Micro MPCs and Macro Counterfactuals: The Case of the 2008 Rebates

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Abstract

We present evidence that the high estimated MPCs from the leading household studies result in implausible macroeconomic counterfactuals. Using the 2008 tax rebate as a case study, we calibrate a standard medium-scale New Keynesian model with the estimated micro MPCs to construct counterfactual macroeconomic consumption paths in the absence of a rebate. The counterfactual paths imply that consumption expenditures would have plummeted in spring and summer 2008 and then recovered when Lehman Brothers failed in September 2008. We use narratives and forecasts to argue that these paths are implausible. We go on to show that reasonable modifications of the model result in general equilibrium forces that dampen rather than amplify micro MPCs. We also show that estimators of the average treatment effect yield smaller micro MPC estimates than the standard two-way fixed effects estimators. The combination of smaller micro MPCs and dampening general equilibrium forces implies general equilibrium consumption multipliers that are below 0.2.

JEL codes:E21, E27, E62

Keywords: marginal propensity to consume, transfers multipliers, heterogeneous agent

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1 Introduction

Numerous studies in the last twenty years have used panel data from households to estimate the marginal propensity to consume out of anticipated, temporary changes in income. Some of the leading studies in this area estimate the effects of the temporary tax rebates of 2001 and 2008. For example, the Shapiro and Slemrod (2003, 2009), Johnson et al. (2006), Sahm et al. (2012), Parker et al. (2013), and Broda and Parker (2014) analyses are exemplars in the use of natural experiments to obtain estimates of this key micro parameter of interest to macroeconomists. Moreover, in some of the best examples of entrepreneurial data collection, these authors added special questions to existing household surveys in order to match the household behavior to the timing of its receipt of the rebate. Shapiro and co-authors found smaller marginal propensities to consume (MPCs), around 30 percent, but Parker and co-authors found some very high estimates. For example, Parker et al. (2013) found a marginal propensity to spend out the temporary tax rebate of 50 to 90 percent on total consumption within three months of receiving the 2008 tax rebate (p. 2531, Table 3).

Estimates from these studies have motivated the thriving literature on heterogeneous agent models in which some households live hand to mouth because of myopia or financial market imperfections. The estimates have been used to calibrate a wide variety of macro New Keynesian heterogeneous agent models and to argue that temporary tax rebates can have large aggregate multipliers. For example, Kaplan and Violante (2014), Kaplan et al. (2018), and Auclert et al. (forthcoming) calibrate their heterogeneous agent models to match an MPC of 25 percent on the nondurables component of consumption expenditures. Government policy in recent years has been guided by the high MPC estimates.

In this paper, we present evidence that the high estimated MPCs from the leading household studies result in implausible macroeconomic counterfactuals. Using the 2008 tax rebate as a case study, we calibrate a standard medium-scale New Keynesian model with the estimated MPCs to construct counterfactual macroeconomic consumption paths in the absence of a rebate. The counterfactual paths imply that consumption expenditures would have plummeted in spring and summer 2008 and then would have recovered when Lehman Brothers failed in September 2008. We use narratives and forecasts to argue that these paths are implausible.

In their early analyses of the aggregate effects of the tax rebates of 2008, Feldstein (2008) and Taylor (2009) found little evidence of a response in aggregate consumer expenditures and suggested that consumers mostly saved the rebate. However, their aggregate analyses were soon overshadowed by the impressive household-level analysis conducted by Parker et al. (2013) and Broda and Parker (2014), which estimated very high propensities to consume out of the rebates.

Sahm et al. (2012) also estimated micro MPCs out of the 2008 rebate from rich survey data, but found lower MPCs than the other household-level studies. They conducted an interesting counterfactual analysis using the Parker et al. (2013) estimates. In particular, they used the Parker et al. (2013) estimate of the marginal propensity to spend the 2008 rebate on new vehicles to calculate the implied fraction of actual motor vehicle sales that were induced by the rebate. They noted that this estimate was "surprisingly high" given that there were no dramatic shifts in motor vehicle sales around that time.[1] They pointed out, however, that their exercise does not allow for any partial or general equilibrium effects.

The literature has overlooked Sahm et al.'s (2012) important calculation, perhaps because it appears in a table at the end of the paper. To demonstrate the striking implied counterfactual path, we update the numbers from their table, calculate the counterfactual path, and graph it relative to the actual path. Figure 1 shows actual expenditures on motor vehicles as the green solid line, along with the implied counterfactual spending estimate depicted by the red dashed line. This counterfactual is created as the difference between the actual spending and the estimated induced spending from the rebate.

