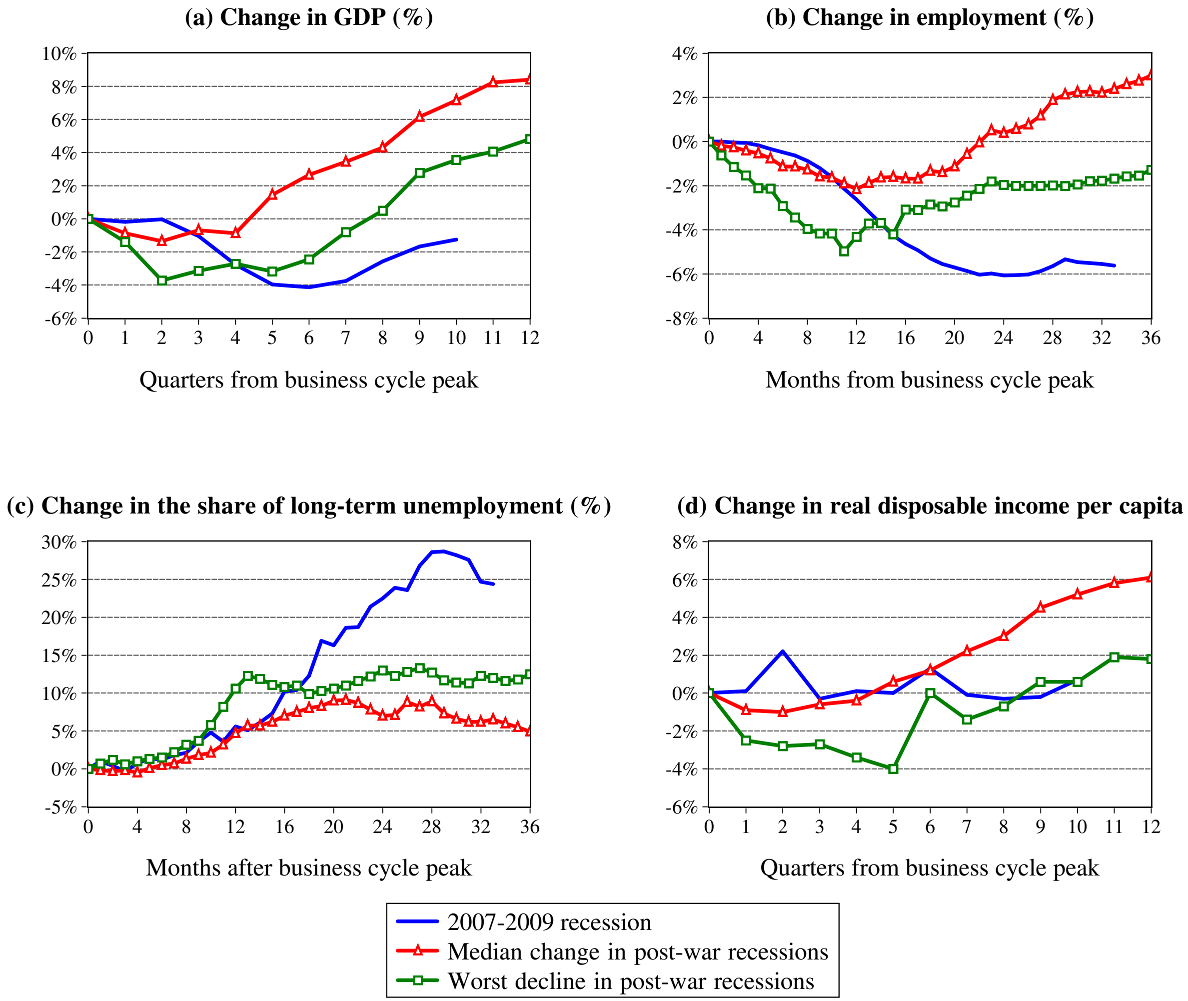
There is, however, one problem in practical use of the GCV criterion $V_g(\lambda)$. Monte Carlo studies by Kim and Gu (2004) demonstrated that $V_g(\lambda)$ may choose too small values of λ, which results in undersmoothing. The problem can be solved by multiplying $\text{tr}(\boldsymbol{H}_S)$ in (17) by a parameter η that increases the cost per trace of $\boldsymbol{H}_S$:

$$\bar{V}_g(\lambda) = \frac{n\|\boldsymbol{y} - \boldsymbol{C}\hat{\boldsymbol{\delta}}\|^2}{[n - \eta \cdot \text{tr}(\boldsymbol{H}_S)]^2}\ .$$

We followed the recommendation of Kim and Gu (2004) and Wood (2006) that a good value for η is 1.4.

