CHARACTERIZING INTERTEMPORAL SUBSTITUTION VIA
PRE-ANNOUNCED CONSUMPTION TAX INCREASE

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Version: February 25, 2015

ABSTRACT

This study measures intertemporal substitution via pre-announced increase in Japan’s VAT rate. Matching the time path of expenditures from a structural model of household consumption to empirical estimates of the expenditure response to the VAT increase, I find that expenditure is sensitive to a future price increase due to accelerated purchases of durables and stockpiling of storables. However, consumption is relatively insensitive. The intertemporal elasticity of substitution in consumption is 0.13, and is precisely estimated. The results suggest policies that alter the future price level will have a large, but short-lived impact on the timing of household expenditure.

Keywords: Intertemporal substitution, consumption, fiscal policy, VAT

JEL Classification: D12  E21  E62  E65  H24  H31

*Federal Reserve Board, Division of Monetary Affairs, email: david.b.cashin@frb.gov. I would like to thank Joel Slemrod, Chris House, James Hines, Matthew Shapiro, Mel Stephens, Daniel Silverman, Justin Wolfers, Daniel Murphy, Luigi Pistaferri, Annette Vissing-Jorgensen, and Erik Hurst, as well as seminar participants at the University of Michigan, U.S. Treasury Office of Tax Analysis, Fall 2012 Midwest Macroeconomic Meetings, 105th Annual Conference on Taxation, Federal Reserve Bank of Chicago, Federal Reserve Board, Congressional Budget Office, Joint Committee on Taxation, Copenhagen Business School, University of Toronto, 69th Annual Conference of the International Institute for Public Finance, and the University of New Mexico for helpful comments and suggestions. I would especially like to thank Takashi Unayama for estimating the regressions.
1. Introduction

The sensitivity of household expenditure to a change in the future price level is of central importance to macroeconomics and public finance. The more sensitive is expenditure, the greater will be the impact of countercyclical policies that alter intertemporal price levels, such as nominal interest rate adjustments by the monetary authority or adjustments to the tax rate on expenditure (herein referred to as a ‘consumption tax’) by the fiscal authority. Alternatively, in an economy operating at full employment, the deadweight loss of tax policies that alter intertemporal prices is increasing in the sensitivity of household expenditure.

In a previous paper, Cashin and Unayama (2015) took a novel approach to measuring the sensitivity of household consumption to a change in the future price level, using a pre-announced increase in Japan’s Value Added Tax (VAT) rate from three to five percent as a natural experiment to estimate the intertemporal elasticity of substitution in consumption (IES). Their estimate of the IES is 0.21 – substantially lower than previous estimates of the IES derived from survey data (e.g. Attanasio and Weber, 1993 and 1995; Vissing-Jorgensen, 2002).

This study builds on the work of Cashin and Unayama (2015) in three ways. First, it characterizes the sensitivity of both household consumption and expenditure to the increase in Japan’s VAT. For storable (e.g. laundry detergent) and durable (e.g. household appliances) goods and services, the timing of consumption and expenditure does not necessarily coincide. Storables can be stockpiled during low price periods for consumption in high price periods, while durables can be purchased during low price periods, with most of the flow of services generated by the durable consumed during a high price period. As a result, expenditure on these goods and services may be sensitive to a change in the future price level even in the absence of a large consumption response. Without accounting for the response of durables and storables, which comprise a sizeable portion of household spending (45 percent in the sample used in this
study), one might mistakenly conclude that expenditure is insensitive to a change in the future price level based solely on a low estimate of the IES.

Second, this study uses a structural estimation approach together with information on the durable and storable expenditure responses to the VAT rate increase to obtain a more precise estimate of the IES. Cashin and Unayama (2015) examine only the response of non-storable non-durable expenditure (e.g. dining out) to the tax rate increase. The additional information provided by the durable and storable responses yields a more precise estimate of the non-durable, non-storable IES by ruling out values of the IES that are inconsistent with expenditure patterns on all three types of goods and services.

Finally, analysis of both the durable and non-durable expenditure responses to the VAT rate increase allows me to obtain a point estimate of the intratemporal elasticity of substitution between durables and non-durables, a parameter for which there appears to be an even broader range of estimates than the IES. Given that the user cost of durables is a decreasing function of the change in price level between the current period and next, it follows that an estimate of the intratemporal elasticity of substitution can be obtained by examining the durable and non-durable expenditure responses just prior to the tax rate increase.

To characterize the sensitivity of household consumption and expenditure to the VAT rate increase, I match the time path of expenditures generated by a dynamic structural model of household consumption to empirical estimates of the expenditure response. Specifically, using household survey data, I estimate the average percentage deviation in durable, storable, and non-storable non-durable expenditures in the months surrounding implementation of the VAT rate increase relative to a base month that followed announcement of the tax rate increase, but

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1 For example, Ogaki and Reinhart (1998) obtain an estimate of 1.167 (standard error of 0.099), while Pakos (2011) finds the historical elasticity of substitution lies in the interval [0.172, 0.194].
preceded implementation. As a result, the estimates should be devoid of any income effect resulting from the tax rate increase, instead capturing only intertemporal substitution effects in the form of stockpiling, accelerated purchases of durables, and intertemporal substitution in consumption, as well as any intratemporal substitution between durables and non-durables that might have been present. I then employ a dynamic structural model of household consumption that predicts the durable, storable, and non-storable non-durable response to the VAT rate increase. The model is governed by parameters such as the IES, the elasticity of substitution between durables and non-durables, and adjustment cost parameters for storables and durables that characterize the sensitivity of household consumption and expenditure to a change in the future price level. The parameter estimates chosen are the set generating the time path of expenditures that most closely match the empirical estimates of the expenditure response to the VAT rate increase.

I find that expenditure responded to the VAT rate increase only in the months immediately prior to and following implementation of the policy. Durable expenditures were 8 and 23 percent higher in the two months before the tax increase. Durable spending then dropped sharply following implementation and returned to trend within a few months of implementation. This suggests that households accelerated purchases that would have otherwise been made after the tax rate increase, and is further supported by the fact that expenditures on goods with higher levels of durability were more sensitive to the VAT rate increase. These results corroborate the evidence presented by Mian and Sufi (2012) for a broader range of durable goods and services.

Expenditure on storable goods was nine percent higher in the month before implementation than it otherwise would have been. Like durable spending, it dropped precipitously in the month of implementation, and gradually returned to trend in the ensuing months, indicating that households engaged in a significant
amount of stockpiling just prior to the price increase. Expenditures on goods with higher levels of storability were more sensitive to the tax rate increase.

Finally, non-storable non-durable expenditure was 1.51 percent higher in the month prior to the tax rate increase than it would have been in its absence, but showed little variation in other months prior to and following implementation. The lack of variation in expenditure prior to and following implementation suggests that the IES is small. The slight jump in expenditure in the month prior to implementation suggests that durables and non-durables are complements, because the reduction in the user cost of durables in that month coincided with an increase in non-storable non-durable expenditure.

The structural parameter estimates confirm these conjectures. The point estimate for the IES is 0.13, with a 95 percent confidence interval given by [0.05, 0.20]. As expected, the additional information provided by the durable and storable expenditure responses to the VAT rate increase yields a more precise estimate of the IES. The intratemporal elasticity of substitution between the durable stock and non-durables is estimated to be -0.03, with a 95 percent confidence interval given by [-0.05, -0.01]. While the estimate is slightly negative, it suggests that durables and non-durables are strong complements, which is consistent with recent work by Pakos (2011).

To assess the external validity and generalizability of the structural parameter estimates, I then compare the time path of expenditures generated by the model to the response of durable and non-durable (storable and non-storable) retail sales to the July 1989 increase in New Zealand’s Goods and Services Tax (GST) rate, which is examined in Cashin (2011). This particular tax rate increase was also announced prior to its implementation, and it featured an increase in the tax rate from 10 to 12.5 percent. The time path of durable and non-durable expenditures generated by the model is similar to the observed response, which suggests the estimates presented in this paper are applicable in other contexts, and
furthermore, that policies that alter the future price level will have a large, but short-lived impact on the timing of household expenditure.

2. The VAT Rate Increase: An Ideal Natural Experiment to Estimate Intertemporal Substitution Behavior

2.1. Japan’s VAT and the April 1997 Rate Increase

Japan’s ‘Consumption Tax’ is a VAT. Unlike VAT in many other countries, it has a single flat rate with relatively few exemptions.² The VAT was introduced in 1989 at a rate of three percent, and the rate was increased from three to five percent in April 1997. The 1997 VAT rate increase, which is the focus of this study, was originally proposed as a part of the Murayama Tax Reform, which passed through the Japanese Diet in late 1994.³ Because the primary purpose of the reform was to continue the shift from direct to indirect taxation, the future VAT rate increase was coupled with immediate cuts in income tax rates.

Although the Murayama reform package set a target date of April 1997 for the VAT rate increase, it was unclear whether the increase would actually be implemented then. This is because the reform legislation also stated that the rate increase would be imposed only if the economy had sufficiently recovered from a prolonged recession from 1991 to 1993, and feeble growth thereafter. Having judged the economy to have sufficiently recovered, the ruling Liberal Democratic Party (LDP) decided to raise the tax rate as scheduled. The bill to raise the VAT

² Exemptions included transfer of lease or land, transfer of securities and transfer of means of payment, interest on loans and insurance premiums, transfer of postal and revenue stamps, fees for government services, international postal money orders, foreign exchange, medical care under the Medical Insurance Law, social welfare services specified by the Social Welfare Services Law, midwifery service, burial and crematory service, transfer or lease of goods for physically handicapped persons, tuition, entrance fees, facilities fees, and examinations fees of schools designated by the Articles of the School Education Law, transfer of school textbooks, and the lease of housing units. For additional information on Japan’s Consumption tax base and its administration, see Beyer (2000).
³ For further discussion of the political process, see Ishi (2001) and Takahashi (1999).
rate passed through the Upper House on June 25, 1996, and the tax rate increase was scheduled to take effect on April 1, 1997.

Even after this passage, the LDP stated that they would revisit the issue of the tax rate increase when they submitted the fiscal year 1997 budget. The VAT rate increase was the central issue in October 1996 elections to the Lower House of the Diet, with the LDP’s opposition promising to postpone the tax rate increase if elected. The LDP narrowly won the election, and on December 26, 1996, the government submitted the fiscal year 1997 budget, which officially increased the VAT rate to five percent on April 1, 1997.

2.2. The VAT Rate Increase as a Natural Experiment

Estimation of intertemporal substitution behavior requires variation in the real interest rate, which is the price of current consumption relative to future consumption. Because the real interest rate is defined as the nominal interest rate minus the expected inflation rate, a change in expected inflation will induce the necessary variation. As a result, the April 1997 VAT rate increase, which represented a plausibly exogenous and expected increase in the future price level during a period in which nominal interest rates, pre-tax prices, and income were stable, presents an ideal natural experiment to estimate intertemporal substitution behavior.

First of all, the tax rate increase can be regarded as a plausibly exogenous change in the future price level. Not only is it the case that the tax system is exogenous from the perspective of individual households, but it is also true that the impact of the tax rate increase is largely independent of consumer behavior. This is because the VAT by and large applies to expenditures regardless of the characteristics of the consumer, the point of purchase, or the type of goods purchased.
While exogenous variation in the real interest rate is a necessary condition for estimating intertemporal substitution behavior, it must also be the case that households were aware of the change, and expected to bear the burden of the tax rate increase in the form of higher prices upon implementation. While I do not provide direct evidence on household awareness of the VAT rate increase, indirect evidence is available in the form of news coverage regarding the VAT rate increase prior to its implementation. Figure 1 reports the number of articles per month that mention the phrase ‘Consumption Tax’ in the Nihon Keizai Shimbun, Japan’s leading business newspaper with a circulation of over three million (in 2010), and the Yomiuri Shimbun, a leading non-business newspaper with a circulation of over 10 million (in 2010). There was a steady upward trend in coverage of the ‘Consumption Tax’ that began just prior to enactment of the June 1996 legislation. Coverage peaked in the Yomiuri Shimbun in October 1996, which coincided with elections to the Lower House of the Diet. Overall coverage in both papers was consistently high in the months following the election but prior to the tax change, with nearly 300 articles in the Nihon Keizai Shimbun mentioning the ‘Consumption Tax’ in March 1997. This suggests that households were aware of the tax rate increase and might therefore engage in intertemporal substitution behavior.