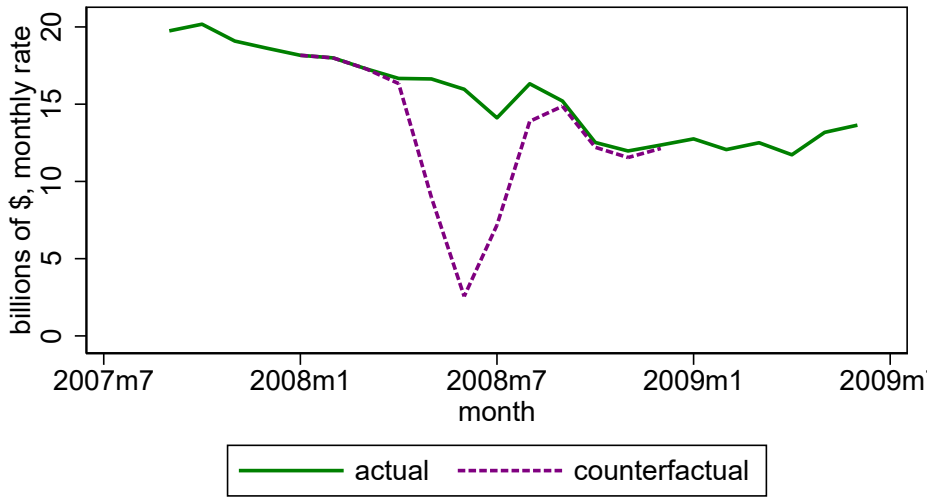
The graph shows that had there been no tax rebates, expenditures on motor vehicles would have declined by over 85 percent from $17.3 billion in March 2008 to only $2.6 billion in June 2008 and then would have rebounded sharply in late summer, averaging $14.4 billion per month in August and September 2008. This counterfactual strains credulity, especially since the lowest actual level of motor vehicle expenditures during the Great Recession was $11.7 billion in April 2009.[2]

In this paper, we extend the logic of the Sahm et al. (2012) exercise to a dynamic general equilibrium setting to study the implications of estimated micro MPCs for the

1. See p. 242 and Table 14 of Sahm et al. (2012).

2. The appendix contains details of the calculation. It also shows that when we allow consumers to smooth the spending over more months, the counterfactual remains implausible.

Figure 1. Expenditures on New Motor Vehicles: Actual vs. Counterfactual



Note. Based on Sahm, Shapiro, and Slemrod calculations applied to revised data.

counterfactual path of consumption in 2008 with no rebates. Our method proceeds as follows. We first construct a medium-scale two-good, two-agent New Keynesian (TG-TANK) model in which some households are life-cycle permanent income households and others are "hand-to-mouth" households who consume all their current income each period. We calibrate the fraction of hand-to-mouth households in the economy to match the MPC estimates from the household-level data. In this model, aggregate consumption rises due to both the direct micro effect of the rebate on consumption at the household level and the induced macroeconomic effect on income through Keynesian multipliers. We call the sum of these two effects on aggregate consumption per dollar of rebate the *general equilibrium marginal propensity to consume* out of the rebate, or GE-MPC for short. We then use the model to simulate the macroeconomic effects of a path of rebates that matches the timing and size of the actual 2008 rebate, which was announced in February and distributed mostly from April through July 2008. To create the counterfactual path of aggregate consumption in 2008 with no tax rebate, we multiply actual aggregate NIPA consumption by the ratio of the model-simulated consumption path to the model steady state.

The counterfactual paths created from our baseline simulations with average household MPCs above 0.2 imply that the path of aggregate consumption in the U.S. economy would have been V-shaped from April 2008 through August 2008 had there been

no rebates. Specifically, the counterfactual implies that consumption would have collapsed from May through July 2008 and recovered in August and September 2008, when Lehman Brothers failed.

Our argument that the counterfactual path of consumption is implausible rests on three pillars: (i) a credible macroeconomic model that produces dynamic general equilibrium responses of aggregate consumption to rebates; (ii) the absence of other factors that would have led to a collapse of consumption in summer 2008; and (iii) aggregate monthly consumption data that accurately capture the spending effects of the rebates. For the first pillar, we use a standard New Keynesian model that features the type of general equilibrium amplification that is widely used in the literature and policy models. We allow more lags in the response to spending to the rebate than estimated in order to mute the V-shape, yet the implied paths are still implausible. For the second pillar, we demonstrate that other events, such as the dramatic peaking of gasoline and other energy prices in July 2008 or the bankruptcy of Lehman Brothers in September 2008, were unlikely to have induced a V-shape of consumption absent rebates. Our evidence is based on both professional forecasts at the time and our own time series forecasts using a variety of alternative assumptions. Neither the professional forecasts nor any of the variations on our forecasting model predict a V-shape in consumption in late spring and summer of 2008. For the third pillar, we present evidence that monthly NIPA consumption does not mismeasure the consumption response during that period. To explore the possibility that aggregate consumption rose more than is reflected in the monthly NIPA numbers, we study how alternative measures of consumption, such as unit sales of automobiles, retail sales, and our own aggregates constructed from the Consumer Expenditure Survey (CEX), behaved during this period. We find no evidence of a burst in aggregated consumption from any of those sources that would be consistent with a high MPC.

Our claim about counterfactual aggregate consumption paths begs the question: how does one reconcile the high estimated micro MPCs from the literature with the implausible general equilibrium counterfactuals? One possibility is that general equilibrium forces, rather than magnifying the micro MPCs, actually dampen them. A second possibility is an upward bias in the existing household MPC estimates. We explore each of these explanations and conclude that both are key to explaining the implausible counterfactuals.

To assess the impact of dampening general equilibrium forces, we recalibrate our New Keynesian model, which has a perfectly elastic supply of durable goods, to one with a supply elasticity of five. We find that this dampening goes far toward eliminating implausible counterfactuals. However, this dampening means that even high micro MPCs do not result in sizeable Keynesian general equilibrium multipliers.

