European University Institute

Department of Economics

EUI Working Papers

ECO 2008/05

The Aggregate Effects of Anticipated and Unanticipated U.S. Tax Policy Shocks: Theory and Empirical Evidence

Karel Mertens and Morten O. Ravn

EUROPEAN UNIVERSITY INSTITUTE
DEPARTMENT OF ECONOMICS

The Aggregate Effects of Anticipated and Unanticipated U.S. Tax Policy Shocks: Theory and Empirical Evidence

KAREL MERTENS

and

MORTEN O. RAVN

EUI Working Paper **ECO** 2008/05

This text may be downloaded for personal research purposes only. Any additional reproduction for other purposes, whether in hard copy or electronically, requires the consent of the author(s), editor(s). If cited or quoted, reference should be made to the full name of the author(s), editor(s), the title, the working paper or other series, the year, and the publisher.

The author(s)/editor(s) should inform the Economics Department of the EUI if the paper is to be published elsewhere, and should also assume responsibility for any consequent obligation(s).

ISSN 1725-6704

© 2008 Karel Mertens and Morten O. Ravn

Printed in Italy
European University Institute
Badia Fiesolana
I – 50014 San Domenico di Fiesole (FI)
Italy

http://www.eui.eu/
http://cadmus.eui.eu/

The Aggregate Effects of Anticipated and Unanticipated U.S. Tax Policy Shocks: Theory and Empirical Evidence*

Karel Mertens† Morten O. Ravn‡

Cornell University *EUI and the CEPR*

January 2008

Abstract

We provide empirical evidence on the effects of tax liability changes in the United States. We make a distinction between "surprise" and "anticipated" tax shocks. Surprise tax cuts give rise to a large boom in the economy. Anticipated tax liability tax cuts are instead associated with a contraction in output, investment and hours worked prior to their implementation. After their implementation, anticipated tax liability cuts lead to an economic expansion. We build a DSGE model with changes in tax rates that may be anticipated or not, estimate key parameters using a simulation estimator and show that it can account for the main features of the data. We argue that tax shocks are empirically important for U.S. business cycles and that the Reagan tax cut, which was largely anticipated, was a main factor behind the early 1980's recession.

Key words: Fiscal policy, tax liabilities, anticipation effects, structural estimation.

JEL: E20, E32, E62, H30

---

*We are grateful to Eric Leeper for comments. The responsibility for any errors is our's.

†**Contact details:** Department of Economics, Cornell University, Ithaca, NY. Email: km426@cornell.edu

‡**Contact details:** Department of Economics, European University Institute, Villa San Paolo, via della Piazzuola 43, FI-50133 Florence, Italy. Email: morten.ravn@eui.eu

1 Introduction

This paper investigates the dynamic effects on the aggregate economy of changes in taxes. We study U.S. time series data and derive estimates of adjustment of key macroeconomic aggregates to changes in tax liabilities. We confront a dynamic stochastic general equilibrium model with the empirical evidence and examine whether it can account for the way in which changes in tax liabilities affect the U.S. economy. A key aspect of our analysis is that we make a distinction between unanticipated and anticipated changes in taxes. Anticipated tax liability changes are relevant empirically because fiscal interventions frequently are associated with implementation lags. Moreover, given the fact that the time lag between the announcements of tax liability interventions and their implementation are at least partially observable, tax liability changes provide an interesting testing-ground for examining how anticipation effects may give rise to fluctuations in the economy.

Our empirical analysis makes use of Romer and Romer's (2007a) narrative account of U.S. tax liability changes. These authors identify 49 "significant" legislated federal tax policy initiatives, many of which consist of multiple separate tax liability changes, during the post World War II period. We focus on the tax liability changes that Romer and Romer (2007a) deem exogenous. We use information on the dates at which the changes in tax liabilities were legislated and on the dates at which the tax liabilities were introduced in order to discriminate between unanticipated and unanticipated tax policy interventions. We categorize tax policy changes as anticipated if the difference between the date at which they were signed by the President and the date at which they were implemented was more than 90 days. In practice, this means that all the anticipated tax changes in our sample have at least two quarters of anticipation.

We examine the responses of key aggregate variables to tax liability changes using a vector autoregression (VAR) approach. We find that unanticipated decreases in tax liabilities give rise to substantial expansions in aggregate output, consumption of nondurables and services, purchases of consumer durables, investment, and an increase in aggregate hours worked. The boom in the economy is persistent and reaches its maximum impact around 2.5 years after decreases

in tax liabilities. At this horizon, a one percent decrease in tax liabilities gives rise to a 2.2 percent increase in output per capita, a 1.1 percent increase in private sector consumption of nondurables and services per capita, a 7.3 percent increase in consumer durable purchases, a 7.6 percent increase in private sector investment, and a 1.1 percent increase in hours worked.

A key finding is that anticipated tax liability decreases are associated with major contractions in the economy in the period *prior* to its implementation. The contraction occurs in output, hours worked and is especially sharp for investment that falls by almost 5 percent in response to a 1 percent anticipated tax liability decrease which we assume is announced 6 quarters in advance. Consumption of nondurables and services instead reacts little to the announcement of lower taxes and displays a flat profile throughout the pre-implementation period. Once the tax cut is implemented, however, the economy reacts much the same way to anticipated and unanticipated tax decreases.

These results are consistent with Romer and Romer (2007b) who find that output contracts in reaction to an anticipation of future tax cuts, but booms in reaction to implemented tax cuts. Blanchard and Perotti (2002) find little anticipation effects of tax policy changes but focus on very short anticipation horizons.[1] Consistently with their results, we show that the pre-implementation contraction is smaller the shorter is the implementation lag. However, in the U.S. data, the typical pre-implementation lag (around 1.5 - 2 years), is associated with a significant pre-implementation contraction.

We then construct a dynamic stochastic general equilibrium model with fiscal policy. Output is produced by competitive firms. Households consume nondurables and durables and rent out labor and capital to firms in the production sector. The government taxes capital income and labor income and uses the proceeds to finance government spending and lump sum transfers to the household sector. Income tax rates are assumed to be stochastic but changes in them may be either anticipated or unanticipated. We estimate the key parameters of the model using a simulation estimator which imposes a VAR structure on the model data when matching it with the empirical impulse response functions. We find that the model can account very well for the

[1] Their focus on short anticipation lags is dictated mostly by their identification strategy.

main features of the U.S. data. In particular, the model accounts with a high degree of accuracy for both the expansionary effects of implemented tax changes and for the pre-implementation slump in the economy in response to pre-announced tax cuts.

Our empirical results complement earlier studies that have examined how anticipated tax changes affect the economy. Examining U.S. household consumption expenditure data, Poterba (1988) tests whether consumption reacts to *announcements* of future tax changes and fails to find robust evidence in favor of this hypothesis.[2] Using household level data from the Consumer Expenditure Survey, Parker (1999) and Souleles (1999, 2002) study how consumption responds to actual changes in taxes when these were known in advance of their implementation.[3] These authors find significant impact of anticipated tax changes at the implementation dates. These results are usually interpreted as evidence of lack of forward looking behavior, the presence of binding liquidity constraints or other aspects that prevent consumers from adjusting their consumption plans in advance in response to predictable changes in income. Our empirical results are consistent with this earlier literature, but we show that the lack of a strong response of consumption to announcements about future taxes, and the response of consumption to actual changes in taxes when these were pre-announced, are not necessarily inconsistent with a DSGE model that abstracts from liquidity constraints and that assumes rational expectations.

The idea that the economy might adjust prior to the introduction of pre-announced tax liability changes bears similarities with the "news" views of business cycles of Pigou (1927) as recently revived by e.g. Beaudry and Portier (2004, 2006), Cochrane (1994), Danthine, Donaldson and Johnsen (1998), den Haan and Kaltenbrunner (2006), or Jaimovich and Rebelo (2006). An important obstacle to empirical tests for news driven business cycle is that expectations are inherently difficult to estimate as they are unobserved by the econometrician. However, in

[2]Poterba (1988) identifies five such episodes: February 1964, June 1968, March 1975, August 1981, and August 1986. We exclude the second and third of these episodes because Romer and Romer (2007a) categorize these tax changes as endogenous.

[3]Parker (1999) examines the impact of Social Security changes during the 1980's while Souleles (2002) investigates the Reagan tax cut of the early 1980's.

the application to tax changes one can reasonably assume that agents (and econometricians) are informed about pre-announced tax liability changes. Therefore, our finding that a pre-announced tax cut gives rise to a pre-implementation contraction in the economy may be important for understanding how news shocks help shape fluctuations in the economy.

Finally, we ask whether tax liability changes are important impulses to the U.S. business cycle. We examine this issue on the basis of a counterfactual analysis in which we simulate the path of the U.S. economy in response to tax liability changes assuming that there were no other shocks to the economy. We find that changes in tax liabilities are very significant impulses to the U.S. business cycles. Together anticipated and unanticipated tax shocks can account for 43 percent of the standard deviation of output at business cycle frequencies and for 47 percent of the standard deviation of investment. Moreover, we show that the effects of anticipated tax shocks account for a large fraction of the early 1980's recession.

2 Empirical Evidence

In this section we analyze of the impact of anticipated and unanticipated tax shocks in the U.S. For this purpose, we make use of Romer and Romer's (2007a) narrative account of U.S. tax liability changes. These authors identify 49 significant legislated federal tax acts in the period 1947-2006.[4] Since tax acts often consist of multiple separate pieces of tax liability changes, a total of 104 separate changes in tax liabilities are identified. Romer and Romer (2007) categorize each of the tax liability changes according to whether they were endogenous responses to the state of the economy or to government financial needs, or whether they were introduced due to long term growth or deficit objectives. We built our empirical approach upon the assumption that the tax liability changes can be regarded as exogenous shocks that are orthogonal to other structural shocks. For that reason we focus only upon those tax liability changes that Romer

[4] The main sources of information used by Romer and Romer (2007a) are the Economic Report of the President, the Annual Report of the Secretary of the Treasury on the State of Finances, the Budget of the United States Government, and presidential speeches.

and Romer (2007a) classify as "exogenous due to long-term growth objectives" or exogenous due to "deficit concerns". The former of these are tax changes that were introduced without any explicit concerns about the state of the economy while the latter are identified as tax changes introduced to address inherited budget deficits not due to contemporaneous spending concerns. These two types of tax liability changes, according to Romer and Romer's (2007a) identification, were thus introduced regardless of their potential effects on the current state of the economy. This classification, we believe, allows us to assume that the tax liability changes that we focus upon can be assumed orthogonal to other structural shocks. This selection leaves us with 67 tax liability changes stemming from 34 different federal tax policy acts which we list in Table A.1.

Romer and Romer (2007a) identify both the dates at which the tax legislations were signed by the President and the dates at which the tax liability changes were implemented. We use this information to differentiate between anticipated and unanticipated tax liability tax changes. We define a tax liability change as *anticipated* if the time lag between the date at which the legislation was signed by the President and the date of its implementation was above 90 days. In practise, this implies that all the tax liability changes that we deem anticipated are associated with at least 2 quarters of anticipation. Tax acts with a shorter implementation lag are defined to be surprise tax cuts (and their timing is set according to the date of implementation). Our assumption regarding the minimum anticipation lag helps ensure that the results are too sensitive to the exact timing of the legislation within a quarter.[5] Based on this taxonomy, 36 of the tax liability changes are deemed anticipated and 31 are defined as surprise tax shocks. We illustrate the resulting tax shocks in Figure 1 measured in terms of percentages of GDP. The top panel shows the unanticipated shocks and the middle panel the anticipated shocks dated by the quarter of implementation. The bottom panel shows the anticipation horizon of the anticipated tax shocks measured in quarters (truncated at 4 years)

The Kennedy and the Reagan tax initiatives were associated with major anticipated tax

[5]Romer and Romer (2007b) use a similar approach to measuring expected tax liability changes. Lustig, Sleet and Yeltekin (2007) use information on "abnormal" return to measure expected government defense spending shocks.

changes. The Kennedy tax initiative, the Revenue Act of 1964, was signed in February 1964 and incorporated tax liability changes implemented in the second quarter of 1964, the third quarter of 1964 and the first quarter of 1965. The former and largest of these is classified as a surprise change, while the latter two are classified as anticipated changes. The Economic Recovery Act of 1981, passed by Congress in August 1981 during the first Reagan administration, consisted of five separate changes in tax liabilities which were due in 1981:3 (a 0.84 percent cut), 1981:4 (a 0.56 percent increase), 1982:1 (a 1.53 percent cut), 1983:1 (a 1.69 percent cut), and 1984:1 (a 1.28 percent cut). The first two of these initiatives are defined as surprise cuts according to our taxonomy while the last three initiatives are defined as anticipated policy changes. This sequence of Reagan tax cuts as a whole constitutes by far the largest anticipated tax changes in the sample that we study.

The anticipation lags - the differences in the timing between the implementation of the anticipated tax changes and the date at which they were signed by the the President - differ substantially across the tax legislations (see the bottom panel of Figure 1). The median anticipation lag is 6 quarters. The largest anticipation lag is associated with the Social Security Amendments of 1983 which was signed by the President in April 1983 but had tax liability changes taking place as far out in the future as 1990.

We assume that the date at which the public becomes informed about the changes in tax liabilities coincides with the date at which the legislations were passed by Congress. It is perceivable that in some instances the public might have expected the tax changes prior to the date at which they were signed by the the President. Indeed, many U.S. presidential elections have been fought over tax policies. Our approach therefore, if anything, underestimates the extent to which tax policy changes were anticipated.[6]

[6] A related issue concerns our implicit assumption that the tax liability changes are fully credible. One might worry about the extent to which the private sector ascribes some likelihood to the possibility that subsequent tax liability changes might not cancel out, or reduce, pre-announced initiatives. If such doubts about credibility are relevant, it should be harder for us to find evidence of anticipation effects.

2.1 Empirical Approach

We study U.S. quarterly data for the sample period 1947:1 - 2006:4. The starting point of our analysis is the following VAR:

$$X_t = A + Bt + C(L) X_{t-1} + D(L) \tau_t^u + F(L) \tau_{t,t}^a + \sum_{i=1}^{K} G_i \tau_{t+i,t}^a + e_t \quad (1)$$

where $X_t = [x_{1t}, .., x_{Nt}]'$ is a vector of endogenous variables, A and B control for a constant terms and a linear trend, $C(L)$ is P-order lag polynomial, $D(L)$ and $F(L)$ are $(R+1)$-order lag polynomials. τ_t^u denotes surprise tax liability changes implemented at date t, and $\tau_{t+i,t}^a$ denotes tax liability changes known at date t and implemented at date $t+i$. The tax shocks are measured by the tax liability changes divided by aggregate U.S. GDP (at the time of their implementation). This contrasts with the standard "dummy variable" measurement of the policy interventions usually adopted in the narrative approach, see e.g. Ramey and Shapiro (1998).[7] Our approach imposes a linearity constraint on the measurement of the tax shock but allows us to aggregate the evidence on the effects of tax shocks across different episodes. Romer and Romer (2007b) adopt the same measurement of the size of the tax policy shocks.

Equation (1) includes the current values and R lags of the tax changes implemented at t. We allow for differential effects of the *implemented* tax liability changes depending on whether they are categorized as surprise tax changes or as anticipated tax changes. To allow for persistence in the tax liability changes, the VAR includes the lagged values of τ_t^u and $\tau_{t,t}^a$.

The effects of anticipated tax liability changes are captured through the coefficient vectors $G_1 - G_K$ where $K > 1$ denotes the maximum announcement horizon that we allow for. Our measure of $\tau_{t+i,t}^a$ is given as:

$$\tau_{t+i,t}^a = \sum_{j=0}^{M-i} s_{t-j,t+i}^{a,i+j} \quad (2)$$

where $s_{t-j,t+i}^{a,i+j}$ denotes tax liability changes announced at date $t-j$ (with an implementation lag of $i+j$ periods) to be implemented at date $t+i$ (subject to $i+j \geq 2$). M denotes the maximum

[7] Perotti (2007) provides an insightful survey of the literature that has examined the consequences of government spending shocks using the narrative approach.

implementation lag observed in the data. Therefore, $\tau^a_{t+i,t}$ aggregates together tax changes based on their *remaining* implementation lag. Ideally, we would like to consider separately anticipated tax changes of different announcement horizons but such an approach is not feasible given the implied loss of degrees of freedom.