The news coverage also suggests that households were aware of the effects of the Murayama reform package as a whole. Figure 1 shows that coverage initially peaked in September 1994, which coincided with the passage of the Murayama reform package. Accordingly, households may have known about the VAT rate increase well in advance of its implementation, and furthermore, that it was intended to be compensated in the form of the front-loaded income tax cuts. As a result, one might expect any income effect associated with the VAT rate increase to have been small, and to have taken effect well in advance of its implementation. This conjecture is important because it suggests that deviations
in expenditure around the time of the VAT rate increase were due solely to intertemporal substitution. Nevertheless, the empirical estimates presented in Section 3.4 will be robust to any income effect that became evident upon ‘announcement’ of the VAT rate increase, which at the latest would be December 1996, when the tax rate increase became a certainty.

In addition to public awareness of the VAT rate increase, it seems likely that households expected to bear the full burden of the tax rate increase in the form of higher prices at the time of implementation. For one, when the VAT was imposed in April 1989 at a rate of three percent, the price of goods and services that had not previously been subject to tax increased by just under three percent upon implementation. Furthermore, the Japanese government made it clear that they expected consumers to bear the full burden of the VAT increase upon implementation.\footnote{When the VAT was introduced in 1989, the government took several steps to ensure this outcome. First, a Special Council on the Transition was formed to promote enforcement of the VAT across agencies. Second, the government carried out an extensive advertising campaign to allay the public’s fear of price hikes and to restrain overcharging by traders. A telephone service was also set up so consumers could report complaints about prices. Finally, the Economic Planning Agency increased the budget for the price monitoring system. The situation was nearly identical in 1997.} It is also worth noting that Carroll et al. (2011) find that full forward shifting at the time of a consumption tax rate increase is the norm across most countries, likely as a result of factor price rigidities.

This appears to be true in Japan’s case as well. The bottom right graph in Figure 2 shows the seasonally-adjusted month-to-month percentage change in the consumer price index for all goods and services subject to the VAT. While inflation was negligible in most months prior to and following implementation of the tax rate increase, the price level increased by just under two percent between March and April 1997, which is consistent with full forward shifting of the two percentage point tax rate increase onto consumers at the time of implementation. As a result, focus can be placed on a one-time price change, and I can ignore the
influence of an additional factor (i.e. variation in pre-tax prices) that affects the real interest rate.

Also note that the VAT rate increase was nearly pushed onto consumers in full at the time of implementation for all three of the composite goods and services with which this study is concerned. Prices increased by 2.11, 1.67, and 1.82 percent in April 1997 for non-storable non-durables, storables, and durables, respectively. Furthermore, Figure 3 demonstrates that relative prices exhibited little variation around time of the VAT increase, which will further simplify the analysis below.

In addition to pre-tax price variation, the influence of the nominal interest rate on the real interest rate around the time of the VAT increase can also be ruled out. Figure 4 presents the average contracted interest rate on short-term loans and discounts, as well as the six-month Treasury bill rate (at auction). The former rate is the average interest rate applied to a contract of less than one year between a commercial bank and lender. Both interest rates fell precipitously throughout 1995, but remained relatively constant thereafter. This suggests that households would not have changed their nominal interest rate expectations in the months surrounding implementation of the VAT rate increase.5

Finally, one might worry that household income changed concurrently with the VAT rate, perhaps because employers offset the burden of the tax rate increase with wage increases. In this case, estimates of the IES could be biased downwards to the extent the income increase was not expected. Figure 5 displays the seasonally-adjusted percentage deviation in disposable household income from the sample average. While the data is somewhat noisy, there does not appear to have been any major change in household income upon implementation of the VAT rate increase. Furthermore, income was relatively stable in the years

5 Alternatively, the figure suggests that households did not demand higher nominal interest rates in response to the one-off increase in the price level.
leading up to and the months following the tax rate increase. Consequently, it seems unlikely that income changes would significantly bias the results upwards or downwards.

The facts presented above imply that the tax rate increase can be regarded as an exogenous change in the real interest rate, which allows for consistent estimation of the intertemporal substitution response using ordinary least squares (OLS). Previous studies of intertemporal substitution (e.g. Hall, 1988; Attanasio and Weber, 1993 and 1995; Ogaki and Reinhart, 1998) have relied on an instrumental variables approach to address the well-documented endogeneity between the real interest rate and consumption growth. However, there are several potential issues with the instruments that have been employed. First, as Yogo (2004) notes, it is notoriously difficult to predict the real interest rate, and therefore, some of the previous studies in this literature (especially those using aggregate data) suffer from the weak instrument problem. Weak instruments lead to estimates of the IES biased in the direction of OLS, which itself is likely to suffer from a downward bias. Furthermore, Attanasio and Weber (1993, 1995) show that studies using lagged instruments and aggregate non-durable expenditure data suffer from a downward bias in estimates of the IES known as aggregation bias. This study avoids these issues by using an exogenous institutional price change.

To summarize, the April 1997 VAT rate increase presents an ideal natural experiment to estimate intertemporal substitution behavior for the following

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6 For example, an increase in the real interest rate will induce an income effect in addition to the intertemporal substitution effect. If households are net savers, then failure to account for the innovation in income will lead to an OLS estimate of the IES that is biased downwards (see Appendix Figure A.1 for a simple demonstration in a two-period setting).

7 Using OLS, Gruber (2006) obtains an estimate of the IES of -0.55, which is significantly less than his estimates when instrumenting for the after-tax real interest rate. Vissing-Jorgensen (2002) finds that estimates of the IES converge towards zero as the number of instruments is increased. This is because the weak instrument problem is increasing in the degree of overidentification.
reasons: the tax rate increase can be regarded as a plausibly exogenous change in the real interest rate; the tax rate increase was predictable and consumer awareness was high; households could reasonably expect to bear the full burden of the tax rate increase in the form of higher prices, and did; other factors affecting the real interest rate were relatively stable prior to and following implementation; and there was little to no change in income or the relative pre-tax price of durables, storables, and non-storable goods and services around the time of the tax rate increase.

3. Estimates of the Expenditure Response to the VAT Increase

3.1. Data

The Japanese Family Income and Expenditure Survey (JFIES) is used to estimate the expenditure response to the VAT rate increase. The JFIES is a rotating panel survey in which households are interviewed for six consecutive months, and approximately 8,000 households are interviewed each month.

The estimates make use of JFIES data from the period between April 1992 and March 2002, a symmetric five-year window around the April 1997 tax rate increase. Data from the “bubble” period (before April 1992) are excluded because household expenditures grew at a much faster pace than they did after the bursting of the economic bubble in 1991, while remaining more or less flat after that. The sample period ends in March 2002, which coincided with the beginning of another boom.

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8 See Stephens and Unayama (2011, 2012) for more information regarding the JFIES design and content.
9 Until 2002, single-person and agricultural households were excluded from the JFIES. As of the 2009 JFIES, single-person households comprised 11.8 percent of the population and were responsible for 18.1 percent of expenditures, while agricultural households accounted for 2.0 percent of the population, and 2.1 percent of expenditures.
The sample is limited to households who complete all six interviews, but nearly all households can be used, as the response rate of the JFIES is quite high. Although data for agricultural households is available in the JFIES after 1999, they are excluded from the analysis to maintain consistency over the sample period. Also, the analysis restricts the sample to male-headed households and those whose head does not change his job. The latter restriction is imposed because March is the end of the fiscal year in Japan. As a result, several job changes are observed, which may cause systematic changes in consumption around the time of the VAT rate increase. After imposing the sample restrictions, the dataset includes 646,900 observations from 129,380 households. Table 1 presents summary statistics for the sample.

The JFIES expenditure data is highly disaggregated by item type, which allows for an accurate categorization of goods and services. For the purposes of this study, it is critical to distinguish not only between taxable and tax-exempt goods and services, but also between durables, storable, and non-storable non-durables.

To construct the expenditure data, expenditures on goods and services that are not subject to the VAT, \( E \), are separated from expenditures on taxable items. While \( E \) will not formally be used in the analysis below, I will examine it to determine whether there might be aggregate factors other than the VAT rate increase affecting expenditure around the time of the tax rate increase. As shown in Table 1, expenditure on taxable items comprised 70% of total expenditure, while most tax-exempt expenditure consists of rent for housing and education (e.g. tuitions for school).

The second step is to divide goods and services that are subject to the VAT into three sub-categories: durables \((D)\), storable \((S)\), and non-storable non-durables \((N)\). \( N \) are defined as goods and services which are neither storable nor durable. That is, they depreciate relatively quickly over time when not in use, and
when in use, are fully consumed. For example, fresh fruit, if not eaten, will spoil, and is fully consumed with use. This category also includes services such as taxi fare and dining out, which are consumed at the point of purchase. It follows that monthly expenditure on \( N \) should approximately coincide with monthly consumption of \( N \).

\( S \) are defined as goods and services that depreciate slowly over time if not used and fully if used. For example, laundry detergent can be stored for long periods of time with little to no effect on its ability to clean clothing, but once it is put into use, whatever amount was used has been fully consumed. This category also includes public transit (rail and bus) passes, due to the fact that many Japanese households purchase passes which are good for train travel for several months after first use. Thus, one might expect that a household would purchase a pass good for several months during a low price period, and begin using the pass during a relatively high price period. More generally, the characteristics that define \( S \) allow for stockpiling during low price periods in order to consume in relatively high price periods. As a result, monthly expenditure on \( S \) does not necessarily coincide with consumption, and expenditure on \( S \) should be more sensitive to changes in intertemporal prices than \( N \).

Finally, \( D \) are defined as goods and services which depreciate relatively slowly over time if not used and do not depreciate fully with use. This category includes traditional durables such as refrigerators and automobiles, as well as goods such as clothing and footwear that are classified as semi-durables in the JFIES. In addition, this category includes a select group of services such as home repair and tailoring, which consumers derive benefits from long after the service is provided. Like \( S \), expenditure on \( D \) should be more sensitive to changes in intertemporal prices than \( N \). This is because \( D \) can be purchased during a low
price period, with most of its service flow consumed during a relatively high price period.\textsuperscript{10} See Appendix Table A.1 for a complete categorization of $N, S, D$, and $E$.

Monthly expenditures on $N, S, D$, and $E$ are then deflated using tax-inclusive consumer price indices specific to each category.\textsuperscript{11} The analysis thus makes use of real monthly expenditures for Japanese households from April 1992 through March 2002. Table 1 shows that more than half of taxable expenditure is on $N$, while expenditure on $S$ and $D$ is similar.

3.2. Empirical Model

Suppose that the logarithm of real monthly expenditure by household $h$ on good-type $j \in \{D, S, N\}$ in year $y$ and month $m$ can be expressed as

$$
\ln E_{h,y,m}^j = \mu_h^j + \delta_m^j Z_m + \phi^j X_{h,y,m} + \gamma_{y,m}^j D_{y,m} + B_{y,m}^j + \epsilon_{h,y,m}^j
$$

where $\mu_h^j$ is a household fixed effect; $Z_m$ is a vector of month dummies intended to capture seasonality effects; $X_{h,y,m}$ is a vector of time-varying household characteristics, including the number of household members, the number of workers, the number of household members under the age of 18, the number of household members over age 65, and interview dummies, which control for “survey fatigue”, the tendency of households to report lower expenditure in later interviews; $D_{y,m}$ is a vector of dummies for months surrounding the VAT rate increase, where $\gamma_{y,m}^j$, a vector of the coefficients of interest, are intended to capture the percentage deviation in expenditure on good $j$ relative to some base

\textsuperscript{10} Barrell and Weale (2009) refer to this as an ‘arbitrage’ effect.

\textsuperscript{11} Laspeyres price indices are constructed for each of the four categories using item-specific price indices and expenditure shares in 1990 for each of these items as the weights.
month, which in practice is the month preceding the first $D_{y,m}$ dummy;\footnote{Halvorsen and Palmquist (1980) demonstrate that in regressions with a logarithmic dependent variable, it is incorrect to interpret the coefficient on a dummy variable multiplied by 100 as the percentage effect of that variable on the variable being explained. Nonetheless, when the coefficients on the dummy variables are close to zero, as is the case in this study, multiplying the coefficient by 100 provides a good approximation to the actual percentage effect of the independent variable on the dependent variable.} $B_{y,m}$ accounts for aggregate factors other than the tax rate increase that impact household expenditure, such as the business cycle and other policies that impact household expenditure; and $\epsilon_{h,y,m}^j$ accounts for unobservables that impact monthly household expenditures on good-type $j$.