With regard to a possible upward bias in the existing household MPC estimates, we re-examine the Parker et al. (2013) estimates from the CEX in light of the recent econometric papers highlighting potential problems with event studies. Those papers, such as Sun and Abraham (2020), Borusyak and Jaravel (2017), Borusyak et al. (2021) and others, have raised questions about event study estimates based on standard OLS two-way fixed effects estimators. These estimators implicitly adopt the assumption that the treatment effect is homogeneous in the population. To maximize efficiency these estimators then assign large weights to certain treatment effects and small or negative weights to others. When treatment effects are heterogeneous, this weighting scheme can result in estimates of the aggregate treatment effect that are very different from the Average Effect of Treatment on the Treated (ATT). We apply Borusyak et al.'s (2021) new method for computing an average MPC among treated households in the CEX data and find smaller estimates of the MPC than the original Parker et al. (2013) paper does.

The combination of dampening general equilibrium forces and more modest micro MPC estimates yields macroeconomic counterfactuals that we consider plausible. However, they also imply that the effect of the rebate on consumption expenditures in general equilibrium was modest. With our preferred micro MPC of 0.3, we find that the general equilibrium increase in total consumer spending was only 16 cents per dollar of the total rebate.

Section 2 begins with a narrative of details of the 2008 tax rebate and the behavior of other key variables in 2008. It then presents alternative measures of consumption expenditures that support the patterns indicated by the NIPA data. Finally, it presents contemporaneous forecasts as well as our forecasts for consumption in 2008 before the rebate was passed. Section 3 presents the counterfactual experiments. It begins by presenting a medium-scale New Keynesian model with two goods and two types of agents. It then calibrates the model and uses it to perform DSGE simulations of the effects of rebates. It uses the simulated impulse responses to infer what actual consumption would have been had there been no rebate. It then modifies the model to incorporate more dampening effects in general equilibrium to produce alternative

counterfactual paths. Section 4 re-examines the micro MPC estimates. It begins with a brief discussion of potential issues with past micro MPC estimates and then applies Borusyak et al. (2021) to re-estimate micro MPCs from 2008. Section 5 summarizes and concludes.

2 The U.S. Macroeconomy in 2008

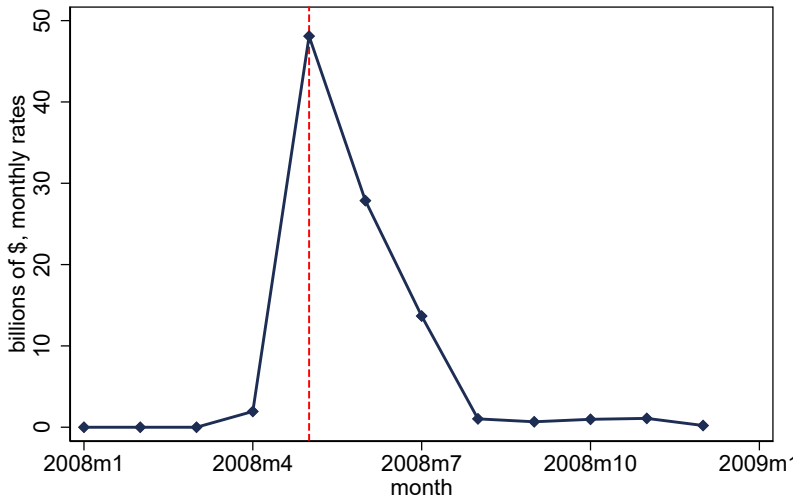
This section sets the stage for thinking about the plausibility of counterfactual paths by reviewing the tax rebates and the behavior of other key macroeconomic aggregates in 2008. The first subsection reviews the nature and timing of the tax rebates and then shows the behavior of disposable income, consumption, inflation, oil prices, and monetary policy. The second subsection provides alternative measures of consumption expenditures that support the patterns displayed in the standard NIPA measures. The third subsection shows two types of forecasts of consumption in 2008. The first type is professional forecasts of aggregate consumption, based on information before the rebates were passed. The second is our own set of time series forecasts of consumption during the Summer 2008.

2.1 Narrative of 2008

In early January 2008, numerous forecasters and policymakers began to discuss the possibility of a recession in 2008. The employment report released on January 4, 2008 showed a jump in the unemployment rate from 4.7 percent to 5 percent in December; this jump followed an earlier rise from a low of 4.4 percent in May 2007. After release of the report, Goldman Sachs forecasted that the U.S. was either in a recession or would enter one shortly, but predicted that it would be a mild downturn. That forecast assumed that the federal funds rate target would be cut from 4.25 to 2.5 by the end of the year, with the first 50 basis point cut at the next FOMC meeting on January 30th.