The responses to the anticipated tax liability shocks during the pre-implementation period are purely expectational in nature. In order to examine their importance we examine the impulse responses to the two types of tax liability changes. From these we evaluate the importance of expectations regarding future tax liability changes on the basis of the response to the tax shock during the pre-implementation horizon.

We consider the following set of endogenous variables:

$$X_t = \left[\begin{array}{ccccc} y_t, & c_t, & d_t, & i_t, & h_t \end{array} \right]'$$

where y_t denotes the logarithm of U.S. GDP per adult in constant (chained) prices, c_t is the logarithm of the real private sector consumption expenditure on nondurables and services per capita, d_t is the logarithm of private sector consumption expenditure on durables per capita, i_t is the logarithm of real aggregate gross investment per capita. h_t is the logarithm of average hours worked per adult. Precise definitions and data sources are given in Table A.2 in the appendix.

2.2 Empirical Results

Consistent with the median anticipation lag in the data that we study, we assume that $K = 6$. In order to allow for persistence in the tax changes, we assume that $D(L)$ and $F(L)$ are 12 order lag polynomials. We assume that $P = 1$ (but the results are robust to assuming longer lag structures). We report the impulse response functions to a one percentage point increase in the tax liabilities along with 68 percent (non-parametric) non-centered bootstrapped confidence intervals.[8] The impulse response functions are shown for a forecast horizon of 24 quarters for unanticipated tax liability shocks, and for 6 quarters before the tax cut is implemented to 24 quarters after its implementation in the case of anticipated shocks.

[8] The confidence intervals are computed from 10000 replications.

Figure 2 illustrates the impact of the two types of tax liability changes. The left column reports the results for an unanticipated tax liability cut. The decrease in taxes sets off a major boom in the economy and the effects are very persistent. The responses of all the endogenous variables follow hump shaped dynamics. Investment and consumer durables purchases display by far the largest elasticity to the cut in tax liabilities. Upon impact, investment increases by around 1 percentage point and continues to rise until 11 quarters after the change in tax liabilities where it peaks at 7.6 percent above trend. Consumer durables purchases respond much the same way as investment and peaks at 7.25 percent above trend 10 quarters after the tax cut.

Along with the increase in investment and consumer durables, output and hours worked also increase. Output rises upon impact and increases gradually until a peak increase of 2.17 percent is reached 11 quarters after the change in taxes. The impact on hours worked, instead, is estimated to be close to zero until around a year and a half after the change in taxes. After that, hours worked increase gradually and peak at 1.16 percent above trend 12 quarters after the tax shock.

The impact on consumption of nondurables and purchases of durable consumption goods is qualitatively different from the other variables. In particular, the increase in private consumption occurs earlier than in the other variables in the VAR and after 6 quarters, the impact on consumption is basically flat over most of the forecast period. The peak response of consumption (a 1.07 percent rise above trend) is reached 7 quarters after the decrease in tax liabilities, i.e. around 1 year earlier than the peak responses of output, investment, and hours worked. The size and persistence of the responses of the endogenous variables to the unanticipated tax liability changes reveal that fiscal policy may be an important impulse to the U.S. business cycle.

The responses to unanticipated tax liability changes that we derive from the VAR in equation (1) are similar to the results of Romer and Romer (2007b). These authors, like us, examine the response of the economy to tax liability changes. Although they do not discriminate between anticipated and unanticipated shocks, Romer and Romer (2007b) find large and protracted responses to changes in tax liabilities. Relative to Blanchard and Perotti (2002), the response of output to tax liability shocks occur more gradually than the output response to the tax shock

that these authors identify with a structural VAR approach. However, our results are similar to theirs in terms of the persistence of the output response.

In the right column of Figure 2 we show the responses of X_t to anticipated tax liability changes. There is strong evidence in favor of anticipation effects: The anticipation of a future tax liability reduction sets off a recession in the economy that lasts until the tax cut is eventually implemented. We find that output drops by up to 1.16 percent with the largest drop taking place 3 quarters before the tax liability cut is implemented. The decrease in output is statistically significant from zero during much of the pre-implementation period. Similarly to output, hours worked drop below trend throughout the announcement period peaking at 1.9 percent below trend 4 quarters before the tax cut. The most dramatic results pertain to investment which drops 4.9 percent below trend one year before the tax cut is implemented. Thus, not only does investment react very elastically to surprise tax cuts, but the expectations effect is particularly relevant for this variable. Common to all these variables is also that, when the tax cut is eventually implemented, they are all below trend.

The response of private sector consumption of nondurables and services differs from the other variables. The response of consumption is very mild during the pre-implementation period and, at the time of implementation, consumption is back to trend. Consumers' purchases of durable goods drop by 3.3 percent 5 quarters before the tax cut but then return to trend before the tax cut is implemented. Thus, the expectations effects affect consumption variables very differently from the other variables that we investigate.

Once the anticipated tax cut is implemented, we find that the economy goes into a boom period. Apart from hours worked, the up-take in activity actually occurs slightly faster than in response to unanticipated tax cuts. At forecast horizons beyond two years, anticipated and unanticipated changes in taxes have very similar effects. The maximum increase in output (a 1.5 rise above trend) occurs 9 quarters after the tax cut is implemented, while investment booms at 7.1 percent above trend (also 9 quarters after the cut in the taxes). As in the case of unanticipated tax cuts, the consumption response is very flat and reaches its new higher level quickly (5 quarters after the tax cut). The response of hours worked is somewhat weaker than

the other variables in the post-implementation period (and imprecisely estimated). The sizes of the implementation-to-peak responses of the endogenous variables in response to the anticipated tax cut are extremely similar to the peak impacts in response to the unanticipated tax cuts. Thus, the main differences between the response of the endogenous variables to an anticipated and an unanticipated changes in taxes is that the peak response occurs earlier in the latter case.

Our approach to estimating the expectational effects gives strong support to the presence of anticipation effects. Romer and Romer (2007b) examine instead if the expected present value of future (but not yet implemented) tax changes affect the current level of key macroeconomic aggregates. Like us they find that the pre-implementation response is oppositely signed of the post-implementation response. They conclude that there is mild evidence in favor of expectational effects. The advantage of our approach is that we analyze the full path of the adjustment of the economy from when the tax liability changes are announced until several quarters after its implementation.

It is also interesting to relate our results to the line of papers that have examined how anticipated tax changes affect consumption choices. Poterba (1988) fails to derive a significant consumption response to announced future tax cuts while Parker (1999) and Souleles (2002) find that consumption react to the implementation of announced tax changes. These results are consistent with ours given the lack of response of consumption of nondurables and services during the pre-implementation period and the increase in consumption when the tax cut is implemented. This evidence is often interpreted in terms of the presence of binding liquidity constraints, irrationality or other factors that prevent households from changing their consumption streams in response to forecastable changes in real income. However, we will show below that this dynamic response of consumption is consistent with a DSGE model that abstracts from liquidity constraints and in which agents have rational expectations.

2.2.1 Sensitivity to the Anticipation Lag

The analysis above assumed a maximum anticipation horizon of 6 quarters. Recall that this assumption implies that the information set used in the VAR includes future tax changes from

a maximum 6 quarters before their implementation. We now examine the extent to which the effects of anticipated changes in tax liabilities are sensitive to this assumption. Figure 3 illustrates the impact of an anticipated tax liability cut when we vary K, the maximum anticipation horizon, between 4 and 10 quarters.

The results are very robust to changes in K within the interval of values considered here. Regardless of the value of K, the pre-implementation period is characterized by a recession and once the tax cut is implemented, the economy goes into a boom. However, the depth of the pre-implementation recession and the size of the post-implementation boom are sensitive to K. In particular, the longer the assumed maximum anticipation horizon, the deeper is the pre-implementation recession and the milder is the post-implementation expansion.

The sensitivity of the anticipation effects to the assumed length of the maximum anticipation horizon reconciles our findings with those of Blanchard and Perotti (2002). These authors identify output tax shocks using a structural VAR technique based on timing assumptions. They find little evidence of anticipation effects but allow only for a one quarter anticipation horizon.[9] Our results indicate that for longer, and empirically relevant, anticipation horizons, there are significant pre-implementation effects of tax liability changes.

2.2.2 Stability

One potential worry about our results regarding the anticipation effects is that the results derive from particular tax interventions in the sample and that the results are not representative of how anticipated tax changes affect the economy. We now examine this issue by considering the robustness of the results across alternative sample periods. We first consider the sample period 1965:2 - 2006:4 which excludes the Kennedy tax initiative (the Revenue Act of 1964). Secondly, we exclude the Bush tax initiatives (the Economic Growth and Tax Relief Reconciliation Act of 2001 and the Jobs and Growth Relief Reconciliation Act of 2003) by excluding the last five years of the sample. Third, we exclude the Reagan tax cut (the Economic Recovery Tax Act of 1981). This tax initiative occurs in the middle of the sample and is therefore a bit less straightforward

[9] This choice of a short anticipation horizon is dictated by their identification strategy.

to deal with. We consider the sample period 1947:4-1981:2 which therefore excludes the last 25 years of the sample.

Figure 4 shows the estimated response of output to anticipated and unanticipated tax liability changes for the full sample period and the three alternative sample periods. The impact of anticipated tax changes estimated for the full sample is basically identical to the estimates for the samples where we eliminate either the Kennedy tax act of the Bush tax acts. Regardless of the sample period, an unanticipated tax cut is associated with a large expansion in aggregate output. The results are more sensitive to eliminating the last 25 years of the data. Using this sample period, we find much larger effects of anticipated tax cuts and we also find that the expansion in aggregate output following the implementation of an anticipated tax cut takes place somewhat faster. Nevertheless, the presence of a pre-implementation contraction in the economy appears to be extremely robust. Therefore, we conclude that the results that we have derived are robust across the tax interventions in the sample.

3 Theory

We now examine whether a dynamic stochastic general equilibrium model with fiscal policy can account for the empirical results derived above. We extend earlier DSGE models of distortionary taxation such as Braun (1994) and McGrattan (1994)[10] by introducing features such as habit formation, consumer durables, and variable capacity utilization. The economy consists of households, firms, and a government. There is a continuum of identical infinitely lived households with rational expectations. Households own the factors of production which they rent out to the firms, they purchase market goods and have access to a home-production technology which produces consumption services from their holdings of durable consumption goods. Households pay taxes on their factor income and receive government transfers. Firms are competitive and have access to a constant returns to scale production function. The government purchases market goods, taxes capital and labor income and makes lump-sum transfers to the household sector.

[10] See also Leeper and Yang, 2006, and Yang, 2005.

3.1 The Model

Households derive utility from consumption of goods and disutility from working. The consumption bundle is an aggregate of the household's purchases of nondurables and the service flow from the household's stock of durable consumption goods. We allow for the presence of habit persistence and assume the utility function:

$$U_t = E_t \sum_{s=t}^{\infty} \beta^{s-t} \left[\frac{x_s^{1-\sigma} - 1}{1-\sigma} - z_s^{1-\sigma} \omega n_s \right] \tag{3}$$

where E_t denotes the mathematical expectations operator conditional on all information available at date t. In equation (3), $\beta \in (0,1)$ denotes the subjective discount factor, $\sigma > 0$ is a curvature parameter, $\omega > 0$ is a preference weight, and n_s denotes the household's labor supply. We assume that labor is indivisible and that the household's disutility from work grows at the rate of labor augmenting technological progress.[11]

The variable x_s is defined as:

$$x_s = C_s^{\gamma} \left(H_s\right)^{1-\gamma} - \kappa C_{s-1}^{\gamma} \left(H_{s-1}\right)^{1-\gamma} \tag{4}$$

where $\gamma \in (0,1)$ is a share parameter, $\kappa \in [0,1)$ is a habit persistence parameter, and C_s denotes consumption of consumer nondurables. The variable H_s denotes the service flow from the household's stock of consumer durables. We assume that this service flow from consumer durables is derived from a household home-goods production function specified as:

$$H_s = u_s^v V_s \tag{5}$$

where $u_s^v \geq 0$ denotes the capacity utilization rate of the household's stock of consumer durables. The household faces a trade off in choosing the capacity utilization rate of the consumer durables stock. A higher capacity utilization rate increases the instantaneous service flow from its stock of durables but also leads to faster depreciation of the durables stock.

We assume that:

$$V_{s+1} = \left(1 - \Phi_v \left(\frac{D_s}{D_{s-1}}\right)\right) D_s + \left(1 - \delta_v - \Psi_v \left(u_s^v\right)\right) V_s \tag{6}$$

[11] This is reflected in our assumption that z_s, the level of technology, enters the last term in the utility function.

where D_s denotes the household's purchases of new consumer durables, $\Phi_v\left(\frac{D_s}{D_{s-1}}\right)$ captures consumer durables adjustment costs, $\delta_v+\Psi_v\left(u_s^v\right)$ is the gross rate of depreciation of the consumer durables stock due to wear and tear of the consumer durables stock allowing for this to depend on the utilization rate. We assume that $\Phi_v', \Phi_v'' \geq 0$ and that $\Phi_v\left(\gamma_z\right)=0$ where $\gamma_z \geq 1$ denotes the rate of technological progress. This implies that adjustment costs are zero along the balanced growth path. We also assume that $\Psi_v', \Psi_v'' \geq 0$ and that $\Psi_v\left(1\right)=0$. Thus, δ captures the depreciation rate of the stock of consumer durables when the capacity utilization rate is "normal" which we normalize to $u_s=1$.

The household derives income from renting out capital and labor to firms, pays taxes on its factor income, and receives government lump sum transfers. It maximizes its utility stream subject to a sequence of flow budget constraints. The flow budget constraint in period s is given as:

$$C_s+D_s+I_s \leq \left(1-\tau_s^n\right)W_s n_s+\left(\left(1-\tau_s^k\right)r_s u_s^k+\tau_s^k\delta_k\right)K_s+T_s \tag{7}$$

where I_s denotes household spending on new capital, τ_s^n is the labor income tax rate, W_s is the real wage, τ_s^k is the capital income tax rate, r_s is the capital rental rate, u_s^k is the capital capacity utilization rate, K_s is the household's holdings of capital, and T_s denotes the household's receipts of government lump sum transfers. The household budget constraint assumes that households receive a capital tax credit on normal depreciation expenditures.

The household's capital stock evolves according to:

$$K_{s+1}=\left(1-\Phi_k\left(\frac{I_s}{I_{s-1}}\right)\right)I_s+\left(1-\delta_k-\Psi_k\left(u_s^k\right)\right)K_s \tag{8}$$

where $\Phi_k\left(\frac{I_s}{I_{s-1}}\right)$ denotes investment adjustment costs and $\Psi_k\left(u_s^k\right)$ denotes the effect of variations in the capital utilization rate on the effective rate of depreciation of the capital stock. As in the case of consumer durables, we assume that $\Phi_k', \Phi_k'', \Psi_k', \Psi_k'' \geq 0$, and that $\Phi_k\left(\gamma_z\right)=\Psi_k\left(1\right)=0$. The adjustment cost formulation adopted here (and also assumed for consumer durables in equation (6)) is proposed by Christiano, Eichenbaum and Evans (2004) and assumes that adjustment costs arise when the growth rate of investment deviates from its steady-state level.

There is a continuum of identical competitive firms. We assume that the production function

is given by the following Cobb-Douglas specification:

$$Y_s = A\left(u_s^k K_s\right)^{\alpha}\left(z_s n_s\right)^{1-\alpha} \tag{9}$$

where Y_s denotes output, $A > 0$ is a constant, $\alpha \in (0,1)$ is the elasticity of output to the effective input of capital services and z_s denotes the level of labor augmenting technology. We assume that the latter grows at the constant rate $\gamma_z \geq 1$. Firms rent capital services and labor from the households at the prices r_s and w_s.

The government purchases goods from the private sector, G_s, which it finances with capital and labor income taxes. It is assumed to run a balanced budget and to transfer any differences between its current expenditure and its tax revenue back to the household sector in the form of lump sum transfers:

$$G_s + T_s = \tau_s^n W_s n_s + \tau_s^k\left(r_s u_s^k - \delta_k\right) K_s \tag{10}$$

We will assume that G_s grows at the constant rate γ_z. Thus, government lump-sum transfers vary endogenously in response to variations in government tax revenue. Allowing for endogenous variations in government debt would deliver exactly the same results.[12]

The capital income and labor income tax rates are assumed to evolve according to the stochastic processes:

$$\tau_s^n = \left(1-\rho_1^n-\rho_2^n\right)\tau^n + \rho_1^n\tau_{s-1}^n + \rho_2^n\tau_{s-2}^n + \varepsilon_s^n + \xi_{s-b}^n \tag{11}$$

$$\tau_s^k = \left(1-\rho_1^k-\rho_2^k\right)\tau^k + \rho_1^k\tau_{s-1}^k + \rho_2^k\tau_{s-2}^k + \varepsilon_s^k + \xi_{s-b}^k \tag{12}$$

where $\tau^n, \tau^k \in [0,1)$ are constants that determine the long run unconditional means of the two tax rates. We follow McGrattan (1994) and allow for an AR(2) structure of the tax processes with the restriction that $|\rho_1^n + \rho_2^n| < 1$ and $\left|\rho_1^k + \rho_2^k\right| < 1$.[13]

[12] To be precise, for given sequences of distortionary taxes and government spending, the equilibrium allocations assuming either endogenous variations in lump-sum transfers keeping government debt constrant or endogenous variations in government debt keeping lump-sum transfers constrant are identical. This follows from Ricardian equivalence.