Taking the first difference of (1) removes the household fixed effect, which yields

$$\Delta \ln E_{h,y,m}^j = \Delta (\delta_m^j Z_m) + \phi^j \Delta X_{h,y,m} + \Delta (y_{y,m}^j D_{y,m}) + \Delta B_{y,m}^j + \Delta \epsilon_{h,y,m}^j$$

(2)

In order to separately identify the impact of the VAT rate increase on household expenditures from the impact of changes in $B_{y,m}^j$, additional restrictions must be placed on $B_{y,m}^j$. Suppose that $B_{y,m}^j$ follows either of the two conditions listed below:

1) There is no change in $B_{y,m}^j$ from one month to the next.

2) $B_{y,m}^j$ follows a linear trend.

Under condition (1), the term $\Delta B_{y,m}^j$ drops out, while under condition (2), the term $\Delta B_{y,m}^j$ becomes a constant, $c^j$. More generally, if there is little change in $B_{y,m}^j$ other than the linear trend, (2) can be rewritten as

$$\Delta \ln E_{h,y,m}^j = c^j + \Delta (\delta_m^j Z_m) + \phi^j \Delta X_{h,y,m} + \Delta (y_{y,m}^j D_{y,m}) + (\Delta B_{y,m}^j - c^j + \Delta \epsilon_{h,y,m}^j)$$
\[ \Delta \nu_{h,y,m} = \Delta \epsilon_{h,y,m} + \Delta B_{y,m} \]

where \( \epsilon_{h,y,m} \) and \( B_{y,m} \) are deviations and perturbations in consumption from the baseline levels. I address the plausibility of the restriction on \( B_{y,m} \) around the time of the tax rate increase at the end of the next section.

3.3. Empirical Specification

Japan’s VAT rate increase took effect in April 1997. I am therefore interested in percentage deviations in expenditure in the months prior to and following April 1997. These deviations will inform us of the nature of household substitution behavior, such as whether it is driven by changes in the timing of consumption (i.e. intertemporal substitution in consumption), the timing of expenditure (e.g. the stockpiling of storables), the composition of consumption (i.e. intratemporal substitution), or all of the above, and will be used in conjunction with the dynamic structural model of household consumption introduced in Section 4.1 to generate the structural parameter estimates.

The baseline specification used to generate the empirical estimates of the expenditure response to the VAT rate increase is

\[
\Delta \ln E_{h,y,m} = c + \Delta (\delta_{m} Z_{m}) + \phi \Delta X_{h,y,m} + \Delta (\gamma_{y,m} D_{y,m}) + \Delta v_{h,y,m} \quad (4)
\]

where \( \gamma_{y,m} \) is the average percentage deviation in household expenditures on good-type \( j \) in year \( y \) and month \( m \) relative to December 1996, after controlling for household fixed effects, a linear trend in expenditure growth, seasonality, and
time-varying household characteristics. Standard errors are clustered by household, and are thus robust to heteroskedasticity and serial correlation of unknown form within households.

I choose December 1996 as the base month against which expenditure in the months surrounding the VAT rate increase are compared because it coincided with passage of the fiscal year 1997 budget, which made the tax rate increase a certainty, and because news coverage of the proposed tax rate increase had been high for the previous few months. Therefore, households knew that the tax rate increase would be implemented in April 1997 as planned, and should have responded accordingly no later than December 1996. This further implies that the \( \gamma_{y,m} \) will capture only the stockpiling, accelerated durable purchase, (negative) intertemporal substitution in consumption, and intratemporal substitution effects associated with the VAT rate increase, as intended. Nonetheless, it is worth noting that the empirical estimates presented in the next subsection and the structural parameter estimates presented in Section 4.3 are robust to the choice of earlier base months as well. For additional clarification regarding identification of \( \gamma_{y,m} \) using first differenced year-month dummies, see Appendix B.

In the structural estimation procedure described below, I do not utilize the estimates of \( \gamma_{y,m} \) beyond July 1997 for two reasons. First, identification of the structural parameters I am concerned with requires only the few months prior to

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13 To avoid taking the logarithm of zero, monthly durable expenditure is set to ¥100, or approximately U.S. $1, in months that a household reported zero expenditure on durables. The results are robust to different choices of minimum durable expenditure values (e.g. ¥1 or ¥1000). Overall, 94 percent of the monthly observations report positive durable expenditures.

14 As a robustness check, year dummies were also added to the empirical specification given in Equation (4). These dummies capture average monthly growth rates in household spending within a year relative to the omitted year (captured by \( c \)), and are important if growth rates varied considerably over the sample period. I find that inclusion of year dummies does not significantly impact the results of the baseline specification.

15 In particular, I chose October 1996, the election month that made the tax rate increase a relative certainty, as an alternative base month.
and following the VAT rate increase. In fact, I obtain similar estimates of the structural parameters presented in Section 4.3 below using only the estimates of $\gamma_{y,m}^j$ from February to May 1997. Second, estimates of $\gamma_{y,m}^j$ beyond July are likely biased due to unseasonably warm weather in the second quarter of 1997 (which significantly increased electricity costs in the third quarter) and the onset of the Japanese banking crisis in November 1997.

Related to the last point, a possible concern with the specification given in (4) is that $B_{y,m}^j$ could deviate significantly from $c_j$ in the months surrounding the VAT rate increase, and hence bias the estimates of $\gamma_{y,m}^j$ intended to capture substitution behavior resulting from the tax rate hike. However, as shown in Section 2.2, neither income nor relative pre-tax prices changed much around the time of the tax rate increase, alleviating some of this concern.

One can also examine expenditure on tax-exempt goods and services, $E$, to assess whether aggregate factors other than the VAT rate increase had an impact on expenditure during the period of interest, since $E$ is not affected by intertemporal substitution incentives, but will be affected by the same aggregate factors as $D$, $S$, and $N$ if the $B_{y,m}^j$’s share a common component. This seems likely since the residuals from (4), which contain deviations in $B_{y,m}^j$ from $c_j$, are positively and significantly correlated between $E$ and the three taxable good types.\textsuperscript{16} Figure 6 shows that $E$ did not change significantly during the period surrounding the VAT rate increase, suggesting that deviations in $B_{y,m}^j$ from $c_j$ for $D$, $S$, and $N$ were also small. That said, $E$ fell between March and April 1997 by nearly four percent. If this decline is indicative of an aggregate factor that

\textsuperscript{16}The correlations between the residuals from (4) for $E$ and $D$, $S$, and $N$ (excluding observations from 1997 when intertemporal substitution incentives were present for $D$, $S$, and $N$, but not $E$) are 0.03 (0.00), 0.03 (0.00), and 0.09 (0.00), respectively. P-values are listed in parentheses.
negatively impacted expenditures at the time of the tax rate increase, then the estimate of the IES in Section 4.3 could suffer from an upward bias.

3.4. Empirical Estimates

Figure 7 presents estimates of $\gamma_{y,m}^j$ for durables, storables, and non-storable non-durables for January to July 1997, along with the corresponding 95 percent confidence intervals. On average, there was little change in non-storable non-durable expenditure prior to and following implementation of the VAT rate increase. Note, however, that non-storable non-durable expenditure was 1.51 percent higher in March 1997 than it otherwise would have been, which is significant at the ten percent level. One might suspect that this increase is due to a limited amount of storability for the goods and services that make up $N$. However, if this were the case, we would expect to observe an equal and offsetting decrease in expenditure on $N$ in April 1997, which is not apparent. Instead, given that the user cost of durables fell in March 1997, the result suggests that durables and non-durables are complements, while the lack of variation in expenditures in all months excluding March suggests the IES estimate will be small. The intuition for both conjectures is discussed further in Section 4 with the aid of the model.

The top right graph in Figure 7 shows the expenditure response for storables. Expenditure in March 1997 was nine percent higher than it otherwise would have been. In April 1997, storable non-durable expenditure was 7 percent lower than it would have been in the absence of the VAT rate increase, and gradually increased over the next few months. This pattern suggests that households stockpiled goods just prior to implementation, and then consumed from their storable inventory over the next few months.

This explanation is further reinforced by comparing the response for storable non-durables that possess different levels of storability. The top four plots
in Figure 8 examine the response of domestic household goods (e.g. laundry detergent, toilet paper), personal care items (e.g. medicine, shaving cream), beverages (alcoholic and non-alcoholic), and storable foods (e.g. butter, noodles, yogurt) to the VAT rate increase. Domestic household goods and personal care items are storable for long periods of time, while beverages and foods are storable for a relatively shorter period. As Hendel and Nevo (2006) note, this is at least in part because storability for the latter groups decreases once the container or packaging is opened. I find that expenditure is more sensitive for goods with higher levels of storability, which is consistent with the consumer inventory model of stockpiling behavior (see Hendel and Nevo, 2004 and 2006). It is also worth noting that there was a highly significant expenditure response for public transit passes in March 1997, as hypothesized in Section 3.1.

The bottom left graph in Figure 7 presents estimates of the durable response to the tax rate increase. Expenditures in the final two months prior to implementation were 8 and 23 percent higher than they otherwise would have been. Expenditure in April 1997 was 13 percent lower than it would have been in the absence of the VAT rate increase, and gradually returned to trend over the next few months. This pattern is consistent with accelerated purchases of durables that would have otherwise been bought after the tax rate increase. Mian and Sufi (2012) find similar evidence for automobiles in response to the intertemporal substitution incentives provided by the Cash for Clunkers program. One can then think of the durable results presented in this study as extending Mian and Sufi’s results to a broader range of goods and services.

The bottom four plots in Figure 8 examine the expenditure response to the VAT rate increase for several types of durable goods and services. Note that the response in March 1997 was largest for furniture and household appliances,
followed by consumer electronics, with almost no response for automobiles.\textsuperscript{17} Perhaps not coincidentally, there is some evidence of an inverse relationship between the expenditure response observed in March 1997 and the depreciation rate estimates associated with each good type in Fraumeni (1997).\textsuperscript{18} All else equal, a dynamic model of durable consumption would predict that expenditure in the month prior to implementation would be more sensitive for goods with lower depreciation rates, and the estimates in Figure 8 are generally consistent with this prediction. Finally, it is interesting to note that the dip in durable expenditures in July 1997 is due primarily to a reduction in expenditures on household appliances, and specifically, air conditioners. This suggests that households were forward looking enough to purchase air conditioners in March 1997 that would not be used until later in the year.

In summary, the empirical results suggest that the timing of expenditure was sensitive to the VAT rate increase, but the timing of consumption was relatively insensitive. And while expenditure did respond to the price change, the response was confined to the months immediately preceding and following implementation. That said, it is possible that the response is biased downward to some extent by borrowing constrained households. To explore this possibility, Figure 9 displays point estimates of the expenditure response for households with incomes above and below the median, under the assumption that households with incomes below the median are more likely to be constrained. The responses are remarkably similar, which suggests that borrowing constraints are not biasing the point estimates for the overall sample downwards.

\textsuperscript{17} The lack of response for automobiles is surprising, especially given that automobile prices rose approximately two percent between March and April 1997. One possibility is that high transaction costs associated with the sale or disposal of an existing automobile dissuaded households from making a new automobile purchase.

\textsuperscript{18} The annual rates of depreciation given in Fraumeni (1997) are the following: furniture (0.12), household appliances (0.15), home electronic equipment (0.18), and motor vehicles (0.17).
4. Characterizing the Intertemporal Substitution Response to the VAT Increase

4.1. The Household’s Problem

This section develops a dynamic model of household consumption of durables, storable, and non-storable non-durables that mimics the environment that characterized the Japanese economy around the time of the VAT rate increase. Its purpose is to allow for the estimation of structural parameters that fully characterize the intertemporal and intratemporal substitution response to a VAT rate increase. Furthermore, unlike the standard approach to estimation of the IES, the model will allow me to incorporate the storable and durable expenditure responses into the estimate of this important policy parameter, allowing for more precision.