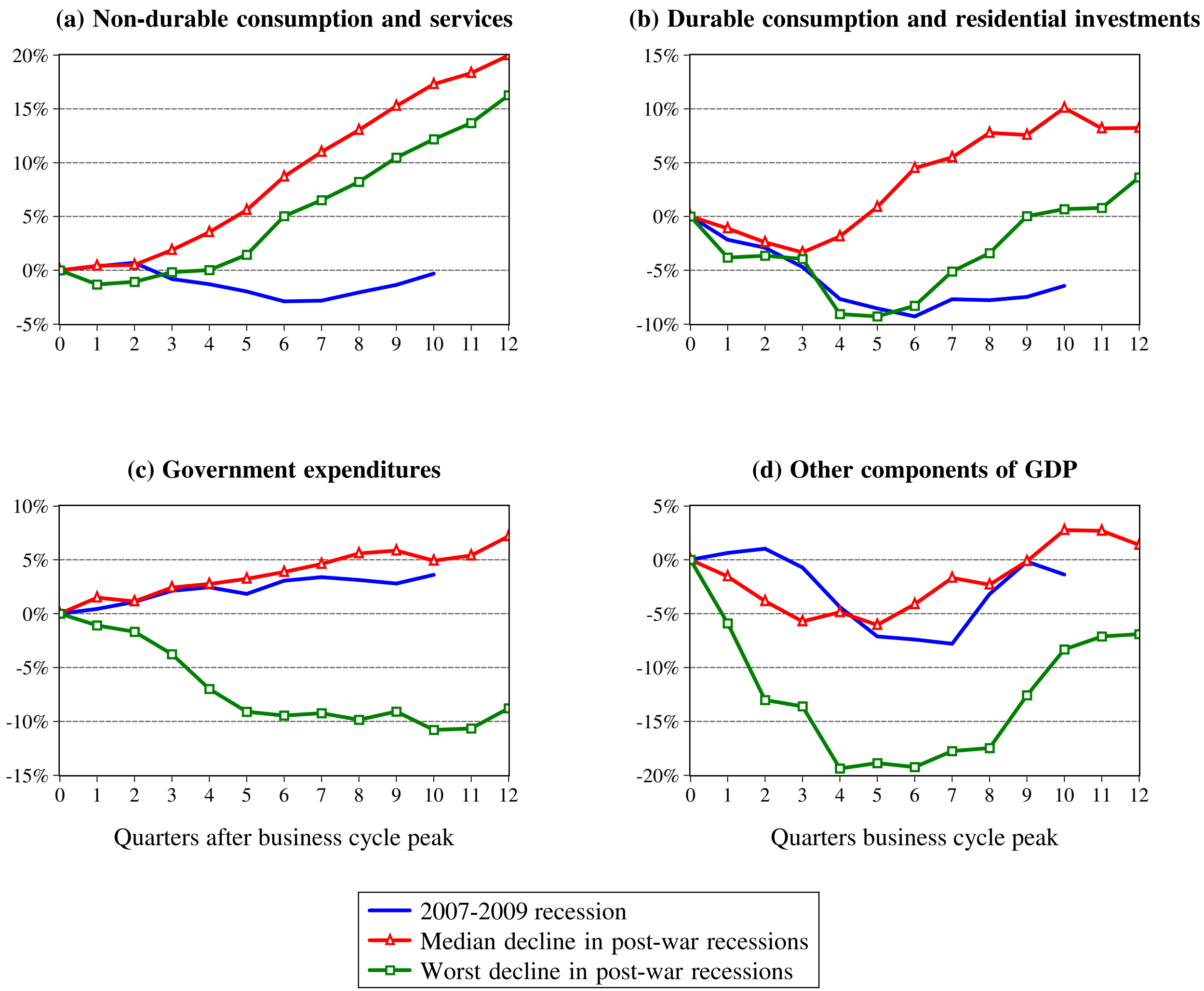
Once the smooth function $f(c)$ is estimated by spline basis functions, the reduced specification (14) can be easily extended back to the full semiparametric model (9). Define the parametric part of (9) by the matrix $\boldsymbol{W}$ that contains dummy variables for age and year effects D_a and D_t, and the vector of other control variables z. Let a new design matrix be defined as $\tilde{\boldsymbol{C}} = [\boldsymbol{C}, \boldsymbol{W}]$. With the expanded design matrix, the truncated cubic basis (15) still has the form $\boldsymbol{y} = \tilde{\boldsymbol{C}}\tilde{\boldsymbol{\delta}} + \varepsilon$, but the basis $\tilde{\boldsymbol{C}}$ now includes the expanded design matrix with all parametric components. The estimate of $\tilde{\boldsymbol{\delta}}$ is obtained from (16), where the smoothing parameter λ is found by minimizing either $V_g(\lambda)$ or $\bar{V}_g(\lambda)$.

Figure 1. Indicators of relative severity of the 2007-2009 recession.



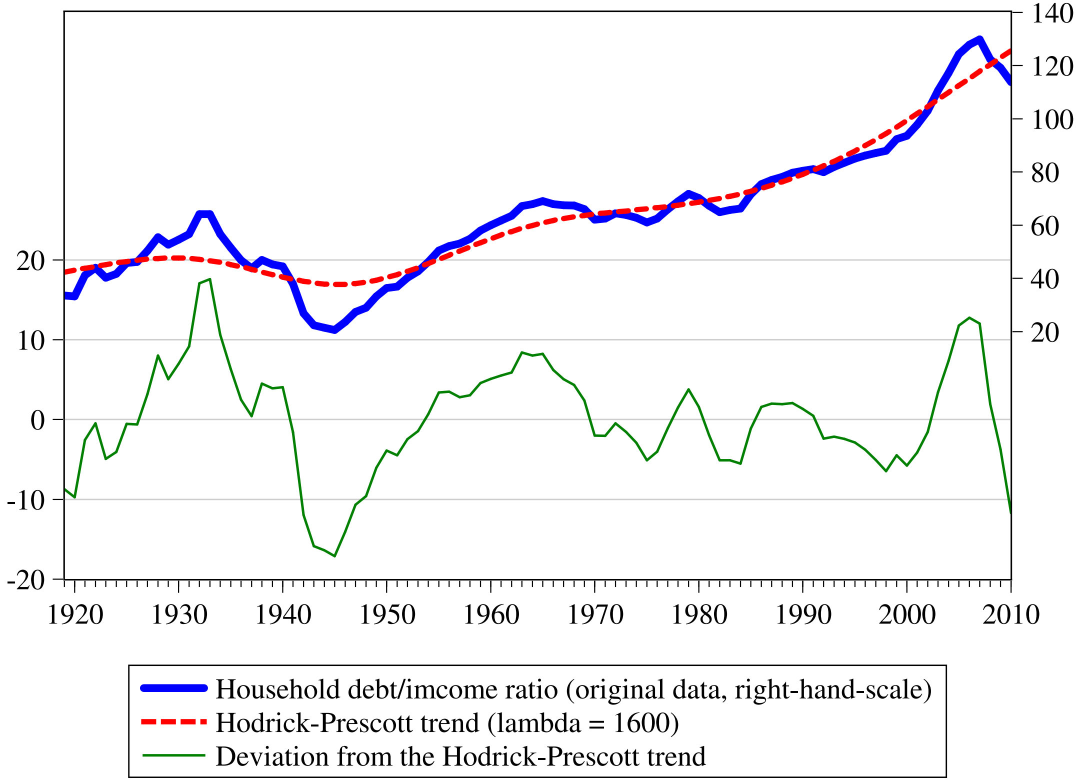
Note: Data sources and definitions are provided in Appendix B.