[13] In the estimation step below, we found it useful to introduce a slightly stronger assumption, namely that ρ_1^n, $\rho_1^k \geq 0,\ \rho_2^n,\ \rho_2^k \leq 0$ and $|\rho_1^n + \rho_2^n|,\ \left|\rho_1^k + \rho_2^k\right| < 1$.

There are two types of innovations to the tax rate processes, unanticipated shocks, ε_s^n and ε_s^k, and anticipated shocks, ξ_{s-b}^n and ξ_{s-b}^k where $b \geq 1$ denotes the anticipation horizon. The notation pertaining to these innovations indicates that, as of period s, the tax rates in period $s+1$ are stochastic due to the unanticipated shocks. The anticipated tax shocks to the tax rates in period $s+1$ on the other hand enter the households' information set at the time that they are announced, i.e. in period $s-b+1$. This means that at date s, the consumer is informed about the current period's surprise tax changes, ε_s^n and ε_s^k, and receives new information about the pre-announced component of tax rate changes in period $s+b$, ξ_{s+b}^n and ξ_{s+b}^k. We assume that the innovations to the tax rates are i.i.d. with zero mean, $\varepsilon_s \sim iid\left(0, \Omega_\varepsilon\right)$ and $\xi_s \sim iid\left(0, \Omega_\xi\right)$ where $\varepsilon_s = \left[\varepsilon_s^n, \varepsilon_s^k\right]'$ and $\xi_s = \left[\xi_s^n, \xi_s^k\right]'$. The innovations to the tax rates are allowed to be correlated but we assume that ε_s and ξ_{s-b} are orthogonal.

The aggregate resource constraint in the economy is given by:

$$C_s + D_s + I_s + G_s \leq Y_s \tag{13}$$

Our inclusion of consumer durables, habit formation, and variable capacity utilization in the home-production sector is potentially important for the response of consumption of nondurables and services to anticipated changes in taxes during the pre-implementation period. When a tax cut is announced but not yet implemented, the main channel through which the economy is affected is through the effect on household wealth. In a model without the aspects just listed, the wealth effect will tend to be associated with an immediate increase in consumption of nondurables and services regardless of whether the change in taxes relates to labor income tax rates or capital income tax rates. Clearly, this prediction is in contrast to the empirical results of Section 2. Due to habit formation, households are less willing to choose consumption streams that give rise to sudden changes in consumption. For that reason, habit formation potentially allows for a smoother increase in consumption during the pre-implementation period. The presence of durable consumption goods and the complementarity between consumption of nondurables and consumption of the service flow of the durables stock, implies less tendency for an increase in nondurables consumption during the pre-implementation period. The reason for this is that the

drop in savings that occurs due to the wealth effect, depresses consumer durables spending. This effect is reinforced by variable capacity utilization in the home-production sector. Whether these aspects allow us match the dynamics of consumption clearly depends on the parameter values which we will estimate in the next section.

3.2 Estimation

We examine the extent to which the model can account for the VAR evidence on the effects of tax liability changes in the U.S. that we documented in Section 2. For this purpose we estimate the parameters describing preferences, technology, and fiscal policy.

We adopt the following estimation strategy. We partition the set of parameters into two subsets: $\Theta = [\Theta_1', \Theta_2']'$ where Θ_1 is a vector of parameters that we will calibrate and Θ_2 is a vector of parameters that we will formally estimate. The vector of parameters that we calibrate contains those parameters that are either difficult to estimate econometrically or for which we believe that there are good grounds for selecting their value through a calibration exercise. We first discuss the calibration of the parameters in Θ_1.

In order to match the frequency of the observed data, we set one model period equal to 3 months. Given this, we calibrate β, the subjective discount factor, to match a 3 percent annual real interest rate. We calibrate ω, the preference weight on the disutility of work, so that steady state hours work are equal to 25 percent. The share parameter γ determines households' expenditure on durable consumption goods relative to nondurables and services. This parameter is calibrated so that durables consumption expenditure accounts for 11.9 percent of total consumption expenditure. This number matches the expenditure share of consumer durables (relative to total consumption expenditure) in the U.S. in the sample that we studied in Section 2.

We normalize steady state output (divided by the level of labor augmenting technology) to 1 and calibrate the constant A that enters equation (9) to match this normalization. The rate of labor augmenting technological progress, γ_z, is assumed to be equal to 1.005 to match a long run annual growth rate of the economy equal to approximately 2 percent, the average growth rate of real per capita U.S. GDP in the post war period. Along the balanced growth path, the

rates of capacity utilization in the home-production and in the market sector are normalized to unity. Therefore, δ_v and δ_k denotes the depreciation rates of the two capital stocks along the balanced growth path. We assume that $\delta_v = \delta_k = 0.025$ so that the annual rate of depreciation at a normal rate of capacity utilization is approximately 10 percent. We set α equal to 36 percent which produces income shares close to those observed in the U.S.

In order to match our measurement in Section 2, we assume that the announcement horizon is equal to 6 quarters. Thus, we set the parameter b in equations $(11) - (12)$ equal to 6. Next, we set the steady state tax rates, τ^n and τ^k, equal to 26 percent and 42 percent, respectively, These values match the average effective U.S. tax rates for labor and capital income estimated by Mendoza, Razin and Tesar (1994). Finally, we assume that tax liability shocks give rise changes in both the capital income tax rate and in the labor income tax rate and that the two tax innovations are of equal size. Our motivation for this assumption is that most of the tax liability changes listed in Table A.1 affect the taxation of both types of income. Ideally, we would like to discriminate between these two forms of taxation but the tax data do not allow for this. We will later examine the consequences of this assumption. Table 1 summarizes the calibration of the vector Θ_1.

The vector of parameters that we estimate formally consists of the following parameters, $\Theta_2 = \left[\sigma, \kappa, \phi_v, \phi_k, \psi_v, \psi_k, \rho_1^n, \rho_2^n, \rho_1^k, \rho_2^k\right]'$ where ϕ_v denotes $\Phi_v''(\gamma_z)$, ψ_v denotes $\Psi_v''(\gamma_z)/\Psi_v'(\gamma_z)$, and ϕ_v and ψ_v are defined symmetrically.

We estimate this parameter vector by matching the empirical impulse response functions that we derived in Section 2. However, the model does not give rise to a finite order VAR representation of the vector of observables that were included in the empirical VAR. Thus, rather than matching the exact model based impulse response functions with the empirical impulse responses, we apply a simulation estimator.[14] To be precise, we estimate Θ_2 as the vector of

[14]See Cogley and Nason (1995) for an early application of such an approach and Kehoe (2006) for a recent discussion of its advantages.

variables that solves the following minimization problem:

$$\widehat{\Theta}_2 = \arg\min_{\Theta_2} \left[\left(\widehat{\Lambda}_T^d - \Lambda_T^m \left(\Theta_2 | \Theta_1 \right) \right)' \Sigma_d^{-1} \left(\widehat{\Lambda}_T^d - \Lambda_T^m \left(\Theta_2 | \Theta_1 \right) \right) \right] \tag{14}$$

where $\widehat{\Lambda}_T^d$ denotes the (vectorized) empirical responses that we aim at matching, $\Lambda_T^m \left(\Theta_2 | \Theta_1 \right)$ are the equivalent estimates from the theoretical model and Σ_d^{-1} is a weighting matrix. The empirical responses include the responses of the five variables in X_t for a forecast horizon at T quarters in response to unanticipated tax liability changes and the responses of X_t to the anticipated tax liability change for K quarters before its implementation until T quarters afterwards. We set the forecast horizon equal to 24 quarters (as in Section 2) and we allow for 6 quarters of pre-announcement effects in the case of anticipated tax shocks. We choose the weighting matrix to be a be a diagonal matrix with the estimates of the inverse of the sampling variance of the relevant impulse responses along its diagonal.

We calculate the model equivalent of the empirical impulse responses in the following fashion:

1. First, we simulate the model in response to anticipated and unanticipated tax liability changes. We do this by drawing 100 sequences of tax innovations from observed U.S. data (with replacement) each for a time-horizon of 228 quarters (which matches the length of the U.S. data that we use for estimation of the empirical VAR). We then simulate the economy in response to this sequence of tax innovations. In order to compute the competitive equilibrium allocation, we first make a stationarity inducing transformation of the economy. We accomplish this by dividing each of the variables that are growing over time by z_t. Next, we log-linearize the first order necessary optimality conditions of the model around the deterministic steady state. The competitive equilibrium is then derived by solving the resulting set of (log) linear stochastic difference equations with a standard numerical method. After this, we convert the simulated time paths of the variables into their log-levels by adding the log steady-state levels and adding the logarithms of z_t (to the growing variables). This gives us 100 sample paths of the vector X produced by the model given the parameter vector Θ (each of a length of 228 quarters). Denote this collection of vectors by $X^j \left(\Theta_2 | \Theta_1 \right)$ where $j = 1, .., 100$ denotes the j'th replication.

2. The empirical VAR cannot directly be estimated on this artificial data due to stochastic singularity. Therefore, as a second step we add a small amount of measurement error to $X^j(\Theta_2|\Theta_1)$. Let $\widetilde{X}^j(\Theta_2|\Theta_1)$ denote the resulting artificial samples of X.

3. For each of these artificial datasets we estimate the following VAR:

$$\widetilde{X}_t^j(\Theta_2|\Theta_1) = \mathfrak{A}^j + \mathfrak{B}^j t + \mathfrak{C}^j(L)\widetilde{X}_{t-1}^j(\Theta_2|\Theta_1) + \mathfrak{D}^j(L)\widetilde{\tau}_t^{u,j} + \mathfrak{F}^j(L)\widetilde{\tau}_{t,t}^{a,j} + \sum_{i=1}^{K}\mathfrak{G}_i^j\widetilde{\tau}_{t+i,t}^{a,j} + \widetilde{e}_t^j$$

where $\widetilde{\tau}_t^{u,j}$ and $\widetilde{\tau}_{t+1,t}^{a,j}$ denote the sequences of tax liability shocks that we have drawn for the j'th replication. From the artificial VARs we then estimate the model equivalent of the empirical impulse response functions. Finally, we average the impulse responses over the 100 replications and this gives us the estimate of $\Lambda_T^m(\Theta_2|\Theta_1)$.

Following Hall et al (2007) , we compute the standard errors of the vector Θ_2 from an estimated of its asymptotic covariance matrix as:

$$\Sigma_{\Theta_2} = \Lambda_{\Theta_2}\frac{\partial\Lambda_T^m(\Theta_2|\Theta_1)'}{\partial\Theta_2}\Sigma_d^{-1}\Sigma_S\Sigma_d^{-1}\frac{\partial\Lambda_T^m(\Theta_2|\Theta_1)}{\partial\Theta_2}\Lambda_{\Theta_2}$$

where:

$$\begin{aligned}\Lambda_{\Theta_2} &= \left[\frac{\partial\Lambda_T^m(\Theta_2|\Theta_1)'}{\partial\Theta_2}\Sigma_d^{-1}\frac{\partial\Lambda_T^m(\Theta_2|\Theta_1)}{\partial\Theta_2}\right]^{-1}\\ \Sigma_S &= \Sigma + \frac{1}{S^2}\sum_{s=1}^{S}\Sigma_s\end{aligned}$$

where Σ is the covariance matrix of the impulse responses that we estimated empirically in Section 2, and Σ_s is the covariance matrix of the s'th replication of the model based impulse responses.

4 Results

Table 2 contains the results of the estimation of Θ_2. We find a point estimate of the habit persistence parameter, κ, of 0.874 which implies a large effect of past consumption on consumers' current marginal utility of consumption. This value is very similar to the estimates of e.g. Altig

et al (2004). The curvature parameter σ is estimated to be equal to approximately 2.4 with a tight confidence interval. The estimate of the adjustment cost parameter ϕ_k is 2.4. This implies moderately high adjustment costs of the capital stock. The adjustment cost parameter for consumer durables, ϕ_k, is estimated to be 3.2. Thus, according to our estimates, it is more costly to quickly adjust the capital stock in the home-production sector than in the market sector. Similarly, we find that variations in the rate of capital utilization of the stock of durables is more costly in terms of wear and tear than variations in the capital stock used for the production of market goods. Our point estimates of these parameters are $\psi_k = 0.044$ and $\psi_v = 0.496$.

We find that it is important to model the tax processes as second order autoregressive processes rather than simple first order autoregressions. Our point estimates for the labor income tax process are $\rho_1^n = 1.426$ and $\rho_2^n = -0.427$ while those for the capital income tax process are $\rho_1^k = 1.091$ and $\rho_2^k = -0.221$. Figure 5 illustrates the resulting responses of the tax rates to a one percentage point fall in total tax liabilities. The implied change in the labor income tax rate is extremely persistent and while the response of the capital income tax rate is much less persistent with most of the initial change having dissipated 2 years after the change in tax liabilities. Our estimates of the autoregressive parameters (and therefore of the dynamics of taxes) are extremely similar to the maximum likelihood estimates of McGrattan (1994) although she finds an even higher estimate of ρ_1^n (and a correspondingly lower estimate of ρ_2^n).[15] The similarity between our results and those of McGrattan's (1994) is reassuring given the difference in the approach to estimating the parameters of the tax processes.[16]

Given the parameter set $\widehat{\Theta}$, we find that the DSGE model constructed in Section 3 accounts extremely well for almost all the VAR moments of the U.S. data that we estimated in Section 3. In particular, the model economy reproduces the sizes and shapes of the response of the

[15] McGrattan's (1994) estimates of these two parameters are $\rho_1^n = 1.76$ and that $\rho_2^n = -0.775$. The estimates, however, are not entirely comparable because McGrattan (1994) allows technology shocks to affect tax rates and assumes spillovers between the two tax rates.

[16] McGrattan (1994) estimates the parameters of the tax processes (and other structural parameters) with maximum likelihood treating the tax rates as observable but the tax shocks as unobservable.

economy to an unanticipated tax cut, the pre-implementation lump of the economy in response to an anticipated tax cut, and the size and shapes of the responses to an anticipated tax cut once implemented.

Figure 6 illustrates the impact of a one percentage point change in tax liabilities for an unanticipated tax cut (the left column) and an anticipated tax cut (in the right column). In each of these figures we illustrate (a) the VAR based impulses that we estimated using U.S. data in Section 2 (along with their confidence intervals), (b) the VAR based model impulse responses, and (c) the exact model based impulse responses. The difference between the latter two impulse response functions is that the exact impulse responses do not impose the VAR structure but instead are derived directly from the solution to the model. Our estimation results imply that there are only minimal differences between the exact model based impulse responses and the VAR based model impulse responses.

As in the U.S. data, an unanticipated tax cut sets off a major expansion in the economy and in no case do the impulse responses generated by the model economy deviate significantly from the empirical estimates for more than a few quarters during the 6 year forecast horizon. Moreover, as in the U.S. data, the boom in consumption occurs earlier than in output and in investment. We also find a short lived drop in hours worked before it eventually goes above trend. Importantly, the model is consistent with our empirical finding that the elasticity of the investment response is much higher than that of any other variable. The only notable discrepancy between the empirical impulse responses to the unanticipated tax cut and those of the model is that consumer durables purchases are less sensitive to the tax cut in the model than in the data. The theoretical impulse responses, however, are within the 68% confidence intervals of the empirical impulse responses.

In response to an anticipated tax cut, the model implies a major contraction in output, investment, and hours worked during the pre-implementation period. The size and timing of the response of investment in the model economy is as good as identical to the empirical VAR estimates. The model also accounts very well for the dynamics of hours worked and output in response to the anticipated tax cut albeit both of these variables go above trend earlier in the

model economy than in the data.