In fact, the Federal Reserve enacted an inter-meeting cut in the funds rate of 75 basis points on January 23rd, and another 50 basis points at the January 30th FOMC meeting. The Greenbook forecasts prepared for that meeting did not predict declines in GDP or consumption expenditures in any quarter during 2008, but the New York Federal Reserve Bank's Blackbook was more pessimistic, predicting an annualized decline in real

Figure 2. 2008 Tax Rebates



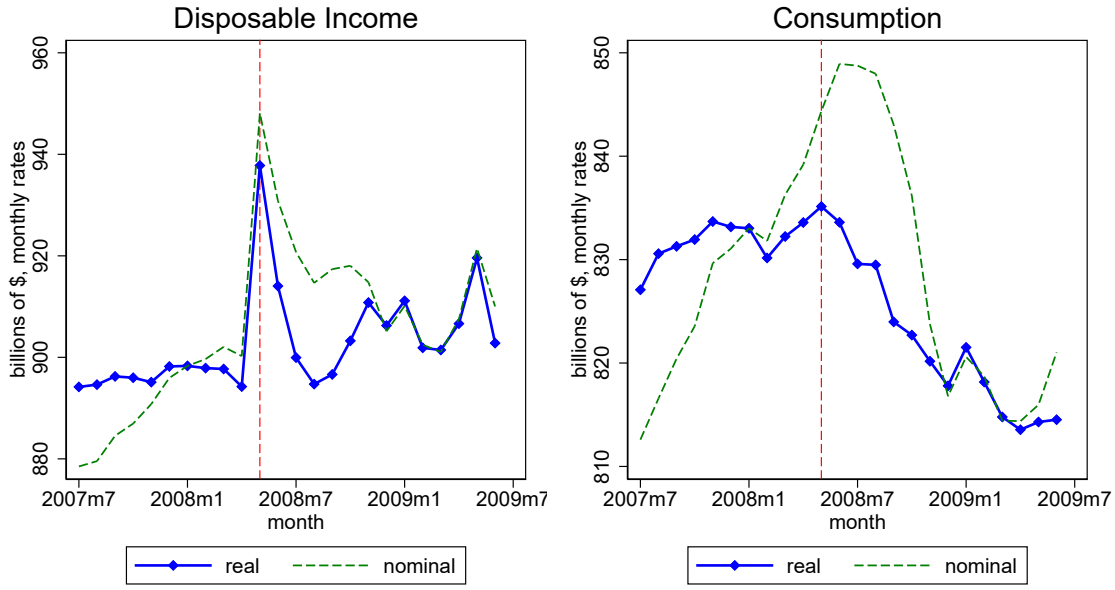
Notes. Data from Shapiro and Slemrod (2009). Rebates are nominal. Vertical red dashed line indicates May 2008.

GDP of -0.8 percent in the first quarter of 2008 with a recovery starting in the second quarter.

The Congress and Administration also recognized that the economy was slowing. They began to discuss tax rebates in January and quickly enacted them in February 2008. Both houses of Congress passed the legislation in the first week of February and President Bush signed it on February 13th. As a result, $100 billion in rebates were distributed from April through July 2008 to approximately 85 percent of households. The $100 billion in rebates was large, totaling eleven percent of January disposable income (measured on a monthly basis). The amount of the rebate depended on tax status and dependents and was phased out at higher income levels. Among households receiving a check, the average amount was $1,000. The timing of distribution was randomized according to the last two digits of the Social Security number. The actual time path of the rebates is shown in Figure 2. The graph shows that almost half of the total amount was distributed in May alone, with most of the remaining rebates distributed in June and July.

Figure 3 shows the behavior of nominal and real NIPA disposable personal income and consumption from mid-2007 through mid-2009. The vertical red dashed line indicates May 2008 when almost half of the rebate checks were distributed. We normalize

Figure 3. Aggregate Disposable Income and Consumption



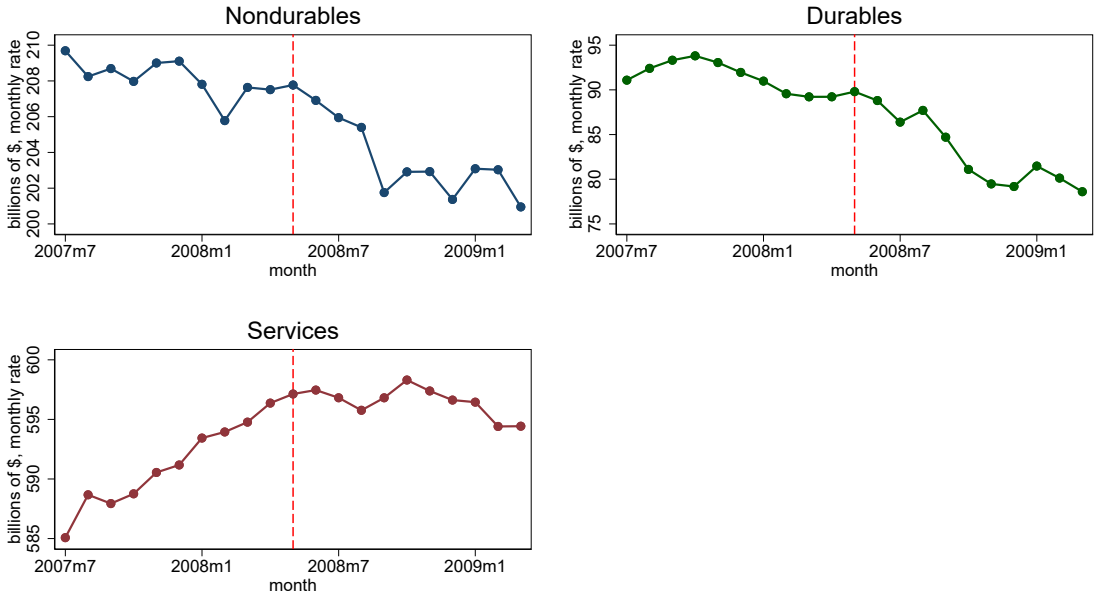
Source. BEA data. Vertical red dashed line indicates May 2008.

real income and consumption to be equal to nominal values in January 2008 for better illustration. Also, note that the range of the y-axis of the graph for disposable income is $80 billion, which is twice the range of the graph for consumption, which has less variability.