Figure 2. Growth contributions of major GDP components during the 2007-2009 recession.



Note: Data sources and definitions are provided in Appendix B.

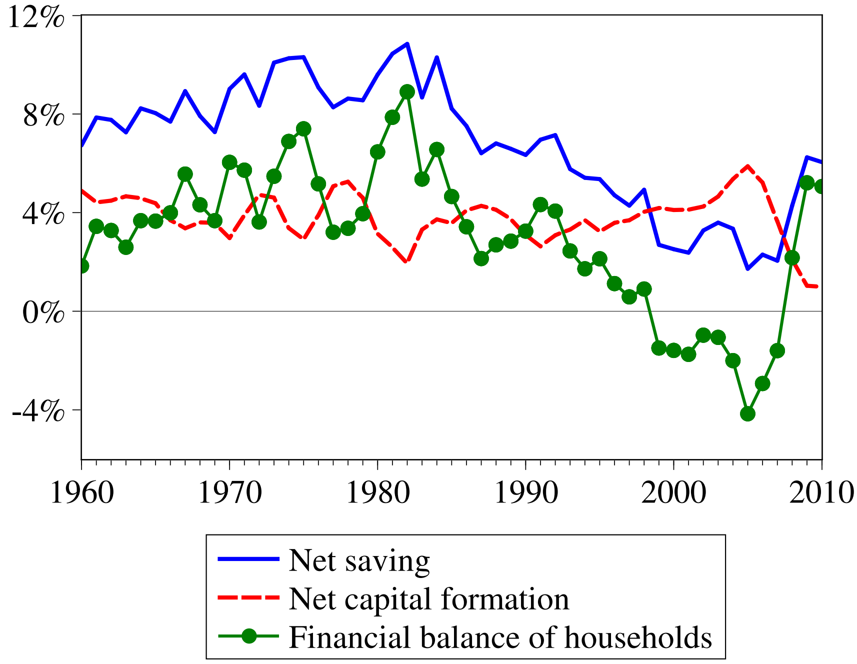
Figure 3. Debt-income ratio of U.S. households compared with its long-term trend, 1919-2010.



Note: Data sources and definitions are provided in Appendix B.Long-term trend of debt-income ratio is estimated with Hodrick-Prescott filter, with $\lambda = 1600$. This value of the smoothing parameter is larger than the conventional choice of $\lambda = 1600$ for annual data. The larger λ smooths produces smoother trends, making more visible long-term changes in the debt-income ratio. Borio and Lowe (2004) suggested the similar choice of λ to identify trends in the private credit to GDP ratio.

Figure 4. Saving-investment balance of U.S. households, as percent of net disposable income, 1960-2010.

The figure illustrates the calculation of financial balance of households in the capital account of the Integrated Macroeconomic Accounts of the United States. Note that this figure uses the traditional definition of financial balances as the difference between net savings and net capital formation.

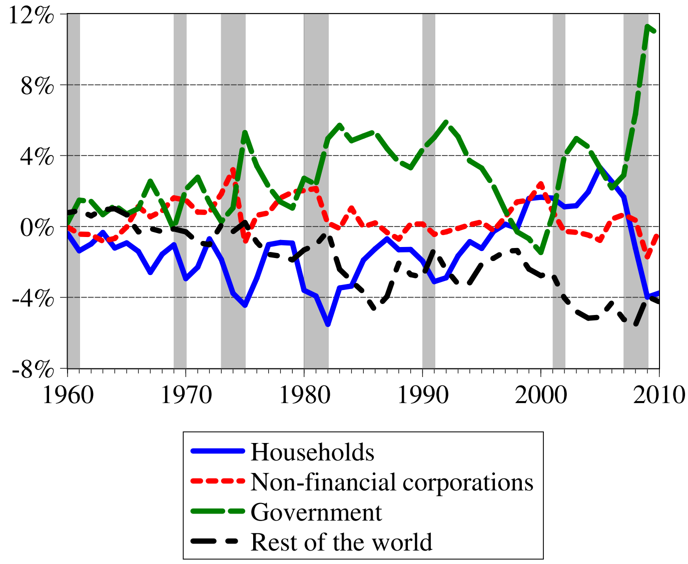


Note: Data sources and definitions are provided in Appendix B.

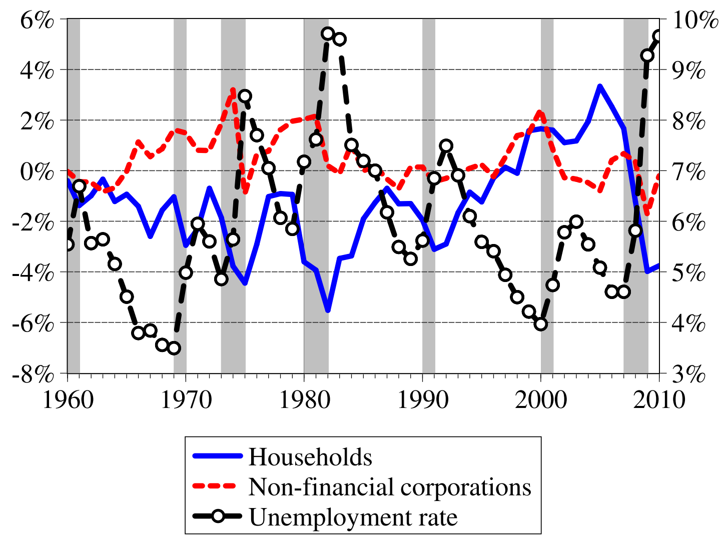
Figure 5. Investment-saving balances of major U.S. institutional sectors.