In the empirical VAR, consumption of both nondurables and services and of durables are basically flat during the pre-implementation period. The model economy implies a slight increase in nondurables consumption while durables consumption declines by up to 3 percent in the pre-implementation period. However, the artificial impulse responses of both these variables are within the confidence bands of the empirical impulse responses. Moreover, although the model economy implies an increase in the consumption of nondurables, the size of the increase is rather small.

Once taxes are actually cut, the model implies a large expansion in the economy and the model-based impulse responses are very similar to the empirical VAR estimates apart from too fast a surge in consumption of nondurables in the model relative to the data. Nevertheless, the model responses of output, investment, durables consumption, and hours worked are extremely similar to the VAR responses.

Recall from Figure 2 that, in the U.S. data, the size of the pre-implementation contraction in output that occurs in response to an anticipated tax cut is smaller the shorter is the assumed implementation lag. We now examine whether the model in Section 2 is consistent with this. For that purpose, we compute the impulse response of output varying the parameter b in equations (11) and (12) from 4 to 10 quarters. We do this using the parameter estimates discussed above. The result is illustrated in Figure 7 and we see that the model produces exactly the same result as the empirical VAR: The shorter is the anticipation horizon, the smaller is the pre-implementation contraction of output while the post-implementation expansion of output is basically unaltered.

Therefore, the DSGE model presented in Section 2 appears to be very well suited for explaining how changes in tax liabilities affect the economy. Not only is the model able to account for the impact of unanticipated tax shocks, but it also can account for the contraction in the economy that occurs during the pre-implementation period in response to anticipated tax liability changes that we documented in the U.S. data.

4.1 Sensitivity Analysis

We now examine the extent to which the results depend on our modeling assumptions. We start by turning our attention to the impact of anticipated tax cuts on the consumption profile. As we have seen above, the model is quite successful in accounting for the flat consumption response during the pre-implementation period. This result goes against standard intuition and we now wish to bring out the sources of this feature of the model.

A key aspect of the model is the presence of consumer durables. Row (2) of Table 2 reports the parameter estimates of Θ_2 when we exclude consumer durables from the model. In this case, we estimate the structural parameters by matching the moments of a version of the VAR in equation (1) in which the vector of endogenous variables, X_t, does not include the purchases of consumer durables. There is little effect of excluding consumer durables on the estimated structural parameters apart from an increase in the estimated sensitivity of the depreciation rate of the capital stock to changes in the capacity utilization rate of the capital stock. Figure 8 shows the resulting impulse response functions along with those of the alternative empirical VAR. The model that abstracts from consumer durables still fits the response of output, investment and hours worked very well albeit the performance is marginally worse that the benchmark model. However, while the benchmark model can account quite well for the flat response of consumption to an anticipated tax cut during the pre-implementation period, the model without durables leads to a steady increase in consumption of nondurables and services during the pre-implementation period. The reason for this difference is that consumption of durables has a tendency to fall in response to the anticipated tax cut due to the implied fall in savings. The fall in purchases of durables is associated with a moderation of the tendency for an increase in consumption of nondurables because the two consumption goods are assumed to be complements. Row (3) of Table 2 re-introduces consumer durables into the model but restricts the capacity utilization rate of durables, u_t^v, to be constant in equations $(5) - (6)$. This restriction has little impact on the estimated parameters but, as shown in Figure 9, it implies a slightly less good fit of the response of consumption to the anticipated tax cut than the benchmark model. The reason for this is that the capacity utilization rate of the durables stock exacerbates the fall in consumer durables

during the pre-implementation period.

Another important aspect of the model in terms of the consumption response to tax changes is that we allow for habit formation. The presence of habits leads consumers to smooth the path of consumption in response to changes in taxes. Table 2, Row (4) reports the estimates of Θ_2 and Figure 10 illustrates the resulting impulse responses when we restrict the habit parameter to be equal to zero, $\kappa = 0$. This restriction leads to an increase in the estimated curvature parameter, σ, and an increase in the persistence of the tax processes. Most importantly, in the absence of habits, the model accounts much less well for the response of consumption to both types of tax changes, see Figure 9. In particular, in response to an unanticipated tax cut, consumption rises almost upon impact and no longer reproduces the steady increasing pattern that we observe in the data. In response to an anticipated tax cut, consumption is basically unaffected throughout the anticipation period but then rises immediately when taxes are eventually cut. Thus, the introduction of consumer durables and habits is essential in terms of accounting for the consumption dynamics.

In our benchmark model we assumed that lump-sum taxes respond to the changes in government tax revenue while government consumption grows at a constant rate. We now examine whether the results are fundamentally affected by assuming that the change in government revenue is absorbed by government spending rather than lump-sum taxes. Row (5) of Table 2 reports the parameter estimates under this alternative set of assumptions and Figure 11 illustrates the resulting impulse response functions. The main effect of this change in the model is that the estimated persistence of the tax processes declines while households' willingness to substitute consumption over time increases (due to a fall in the value of σ). However, the response of the economy to the two types of tax shocks is very similar to the benchmark model. Thus, it appears that this modeling aspect matters little for the results. This is perhaps a little bit surprising but is due to the fact that the response of the economy to changes in marginal taxes much dominates the response to changes in government purchases of goods and services.

Yang (2005) considers the effects of anticipated changes in labor and capital income tax rates separately. Assuming an anticipation horizon of 4 quarters, she shows that in response

to an anticipated cut in the labor tax rate, consumption rises during the pre-implementation period while output, investment and hours worked contract; in response to an anticipated cut in the capital income tax rate instead, the opposite pattern is implied. These results obviously differ fundamentally with ours since we find a flat response of consumption during the pre-implementation period which matches the VAR estimates for the U.S. economy derived in Section 2.

We have already discussed above how the consumption response to anticipated tax changes depend on the existence of consumer durables, variable capacity utilization and on the presence of habit formation. We now also examine whether our results depend critically on whether the tax changes affect labor income taxation or capital income taxation. Row (6) of Table 2 reports the parameter estimates when we assume that the tax liability cut leaves capital income taxes unaffected while Row (7) reports the alternative case with a constant labor income tax. The most notable impact on the estimated parameters is that the capital adjustment cost parameter, ϕ_k, becomes extremely high when we assume that the tax liability change affects only capital income taxes. Moreover, we find that the AR(2) coefficients of the tax processes are equal to zero in both cases.

Figures 12 and 13 report the resulting impulse response functions. We find that the benchmark model in which both tax rates are affected by the tax liability change outperforms either of the two alternative scenarios. When the capital income tax rate is held constant, the model accounts less well for the surge in investment following a cut in tax (regardless of whether the tax cut is anticipated or not) and implies a steady increase in consumption during the pre-implementation period in response to an anticipated tax cut. When the labor income tax rate is held constant, we find that an anticipated tax cut sets off increases in investment and in hours worked during the pre-implementation period, responses that are in contrast to the contractions in investment and hours worked that we estimate in the data. These responses are consistent with the results of Yang (2005). Thus, it appears that our assumption that tax liability changes affect both labor income taxes and capital income taxes is important since it allows us to fit both the consumption response and the impact on hours worked and on investment.

5 Tax Shocks and the Business Cycle

The empirical evidence of Section 2 regarding the effects of tax liability shocks, and the fact that the DSGE model proposed in Section 3 can account very successfully for the dynamic effects of tax policy shocks, makes it interesting to ask whether these shocks are important impulses to the U.S. business cycle. We now turn to this question which we address on the basis of counterfactual experiments. In particular, we use the empirical VAR estimates to simulate the time paths of the output, consumption, investment and hours worked that would have occurred had tax shocks been the only shocks to the economy. We first simulate the VAR when setting $e_t = \tau^a_{t+i,t} = 0$. In this case, all the variations in X_t (around its trend) are due unanticipated tax shocks. Next, we simulate the VAR when setting $e_t = \tau^u_t = 0$ in which case the fluctuations in X_t are due to anticipated tax shocks only. Finally, we simulate the VAR considering both types of tax shocks. We Hodrick-Prescott filter the resulting artificial time series and compare the counterfactual results with the actual Hodrick-Prescott filtered U.S. time series.[17]

The results are presented in Figure 14. Panel A shows the results for unanticipated tax shocks, Panel B reports the case of anticipated tax shocks, and Panel C shows the results when we allow for both types of tax shocks. From Panel A we see that the Revenue Acts of 1962 and 1964 explain much of the expansion output, in private sector nondurables and services consumption, and in private sector real investments in the mid 1960's. Moreover, the Revenue Act of 1971 accounts for a substantial fraction of the pre-OPEC I expansion in the early 1970's. Finally, the Bush tax cuts of the Jobs and Growth Tax Relief Reconciliation Act of 2003 provided a major boost to the economy in the mid 2000's.

Panel B illustrates the impact of anticipated tax liability changes. The results indicate that the Reagan tax initiative (the Economic Recovery Tax Act of 1981) and the Social Security Amendments of 1977 were instrumental for understanding the fluctuations in the economy in the early 1980's. The latter, which included a major anticipated tax increase in 1981, helped boosting the economy prior to its implementation while the former, which was associated with

[17] We use a value of 1600 for the smoothing parameter.

major anticipated tax cuts, depressed from late 1981 up till the end of 1983. When the tax increase associated with the Social Security Amendments of 1977 was eventually implemented in 1981, it reinforced the contractionary effects of the anticipated Reagan tax cuts. As the Reagan tax cut was implemented through 1982 to 1984 it boosted the economy. Together, these anticipated tax cuts therefore boosted the economy prior to 1981, led to a severe contraction from late 1981 to late 1983, and helped the economy recover thereafter. Our results therefore indicate that the early 1980's recession was mainly fiscal in nature rather than due to tight monetary policy during the Volcker monetary regime. Finally, we find that the Economic Growth and Tax Reconciliation Act of 2001 (signed in June 2001, implemented in the first quarter of 2002) provided a major stimulus to the economy after their implementation.

Panel C shows the total contribution of tax liability changes to the U.S. business cycle. The combination of the two tax liability shocks accounts quite well for the U.S. business cycle and tax shocks appear non-trivial as impulses to the business cycle. Over the sample period that we study, the standard deviation of (Hodrick-Prescott filtered) output is 1.62 percent. The standard deviation of the counterfactual series when we feed in the two types of tax policy shocks is 0.70 percent and the cross-correlation between these two time-series is 53 percent. The standard deviation of the counterfactual investment time series when we allow for both types of two shocks is 2.65 percent which corresponds to approximately 47 percent of the standard deviation of the actual time series for investment (5.59 percent).

Thus, our results are supportive of Braun (1994) and McGrattan (1994) who find that tax shocks are important impulses to the U.S. business cycles. Our analysis has added to this literature three main findings. First, empirically it is relevant to distinguish between anticipated and unanticipated tax shocks. Secondly, anticipated tax cuts (increases) are associated with a major contraction (boom) in the economy prior to their implementation. Thirdly, economy theory can account very well for the aggregate effects of anticipated as well as unanticipated tax shocks.

6 Conclusions

We have provided empirical evidence on the aggregate effects of U.S. tax liability changes. Based on Romer and Romer's (2007a) narrative account of U.S. fiscal policy shocks, we made a distinction between anticipated and unanticipated tax liability changes based on the time difference between the dates at which tax liability changes were signed by the President and the dates at which the tax liability changes were due. Using a VAR methodology we showed that the implementation of a tax liability cut gives rise to major expansion in the economy which manifests itself as increases in output, consumption, investment and hours worked. The expansionary effects of tax liability cuts arise regardless of whether it is anticipated or unanticipated. However, during the pre-implementation period of an anticipated tax cut, we find a major contraction in output, investment and hours worked. In other words, there is overwhelming evidence in favor of anticipation effects of tax policy interventions. The anticipation effect is particularly large for investment in capital goods while there is little impact on consumption of nondurables and services.

We showed that economic theory can account for the empirically estimated impulse responses. In particular, we construct a DSGE model that is consistent with both the finding that pre-announced tax cuts are contractionary in the pre-implementation period, and with the finding that once taxes are cut (regardless of whether the tax cut is anticipated or not), the economy moves into an expansionary phase relatively quickly. Moreover, in line with the empirical estimates, the model implies large effects of tax cuts on private sector investment and more muted response of private sector consumption of nondurables and services. Fundamental for our ability to account for the effects of pre-announced tax changes is the fact that we introduce consumption of durable goods, that we allow for variable capacity utilization, that we introduce habit formation, and that we assume that tax liability changes give rise to changes in both labor income tax rates and in capital income tax rates.

We argue that tax liability changes are empirically relevant as impulses to the U.S. business cycle. We show that tax liability changes can account for around 43 percent of the standard

deviation of output at the business cycle frequencies during the sample period that we consider which covers most of the post-WWII period. This is an important result since it implies that such shocks should be observe more attention in the business cycle literature. Moreover, we argue that anticipation effects are also empirically relevant. In particular, we find that the early 1980's recession to a large extent can be accounted for by the recessionary effects of anticipated future tax cuts. Therefore, we believe that tax shocks should receive more attention in the business cycle literature and that it is important to take into account that fiscal shocks often are associated with important implementation lags.

7 References

Beaudry, Paul, and Franck Portier, 2004, "An Exploration into Pigou's Theory of Cycles", *Journal of Monetary Economics* 51, 1183-1216.

Beaudry, Paul, and Franck Portier, 2006, "News, Stock Prices and Economic Fluctuations", forthcoming, *American Economic Review.*

Blanchard, Olivier, and Roberto Perotti, 2002, "An Empirical Investigation of the Dynamic Effects of Changes in Government Spending and Taxes on Output", *Quarterly Journal of Economics*, 1329-68.

Braun, R. Anton, 1994, "Tax Disturbances and Real Economic Activity in the Postwar United States", *Journal of Monetary Economics* 33(3), 441-62.

Christiano, Lawrence, Martin Eichenbaum, and Charles Evans, 2004, "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy", *Journal of Political Economy* 113, 1-49.

Cochrane, John, 1994, "Shocks", *Carnegie-Rochester Series on Public Policy* 41, 295-364.

Cogley, Tim, and James M. Nason, 1995, "Output Dynamics in Real-Business-Cycle Models", *American Economic Review.*79(4), 492-511.

Danthine, Jean Pierre, John B. Donaldson and Thore Johnsen, 1998, "Productivity Growth, Consumer Confidence and the Business Cycle", *European Economic Review* 42, 1113-40.

Den Haan, Wouter J., and Georg Kaltenbrunner, 2006, "Anticipated Growth and Business Cycles in Matching Models", manuscript, University of Amsterdam.

Francis, Neville, and Valerie Ramey, 2005, "Is the Technology Driven Business Cycle Hypothesis Dead? Shocks and Aggregate Fluctuations Revisited", *Journal of Monetary Economics* vol.52(8), 1379-99.

Hall, Alastair, Atsushi Inoue, James M. Nason, and Barbara Rossi, 2007, "Information Criteria for Impulse Response Function Matching Estimation of DSGE Models", manuscript, Duke University.

Jaimovich, Nir, and Sergio T. Rebelo, 2006, "Can News About the Future Drive the Business Cycle?", manuscript, Northwestern University.

Kehoe, Patrick J., "How to Advance Theory with Structural VARs: Use the Sims-Cogley-Nason Approach", Research Department Staff Report 379, Federal Reserve Bank of Minneapolis.

Leeper, Eric M., and Shu-Chun Susan Yang, 2006, "Dynamic Scoring: Alternative Financing Schemes", manuscript, Indiana University.

Lustig, Hanno, Chris Sleet, and Sevin Yeltekin, 2007, "Does the U.S. Government Hedge against Expenditure Risk?", manuscript UCLA.

McGrattan, Ellen R., 1994, "The Macroeconomic Effects of Distortionary Taxation", *Journal of Monetary Economics* 33(3), 573-601.

Mendoza, Enrique G., Assaf Razin and Linda L. Tesar, 1994, "Effective Tax Rates in Macroeconomics: Cross-Country Estimates of Tax-Rates of Factor Incomes and Consumption", *Journal of Monetary Economics*.

Parker, Jonathan A., 1999, "The Reaction of Household Consumption to Predictable Changes in Social Security Taxes", *American Economic Review* vol.89(4), 959-73.

Perotti, Roberto, 2007, "Estimating the Effects of Fiscal Policy in OECD Countries", forthcoming, **NBER Macroeconomics Annual**.

Pigou, Arthur, 1927, **Industrial Fluctuations**, MacMillan: London.