The effect of the 2008 tax rebate on disposable income is clearly evident in the spikes in both the nominal and real disposable income series, shown in the left panel. For both disposable income and consumption, however, the nominal and real paths look quite different from each other because of the behavior of inflation. After falling in February, real consumption rises to a peak in May 2008 before falling through the end of 2008. The sharpest decline is between August 2008 and September 2008, and was likely due to the shock wave caused by the fall of Lehman Brothers in mid-September. Nominal consumption shows a prominent hump in Summer 2008, but real consumption displays only a small bump.

Figure 4 shows real consumption expenditures disaggregated by type: nondurable goods, durable goods, and services. In general, consumption of goods (both nondurable and durable) decline over this period whereas consumption of services rises. In none of

Figure 4. Real Consumption Expenditures by Type of Product



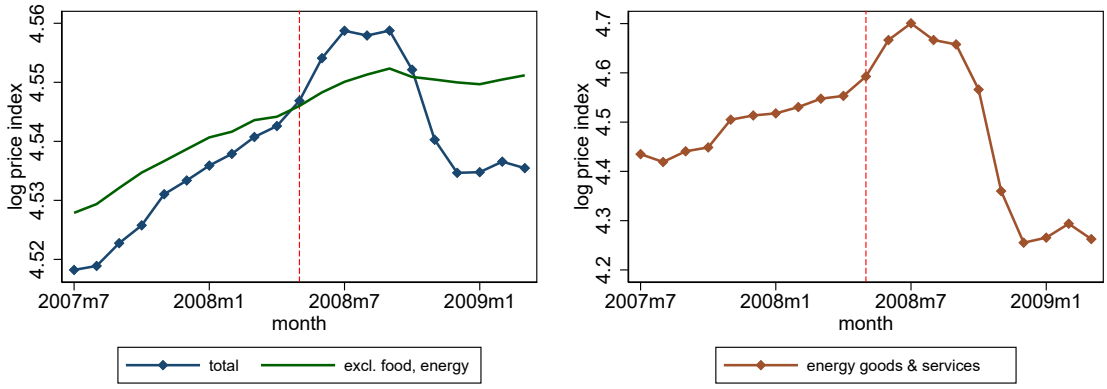
Source. BEA data. Vertical red dashed line indicates May 2008.

the three aggregates is there much evidence of a big boost to spending in May through July 2008.

We now turn to the behavior of other key factors that might have influenced consumption expenditures. The first is the behavior of consumer prices. Figure 5 shows the price indices for total consumption expenditures and consumption expenditures excluding food and energy, transformed to logarithms so that the slope of the path indicates the inflation rate. Consider first the behavior of the price deflator for total consumption. The rate of inflation for total consumption accelerated after April, resulting in July prices that were 1.6 percent above April prices. Price levels then reached a plateau and fell after the failure of Lehman Brothers in September, so that by the end of the year the level of prices was slightly lower than at the start of the year.

In contrast, the price index for consumption excluding the volatile food and energy components showed a more modest rate of inflation, averaging 3.4 percent annualized for January through the peak in September 2008. This price level then declined slightly after the collapse of Lehman Brothers.

Figure 5. Log Price Indices for Consumption



Source. BEA data.

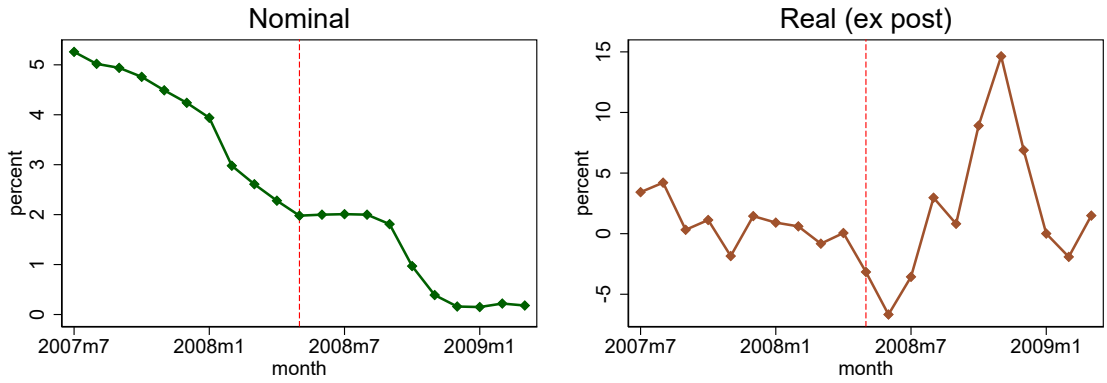
A key source of volatility of consumer prices in 2008 was the behavior of crude oil prices (not shown). The price for West Texas Intermediate rose from $98 per barrel in January 2008 to a peak of $140 per barrel in July 2008. By the end of 2008, it had fallen to only $33 per barrel.