Financial balances in this figure are reported as the difference between net investments and net savings, to show the difference between injection and leakages of funds of major institutional sectors. Note that the definition of financial balances in this figure is the opposite to definition in figure 4. Positive values of investment-saving balances indicate sectors that are net borrowers to finance the excess of investments over savings. Shaded periods indicate official recessions, as defined by the NBER.

(a) Investment-saving balances of major sectors



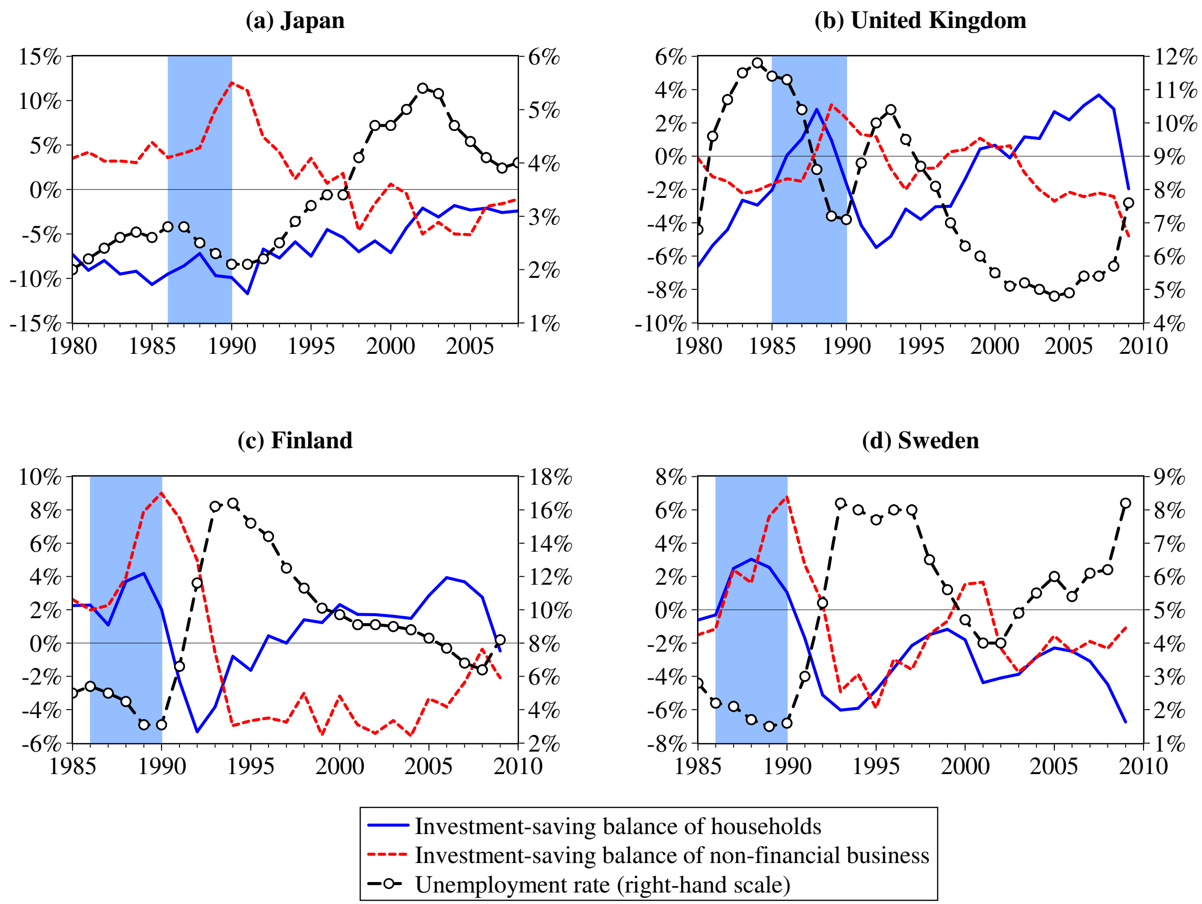
(b) Investment-saving balance of the private sector and unemployment rate



Note: Data sources and definitions are provided in Appendix B.

Figure 6. Investment-saving balances and unemployment rates during major credit booms and busts in the early 1990s.