Poterba, James M., 1988, "Are Consumers Forward Looking? Evidence from Fiscal Experiments", *American Economic Review* vol.78(2), 413-18.

Ramey, Valerie A., and Matthew D. Shapiro, 1998, "Costly Capital Reallocation and the Effects of Government Spending", *Carnegie-Rochester Series on Public Policy*

Romer, Christina D., and David H. Romer, 2007a, "A Narrative Analysis of Postwar Tax Changes", manuscript, University of California, Berkeley.

Romer, Christina D., and David H. Romer, 2007b, "The Macroeconomic Effects of Tax Changes: Estimates Based on a New Measure of Fiscal Shocks", manuscript, University of California, Berkeley.

Souleles, Nicholas S., 1999, "The Response of Household Consumption to Income Tax Refunds", *American Economic Review* vol.89(4), 947-58.

Souleles, Nicholas S., 2002, "Consumer Response to the Reagan Tax Cut", *Journal of Public Economics* vol.85, 99-120.

Yang, Shu-Chun Susan, 2005, "Quantifying Tax Effects Under Policy Foresight", *Journal of Monetary Economics* 52(8), 1557-68.

Table A.1: Tax Liability Changes

Name	Signed	Effective	Type	Size
1. Social Security Amendments of 1947	August 1947	1950 Q1	Anticipated	0.27
2. Revenue Act of 1948	April 1948	1948 Q2	Surprise	-3.74
	April 1948	1948 Q3	Surprise	1.82
3. Social Security Amendments of 1950	August 1950	1954 Q1	Anticipated	0.35
4. Expiration of Excess Profits and	October 1951	1954 Q1	Anticipated	-0.35
Temporary Income Tax				
5. Internal Revenue Code of 1954	August 1954	1954 Q3	Surprise	-1.13
	August 1954	1954 Q4	Surprise	0.72
6. Tax Rate Extension Act of 1958	June 1958	1958 Q3	Surprise	-0.11
7. Social Security Amendments of 1958	August 1958	1960 Q1	Anticipated	0.36
8. Federal-Aid Highway Act of 1959	September 1959	1959 Q4	Surprise	0.12
9. Social Security Amendments of 1961	Jun 1961	1963 Q1	Anticipated	0.33
10. Changes in Depreciation Guidelines	July 1962	1962 Q3	Surprise	-0.68
and Revenue Act of 1962	July 1962	1962 Q4	Surprise	0.45
	October 1962	1962 Q4	Surprise	-0.61
	October 1962	1963 Q1	Surprise	0.45
	October 1962	1963 Q1	Surprise	0.10
11. Revenue Act of 1964	February 1964	1964 Q2	Surprise	-2.55
	February 1964	1964 Q3	Anticipated	1.25
	February 1964	1965 Q1	Anticipated	-0.65
12. Excise Tax Reduction of 1965	June 1965	1965 Q3	Surprise	-0.24
	June 1965	1966 Q1	Anticipated	-0.23
13. Tax Adjustment Act of 1966	March 1966	1966 Q2	Surprise	0.12
14. Public Law 90-26	June 1967	1967 Q3	Surprise	-0.66
	June 1967	1967 Q4	Anticipated	0.46
15. Social Security Amendments of 1967	January 1967	1971 Q1	Anticipated	-0.33

Table A.1 continued

Name	Signed	Effective	Type	Size
16. Tax Reform Act of 1969	December 1969	1971 Q1	Anticipated	-0.09
	December 1969	1972 Q1	Anticipated	-0.09
17. Reform of Depreciation Rules	January 1971	1971 Q1	Surprise	-0.25
18. Revenue Act of 1971	December 1971	1972 Q1	Surprise	-1.23
	December 1971	1972 Q2	Anticipated	0.55
19. 1972 Changes to Social Security	October 1972	1978 Q1	Anticipated	0.13
20. Tax Reform Act of 1976	October 1976	1976 Q4	Surprise	0.13
	October 1976	1977 Q1	Surprise	-0.04
21. Social Security Amendments of 1977	December 1977	1979 Q1	Anticipated	0.36
	December 1977	1980 Q1	Anticipated	0.06
	December 1977	1981 Q1	Anticipated	0.56
	December 1977	1982 Q1	Anticipated	0.05
22. Revenue Act of 1978	November 1978	1979 Q1	Surprise	-0.77
23. Crude Oil Windfall Profit	April 1980	1980 Q2	Surprise	0.30
Tax Act of 1980	April 1980	1981 Q1	Anticipated	0.13
	April 1980	1982 Q1	Anticipated	0.13
24. Economic Recovery Tax Act	August 1981	1981 Q3	Surprise	-0.84
of 1981	August 1981	1981 Q4	Surprise	0.56
	August 1981	1982 Q1	Anticipated	-1.53
	August 1981	1983 Q1	Anticipated	-1.69
	August 1981	1984 Q1	Anticipated	-1.28
25. Tax Equity and Fiscal	September 1982	1983 Q1	Anticipated	0.78
Responsibility Act of 1982				

Name	Signed	Effective	Type	Size
26. Social Security Amendments	April 1983	1984 Q1	Anticipated	0.32
of 1983	April 1983	1985 Q1	Anticipated	0.21
	April 1983	1986 Q1	Anticipated	0.10
	April 1983	1988 Q1	Anticipated	0.31
	April 1983	1990 Q1	Anticipated	0.18
27. Deficit Reduction Act of 1984	July 1984	1984 Q3	Surprise	0.20
28. Tax Reform Act of 1986	October 1986	1986 Q4	Surprise	0.50
	October 1986	1987 Q1	Surprise	-0.31
	October 1986	1987 Q3	Anticipated	-0.42
29. Omnibus Budget Reconcialiation	December 1987	1988 Q1	Surprise	0.22
Act of 1987				
30. Omnibus Budget Reconcialiation	November 1990	1991 Q1	Surprise	0.60
Act of 1990				
31. Omnibus Budget Reconcialiation	August 1993	1993 Q3	Surprise	1.02
Act of 1993	August 1993	1993 Q4	Surprise	0.59
	August 1993	1994 Q1	Anticipated	0.19
32. Tax Payer Relief Act and	August 1997	2000 Q1	Anticipated	0.02
Balanced Budget Act of 1997	August 1997	2002 Q1	Anticipated	0.01
33. Economic Growth and Tax Relief	June 2001	2002 Q1	Anticipated	-0.80
Reconciliation Act of 2001				
34. Jobs and Growth Tax Relief	May 2003	2003 Q3	Surprise	-2.86
Reconciliation Act of 2003	May 2003	2004 Q3	Anticipated	1.70
	May 2003	2005 Q1	Anticipated	0.56

Source: Romer and Romer, 2007a and Bureau of Economic Analysis. Tax liability changes with more than 90 days difference between the signing of the legislation and their implementation are classified as anticipated tax liability changes. Sizes are measured by the implied tax liability impact divided by that quarter's current price GDP at the annual rate.

Table A.2: Definitions of Variables

Variable	Definition	Source
Output	Nominal GDP divided by its implicit deflator and by population	Bureau of Economic Analysis
Consumption	Consumers nominal expenditure on non-durables divided by its deflator and expenditure on services divided by its deflator and by population	Bureau of Economic Analysis
Durables	Consumers nominal expenditure on durables	Bureau of Economic Analysis
Purchases	divided by its deflator and by population	
Investment	Sum of private sector gross investment divided by its deflator and government investment divided by its deflator. The sum is divided by population.	Bureau of Economic Analysis
Hours worked	Product of hours per worker and civilian non-farm employment divided by population combined with Francis and Ramey (2002) hours worked series.	Bureau of Economic Analysis and Francis and Ramey (2002)
Population	Population above 16 years of age	Bureau of Labor Statistics

Table 1: Baseline Calibration

Calibrated parameters		
Parameter	**Value**	
$1-\alpha$	0.64	The elasticity of output to hours worked
β	$1.03^{-0.25}$	Subjective discount factor
δ	0.025	Steady-state depreciation rate
τ^k	0.42	Steady-state capital income tax rate
τ^n	0.26	Steady-state labor income tax rate

Table 2: Estimation Results

	Parameter									
Model	σ	κ	ϕ_k	ψ_k	ϕ_v	ψ_v	ρ_1^n	ρ_2^n	ρ_1^k	ρ_2^k
(1) Benchmark	2.421	0.874	2.430	0.044	3.239	0.496	1.426	-0.427	1.091	-0.221
	(0.228)	(0.109)	(0.130)	(0.008)	(0.454)	(0.312)	(0.138)	(0.134)	(0.205)	(0.262)
(2) No durables	2.543	0.883	2.321	0.089	-	-	1.479	-0.480	1.196	-0.294
	(0.191)	(0.089)	(0.233)	(0.015)			(0.181)	(0.191)	(0.197)	(0.205)
(3) Fixed utilization	2.363	0.907	2.481	0.064	4.189	-	1.469	-0.469	1.200	-0.315
of durables	(0.191)	(0.071)	0.203)	(0.010)	(0.540)		(0.158)	(0.170)	(0.201)	(0.193)
(4) No habits	4.092	-	3.238	0.079	4.290	0.198	1.538	-0.539	1.318	-0.396
	(0.377)		(0.186)	(0.025)	(0.494)	(0.105)	(0.134)	(0.091)	(0.192)	(0.128)
(5) Variable governm.	1.328	0.900	1.716	0.022	1.846	0.128	1.107	-0.108	0.829	0^*
spending	(0.121)	(0.055)	(0.057)	(0.003)	(0.109)	(0.042)	(0.102)	(0.247)	(0.091)	
(6) Fixed capital tax	1.334	0.918	2.062	0.275	2.558	1.553	0.999^*	0^*	-	-
	(0.076)	(0.059)	0.064)	(0.030)	(0.196)	(0.412)				
(7) Fixed labor tax	1^*	0.741	178.65	0.149	1.687	0.056	-	-	0.973	0^*
		(0.016)	(141.66)	(0.022)	(0.108)	(0.021)			(0.026)	

Standard errors are given in the parentheses.

$*$: The parameter was up against the boundary of the permissable parameter set.

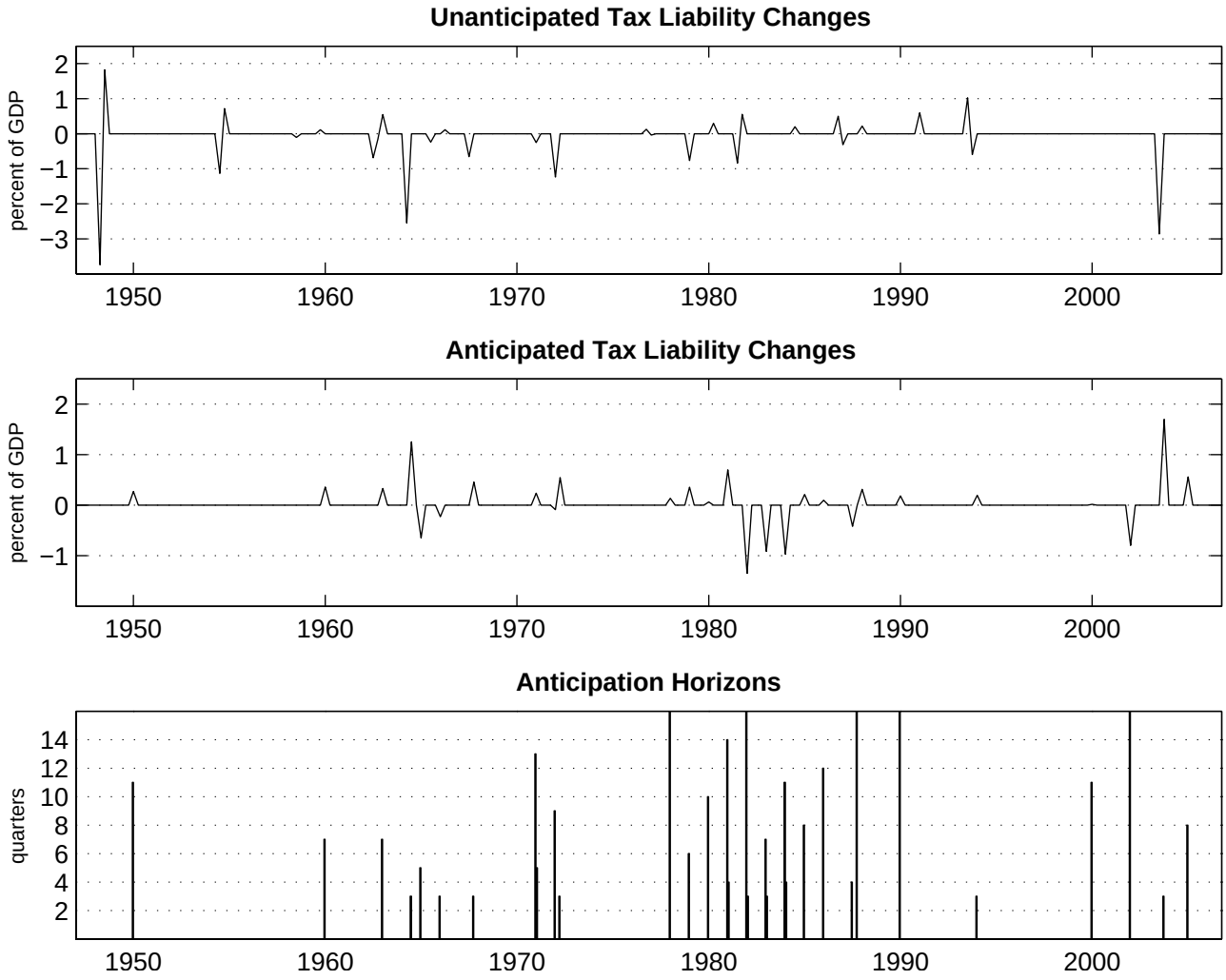

Figure 1: Tax Liability Changes

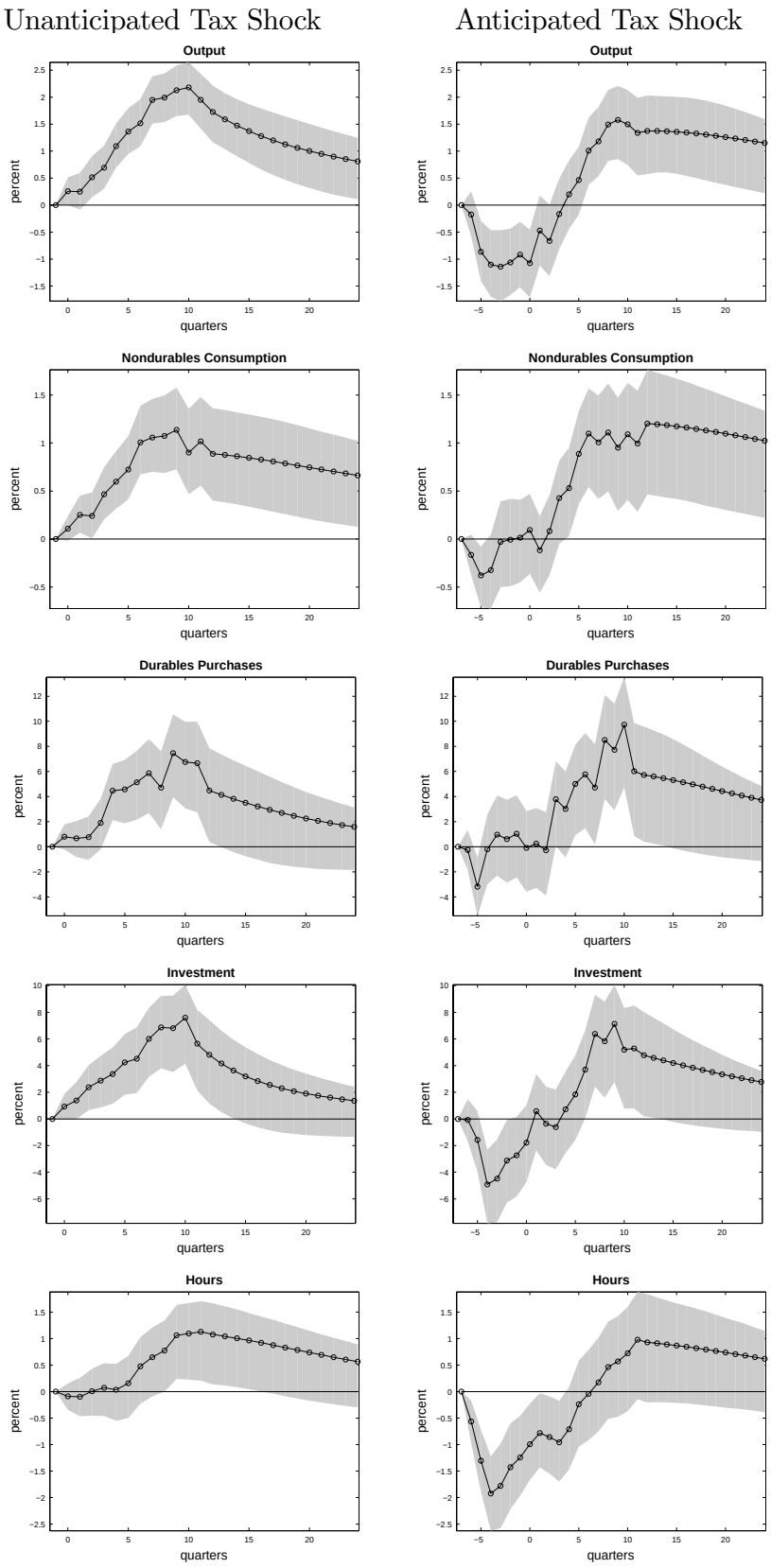

Figure 2: The Responses to Tax Shocks in the U.S.