Turning to interest rates, Figure 6 shows the behavior of the nominal and ex post real federal funds rate, constructed from the monthly rate of inflation of PCE. The nominal series shows cuts every month from mid-2007 to May 2008, a leveling off from May through August, and then cuts until the zero lower bound was reached. The combination of the cuts and the higher rates of inflation result in negative real interest rates in May through July.[3]

To summarize, these graphs reveal several key aspects of 2008. First, the rebate was large relative to aggregate disposable income. Second, most of the rise in nominal consumption in the first half of 2008 was due to inflation. Real consumption expenditures show a bounce from February to the peak in May 2008, the month with the largest rebate payments, but the magnitude is modest. Third, consumer expenditure prices were volatile during 2008. Oil prices and the PCE deflator hit a peak in July and then fell. Fourth, the Fed paused the downward trajectory of the funds rate near the end of May; however the ex post real rate turned negative in Summer 2008 because of the behavior of inflation.

3. If we instead use the PCE price deflator excluding food and energy, the real interest rates are still negative in May through July, but are between 0 and minus 1 percent.

Figure 6. Federal Funds Rate



Source. FRED, based on Federal Reserve Board of Governors. The ex post real interest rate is constructed using the annualized monthly rate of inflation in PCE.

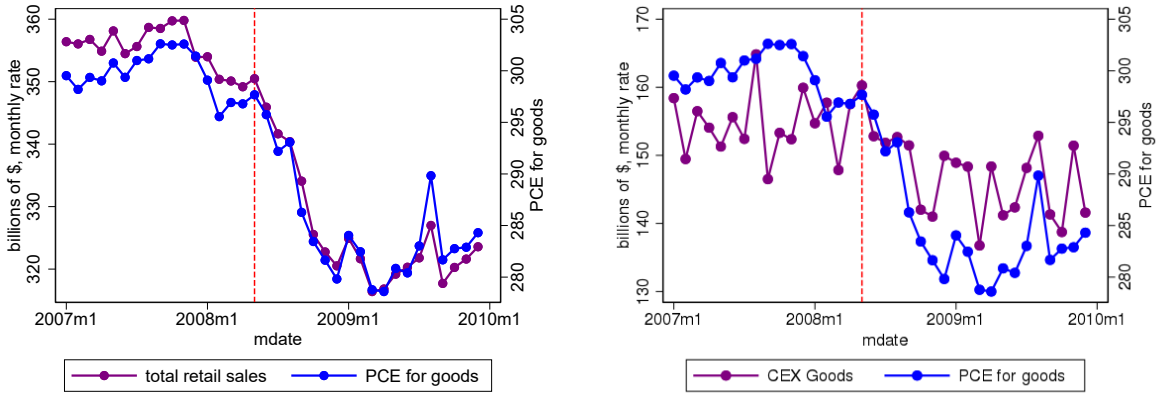
2.2 Alternative Measures of Consumption Expenditures

In this section, we show alternative measures of consumption expenditures. The motivation is twofold. First, because the monthly NIPA consumption data are based on combining and smoothing various data sources, we want to provide supplemental evidence that the patterns we showed in consumption expenditures in the last section are not due to smoothing procedures. Second, since the micro estimates suggest that a large portion of the rebate was spent on motor vehicles, it is useful to look at the behavior of aggregate spending on motor vehicles.

We first compare the NIPA measures of personal consumption expenditures (PCE) on goods to two other series: the Census series on retail sales of goods and our own constructed series based on the CEX data that is the basis for the micro estimates. As described by Wilcox (1992), government statisticians use retail sales as an input to monthly consumption, but then make a number of adjustments. To make sure those adjustments are not smoothing out jumps in consumption due to the rebate, we examine the key underlying series as well as our constructed alternative from the CEX. For all series, we use the PCE goods deflator to create real spending series.

Figure 7 shows the comparisons from 2007 through 2009. Consider first the left side graph, which compares PCE on goods to retail sales. The movements in the two series match up very well over the two years. Both show a slight blip up in May 2008, with

Figure 7. Comparison of PCE to Retail and CEX



Source. PCE (Personal Consumption Expenditures) from BEA; Retail sales from Census; Authors' aggregation from CEX. Vertical red dashed line indicates May 2008.