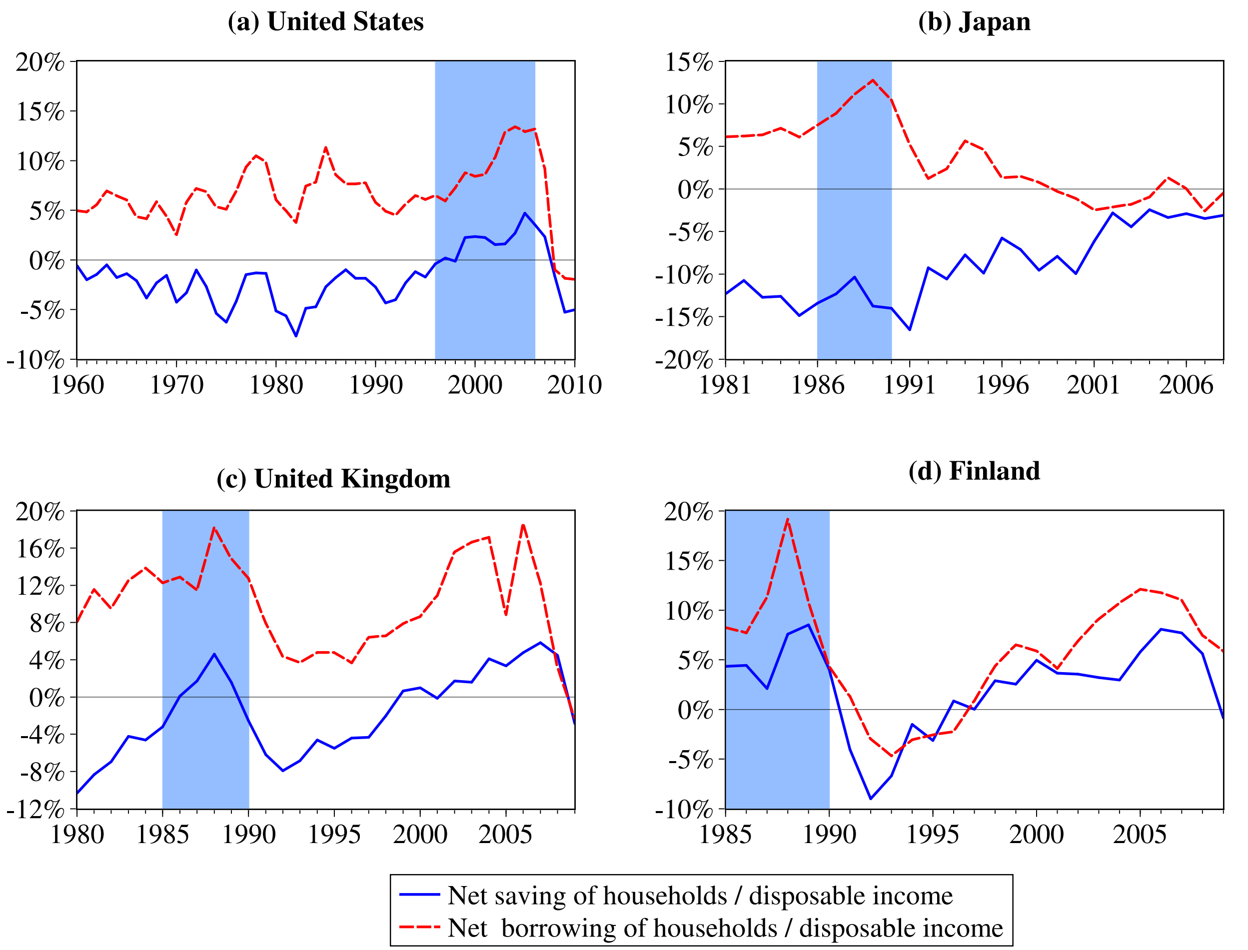
The figure shows financial balances during credit bubbles and subsequent credit busts in the early 1990s. Financial balances are the difference between net investment and net saving. Unemployment rates are compiled by the OECD, and harmonized across countries.



Note: Data sources and definitions are provided in Appendix B.

Figure 7. Net borrowing and investment-saving balances of households during credit booms and busts.

The figure illustrates how investment-saving balances of households were associated with their net borrowing. Financial balances and the net flow of household debt are normalized nominal disposable income of households.



Note: Data sources and definitions are provided in Appendix B.

Figure 8. Age, cohort and year effects on household consumption in the basic life cycle model.

The figure reports estimates of standard life-cycle model of household consumption, specified by equation 9. Estimates of age and year effects are from corresponding dummy variables for the age of household head, and for the current year. Cohort effects are represented by a smooth nonlinear function. The y-axes of panel (b) reports the estimated number of degrees of freedom to approximate the shape of cohort effect.

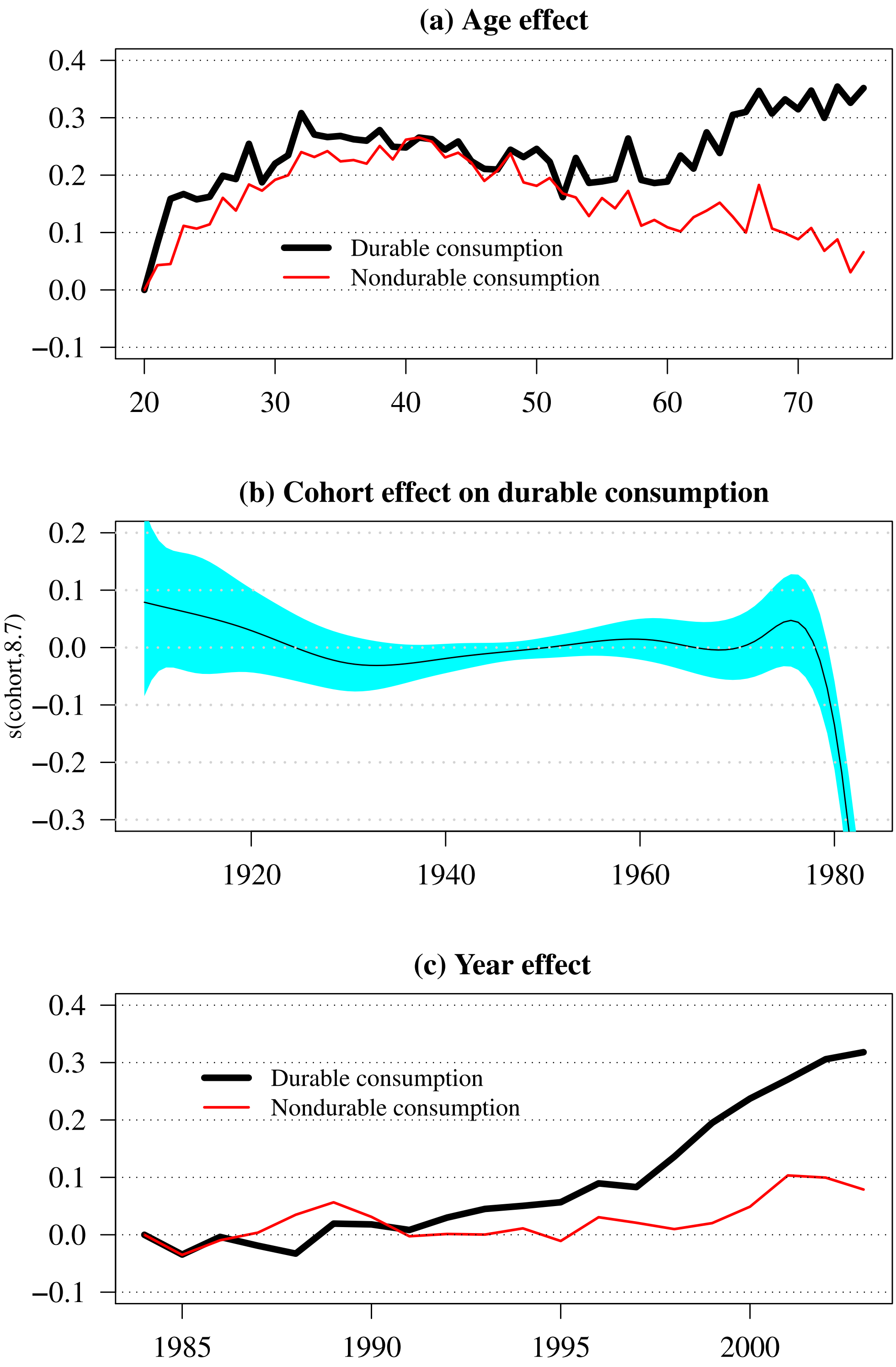
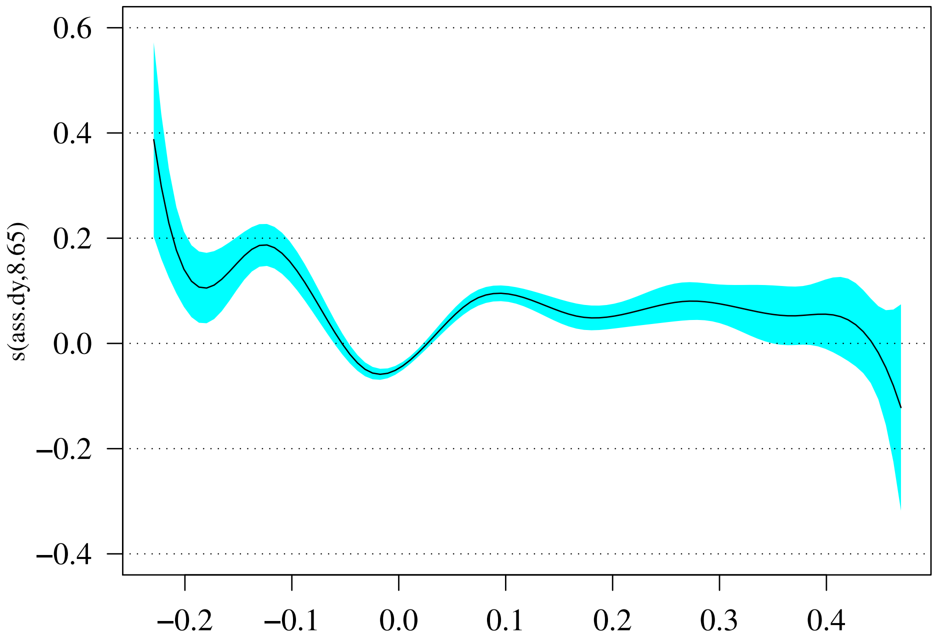