The model is constructed as follows. In each period $t$, taken here to be one month, a representative household chooses non-storable non-durable consumption, $C^N_t$; storable consumption, $C^S_t$; storable expenditure, $X^S_t$; the stock of storable, $S_t$, that will be carried over into period $t + 1$; the durable stock, $D_t$, which provides a flow of consumption services; durable expenditure, $X^D_t$; and financial assets, $A_t$, to maximize the present value of lifetime utility, $U$, subject to the budget constraint, laws of motion for $S_t$ and $D_t$, and stochastic processes for the tax rate on expenditure, $\tau_t$, and income, $Y_t$. Formally, the household solves
\[ U = \sum_{t=0}^{\infty} \beta^t \left( \frac{\sigma}{\sigma - 1} \right) u_t^{\frac{1}{\sigma}} \]

subject to

1) \[ A_t = (1 + i)A_{t-1} + Y_t - (1 + \tau_t)(C_t^N + X_t^S + X_t^D) - \frac{\zeta^D}{2}(D_t - D_{t-1})^2 \]

\[ - \frac{\zeta^S}{2} (S_t - S^*)^2 \]

2) \[ S_t = S_{t-1} + X_t^S - C_t^S \]

3) \[ D_t = (1 - \delta)D_{t-1} + X_t^D \]

4) \[ \tau_t = \tau_{t-1} + \epsilon_{\tau_{t-1}} \]

5) \[ Y_t = Y_{t-1} + \epsilon_{Y_{t-1}} \]

where

\[ u_t = \left[ (1 - \psi^D)\epsilon^{1/\psi^D} \left\{ (1 - \psi^S)\epsilon^{1/\psi^S} \left[ C_t^N \epsilon^{1/\psi^N} + \psi^S \epsilon^{1/\psi^S} C_t^S \epsilon^{1/\psi^S} \right] \epsilon^{1/\psi^D} \right\} + \psi^D \epsilon^{1/\psi^D} D_t \epsilon^{1/\psi^D} \right] \frac{\epsilon^D}{\epsilon^{D-1}}. \]

Intertemporal preferences are assumed to be iso-elastic and governed by the IES, \( \sigma \), which is one of the parameters to be estimated. Note that the value of \( \sigma \) will be determined by changes in \( C_t^N \), \( C_t^S \), and \( D_t \) in response to the VAT rate increase. As noted earlier, a potential advantage of the approach employed in this study is that information from consumption of all three goods will be used to determine \( \sigma \). While \( C_t^S \) and \( D_t \) are not directly observable, their values can be inferred using observable expenditures, \( X_t^S \) and \( X_t^D \), in conjunction with the laws of motion for \( S_t \) and \( D_t \).
The intratemporal preference specification is assumed to take a nested constant elasticity of substitution (CES) form. Under this specification, preferences over the durable stock and the non-durable composite good are homothetic. In contrast, Pakos (2011) provides evidence that durables are luxuries and non-durables are necessities, and that the assumption of homotheticity when preferences are actually non-homothetic biases estimates of $\sigma$ upward. However, given the fact that the VAT rate increase was intended to be compensated and that any income effect associated with the tax reform should have occurred prior to the period I am concerned with, the simplifying assumption of homotheticity seems reasonable.

Preferences over the durable stock and a non-durable composite good are governed by $\psi^D$, a parameter measuring the overall importance of the durable stock in generating utility, and $\varepsilon^D$, the elasticity of substitution between durables and non-durables. The value of $\varepsilon^D$ will also be estimated using the expenditure response to the VAT rate increase. In particular, it is identified off of the change in the durable to non-durable consumption ratio resulting from the reduction in the user cost of durables prior to the VAT rate increase. It is worth noting that because I allow for non-separable preferences over durables and non-durables (i.e. $\varepsilon^D$ is not restricted to be equal to $\sigma$), the estimate of $\sigma$ should be free from intratemporal substitution bias. Preferences over the non-durable composite good are also assumed to be of the CES form, where $\psi^S$ is the share of storables

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19 As in many previous studies of durable goods, such as Bernanke (1985), I assume that the service flow derived from durables is proportional to the durable stock.
in non-durable consumption, and \( \epsilon^S \) is the elasticity of substitution between storable and non-storable non-durables. \(^{21,22}\)

The following assumptions are made with respect to prices. The nominal interest rate, \( i \), is constant, since Japan’s benchmark nominal interest rate was constant in the years prior to and following the VAT rate increase. The model abstracts from time-varying pre-tax prices on the three composite goods, as the price ratios for these goods were stable during the period of interest. Finally, the burden of the VAT is assumed to fall entirely on the representative consumer in the form of higher prices, which is consistent with Japan’s experience and the experience of other countries with a VAT.

The budget constraint also includes durable and storable adjustment cost functions, both of which take quadratic functional forms. \(^{23}\) The durable adjustment cost function is intended to capture the time cost of shopping for durable goods and services. This is because a durable purchase is an infrequent event requiring more effort than a non-durable purchase. The adjustment cost is increasing and convex in net expenditure, reflecting the fact that the time devoted to shopping for a durable is likely increasing in expenditure, and the opportunity cost of one’s time is an increasing and convex function. The assumption of a quadratic adjustment cost is made more plausible by the fact that durable expenditures include maintenance and repairs on durable goods. The parameter

\(^{21}\psi^S\) represents a share only if preferences are Cobb-Douglas, or if prices are assumed to be one, as in this study.

\(^{22}\) The nested CES form restricts the intratemporal elasticity of substitution between storables and durables and non-storables and durables to be the same. To test the validity of this assumption, I used a quadratic specification that allowed for an interaction term between storables and durables, as well as non-storables and durables. After doing so, the implied intratemporal elasticities of substitution between storables and durables and non-storables and durables were similar.

\(^{23}\) Including the adjustment cost functions in the budget constraint rather than the preference specification does not significantly impact the time path of expenditures generated by the model, though it will impact the point estimate for the parameters \( \zeta^D \) and \( \zeta^S \).
associated with the adjustment cost function, $\zeta^D$, is another parameter which I will estimate based on the expenditure response to the VAT rate increase. It is identified by the difference between the durable expenditure response that would be observed in the months preceding and following implementation (holding the other parameters fixed) in the absence of frictions and the observed response, and is increasing in that difference.

The adjustment cost function for storables depends on two parameters, $S^*$ and $\zeta^S$. $S^*$, which is assumed to be greater than zero, is a storable inventory bliss point. $S_t > S^*$ generates a cost to the household due to space constraints and the time cost associated with stockpiling. $S_t < S^*$ also generates a cost due to the inconvenience of holding too few storables. For example, there is a time cost associated with having to make a shopping trip to pick up a new tube of toothpaste after the previous tube runs empty. $\zeta^S$ is a parameter to be estimated based on the expenditure response to the VAT rate increase. In particular, it will be identified primarily by the difference between the storable non-durable expenditure response in March 1997 that would be observed in the absence of frictions (again holding the other parameters fixed) and the observed response, and is increasing in that difference.

The law of motion for the stock of storables is the same as that used by Hendel and Nevo (2006). Note that the stock of storables carried over from one period to the next does not depreciate. This seems plausible for highly storable items like laundry detergent, but perhaps less so for storable foods that have been opened. In effect, I assume that these foods are fully consumed before they perish. The law of motion for durables is standard and depends on the durable depreciation rate, $\delta$.

The tax rate on expenditure in period $t$, $\tau_t$, is set equal to last period’s tax rate, plus any shock to the tax rate that was announced $l$ periods prior. Recall that
Japan’s VAT rate increase was part of a compensated tax reform package introduced in September 1994, 31 months prior to its implementation in period $t^*$. Thus, I set $\epsilon_{t^*-31} = 2$, while $\epsilon_{t-31} = 0$ in all other periods, though introducing the VAT rate increase with a shorter lag between announcement and implementation does not significantly impact the time path of expenditures generated by the model in the months immediately surrounding the tax rate increase.

The model abstracts away from a formal income process since there was little change in household income around the time of the VAT rate increase. To account for the income tax cuts that took effect immediately upon passage of the reform package, households are compensated for the two percentage point increase in the tax rate on expenditure with a 1.94 percent increase in income in period $t^* - 31$. The tax rate increase and the offsetting compensation are known to the representative household well before $t^*$, and thus any change in expenditure around the time of the tax rate increase that is generated by the model will be attributable to substitution effects.

Finally, the model does not incorporate borrowing constraints or the labor/leisure decision. Recall from Section 3.4 that the intertemporal substitution response for households above and below the median income were similar. Consequently, it seems unlikely that borrowing constraints played a significant role in generating the response observed for the entire sample. I ignore the labor/leisure decision since the empirical estimates to which the model is matched are restricted to households whose job status did not change while in the sample.

4.2. Econometric Methodology

To estimate the model, the parameters are separated into three groups. The first group includes $i, \beta, \psi, \delta, e^S$, and $S^*$, which are fixed prior to estimation based on available data. The value of $i$ is set to 0.0015, which corresponds to an
annual interest rate of 0.018. This was the average annual interest rate on short-
term loans and discounts prior to and following the VAT rate increase (see Figure 4). \( \beta \) is set such that \( \beta (1 + i) = 1 \), because the model begins in steady state. \( \psi^S \) is set to 0.29, which was storable non-durable expenditure as a share of non-
durable expenditure in the JFIES in 1996. The value of \( \delta \) is set to 0.022, which
corresponds to an annual depreciation rate of 0.23. This value was computed by
combining good-specific annual depreciation rates from Fraumeni (1997) with
good-specific expenditure shares on durables from the JFIES. The value of \( \epsilon^S \) has
no impact on the time path of expenditure generated by the model, because there
is no change in the price of storable non-storable non-durables. The
output generated by the model is also completely insensitive to the choice of \( S^* \).

The second group of parameters are given by the \( P \times 1 \) vector \( \theta = 
[ \sigma \ \epsilon^D \ \zeta^D \ \zeta^S ]^T \), where \( P = 4 \) is the number of parameters to be estimated.
These parameters will be estimated by minimizing a measure of the distance
between the time path of expenditures generated by the model and the empirical
estimates presented in Section 3.3., a procedure which I discuss further below.

The third group consists of just one parameter, \( \psi^D \), which can be written
as a function of parameters from the first two groups and the ratio of steady state
durable expenditure to non-storable non-durable expenditure, \( \frac{x^D}{c^N} \). I set this ratio to
0.42, which was the ratio in the JFIES in 1996.\(^{25}\) Finally, initial income, \( Y_0 + iA_0 \),
is normalized to 1, and the initial tax rate on expenditure is set to \( \tau_0 = 0.03 \).

\footnote{The difference between \( S_t \) and \( S^* \), which is what generates the storage cost, is independent of
the magnitude of \( S^* \). Rather, this difference is a function of \( \tau_t \), \( i \), and \( \zeta^S \). For example, in steady
state, \( S - S^* = -(1 + \tau_t) \left( \frac{r}{1+r_t} \right) \left( \frac{1}{\zeta^S} \right). \)

\footnote{Specifically, \( \psi^D = \frac{(1-\psi^S)(1/\delta)(r+i)}{(1+(1-\psi^S)(1/\delta)(r+i))} \left( \frac{x^D}{\alpha M} \right). \) This expression is obtained by solving for steady
state durable expenditure in terms of non-storable non-durable expenditure, and then
rearranging and solving for \( \psi^D \).}
To generate a time path of expenditures from the model, the following method is used. Given a full set of model parameters, I first solve for the model’s steady state. I then log-linearize the model around its steady state. The shocks to the tax rate on expenditure and income are then introduced. They propagate through the system of equations, generating a time path of percentage deviations in durable, storable, and non-storable non-durable expenditures from their steady state values.

Recall that \( \hat{\gamma} \), the vector of \( \hat{\gamma}_{y,m}' \)'s to which the time path of expenditures generated by the model will be matched, are percentage deviations in expenditure relative to December 1996, four months prior to implementation of the VAT increase. It follows that in order to make the output generated by the model consistent with the empirical estimates, I must convert the output from percentage deviations in expenditure relative to the steady state to percentage deviations in expenditure relative to expenditure four periods prior to the tax rate increase.

To estimate \( \theta \), I use an econometric procedure similar to that employed by Christiano et al. (2005). I conduct a grid search over combinations of \( \theta \). \( \hat{\theta} \) is the vector of parameter values that minimizes a weighted sum of the squared deviations between the \( M \times 1 \) vector of time-series output generated by the model, \( \gamma(\theta) \), and the \( M \times 1 \) vector of empirical estimates, \( \hat{\gamma} \), depicted in Figure 7. The estimates are chosen to match the durable, storable, and non-storable non-durable empirical estimates from January through July 1997. Thus, \( M = 7 \) months \( \times 3 \) goods = 21. Formally,

\[
\hat{\theta} = \arg\min_{\theta} [\hat{\gamma} - \gamma(\theta)]^{T}W^{-1}[\hat{\gamma} - \gamma(\theta)] \quad (5),
\]
where $W$ is an $M \times M$ matrix that contains the sample variances and covariances of the $\hat{\gamma}_y^m$'s, and $T$ is the transpose operator. The sample variances are the basis of the confidence intervals reported in Figure 7. Standard errors for the structural parameters are estimated using the delta method, which is documented in Appendix C.