(anticipated tax shocks are announced at date -6 and implemented at date 0)

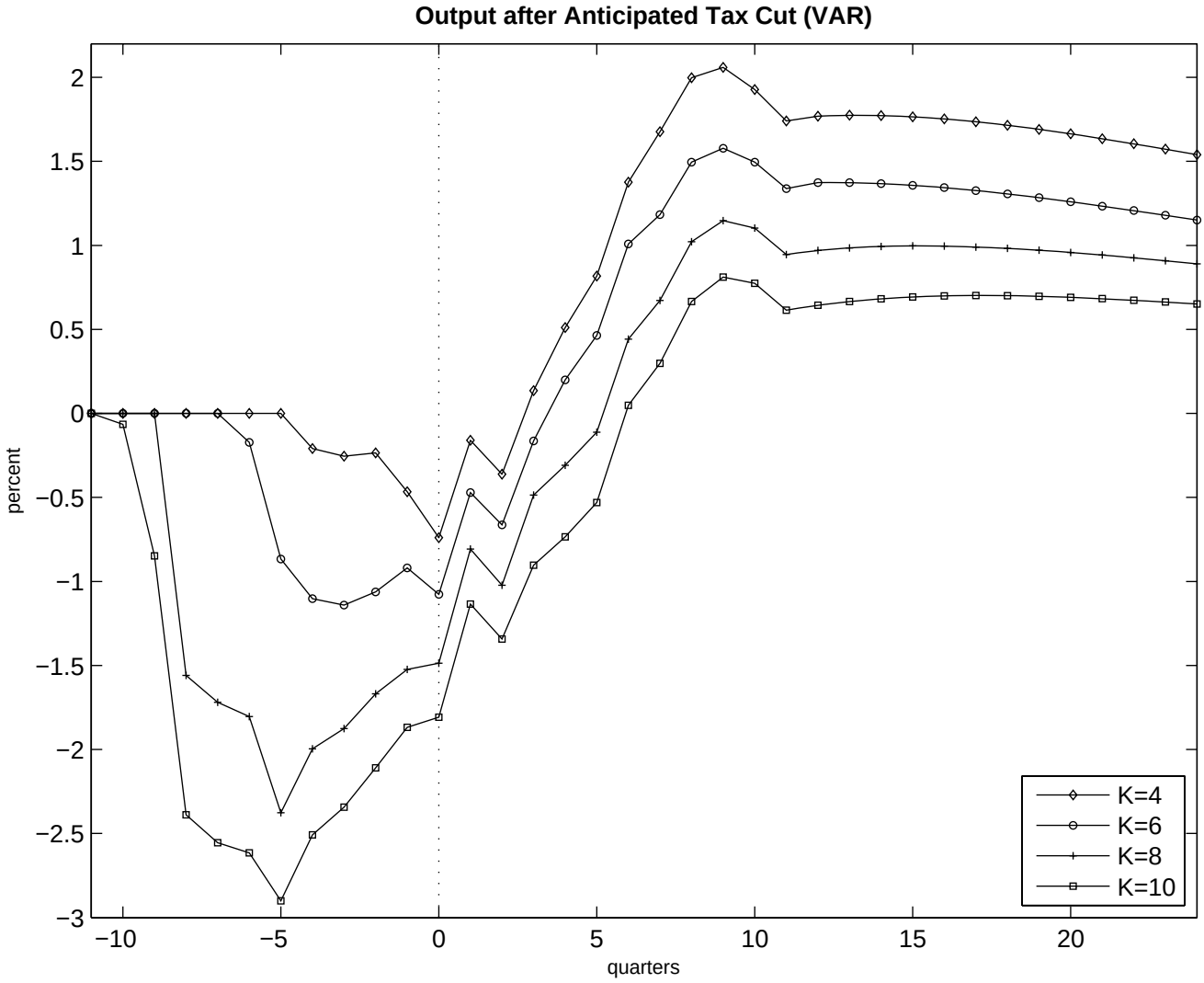

Figure 3: The Effects of Anticipated Tax Cuts for Alternative Anticipation Horizons.

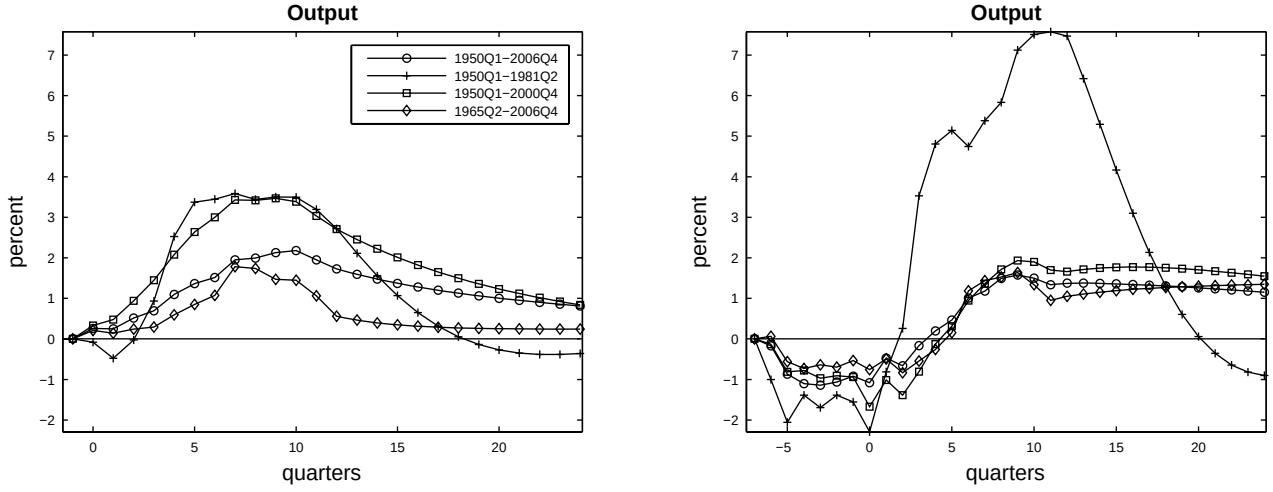

Figure 4. The Effects of Tax Shocks for Alternative Sample Periods

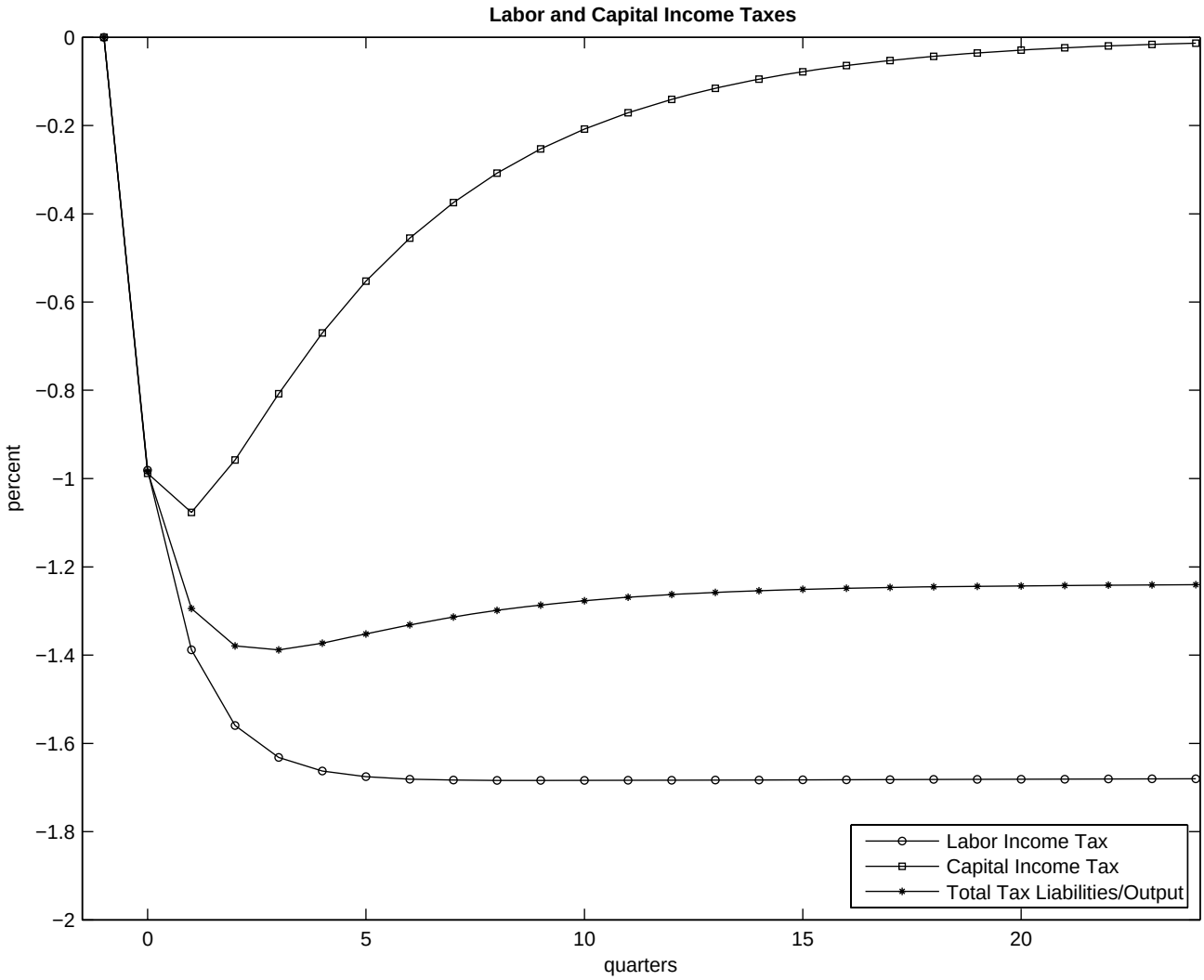

Figure 5: The Dynamics of Taxes in the Model Economy

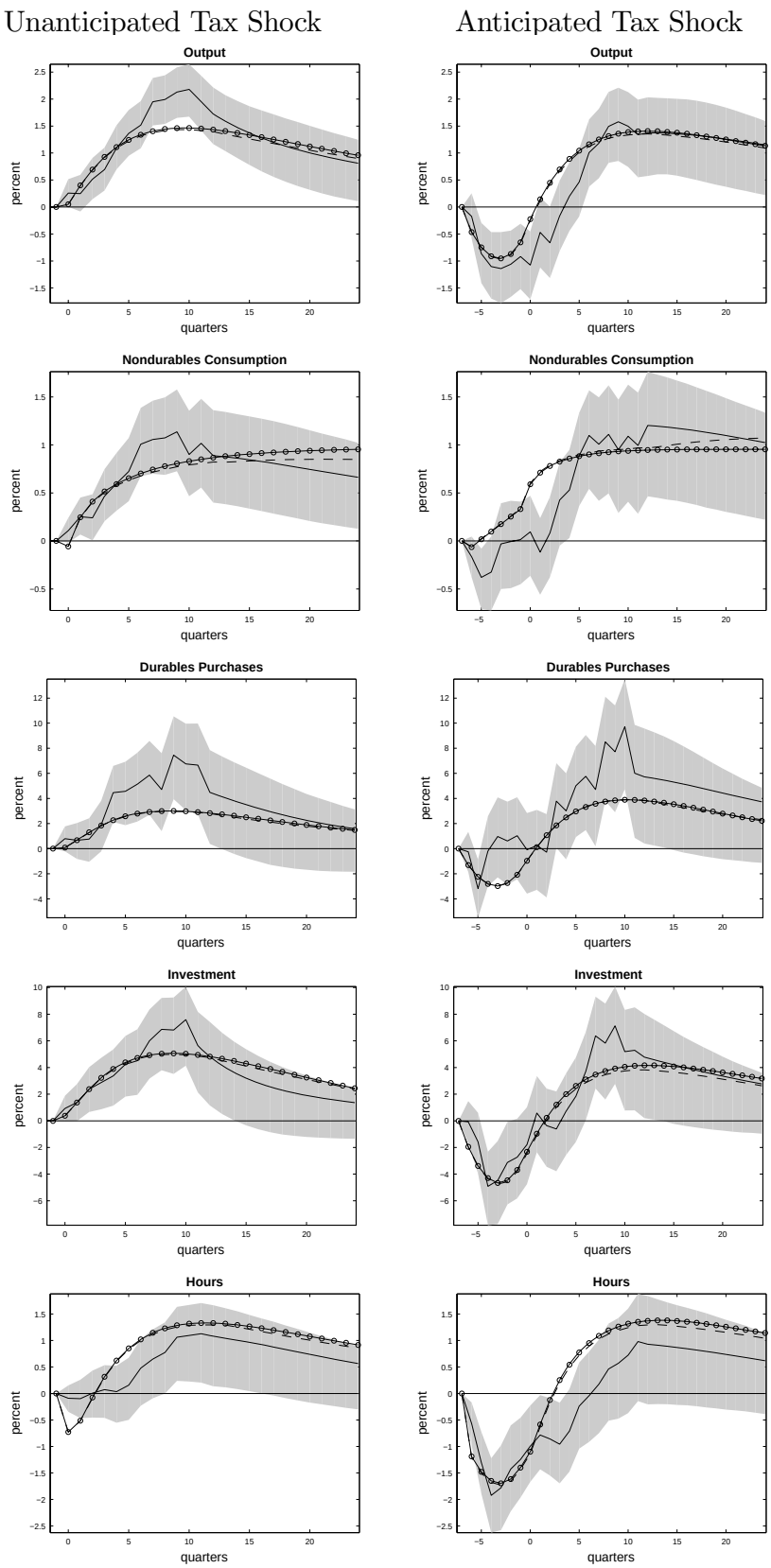

Figure 6: The Impulse Responses of the Benchmark Model (full drawn lines: empirical IRs, dotted lines: the exact model IRs, lines with circles: the model IRs imposing a VAR)