Figure 9. Balance sheet effects on durable consumption

The figure reports estimates of balance sheet effects on the log of real durable consumption. The model is specified by equation (10). Balance sheet effects are defined as net flow of assets and liabilities in year t compared with $t-1$, and normalized by disposable income in year t. The range of balance sheet effects omits households with extreme values of net debt to income ratio, defined as the lowest and highest 5 percent of all households. The y-axes of panels (a) and (b) report the estimated number of degrees of freedom to approximate the shape of cohort effect, with larger values indicating more nonlinear effects. Detailed estimation results are reported in Table 1.

(a) Change in asset/disposable income ratio



(b) Change in debt/disposable income ratio

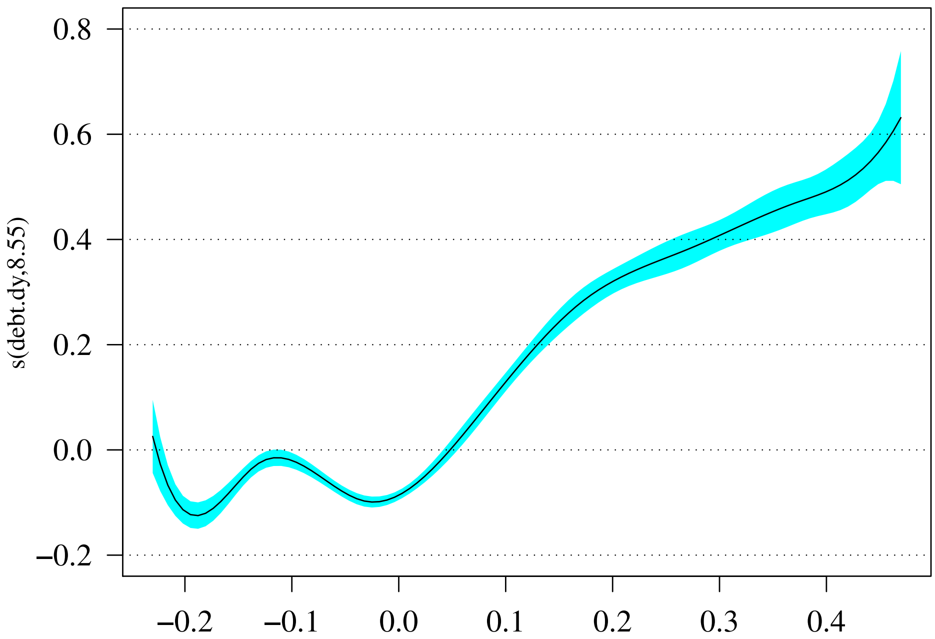
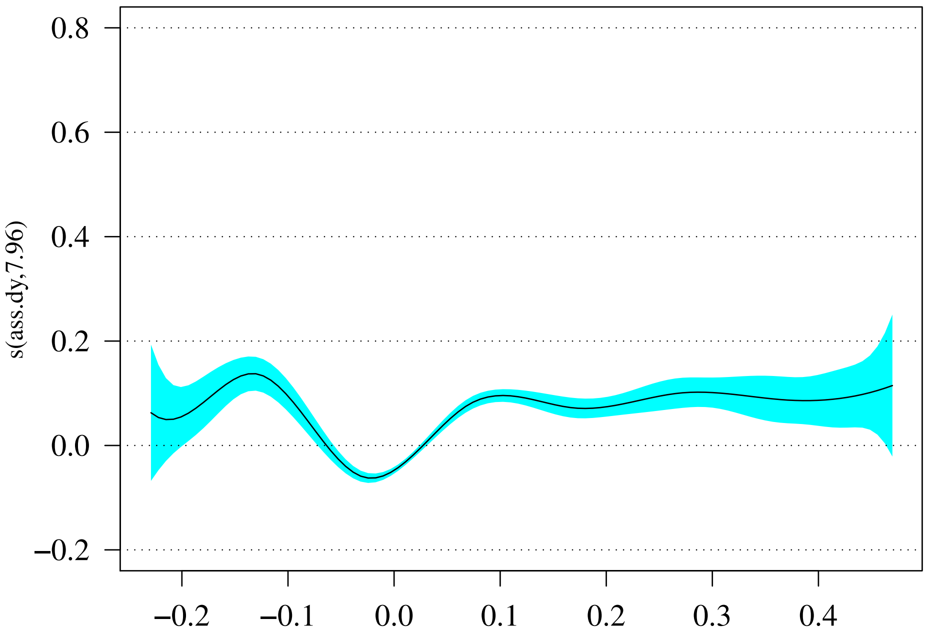