4.3. Structural Parameter Estimates

Table 2 presents point estimates and 95 percent confidence intervals for the model parameters that comprise $\theta$. The estimate of $\sigma$ is 0.13, with a 95 percent confidence interval given by [0.05, 0.20]. The point estimate is similar to, though slightly lower than, the estimate in Cashin and Unayama (2015). However, the confidence interval is much tighter, as expected. The null hypothesis that the IES is zero can be rejected at conventional levels of significance. Nevertheless, the fact that the estimate is close to zero should mitigate concern over the potential for an upward bias in the estimate of $\sigma$ discussed in Section 3.3. The result implies that consumption growth was relatively insensitive to the VAT rate increase. It also suggests that the marginal excess burden associated with pre-announced VAT increases is quite small. This is confirmed in Appendix D, which uses the model and the point estimates in Table 2 to predict the marginal excess burden of Japan’s proposed VAT increase.

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26 The covariances for different goods are assumed to be zero. That is, $cov(\hat{\gamma}_y^m, \hat{\gamma}_z^n) = 0, j \neq k$.
27 There exists a literature (e.g. Watanabe et al., 2001; Poterba, 1988) which finds that the income effect associated with a tax change does not become evident until implementation. If this is true, then the estimate of $\sigma$ will be biased upwards, as the fall in expenditure upon implementation will be attributed solely to the intertemporal substitution effect rather than the income effect.
28 Japan raised its VAT rate from 0.05 to 0.08 in April 2014, and is set to raise the VAT rate from 0.08 to 0.10 in October 2015.
The point estimate of $e^D$ is small and negative. The value is -0.03, with a 95 percent confidence interval given by [-0.05, -0.01]. The null hypothesis that durables and non-durables are perfect complements (i.e. $e^D = 0$) is rejected at conventional significance levels. However, the small point estimate suggests that the assumption of Leontief preferences, where durables and non-durables are consumed in fixed proportions, is a good starting point when jointly modeling durable and non-durable consumption. In addition, the small point estimate of $e^D$ is consistent with the recent findings of Pakos (2011), who finds a smaller value of $e^D$ than previous studies using aggregate expenditure data (e.g. Ogaki and Reinhart, 1998) after allowing for non-homothetic preferences over durables and non-durables.

The null hypothesis that preferences over durables and non-durables are separable is rejected at all conventional significance levels. This finding suggests that the assumption of separability in previous studies may have induced bias in estimates of $\sigma$. In particular, given that I find a high level of complementarity between durable and non-durable consumption, previous estimates of $\sigma$ that assumed separable preferences and were derived from non-durable consumption expenditure data may suffer from an upward bias.

The point estimate for $\zeta^D$, the durable adjustment cost parameter, is 0.09, and is significant at the one percent level. To get a better sense of what this value implies, note that a household will increase its durable stock prior to the VAT rate increase so long as the marginal benefit of adjustment exceeds the marginal cost. The marginal benefit of adjustment is decreasing in $D_t$, which is due to the fact that the marginal utility of the contemporaneous service flow derived from durables is decreasing in $D_t$, and also because accelerated purchases of durables

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29 The Wald test statistic, $W$, for the null hypothesis $H_0: \sigma = e^D$ is $W = 9.64$, which exceeds the critical value of 6.63 when the degrees of freedom equals one, and the significance level is one percent.
today implies additional costly adjustments in the future. The marginal adjustment cost is given by \( \zeta^D (D_t - D_{t-1}) \), and increases linearly in \( D_t \). Substituting the relevant values into the marginal adjustment cost function for March 1997, the month in which durable expenditure was most sensitive to the VAT rate increase, yields a value of 0.0028. That is, the marginal adjustment cost is 0.28 percent of monthly income.

The point estimate for the storage cost parameter, \( \zeta^S \), is 1.30, and is significant at the one percent level. A household will continue stockpiling so long as the marginal benefit of doing so exceeds the marginal cost. The marginal benefit of stockpiling in March 1997 is constant at \( \left( \frac{1 + \tau_{t+1}}{1+i} \right) - (1 + \tau_t) \approx 0.02 \), since \( i \) is small.\(^{30}\) That is, for every purchase of a storable made in March 1997 rather than April 1997, a household saves approximately two percent on the storable’s purchase price. The marginal cost of stockpiling is given by \( \zeta^S (S_t - S^*) \). The lower is \( \zeta^S \), the greater the amount of stockpiling that will be observed in March 1997.

Recall that several of the model parameters were fixed prior to estimation. While the choices of \( \epsilon^S \) and \( S^* \) have no impact on the time path of expenditures generated by the model, the other values were fixed based on available data. It seems reasonable to test the sensitivity of the structural parameter estimates to different values of these fixed parameters. Table 3 presents the results of the sensitivity analysis. In general, the structural parameter estimates, including estimates of \( \sigma \), are robust to alternative fixed parameter values. Given a change in a Group 1 parameter, each new parameter estimate lies within its confidence interval shown in Table 2.

\(^{30}\) This expression holds under the model assumptions that \( \beta (1 + i) = 1 \) and relative pre-tax prices are constant.
Figure 7 plots the time path of expenditures generated by the model against the empirical estimates. Overall, the model matches the empirical estimates reasonably well, though the validity of the model is rejected by the test of overidentifying restrictions. Non-storable non-durable expenditures lie entirely within the confidence interval. The model closely matches non-storable non-durable expenditure in the months prior to implementation, but over predicts expenditure in the month following implementation, which could be due to limited arbitrage opportunities for non-storable non-durables (e.g. buying bananas on March 31, 1997, and consuming them in early April) that the model does not allow.

The model closely matches storable expenditure in the months prior to and including implementation, but the match is rather poor in the months following implementation. This is because the model considers only one storable composite good that is costly to store. It follows that the representative household will fully consume the stockpiled storable good in the month of implementation before making any additional purchases. Storable expenditure will then return to a new steady state in the months following implementation. In reality, some households stockpile, while others don’t. Among those that do, some stockpile a lot, and others stockpile a little. As a result, there is a gradual return to trend in storable expenditure following implementation that the model is not flexible enough to match.

The time path of durable expenditures generated by the model stays within the 95 percent confidence interval in most months used in the estimation of the structural parameters. Furthermore, the pattern of durable expenditure predicted by the model is generally consistent with the empirical estimates. However, the model under predicts the sensitivity of durable expenditure to the VAT rate.

The J-statistic equals 71.84, which exceeds the critical value of 33.41 (df = 17, \( \alpha = 0.01 \)).
increase in February and March 1997, and over predicts the decline in expenditure in April 1997. This is a result of the choice of a quadratic adjustment cost specification, which requires a symmetric expenditure response on either side of the tax rate increase.

4.4. Identifying the Structural Parameters

This section provides intuition for the identification and magnitudes of the structural parameter estimates presented in Section 4.3. In addition, I discuss possible reasons why the structural parameter estimates of $\sigma$ presented in this paper differ from previous studies of intertemporal substitution that rely on survey data of household expenditures.

Identification of $\sigma$ and $\epsilon^D$ are closely linked. Recall that the user cost of durables fell relative to non-durables prior to implementation of the VAT rate increase. As illustrated in Figure 10, if $\sigma < \epsilon^D$, one would observe non-storable non-durable expenditures trending downwards in the months prior to implementation, as households substitute away from non-durables to durables, followed by an upward trend thereafter. In addition, Figure 11 demonstrates that durable expenditures would fall far more drastically upon implementation, and return to trend much more gradually, than was observed. This is because a larger value of $\epsilon^D$ will require a greater fall in durable expenditure after implementation in order to restore the original durable to non-durable consumption ratio. If instead preferences are separable over durables and non-durables (i.e. $\sigma = \epsilon^D$), one would observe no change in non-storable non-durable expenditure in the months prior to implementation, and a fall in expenditure upon implementation that remains constant thereafter. Durable expenditures would exhibit a similar, albeit less pronounced, pattern as was the case when $\sigma < \epsilon^D$. Finally, if $\sigma > \epsilon^D$, one would observe an upward trend in non-storable non-durable expenditure in the months prior to implementation (as households increase non-durable
consumption to complement durable consumption), a fall in expenditure upon implementation, and a slight decline thereafter. This pattern is largely consistent with the empirical estimates. Durable expenditures would exhibit a far less pronounced decline upon implementation, and a quicker return to trend, which is also consistent with the empirical estimates. Consequently, I find that \( \sigma > \epsilon^D \).

Given that \( \sigma > \epsilon^D \), what can be said about the magnitude of \( \sigma \)? Figure 12 illustrates the non-storable non-durable expenditure response for \( \sigma = 0.8, 0.4, \) and 0.13 when the other structural parameters are set to their baseline values. Note that the larger is \( \sigma \), the larger is the fall in non-storable non-durable expenditure following implementation. In addition, Figure 13 demonstrates that larger values of \( \sigma \) imply that the fall in durable expenditure upon implementation greatly exceeds the spike in expenditure in the month prior to implementation. The empirical estimates in Figure 12 show that non-storable non-durable expenditure was not noticeably lower following implementation than it was before. The estimates in Figure 13 show that durable expenditures fell upon implementation, but not by an amount greater than the spike in expenditure in the month prior to implementation. Together, these facts imply that \( \sigma \) is small.

Taking as given that \( \sigma > \epsilon^D \) and that \( \sigma \) and \( \epsilon^D \) are small, Figure 14 demonstrates that \( \zeta^D \) is identified primarily by the spike and trough in durable expenditure in the months prior to and including the VAT rate increase. Simply, the larger is \( \zeta^D \), the smaller will be the spike and trough in durable expenditure in March and April 1997, respectively. Similarly, the larger is \( \zeta^S \), the lower will be the amount of stockpiling in the month prior to implementation, and consequently, the lower will be the jump in storable expenditures.

Finally, previous studies of intertemporal substitution that rely on household-level expenditure data (e.g. Attanasio and Weber, 1993 and 1995; Vissing-Jorgensen, 2002; Gruber, 2013) have found significantly larger estimates
of the IES than this study, generally ranging from 0.8-1, and as high as 2. These studies make the simplifying assumption that preferences are separable over durables and non-durables, which allows for estimation of the IES by examining only the non-durable expenditure (consumption) response to changes in the real interest rate over time. Figure 15 compares the time path of non-storable non-durable and durable expenditures when \( \sigma \) and \( \epsilon^D \) are set equal to 0.8 to the observed response.\(^{32}\) Under this choice of parameters, the model is unable to match the jump in non-storable non-durable expenditure that was observed in March 1997. Furthermore, it over predicts the decline in expenditure upon implementation of the VAT rate increase. The model performs even more poorly in its prediction of the durable expenditure response, missing the spike in expenditures in March 1997 almost entirely, and over predicting the decline in expenditure upon implementation.

This begs the question of what is driving the difference between the estimates of \( \sigma \) in this study and Cashin and Unayama (2015), and those in other studies using household expenditure data. One possibility is that the estimates in this study and Cashin and Unayama (2015) do not account for borrowing constraints, and thus yield an estimate of \( \sigma \) that is biased downwards. Vissing-Jorgensen (2002), for example, finds that the IES is significantly higher for asset holders than non-asset holders. However, when Cashin and Unayama (2015) split their sample between groups that are more and less likely to be borrowing constrained, there is little difference in their estimates of \( \sigma \). Furthermore, as shown in Figure 9, the expenditure response for households above and below median income were quite similar.

Another possibility is that the estimate of \( \sigma \) in this study captures a smaller short-run elasticity, while the previous studies capture a larger long-run

\(^{32}\) \( \zeta^D \) and \( \zeta^S \) are chosen to minimize (5).
elasticity. Vissing-Jorgensen (2002) notes that households may not reoptimize their consumption allocations every quarter, and as a result, she chooses to use semiannual consumption expenditure data for her analysis. She finds that results based on quarterly data were weaker than those using semiannual data. In contrast, this study relies on only seven months of data surrounding the VAT rate increase, and as a result, may only capture a short-run elasticity.

Related to the previous point, Chetty (2012) argues that the price change required to identify a structural elasticity is increasing in the degree of optimization frictions. In the presence of a friction such as habit persistence or inattention, the two percentage point VAT rate increase may not have been large enough to elicit a consumption response, even if the true value of $\sigma$ is significantly larger than the estimate, $\hat{\sigma}$, presented in this study. However, I have shown that the tax rate increase was highly salient, making inattention an unlikely culprit for the muted consumption response. Furthermore, durable and storable expenditures responded strongly to the tax rate increase, which implies that consumers did in fact reoptimize. That said, it is still possible that the VAT rate increase was large enough to overcome frictions associated with the timing of expenditure, but not consumption.