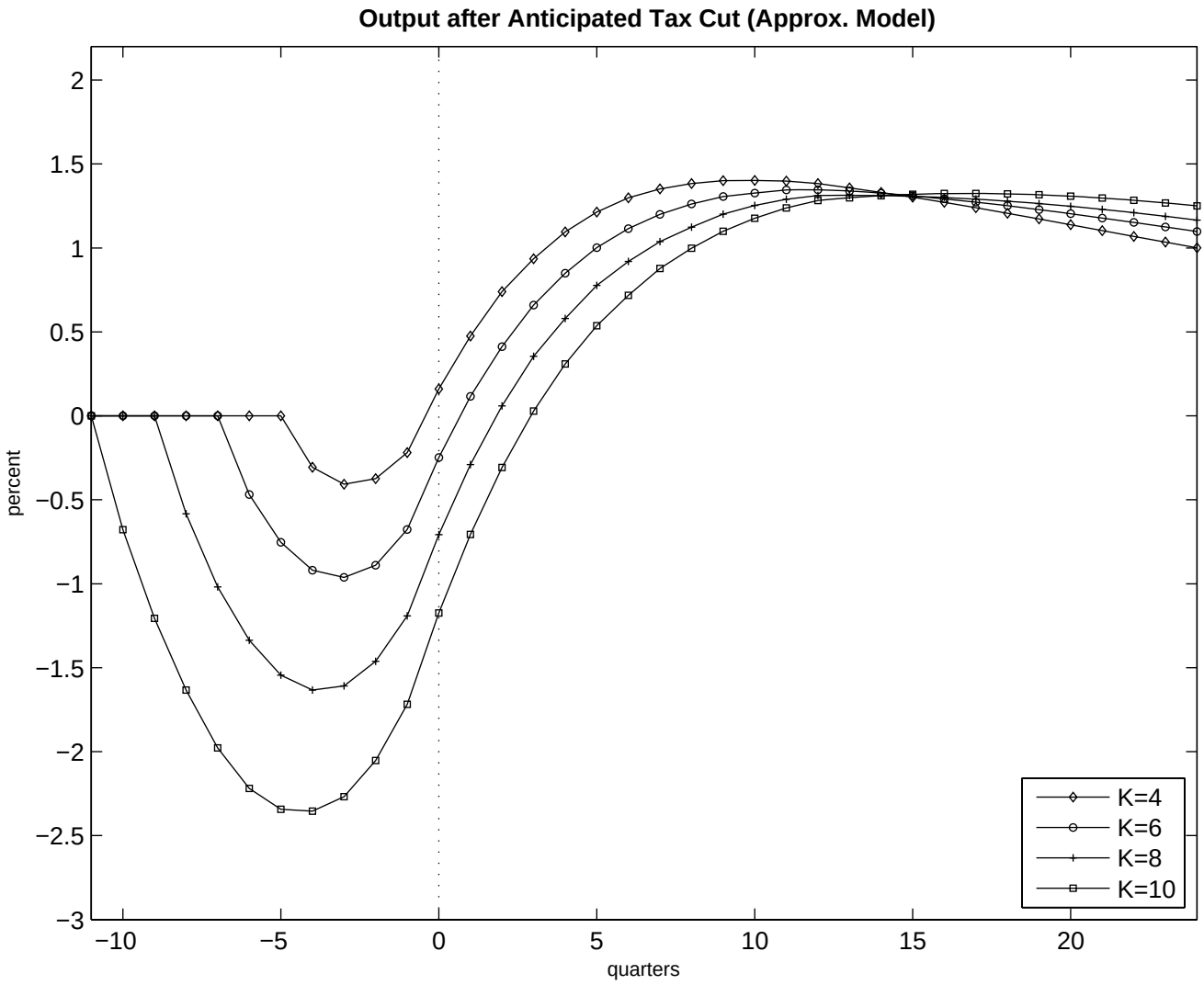

Figure 7: The Dependence of the Dynamics of Output on the Anticipation Lag in the Model