Figure 10. Balance sheet effects on nondurable consumption

The figure reports estimates of balance sheet effects on the log of real nondurable consumption. The model is specified by equation (10). Balance sheet effects are defined as net flow of assets and liabilities in year t compared with $t-1$, and normalized by disposable income in year t. The range of balance sheet effects omits households with extreme values of net debt to income ratio, defined as the lowest and highest 5 percent of all households. The y-axes of panels (a) and (b) report the estimated number of degrees of freedom to approximate the shape of cohort effect, with larger values indicating more nonlinear effects. Detailed estimation results are reported in Table 2.

(a) Change in asset/disposable income ratio



(b) Change in debt/disposable income ratio

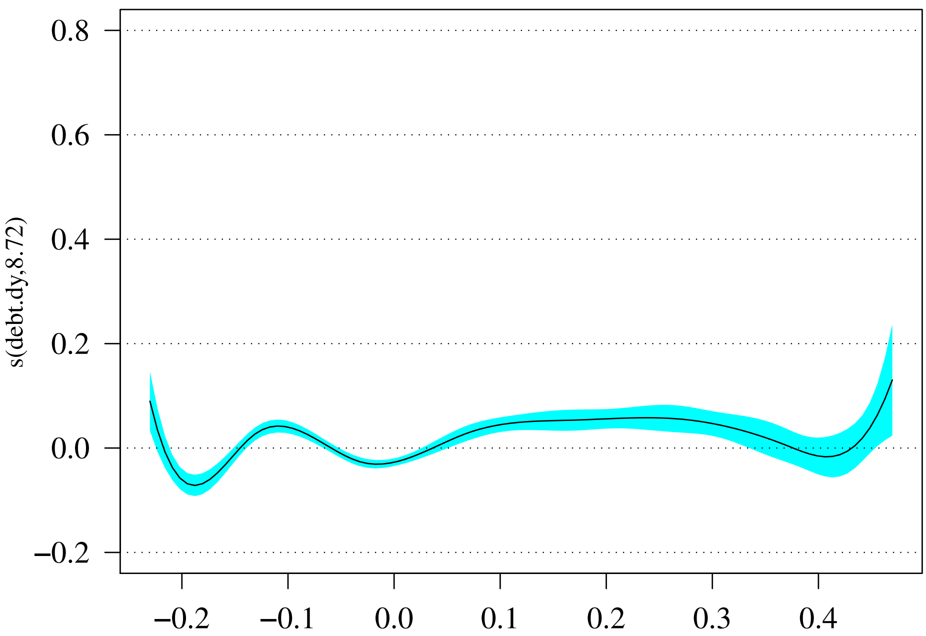


Table 1.
Possible combinations of balance sheet effects on consumption

	Change in assets	**Change in liabilities**	**Change in net worth**	**Example**
Case 1	+	0	+	Accumulation financial assets, financed from saving income, with no new net debt
Case 2	-	0	-	Purchase of nondurables, financed by running down financial assets
Case 3	0	+	-	Purchase of nondurables, financed by new debt, and no use of financial assets
Case 4	0	-	+	Decrease of debt, financed by saved income (*i.e.*, deleveraging)
Case 5	+	+	0	Purchase of non-financial asset, financed by installment credit
Case 6	-	-	0	Reduction of debt, financed by selling off non-financial asset

Table 2.
Model estimates for household consumption of durables.

The figure reports estimates of the basic life cycle model (9) and the extended model (10) with balance sheet effect on the log of durable consumption. The table omits estimates of age and year effects, since they are already reported in panels (a) and (c) of Figure 8. Statistically significant estimates at the level of 10, 5, and 1 percent are shown with *, **, ***, respectively. 'E.d.f.' abbreviates the estimated degree of freedom of smooth nonparametric terms.