While the previous studies utilizing survey data do not suffer from aggregation bias, they may face other methodological issues that would bias the estimate of $\sigma$ upwards. For one, the analyses include storable and some durable expenditures (e.g. apparel). If households stockpile in response to an increase in the future price level (decrease in the real interest rate), these studies would incorrectly attribute the response to increased consumption during the low-price period, and thus a larger estimate of $\sigma$. Working against this explanation, however, is the fact that the previous studies use quarterly or semiannual data, where stockpiling behavior is more difficult to observe. In addition, the changes in the real interest rate that are the subject of those studies are not necessarily
anticipated like the change in this study, further mitigating the amount of stockpiling that is likely to occur.

Finally, the difference in estimates of $\sigma$ may be a result of the previous studies’ assumption of separable preferences over durables and non-durables. Suppose that durables and non-durables are instead strong complements, as found in this study. As stated above, the reduction in the real interest rate prior to implementation of the VAT rate increase will lead to a fall in the user cost of durables. This will in turn lead to even greater non-durable consumption growth, because as strong complements, the two goods will be consumed in nearly fixed proportions regardless of their relative prices. It follows that an estimate of $\sigma$ based only on non-durable consumption growth will be biased upwards, because some of the non-durable consumption growth, which should be attributed to complementarities between durables and non-durables, is instead attributed to the change in the relative price of current and future consumption. Indeed, Cashin and Unayama (2015) obtain an estimate of $\sigma$ of 0.91 under the assumption of separable preferences. This estimate is significantly larger than their baseline estimate of 0.21, which is robust to the possibility of non-separable preferences.

4.5. External validity check

One might question the external validity of the parameter estimates, given that the estimates are derived from one event in one country. To address this concern, I use the model and the baseline structural parameter estimates to predict the expenditure response to New Zealand’s Goods and Services Tax (GST) rate increase from 10 to 12.5 percent, which was announced in March 1989 and implemented in July 1989.

Figure 16 compares the time path of expenditures generated by the model to empirical estimates of the durable and non-durable retail sales response to the GST rate increase, which is documented in Cashin (2011). The empirical
estimates provide seasonally-adjusted percentage deviations in retail sales for May through October 1989 relative to April 1989. The expenditure patterns generated by the model match up quite well with the point estimates for non-durable retail sales (storables and non-storables are summed to match the available retail sales data from New Zealand) before and after implementation, and durable retail sales prior to implementation. The model over predicts the fall in durable retail sales upon implementation, and the recovery of durable expenditure following implementation is quicker than what was observed in New Zealand. This is likely the result of the choice of a quadratic adjustment cost function for durables. Overall, however, this exercise lends additional support to the main finding in this paper, which is that expenditure is sensitive to a change in the future price level, albeit over a short period preceding and following the price change, while consumption growth is not.

5. Conclusion

This study uses a pre-announced increase in Japan’s VAT rate from three to five percent to measure intertemporal substitution behavior. I find that households accelerated purchases of durable goods and stockpiled storable goods just prior to the tax rate increase, but did not change their consumption patterns appreciably for non-storable, non-durable goods. Consequently, the estimate of the intertemporal elasticity of substitution in consumption is small. The results also suggest that durables and non-durables are strong complements.

The intertemporal elasticity of substitution in consumption is an important policy parameter because it dictates the response of aggregate demand to a change in the intertemporal price level. Despite its importance, the intertemporal substitution literature has not reached a consensus on its value. However, if one does not find a strong consumption response to a pre-announced, salient, and relatively large price change for which the timing of durable and storable
expenditure changed significantly (implying that households reoptimized), it seems unlikely that one would observe a strong consumption response to most changes in intertemporal price levels, a conjecture that corroborates recent survey evidence showing household spending attitudes are little affected by inflation expectations (see Bachman et al., 2015).

The results of this study suggest that a change to the intertemporal price level by a government authority, such as an unannounced and temporary VAT rate reduction during a recession, will have a large, but short-lived impact on household expenditure, with changes in the timing of expenditure confined to the months just prior to and following the expiration of the tax rate cut. In fact, surveys from the United Kingdom regarding the household response to the temporary VAT rate cut in 2009 indicate this was indeed the case.33 Whether or not such a policy will reduce unemployment and have a more persistent effect on aggregate demand as intended depends not only on the expenditure response to the VAT rate reduction, but also on inventory levels and the lead time required to produce the goods and services that are purchased in large quantities just prior to the end of the tax rate cut.

*David Cashin, Federal Reserve Board of Governors

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References


Carroll, R.J., Cline, R.J., Diamond, J.W., Neubig, T.S., and Zodrow, G. “Price Effects of Implementing a VAT in the United States,” *Proceedings of the 103rd Annual Conference on Taxation*, National Tax Association, 2011, pp. 56-


### Table 1. JFIES Summary Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of head</td>
<td>51.5</td>
<td>13.7</td>
<td>17</td>
<td>99</td>
</tr>
<tr>
<td>Number of household members</td>
<td>3.38</td>
<td>1.24</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Number of household members under age 15</td>
<td>0.68</td>
<td>0.98</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Number of household members aged 65+</td>
<td>0.47</td>
<td>0.75</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Number of working members</td>
<td>1.52</td>
<td>0.95</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Yearly income (1,000 yen)</td>
<td>7,113</td>
<td>4,652</td>
<td>0</td>
<td>97,043</td>
</tr>
<tr>
<td>Total expenditure (1,000 yen)</td>
<td>317</td>
<td>266</td>
<td>20</td>
<td>14,346</td>
</tr>
<tr>
<td>Excluding Tax Exempted items (1,000 yen)</td>
<td>221</td>
<td>195</td>
<td>15</td>
<td>9,255</td>
</tr>
<tr>
<td>Non-storable non-durables (N) (1,000 yen)</td>
<td>120</td>
<td>78</td>
<td>7</td>
<td>5,523</td>
</tr>
<tr>
<td>Storable non-durables (S) (1,000 yen)</td>
<td>52</td>
<td>32</td>
<td>.58</td>
<td>3,790</td>
</tr>
<tr>
<td>Durables (D) (1,000 yen)</td>
<td>47</td>
<td>138</td>
<td>0</td>
<td>7,678</td>
</tr>
<tr>
<td>Number of Observations</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Number of Households</td>
<td>129,380</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Yearly household income and monthly household expenditures are listed in thousands of yen, with 2005 serving as the base year.
### Table 2. Baseline Structural Parameter Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>95 percent confidence intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma$</td>
<td>0.13***</td>
<td>[0.05, 0.20]</td>
</tr>
<tr>
<td>$\epsilon^D$</td>
<td>-0.03***</td>
<td>[-0.05, -0.01]</td>
</tr>
<tr>
<td>$\zeta^D$</td>
<td>0.09***</td>
<td>[0.01, 0.18]</td>
</tr>
<tr>
<td>$\zeta^S$</td>
<td>1.30***</td>
<td>[1.12, 1.47]</td>
</tr>
</tbody>
</table>

95 percent confidence intervals for the structural parameter estimates above are listed in brackets, and are computed using the delta method (see Appendix D for a full explanation). *** implies significance at the one percent level.
Table 3. Sensitivity of Structural Parameter Estimates to the Fixed Parameter Values

<table>
<thead>
<tr>
<th>Calibrated parameter</th>
<th>Value</th>
<th>$\sigma$</th>
<th>$\epsilon^D$</th>
<th>$\zeta^D$</th>
<th>$\zeta^S$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>See Section 4.2</td>
<td>0.13</td>
<td>-0.03</td>
<td>0.09</td>
<td>1.30</td>
</tr>
<tr>
<td>$i$</td>
<td>0.0008 (0.01)</td>
<td>0.13</td>
<td>-0.03</td>
<td>0.09</td>
<td>1.30</td>
</tr>
<tr>
<td></td>
<td>0.0025 (0.03)</td>
<td>0.13</td>
<td>-0.03</td>
<td>0.10</td>
<td>1.28</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.01 (0.15)</td>
<td>0.08</td>
<td>-0.02</td>
<td>0.11</td>
<td>1.27</td>
</tr>
<tr>
<td></td>
<td>0.03 (0.30)</td>
<td>0.19</td>
<td>-0.04</td>
<td>0.09</td>
<td>1.31</td>
</tr>
<tr>
<td>$\psi^S$</td>
<td>0.25</td>
<td>0.12</td>
<td>-0.03</td>
<td>0.08</td>
<td>1.54</td>
</tr>
<tr>
<td></td>
<td>0.35</td>
<td>0.14</td>
<td>-0.03</td>
<td>0.10</td>
<td>1.05</td>
</tr>
<tr>
<td>$\chi^D$</td>
<td>0.35</td>
<td>0.14</td>
<td>-0.03</td>
<td>0.12</td>
<td>1.22</td>
</tr>
<tr>
<td>$\zeta^N$</td>
<td>0.50</td>
<td>0.11</td>
<td>-0.03</td>
<td>0.07</td>
<td>1.37</td>
</tr>
</tbody>
</table>

Numbers listed in parentheses represent annual values for the fixed parameters.
Figure 1 presents the number of articles per month that mention the phrase ‘Consumption Tax’ in the Nihon Keizai Shimbun and the Yomiuri Shimbun. Source: Author’s calculations. Circulation numbers come from Japan’s Audit Bureau of Circulations.
Figure 2 presents seasonally-adjusted month-to-month percentage changes in the price of goods and services that were subject to the VAT. The vertical dashed line represents April 1997, the month of the VAT rate increase from three to five percent. To generate these estimates, the month-to-month percentage change in price is regressed on month dummies. The residuals from this regression yield the seasonally-adjusted month-to-month percentage change in the price indices.
Figure 3 presents the ratio of seasonally-adjusted durable and storable non-durable prices to non-storable non-durable prices. To remove seasonality, the consumer price indices for durables, storable non-durable, and non-storable non-durable goods and services are regressed on month dummies. The residuals are added to the constant in the regression to obtain seasonally-adjusted price indices. To calculate the ratios, I divide the seasonally-adjusted durable and storable non-durable price by the seasonally-adjusted non-storable non-durable price in each month. The dashed vertical line in the figure is April 1997, the month of implementation.
Figure 4 presents two interest rates. The higher rate is the average contracted interest rate applied to a contract of less than one year between commercial banks and lenders (“Commercial banks”). This data comes from the Bank of Japan. The lower rate is the rate at the monthly auction of the 6-month Treasury bill (“6-month T-bill”). This data comes from Japan’s Ministry of Finance (http://www.mof.go.jp/english/jgbs/auction/past_auction_results/index.html).
Figure 5 presents the percentage deviation in disposable household income relative to the sample average after controlling for household fixed effects, seasonality, and time-varying household characteristics. To generate the plot, the logarithm of disposable income is regressed on a constant, a household fixed effect, month dummies, and time-varying household characteristics. The residuals from the regression are then averaged in each month and plotted.
Figure 6. Tax-exempt goods and services

Figure 6 presents the percentage deviation in tax-exempt expenditures relative to expenditure in this category in December 1996, controlling for household fixed effects, a linear trend in consumption growth, seasonality, and time-varying household characteristics. The solid red line gives the point estimates for each month, which are derived from the regression specification in Equation (4). The dashed blue lines give the 95 percent confidence intervals. Standard errors are panel-robust. The dashed vertical line represents April 1997, the month of implementation.
Figure 7 presents the percentage deviation in durable, storable, and non-storable non-durable expenditures relative to expenditure in these categories in December 1996, controlling for household fixed effects, a linear trend in consumption growth, seasonality, and time-varying household characteristics. I interpret the results as yielding the substitution effects associated with the VAT rate increase. The solid red line gives the point estimates for each month, which are derived from the regression specification in Equation (4). The dashed blue lines give the 95 percent confidence intervals. Standard errors are panel-robust. The time path of expenditures generated by the model is given by the dashed-dotted green line. The dashed vertical line represents April 1997, the month of implementation. If monthly durable expenditure for a household is reported as zero, it is set to ¥100 to avoid taking the logarithm of zero.
Figure 8. Storable and durable response to the VAT rate increase