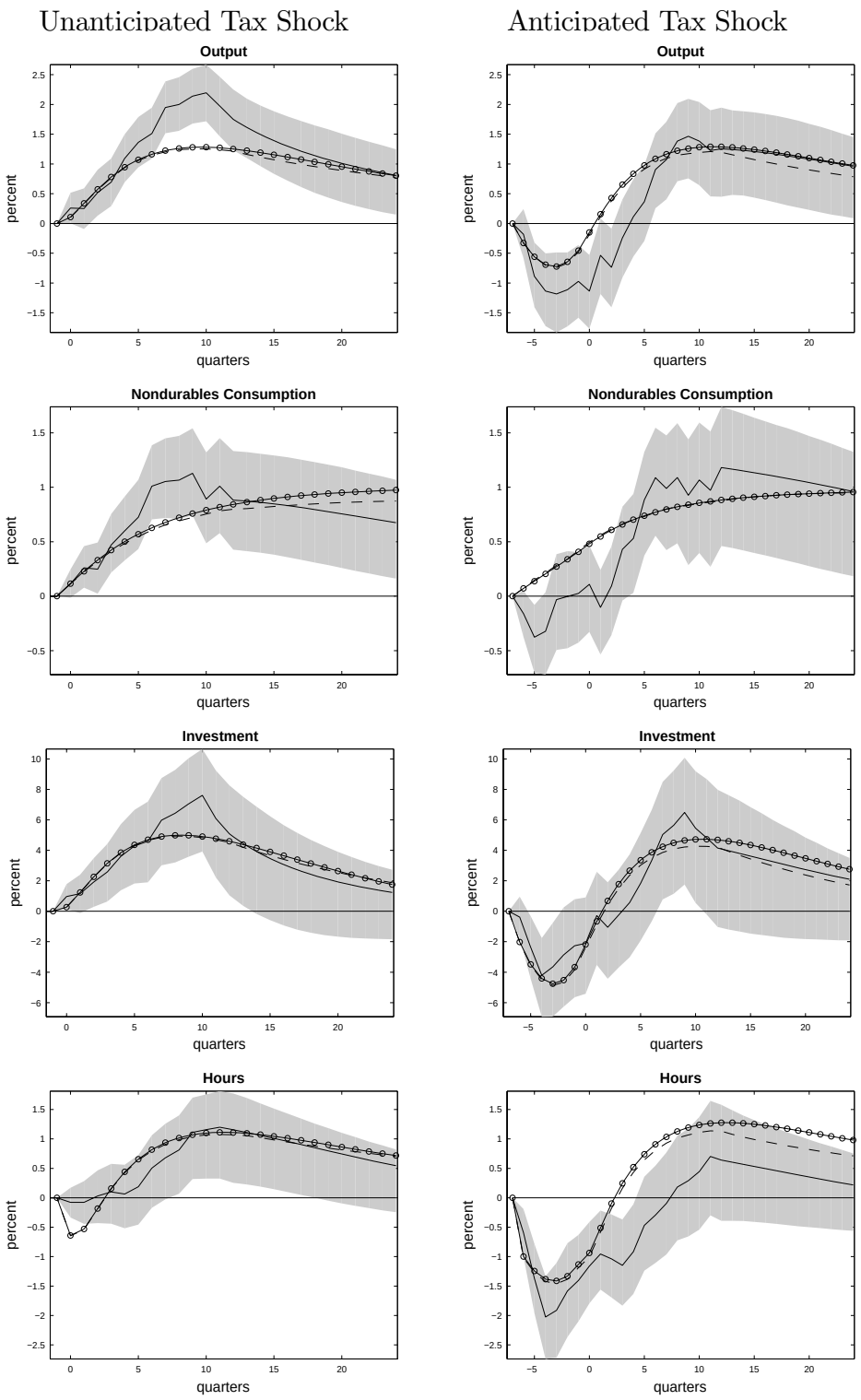

Figure 8: The Model with no Durable Consumption Goods

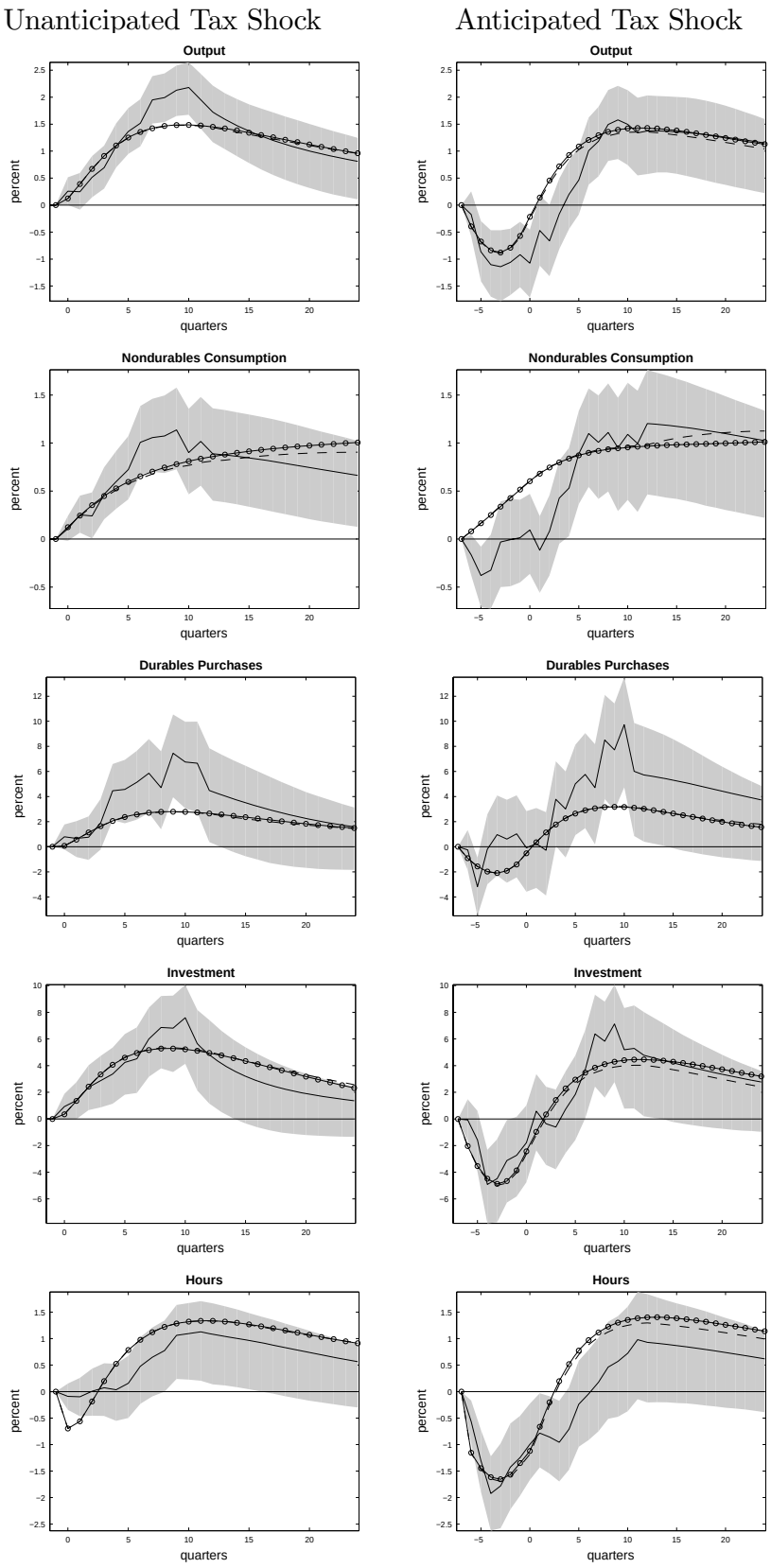

Figure 9: The Model with Fixed Utilization Rate in Home-Production

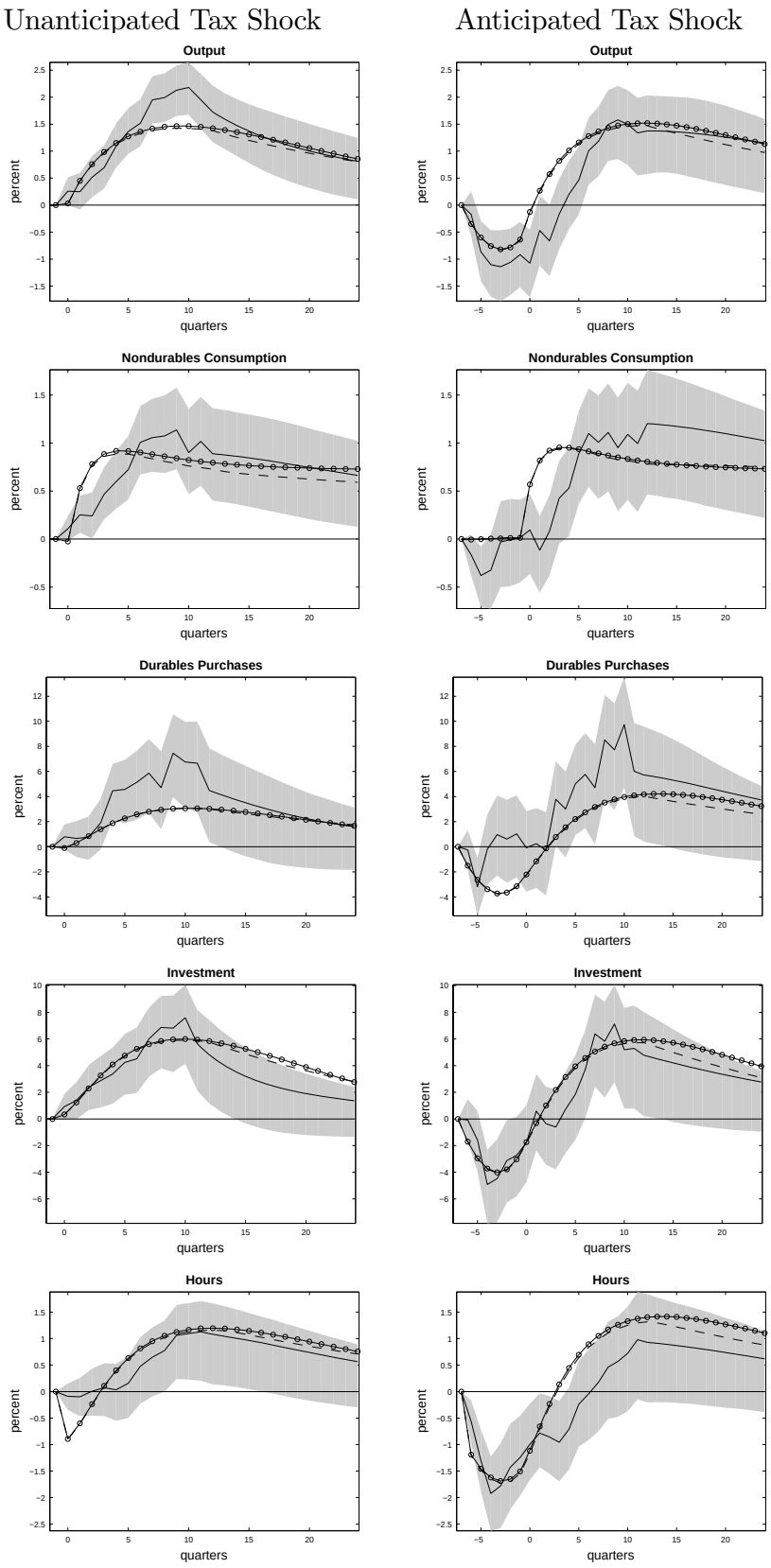

Figure 10: The Model with no Habit Formation

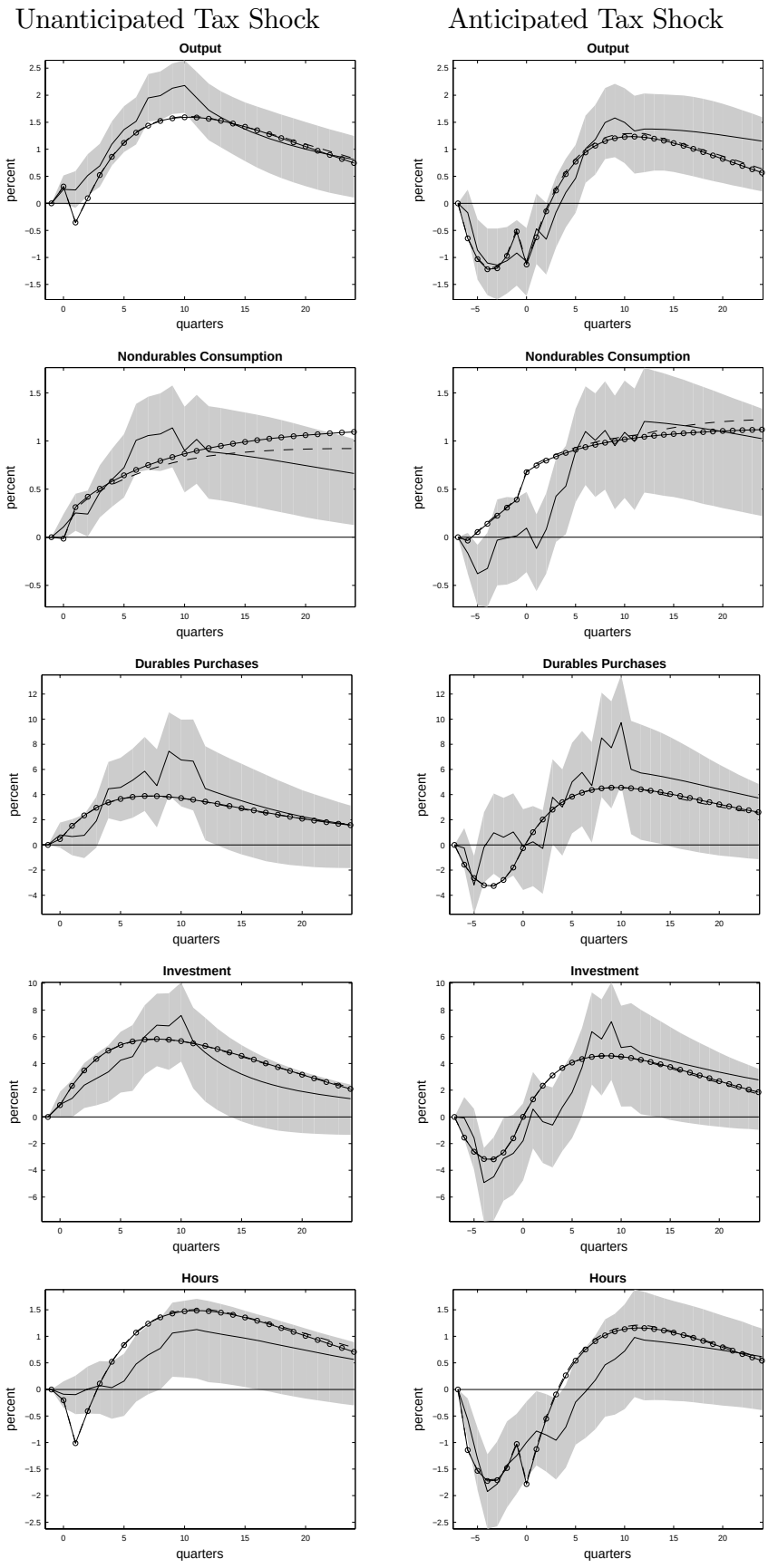

Figure 11: The Model with Endogenous Government Spending

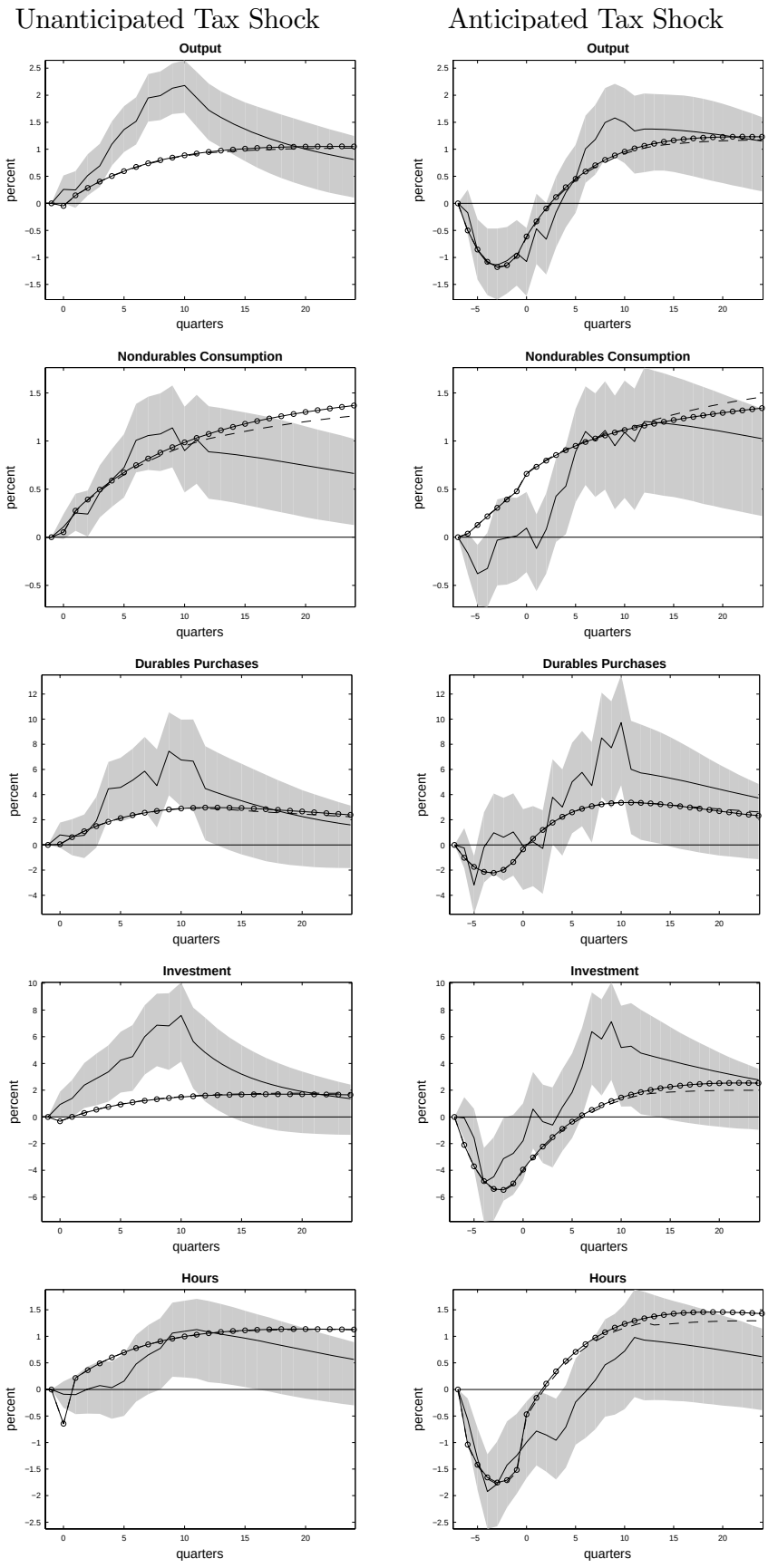

Figure 12: The Model with Constant Capital Income Taxes

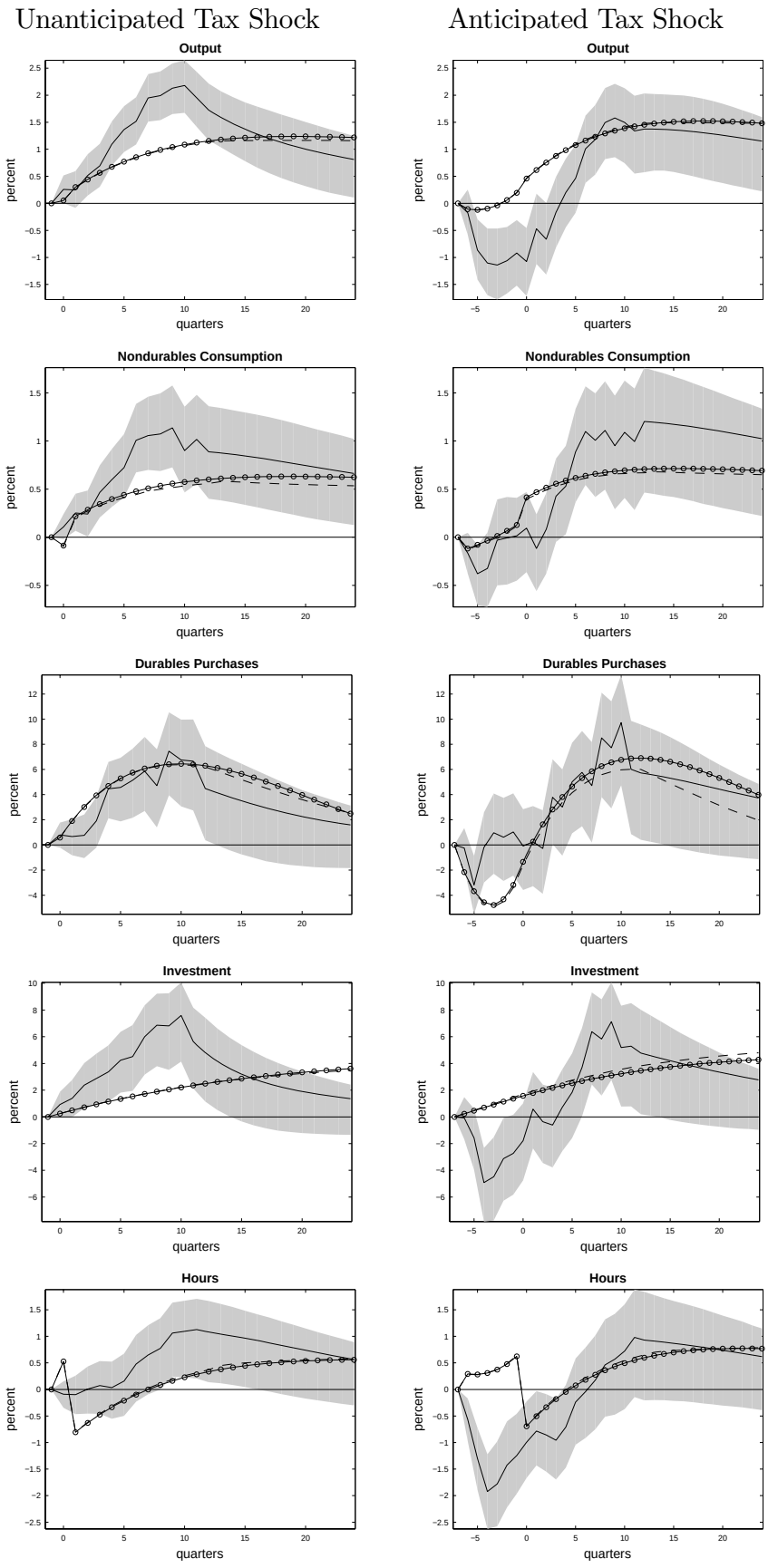

Figure 13: The Model with Constant Labor Income Taxes

A. Surprise Tax Changes

B. Anticipated Tax Changes

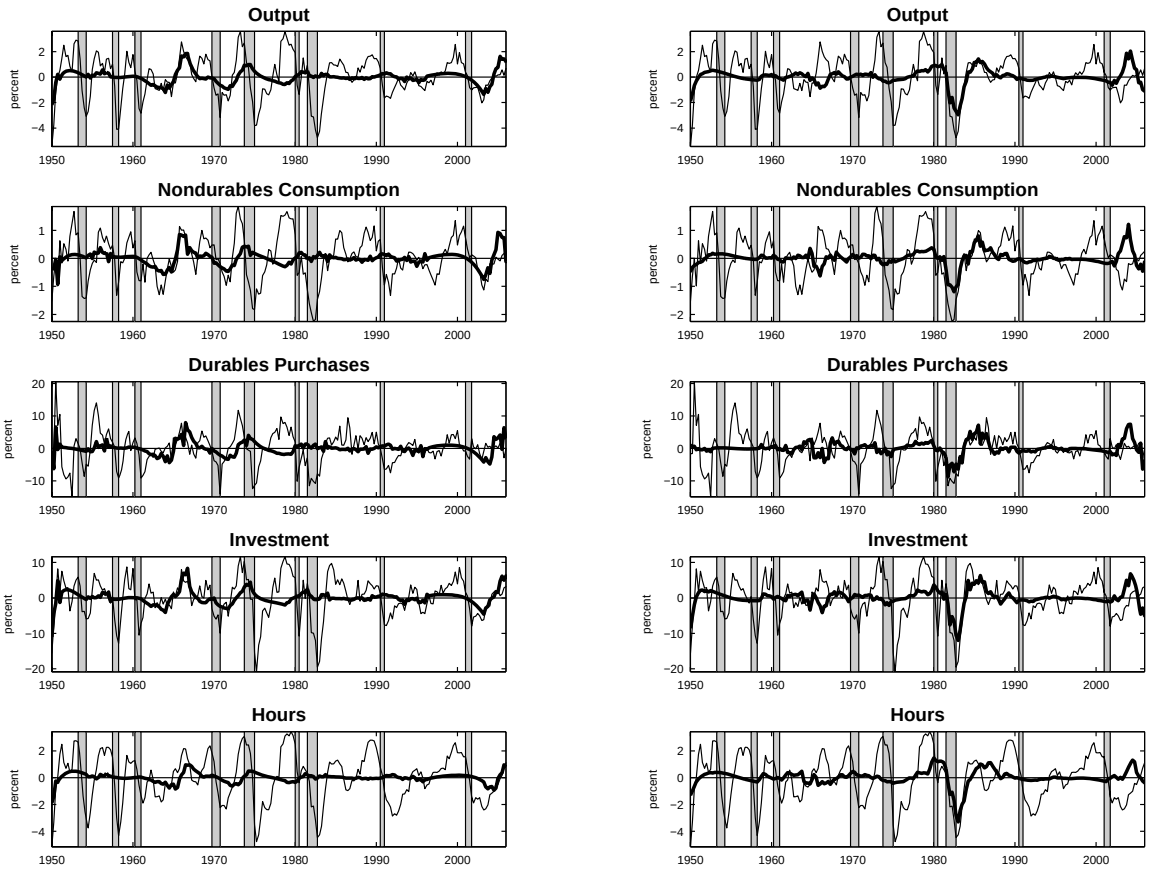

Figure 14: Actual and Counterfactual Time Series

(the thin lines show the actual time series, the thick lines show the counterfactual time series, all time series have been HP-filtered; Shaded areas indicate NBER recessions)

C. All Tax Changes

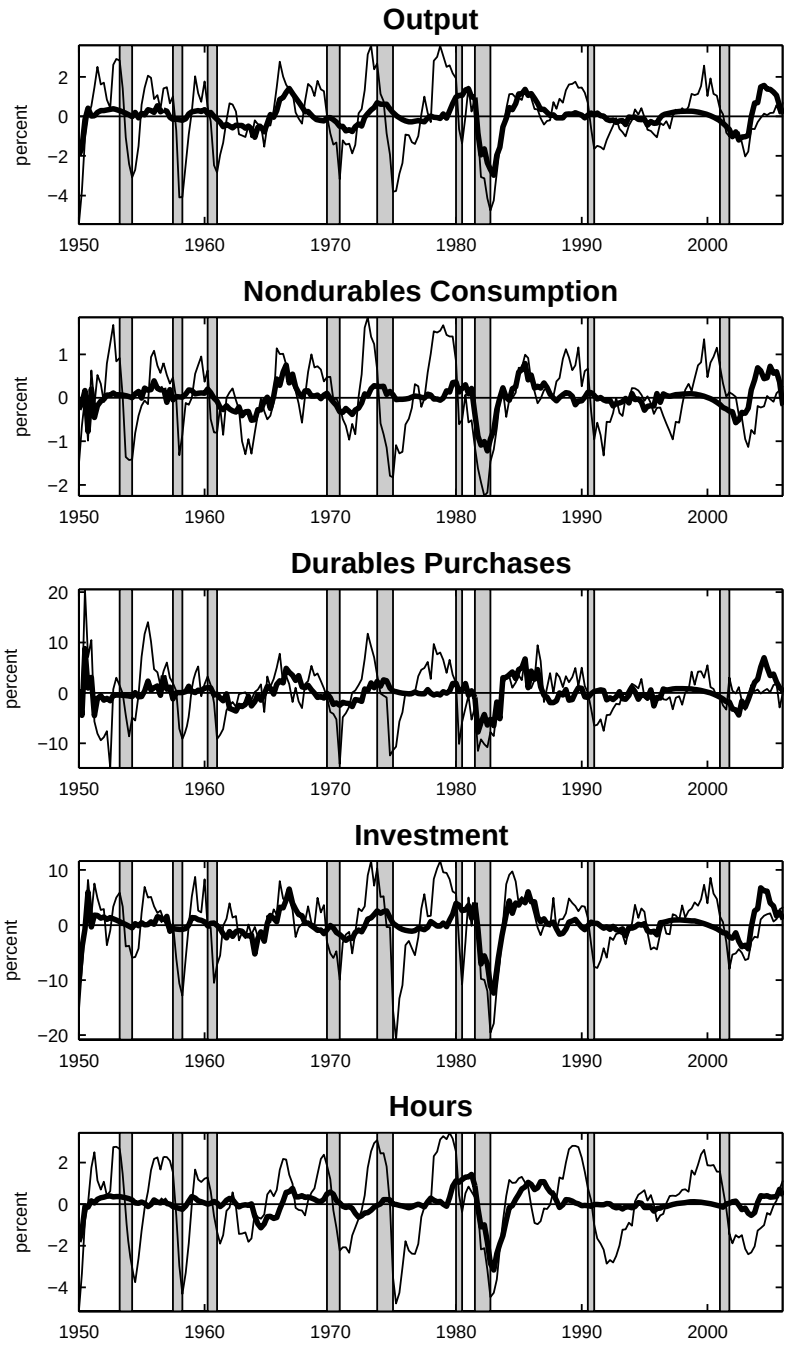

Figure 14: Actual and Counterfactual Time Series

(the thin lines show the actual time series, the thick lines show the counterfactual time series, all time series have been HP-filtered; Shaded areas indicate NBER recessions)