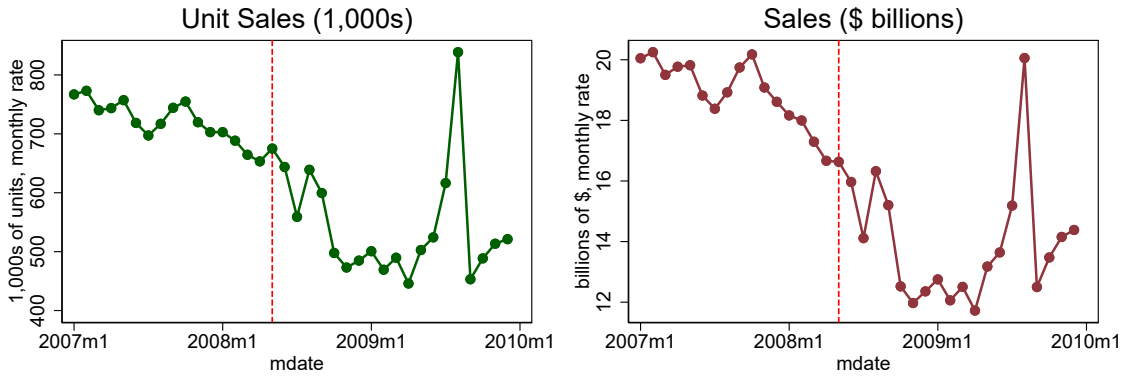
the retail series showing a more muted blip. Thus, it is unlikely that BEA smoothing of retail sales would account for the consumption pattern.

The right-hand side graph compares PCE on goods to our aggregates of household spending on goods using CEX micro data. The CEX aggregate is much noisier than either the PCE data or the retail sales data. The CEX series falls from February to March, recovers in April, and then declines in May and June. These movements look similar to those in other months, suggesting more noise than information. We conclude that the PCE data is not smoothing out a large jump in consumption when the rebates are distributed.

Finally, we consider detailed data on new motor vehicle expenditures since expenditures on motor vehicles and parts constitute the main part of the high MPC estimated by Parker et al. (2013). Another advantage of focusing on motor vehicles is the very high quality of the data. Figure 8 shows sales of new motor vehicles to consumers, measured as units on the left-hand side and as billions of dollars on the right-hand side.

Both the unit measure and the dollar measure of sales follow a downward trend from 2007 to early 2009. The unit sales measure shows a small blip in May 2008. This small blip contrasts with the huge spike that occurs later in August 2009 in response to the cash-for-clunkers program. As Sahm et al.'s (2012) accounting exercise demonstrates, the high MPC estimated by Parker et al. (2013) implies that the bulk of all sales of new motor vehicles in spring and summer 2008 were induced by rebate.

Figure 8. New Motor Vehicle Sales to Consumers



Source. BEA.

2.3 Forecasts of Consumption in 2008

In this section, we present both contemporary forecasts by professional forecasters and our own forecasts that incorporate some of the negative events that occurred in 2008.

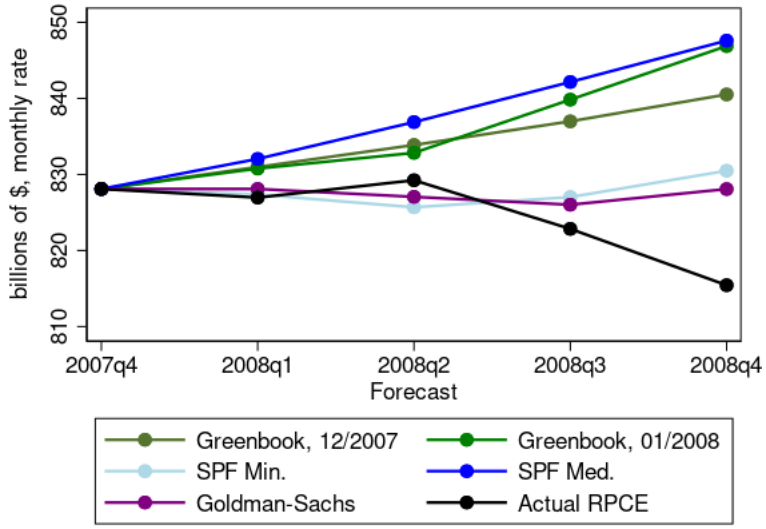
2.3.1 Contemporary Forecasts

As discussed in the narrative section above, the employment report released on January 4, 2008 led policymakers and forecasters to raise their probabilities of recession. We begin by discussing the Goldman Sachs forecast released on January 9, 2008, since they were among the first to predict that the U.S. was already in recession. The Goldman Sachs forecast also contained the following key predictions.[4] First, the Fed would cut the federal funds rate target from 4.25 to 2.5 by the end of the year, with the first 50 basis point cut at the next FOMC meeting on January 30th. Second, housing prices would decrease 20 to 25 percent below their peak. Third, Congress and the President would pass a temporary tax break as part of a fiscal stimulus plan later in the year.

They forecasted no change in real consumption expenditures (PCE) in 2008Q1, a decrease of 0.125 percent (not annualized) in each of 2008Q2 and 2008Q3, and a 0.25 percent increase in 2008Q4. Thus, they forecasted actual declines in real consumption

4. This summary is based on contemporaneous news accounts, such as the CNN Money article "Recession may already be here," January 10, 2008.

Figure 9. Contemporary Real Consumption Forecasts



Source. BEA data, Federal Reserve Board, Survey of Professional Forecasters. All forecasts normalized to monthly real consumption in 2007Q4.