See Figure 7 for an explanation of how these plots were generated.
Figure 9 presents the percentage deviation in income relative to December 1996 for households above and below the median income. See Figure 7 for an explanation of how these plots were generated.
Figure 10 presents non-storable non-durable expenditure patterns in the months prior to and following implementation of the VAT increase for different values of $\epsilon^D$ when $\sigma = 0.13$, which is the baseline estimate for $\sigma$. The squared green, circled cyan, and black diamond lines show expenditure when $\epsilon^D = 0.5$, 0.13, and $-0.03$, respectively. The figure also displays the empirical estimates from the top left plot in Figure 7, where the solid red line represents the point estimates, and the dashed blue lines the 95 percent confidence intervals for the point estimates.
Figure 11 presents durable expenditure patterns in the months prior to and following implementation of the VAT increase for different values of $\epsilon^D$ when $\sigma = 0.13$, which is the baseline estimate for $\sigma$. The squared green, circled cyan, and black diamond lines show expenditure when $\epsilon^D = 0.5$, 0.13, and $-0.03$, respectively. The figure also displays the empirical estimates from the bottom left plot in Figure 7, where the solid red line represents the point estimates, and the dashed blue lines the 95 percent confidence intervals for the point estimates.
Figure 12 presents non-storable non-durable expenditure patterns in the months prior to and following implementation of the VAT increase for different values of $\sigma$ when the other structural parameters are set to their baseline values. The squared green, circled cyan, and black diamond lines show expenditure when $\sigma = 0.80, 0.40$, and $0.13$, respectively. The figure also displays the empirical estimates from the top left plot in Figure 7, where the solid red line represents the point estimates, and the dashed blue lines the 95 percent confidence intervals for the point estimates.
Figure 13 presents durable expenditure patterns in the months prior to and following implementation of the VAT increase for different values of $\sigma$ when the other structural parameters are set to their baseline values. The squared green, circled cyan, and black diamond lines show expenditure when $\sigma = 0.80$, 0.40, and 0.13, respectively. The figure also displays the empirical estimates from the bottom left plot in Figure 7, where the solid red line represents the point estimates, and the dashed blue lines the 95 percent confidence intervals for the point estimates.
Figure 14 presents durable expenditure patterns in the months prior to and following implementation of the VAT increase for different values of $\zeta^D$ when the other structural parameters are set to their baseline values. The squared green, circled cyan, and black diamond lines show expenditure when $\zeta^D = 0.09$, $0.20$, and $0.30$, respectively. The figure also displays the empirical estimates from the bottom left plot in Figure 7, where the solid red line represents the point estimates, and the dashed blue lines the 95 percent confidence intervals for the point estimates.
Figure 15 compares non-storable non-durable and durable expenditure patterns in the months surrounding the VAT rate increase when $\sigma = e^D = 0.8$, and $\chi^D$ and $\zeta^S$ are chosen to minimize Equation (5). The dashed green line shows the time path generated by the model, while the solid red line shows the empirical estimates of the expenditure response to the VAT rate increase based on the JFIES survey data and the specification in Equation (4). The dashed blue lines are 95 percent confidence intervals for the empirical estimates. The dashed vertical line represents April 1997, the month the VAT rate increase was implemented.
Figure 16 compares the time path of expenditures generated by the model using the structural parameter estimates in Table 2 to empirical estimates of the seasonally-adjusted percentage deviation (relative to April 1989) in retail sales in the months surrounding New Zealand’s July 1989 Goods and Services Tax (GST) rate increase from 10 to 12.5 percent, which is documented in Cashin (2011). The rate increase was announced in March 1989 and was uncompensated.
Appendix A

Figure A.1. The Impact of an Increase in the Real Interest Rate when Households are Net Savers

In the figure above, the real interest rate increases from $r$ to $r'$. Prior to the change, the optimizing bundle for the representative consumer is given by bundle 0. Note that the consumer is a net saver since $C_1 < Y_1$, where $C_1$ is first period consumption and $Y_1$ is first period income. Given the increase in the real interest rate, the true intertemporal substitution effect is identified by holding utility constant at $U^*$ while allowing for the increase in the interest rate. The new optimizing bundle would be given by bundle 1. However, the increase in the interest rate also induces an income effect, so the optimizing consumption bundle is given by bundle 1'. The ratio of $C_2$ to $C_1$ is smaller at bundle 1' than it is at bundle 1, and thus a simple regression of the first difference of the log of the consumption ratio on the real interest rate will lead to a downward biased estimate of the IES.
<table>
<thead>
<tr>
<th>Durable $(D)$</th>
<th>Durable (cont.)</th>
<th>Non-storable non-durable (cont)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools</td>
<td>Accessories (e.g. watch)</td>
<td>Water</td>
</tr>
<tr>
<td>Cooking appliance</td>
<td>Other personal effects (e.g. cane)</td>
<td>Flowers</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>Home repair (e.g. plumbing)</td>
<td>Newspaper</td>
</tr>
<tr>
<td>Vacuum</td>
<td>Clothing services (e.g. tailoring)</td>
<td>Eating out</td>
</tr>
<tr>
<td>Washing machine/dryer</td>
<td>Auto repair</td>
<td>Domestic services</td>
</tr>
<tr>
<td>Other household durables (e.g. microwave)</td>
<td>Personal care services (e.g. haircut)</td>
<td>Bus fare</td>
</tr>
<tr>
<td>Air conditioner</td>
<td>Personal effect services (e.g watch repair)</td>
<td>Taxi fare</td>
</tr>
<tr>
<td>Fan heaters</td>
<td>Personal care item (e.g. hair dryer)</td>
<td>Airfare</td>
</tr>
<tr>
<td>Stove</td>
<td></td>
<td>Other public transit</td>
</tr>
<tr>
<td>Other heating and cooling appliances</td>
<td></td>
<td>Automotive fees</td>
</tr>
<tr>
<td>General furniture</td>
<td></td>
<td>Telephone service</td>
</tr>
<tr>
<td>Clock</td>
<td></td>
<td>Recreational good repair</td>
</tr>
<tr>
<td>Lighting</td>
<td></td>
<td>Lodging</td>
</tr>
<tr>
<td>Floor coverings and curtains</td>
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<td>Package tour</td>
</tr>
<tr>
<td>Other interior furnishings</td>
<td></td>
<td>Lesson fees</td>
</tr>
<tr>
<td>Bedding</td>
<td></td>
<td>Television service</td>
</tr>
<tr>
<td>Utensils</td>
<td></td>
<td>Movie or play admission</td>
</tr>
<tr>
<td>Japanese clothing</td>
<td></td>
<td>Other admissions</td>
</tr>
<tr>
<td>Western clothing</td>
<td></td>
<td>Other recreational services</td>
</tr>
<tr>
<td>Women’s coats</td>
<td></td>
<td>Other insurance</td>
</tr>
<tr>
<td>Shirts</td>
<td></td>
<td>Social expenses (e.g. money gifts)</td>
</tr>
<tr>
<td>Underwear</td>
<td></td>
<td>VAT-exempt (E)</td>
</tr>
<tr>
<td>Other clothing</td>
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<td>Rents for dwelling and land</td>
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<tr>
<td>Footwear</td>
<td></td>
<td>Fire insurance premium</td>
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<tr>
<td>Automobile</td>
<td></td>
<td>Medical services</td>
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<td>Other vehicle</td>
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<td>Vehicle insurance</td>
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<td>Postage</td>
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<tr>
<td>Auto parts</td>
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<td>Telephone</td>
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<td>Textbooks</td>
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<td>Textbook</td>
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<td>Religious contributions</td>
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<tr>
<td>Television</td>
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<td>Funeral expenses</td>
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<td>Stereo</td>
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<td>Nursery fees</td>
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<td>Portable audio equipment</td>
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<td>Pocket money</td>
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<tr>
<td>Video recorder</td>
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<td>Donations</td>
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<td>Camera</td>
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<td>Money gifts</td>
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<tr>
<td>Computer</td>
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<td>Remittances</td>
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<td>Musical instrument</td>
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<tr>
<td>Desk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other recreational durable goods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golf equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other sporting goods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sport outfits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toys</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other recreational goods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Books</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal effects (e.g. umbrella)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handbag</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Storable $(S)$
- Grains (e.g. noodles)
- Fish (dried, fish paste)
- Meat (processed)
- Dairy (e.g. butter)
- Vegetable (e.g. beans)
- Fruit (canned)
- Oils, spices, and seasonings
- Sugar
- Sweets (e.g. chocolate)
- Cooked food
- Beverages (e.g. tea)
- Alcoholic beverages
- Light bulbs
- Domestic goods (e.g. laundry detergent)
- Cloth

### Non-storable non-durable $(N)$
- Bread
- Fish (fresh)
- Meat (raw)
- Dairy (e.g. milk)
- Vegetable (fresh)
- Fruit (fresh)
- Cake
- Cooked food (e.g. sushi)
- Electricity
- Natural gas

### VAT-exempt $(E)$
- School lunch
- Rents for dwelling and land
- Fire insurance premium
- Medical services
- Vehicle insurance
- Postage
- School tuitions
- Textbooks
- Religious contributions
- Funeral expenses
- Nursery fees
- Pocket money
- Donations
- Money gifts
- Remittances
Appendix B. Providing Intuition for Identification of $\gamma^i_{y,m}$

It may not be readily apparent how first differenced year-month dummies for the months surrounding the VAT rate increase identify $\gamma^i_{y,m}$. Figure B.1 demonstrates how they do so. In the top portion of this hypothetical example, a household engages in stockpiling in March 1997, the month prior to implementation, which leads to an increase in storable expenditure relative to previous months, and is captured by $\gamma_{Mar}$. In April 1997, there is an equal and offsetting stockpiling effect, as well as the (negative) intertemporal substitution in consumption effect. The combined impact of these two effects is captured by $\gamma_{Apr}$.

When taking the first difference of expenditure, as depicted in the bottom portion of Figure 4, it is clear that inclusion of a dummy variable for April 1997 will yield a coefficient equal to $\gamma_{Apr} - \gamma_{Mar}$ rather than $\gamma_{Apr}$. The solution to this problem is to difference out the effect from the previous month. In practice, this means including the first difference of the March 1997 dummy in the empirical specification, rather than just a March 1997 dummy. That is, a dummy that takes on a value of 1 in March 1997 and a dummy that takes on a value of -1 in March 1997, with the dummies sharing a common coefficient. Doing so, the April 1997 dummy will capture $\gamma_{Apr}$ as intended.34

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34 The empirical specification is robust to non-symmetric stockpiling effects as well.
Figure B.1. Identifying the Intertemporal Substitution Response to the VAT Rate Increase
Appendix C: Computing the Standard Errors

Denote the mapping in Equation (5) as

\[ \hat{\theta} = f(\hat{\gamma}). \]

Provided that

\[ \sqrt{n}(\hat{\gamma} - \gamma_0) \xrightarrow{d} N(0, W), \]

by the delta method, it can be shown that

\[ \sqrt{n}(\hat{\theta} - \theta_0) \xrightarrow{d} N(0, f'(\gamma_0)W f'(\gamma_0)^T), \]

where \( n \) is the number of observations used in the regressions that yield the \( \gamma \)'s, \( f'(\gamma_0) \) is a \( P \times M \) matrix of derivatives, and \( W \) is the asymptotic variance-covariance matrix of \( \sqrt{n}(\hat{\gamma} - \gamma_0) \). In practice, \( W \) is replaced by its sample estimate, \( \hat{W} \).

To compute \( f'(\gamma_0) \), let

\[ L(\hat{\gamma}, \gamma(\theta)) = (\hat{\gamma} - \gamma(\theta))^T W^{-1}(\hat{\gamma} - \gamma(\theta)). \]

Then

\[ \frac{\partial L(\hat{\gamma}, \theta)}{\partial \theta} = L_\theta(\hat{\gamma}, \theta) \]
is a 1 x \(P\) vector, where \(L_\theta(\hat{\gamma}, \hat{\theta}) = 0\). By the implicit function theorem,

\[
L_{\theta, \gamma}(\hat{\gamma}, \theta) + L_{\theta, \theta}(\hat{\gamma}, \theta) \, f'(\gamma) = 0,
\]

and it follows that \(f'(\gamma)\) can be approximated as

\[
f'(\gamma) = -L_{\theta, \theta}(\hat{\gamma}, \hat{\theta})^{-1} L_{\theta, \gamma}(\hat{\gamma}, \hat{\theta}),
\]

where \(f'(\gamma)\) is a \(P \times M\) matrix, \(L_{\theta, \theta}(\hat{\gamma}, \theta)\) is a \(P \times P\) matrix, and \(L_{\theta, \gamma}(\hat{\gamma}, \theta)\) is a \(P \times M\) matrix. Each element of \(L_{\theta, \theta}(\hat{\gamma}, \theta)\) can be expressed as

\[
L_{\theta, \theta}(\hat{\gamma}, \theta)_{pq} = \sum_{i=1}^{M} \sum_{j=1}^{M} \omega_{ij} \left[ \frac{\partial \gamma_i(\theta)}{\partial \theta_p} \frac{\partial \gamma_j(\theta)}{\partial \theta_q} + \frac{\partial \gamma_j(\theta)}{\partial \theta_p} \frac{\partial \gamma_i(\theta)}{\partial \theta_q} \right] \quad \forall \ p = 1, ..., P; \ q = 1, ..., P
\]

where \(\omega_{ij}\) is the element of \(W^{-1}\) found in row \(j\) and column \(i\). Each element of \(L_{\theta, \gamma}(\hat{\gamma}, \theta)\) can be expressed as

\[
L_{\theta, \gamma}(\hat{\gamma}, \theta)_{pm} = -2 \sum_{i=1}^{M} \omega_{im} \frac{\partial \gamma_i(\theta)}{\partial \theta_p} \quad \forall \ m = 1, ..., M; \ p = 1, ..., P.
\]

\(\frac{\partial \gamma_m(\theta)}{\partial \theta_p}\) is computed numerically as

\[
\frac{\partial \gamma_m(\theta)}{\partial \theta_p} = \frac{\gamma_m(\hat{\theta} + he_p) - \gamma_m(\hat{\theta} - he_p)}{2h} \quad \forall \ m = 1, ..., M; \ p = 1, ..., P,
\]
where $h$ is small and $e_p$ is a $P \times 1$ vector with a one in the $p^{th}$ row and a zero in all others.\textsuperscript{35}

\textsuperscript{35} In practice, $h = 1 \times 10^{-6}$. The standard error estimates are robust to larger choices of $h$. 