Dependent variable: log of durable consumption expenditures				
	Basic model		*Model with balance sheet effects*	
	Coef.	p-value	Coef.	p-value
Intercept	9.223	< 0.001 ***	9.238	< 0.001 ***
High school	-0.086	< 0.001 ***	-0.079	< 0.001 ***
College	0.150	< 0.001 ***	0.136	< 0.001 ***
Graduate	0.302	< 0.001 ***	0.297	< 0.001 ***
Full time/Full year	0.452	< 0.001 ***	0.413	< 0.001 ***
Part time/Full year	0.276	< 0.001 ***	0.254	< 0.001 ***
Full time/Part of year	0.309	< 0.001 ***	0.272	< 0.001 ***
Part time/Part of year	0.180	< 0.001 ***	0.158	< 0.001 ***
Employed in agriculture	0.023	0.501	0.031	0.343
Employed in construction	0.084	0.001 ***	0.078	0.001 ***
Employed in manufacturing	0.038	0.048 **	0.026	0.149
Employed in transportation	0.093	< 0.001 ***	0.083	< 0.001 ***
Employed in trade	0.026	0.190	0.025	0.194
Employed in finance	0.150	< 0.001 ***	0.129	< 0.001 ***
Employed in professional services	0.044	0.024 **	0.028	0.124
Employed in other services	0.043	0.063 *	0.042	0.053 *
Employed in public administration	0.085	0.001 ***	0.053	0.031 **
Employed in other industries	0.276	0.002 ***	0.229	0.006 ***
Widowed	-0.258	< 0.001 ***	-0.245	< 0.001 ***
Divorced	-0.266	< 0.001 ***	-0.253	< 0.001 ***
Separated	-0.289	< 0.001 ***	-0.268	< 0.001 ***
Never married	-0.341	< 0.001 ***	-0.316	< 0.001 ***
Black	-0.228	< 0.001 ***	-0.215	< 0.001 ***
American Indian	-0.150	< 0.001 ***	-0.123	< 0.001 ***
Asian	-0.033	0.118	-0.018	0.372
Race n.e.s.	-0.116	0.329	-0.082	0.464
Female	0.008	0.307	0.015	0.036 **
Northeast	0.064	0.002 ***	0.064	0.001 ***
Midwest	-0.028	0.157	-0.041	0.028 **
South	-0.033	0.095 *	-0.042	0.023 **
West	0.126	< 0.001 ***	0.115	< 0.001 ***
Homeowner w/o mortgage	-0.235	< 0.001 ***	-0.226	< 0.001 ***
Renter	-0.751	< 0.001 ***	-0.716	< 0.001 ***
Occupied w/o payment	-0.845	< 0.001 ***	-0.802	< 0.001 ***
Rural	-0.209	< 0.001 ***	-0.213	< 0.001 ***
Number of adults	0.136	< 0.001 ***	0.133	< 0.001 ***
Number of children	-0.042	< 0.001 ***	-0.034	< 0.001 ***
Estimated smooth functions				
	E.d.f.	p-value	E.d.f.	p-value
s(cohort)	8.710	< 0.001 ***	8.700	< 0.001 ***
s(debt/disposable income)			8.550	< 0.001 ***
s(assets/disposable income)			8.650	< 0.001 ***
Deviance explained	0.583		0.628	
GCV score	32,145		28,732	
Number of households	26,463		26,463	

Table 3.
Model estimates for household consumption of nondurables.

The figure reports estimates of the basic life cycle model (9) and the extended model (10) with balance sheet effect on the log of non-durable consumption. The table omits estimates of age and year effects, since they are reported in panels (a) and (c) of Figure 8. Statistically significant estimates at the level of 10, 5, and 1 percent are shown with *, **, ***, respectively. 'E.d.f.' abbreviates the estimated degree of freedom of smooth nonparametric terms.

	Dependent variable: log of nondurable consumption expenditures					
	Basic model			*Model with balance sheet effects*		
	Coef.	p-value		Coef.	p-value	
Intercept	8.961	< 0.001	***	8.966	< 0.001	***
High school	-0.081	< 0.001	***	-0.075	< 0.001	***
College	0.095	< 0.001	***	0.085	< 0.001	***
Graduate	0.254	< 0.001	***	0.236	< 0.001	***
Full time/Full year	0.294	< 0.001	***	0.266	< 0.001	***
Part time/Full year	0.164	< 0.001	***	0.145	< 0.001	***
Full time/Part of year	0.205	< 0.001	***	0.184	< 0.001	***
Part time/Part of year	0.137	< 0.001	***	0.122	< 0.001	***
Employed in agriculture	-0.069	0.009	***	-0.074	0.005	**
Employed in construction	0.018	0.359		0.021	0.264	
Employed in manufacturing	-0.011	0.449		-0.017	0.235	
Employed in transportation	0.058	0.001	***	0.055	0.002	***
Employed in trade	0.007	0.665		0.008	0.604	
Employed in finance	0.083	< 0.001	***	0.074	< 0.001	***
Employed in professional services	-0.006	0.666		-0.015	0.303	
Employed in other services	-0.015	0.402		-0.016	0.370	
Employed in public administration	0.038	0.055	*	0.029	0.144	
Employed in other industries	0.090	0.187		0.079	0.242	
Widowed	-0.238	< 0.001	***	-0.225	< 0.001	***
Divorced	-0.215	< 0.001	***	-0.203	< 0.001	***
Separated	-0.209	< 0.001	***	-0.194	< 0.001	***
Never married	-0.244	< 0.001	***	-0.235	< 0.001	***
Black	-0.069	< 0.001	***	-0.057	< 0.001	***
American Indian	-0.112	< 0.001	***	-0.105	< 0.001	***
Asian	-0.107	< 0.001	***	-0.105	< 0.001	***
Race n.e.s.	-0.103	0.261		-0.104	0.248	
Female	-0.001	0.884		0.002	0.732	
Northeast	0.069	< 0.001	***	0.071	< 0.001	***
Midwest	-0.002	0.876		-0.006	0.668	
South	-0.029	0.058	*	-0.028	0.062	*
West	-0.011	0.492		-0.014	0.375	
Homeowner w/o mortgage	-0.066	< 0.001	***	-0.059	< 0.001	***
Renter	-0.298	< 0.001	***	-0.266	< 0.001	***
Occupied w/o payment	-0.326	< 0.001	***	-0.290	< 0.001	***
Rural	-0.149	< 0.001	***	-0.143	< 0.001	***
Number of adults	0.155	< 0.001	***	0.157	< 0.001	***
Number of children	0.027	< 0.001	***	0.032	< 0.001	***
Estimated smooth functions						
	E.d.f.	p-value		E.d.f.	p-value	
s(cohort)	8.440	< 0.001	***	8.380	< 0.001	***
s(debt/disposable income)				8.720	< 0.001	***
s(assets/disposable income)				7.960	< 0.001	***
Deviance explained	0.510			0.523		
GCV score	19,083			18,603		
Number of households	26,463			26,463		

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