Appendix D: Computing the Marginal Excess Burden of Japan’s Proposed VAT Rate Increase

In August 2012, Japan’s former Prime Minister, Yoshihiko Noda, successfully pushed a bill through Japan’s Diet (legislature) to gradually increase the VAT rate from five to ten percent in an effort to rein in public debt, which now exceeds 200 percent of GDP. Specifically, the bill would increase the VAT rate from five to eight percent in April 2014, and from eight to ten percent in October 2015.

Because the proposed VAT rate increase is pre-announced and phased-in, it has the potential to induce distortions that will generate excess burden, with the excess burden of the tax change increasing in the IES (i.e. $\sigma$), stockpiling of storables, and accelerated purchase of durables.

For this exercise, producer prices are assumed to be fixed, so the entire burden of the tax rate increase is borne by consumers in the form of higher prices. Using the structural model presented in Section 4.1, fixed parameter values presented in Section 4.2, and point estimates from Section 4.3, I predict the present discounted value (PDV) of tax revenue generated by Japan’s proposed VAT rate increase (without compensation), where the price vector under the pre-announced and phased-in tax rate change is given by

\[ p' = \begin{bmatrix} 1.05, t = t_{Aug '12}, ..., t_{Mar '14}; 1.08, t = t_{Apr '14}, ..., t_{Sep '15}; 1.10, t \\ t_{Oct '15}, ..., t_{\infty} \end{bmatrix}. \]
I then find the constant VAT rate, \( \tau^* \), that generates the same PDV of revenue as the proposed VAT rate increase.\(^{36}\) Let the vector of prices under the constant tax scenario be given by

\[
p_1 = 1 + \tau^* \forall t.
\]

Next, I compute the PDV of lifetime utility associated with the constant tax scenario, \( U_C \). Holding the PDV of lifetime utility constant at \( U_C \), I generate the (Hicks) compensated time path of expenditures for each price change associated with the proposed VAT rate increase, where the vector of prices for each price change are given by

\[
p_2 = \left[ 1.05, t = t_{Aug 12}, \ldots, t_{Mar 14}; 1 + \tau^*, t = t_{Apr 14}, \ldots, t_\infty \right],
\]

\[
p_3 = \left[ 1.05, t = t_{Aug 12}, \ldots, t_{Mar 14}; 1.08, t = t_{Apr 14}, \ldots, t_{Sep 15}; 1 + \tau^*, t = t_{Oct 15}, \ldots, t_\infty \right],
\]

and

\[
p_4 = \left[ 1.05, t = t_{Aug 12}, \ldots, t_{Mar 14}; 1.08, t = t_{Apr 14}, \ldots, t_{Sep 15}; 1.10, t = t_{Oct 15}, \ldots, t_\infty \right],
\]

respectively. Figure E.1 depicts the Hicks compensated time path of expenditures for each price change. Finally, let

\(^{36}\) Under the baseline parameter values, the constant VAT rate is 0.0979.
\[ p_0 = 1 \forall t \]

represent the vector of prices in the absence of a VAT.

To calculate the marginal excess burden associated with the pre-announced and phased-in tax rate increase, begin with the compensating variation measure of marginal excess burden (in present value) in the presence of a pre-existing tax, given by

\[
EB_C = \sum_{j=2}^{4} \sum_{t=t_{Aug}^{12}}^{\infty} \left( \frac{1}{1+i} \right)^{t-t_{Aug}^{12}} \left[ E(p_{j,t}; U_{1}) - E(p_{j-1,t}; U_{C}) \right] 
- \left[ R(p_{j,t}, p_{0,t}; U_{C}) - R(p_{j-1,t}, p_{0,t}; U_{C}) \right] 
\]

where \( i \) is the nominal interest rate, \( [E(p_{j,t}, U_{C}) - E(p_{j-1,t}, U_{C})] \) is the amount required in period \( t \) to leave a household as well off (in terms of the present value of lifetime utility under the constant tax scenario, \( U_{C} \)) after the tax change \( (p_{j,t}) \) as it was beforehand \( (p_{j-1,t}) \), and \([R(p_{j,t}, p_{0,t}; U_{C}) - R(p_{j-1,t}, p_{0,t}; U_{C})]\) is the change in compensated tax revenue in period \( t \) between the tax regimes \( j \) and \( j-1 \), where

\[
R(p_{j,t}, p_{0,t}; U_{C}) = (p_{j,t} - p_{0,t}) x^C(p_{j,t}; U_{C})
\]

is compensated tax revenue under tax regime \( j \), and \( x^C(p_{j,t}; U_{C}) \) is compensated demand in period \( t \) under tax regime \( j \).
Excluding the subscript \(t\) for simplicity, one can then rewrite the period-specific marginal excess burden, \(EB_c(p_j, p_{j-1}, p_0; U_1)\), as

\[
EB_c(p_j, p_{j-1}, p_0; U_c) = E(p_j; U_c) - E(p_{j-1}; U_c) - (p_j - p_{j-1})x^c(p_j; U_c) \\
+ (p_{j-1} - p_0)[x^c(p_{j-1}; U_c) - x^c(p_j; U_c)] 
\]

Taking a second-order Taylor series approximation of (2) around \(p_{j-1}\) and ignoring the curvature terms of the compensated demand function, \(\frac{d^2x^c(p; U_c)}{dp^2}\), yields

\[
EB_c(p_j, p_{j-1}, p_0; U_{c1}) \\n\approx \left. \frac{dEB_c}{dp} \right|_{p_{j-1}} (p_j - p_{j-1}) \\
+ \frac{1}{2} \left. \frac{d^2EB_c}{dp^2} \right|_{p_{j-1}} (p_j - p_{j-1})^2 \\
\approx -(p_{j-1} - p_0) \left. \frac{dx^c(p; U_c)}{dp} \right|_{p_{j-1}} (p_j - p_{j-1}) \\
- \frac{1}{2} \left. \frac{dx^c(p; U_c)}{dp} \right|_{p_{j-1}} (p_j - p_{j-1})^2 \\
= -\left[ (p_{j-1} - p_0) \Delta x^c(p_{j-1}; U_c) \\
+ \frac{1}{2}(p_j - p_{j-1}) \Delta x^c(p_{j-1}; U_c) \right], \quad (3)
\]
where the last equality follows from the fact that the Slutsky term, $S$, is equal to $\frac{dx_c}{dp}$, and $\Delta x^c = S \left( p_j - p_{j-1} \right)$. For more information, see Auerbach (1985).

Plugging (3) into (1) yields the following equation, which is used to compute the marginal excess burden of Japan’s proposed VAT rate increase:

$$EB_c = -\sum_{j=2}^{4} \sum_{t=Aug}^{\infty} \left( \frac{1}{1+i} \right)^{t-Aug} \left( p_{j-1,t} - p_{0,t} \right) \Delta x^c \left( p_{j-1,t} ; U_c \right)$$

$$+ \frac{1}{2} \Delta p_{j,t} \Delta x^c \left( p_{j-1,t} ; U_c \right)$$

where $\Delta p_{j,t} = p_{j,t} - p_{j-1,t}$.

Appendix Figure E.2 illustrates the marginal excess burden of the proposed VAT rate increase relative to the constant tax scenario when the IES is positive, but households cannot stockpile storables or accelerate purchases of durables. The three rows of figures illustrate the change in the excess burden associated with shifting the tax regime from $p_1$ to $p_2$, $p_2$ to $p_3$, and $p_3$ to $p_4$, respectively. The first column in each row shows the change in excess burden for the months between August 2012 and March 2014, while the second and third columns in each row illustrate the change in excess burden for April 2014 to September 2015 and October 2015 and beyond.

For example, the first column in the first row of Figure E.2 illustrates the reduction in excess burden that results from the fall in the tax rate from $\tau^*$ to $\tau = 0.05$ between August 2012 and March 2014. Area $A$ corresponds to the second term in brackets in Equation (4), while area $B$ corresponds to the first term in brackets in (4). Because the tax rate falls between August 2012 and March 2014, consumption in April 2014 and beyond is relatively more expensive. As a result, compensated demand falls in those periods. This is depicted in the second and third columns of the
first row of Figure E.2, where compensated demand falls from $x_1$ to $x_2$. Areas $C$ and $D$ represent the tax revenue lost as a result of the decrease in compensated demand in April 2014 and beyond, and they contribute to the marginal excess burden of the price change from $p_1$ to $p_2$. Summing over areas $-A, -B, C$, and $D$ yields the change in excess burden resulting from the tax change $\tau^*$ to $\tau = 0.05$ between August 2012 and March 2014. A similar exercise yields the change in excess burden for the other two tax changes. Summing over all three tax changes yields the marginal excess burden of Japan’s proposed VAT rate increase.

Using a compensating variation measure of marginal excess burden, I compute the marginal excess burden for each price change. That is, I compute the marginal excess burden associated with moving from $p_1$ to $p_2$, $p_2$ to $p_3$, and $p_3$ to $p_4$. Summing over the marginal excess burden calculations for each price change yields the marginal excess burden of the proposed VAT rate increase.

I find that the marginal excess burden of the pre-announced and phased-in VAT rate increase is just 0.002 percent of the revenue that would be raised under the constant tax scenario. In contrast, suppose that preferences over durables and non-durables are assumed to be separable, and $\sigma = 0.8$, as found in previous studies on intertemporal substitution. In this case, the marginal excess burden of the VAT rate increase is 0.05 percent of the revenue raised under the constant tax scenario, or 22 times larger than it is when using the structural parameter estimates from Section 4.3. The structural parameter estimates presented in this paper suggest that the efficiency consequences of pre-announced and/or phased-in tax-rate increases should not be of great concern to policymakers, given their small magnitude in both relative and absolute terms.
Figure D.1. The Hicks Compensated Expenditure Response to Japan’s Proposed VAT Rate Increase

Figure E.1 displays the (Hicks) compensated expenditure response to each price change associated with Japan’s proposed VAT rate increase, using the baseline parameter estimates presented in Table 2. Under each scenario, the representative household is compensated to make it as well off (in terms of the present discounted value of lifetime utility) as it would be under a constant tax, $\tau^*$, that generates the same present discounted value of revenue as the proposed VAT rate increase.

The solid red line gives the time path of compensated expenditure under price vector $p_2 = [1.05, t = t_{Aug '12}, \ldots, t_{Mar '14}; 1 + \tau, t = t_{Apr '14}, \ldots, \infty]$. The dashed blue line gives the time path of compensated expenditure under price vector $p_3 = [1.05, t = t_{Aug '12}, \ldots, t_{Mar '14}; 1.08, t = t_{Apr '14}, \ldots, t_{Sep '15}; 1 + \tau, t = t_{Oct '15}, \ldots, \infty]$. Finally, the dashed-dotted black line gives the time path of compensated expenditure under price vector $p_4 = [1.05, t = t_{Aug '12}, \ldots, t_{Mar '14}; 1.08, t = t_{Apr '14}, \ldots, t_{Sep '15}; 1.10, t = t_{Oct '15}, \ldots, \infty]$. 

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Figure E.2. Illustration of the Marginal Excess Burden of Japan’s Proposed VAT Increase

\[ p = 1 + \tau^* \]

\[ t = t_{Aug'12}, \ldots, t_{Mar'14} \]

\[ p_1 \rightarrow p_2 \]

\[ t = t_{Apr'14}, \ldots, t_{Sep'15} \]

\[ p_2 \rightarrow p_3 \]

\[ t = t_{Oct'15}, \ldots, t_{\infty} \]

\[ p_3 \rightarrow p_4 \]