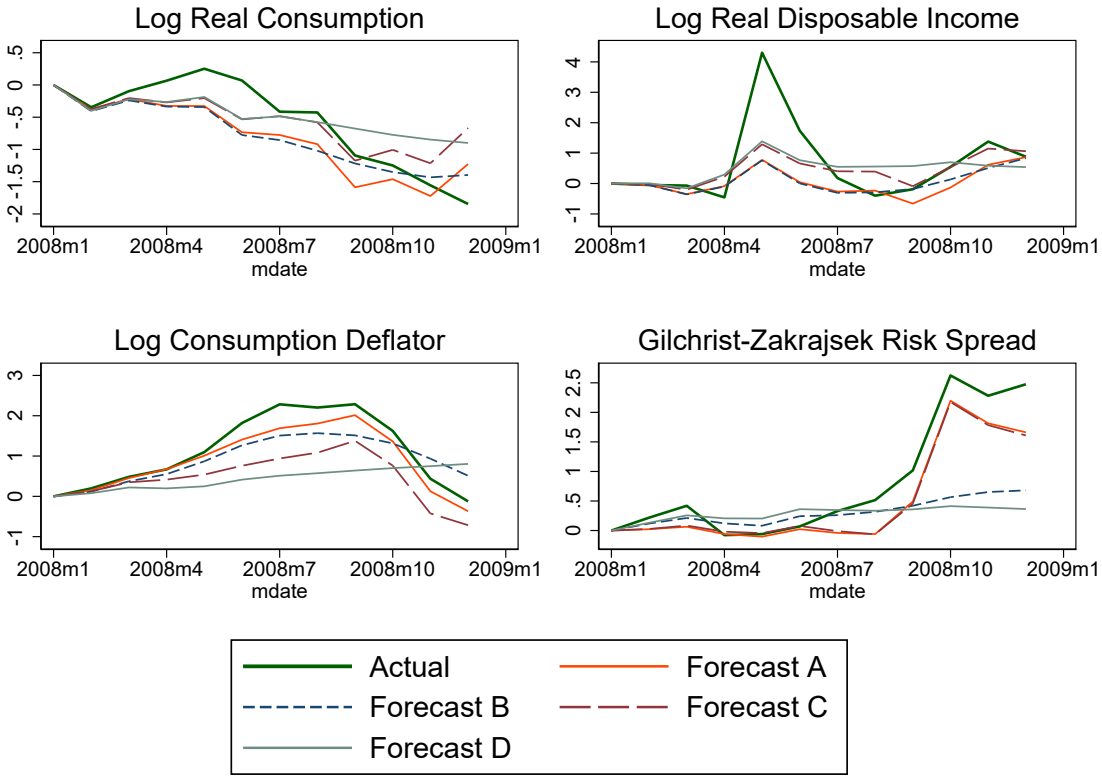
expenditures, but they were tiny in magnitude. Similarly, contemporary forecasts from the Federal Reserve Board Staff (Greenbooks) and the Survey of Professional Forecasters also did not predict large drops of consumption in summer 2008. Most forecasters predicted an increase in real consumption and even the most pessimistic forecaster from the Survey of Professional forecasters only predicted a small decrease in consumption in summer 2008. We show all these forecasts alongside actual values in figure 9.[5]

2.3.2 Our 2008 Consumption Forecasts

In the last section, we showed that even the more pessimistic forecasts did not predict a significant U-shape or V-shape of real consumption between the second and third quarters of 2008. However,, the forecasts in January 2008 did not foresee the rapid run-up in oil prices in spring and summer or the failure of Lehman Brothers in September, both of which could have affected consumption. Thus, we construct our own forecasts

5. In each case, we select the last survey prior to the passage of the Economic Stimulus Act of 2008 since afterward forecasters would include the rebate response as part of their forecast.The January Greenbook actually does incorporate the tax rebates in their consumption forecasts, however, they predict that the rebates will be received in the second half of 2008, not in the second quarter when most of them were received.

Figure 10. Forecasts from Our Four Models



Forecasts are based on information through January 2008, with exception of models in which oil prices are exogenous and Lehman Brothers dummies are included. Real oil prices are assumed to be exogenous in Models A and B; Lehman Brothers bankruptcy dummy variables are included in Models A and C.

that factor those negative events in to create more pessimistic forecasts to compare to our counterfactuals.

Our forecasting model is a simple monthly frequency time series model with the following endogenous variables: log real consumption, log real disposable income, log consumption deflator, and the Gilchrist and Zakrajšek (2012) excess bond premium. We also include a dummy variable for recession, log real oil prices, and a dummy variable for the Lehman Brothers bankruptcy in September 2008. We explored the addition of a number of other variables, such as consumer confidence but they did not noticeably change the forecasts and/or were not statistically significant. We use six lags of each variable, except for the Lehman Brothers dummy variable where we use current and

two lags. We include current values of the recession dummy, oil prices, and the excess bond premium in the equations for the endogenous variables. We estimate the model on data from 1984m1 - 2019m12 and forecast dynamically starting in January 2008. We start the estimation period in 1984 because the effects of oil prices on consumption expenditures changed significantly post-1984 (e.g. Edelstein and Kilian (2009)).

We produce four forecasts by varying our assumptions on the exogeneity of oil prices and whether Lehman Brothers went bankrupt. The most pessimistic forecasts are those in which oil prices are assumed to follow their actual path exogenously and in which the Lehman Brothers bankruptcy dummy variable is included in the forecasting equation. We keep the current and lagged recession dummy variable in all forecasts; if we omit them, the forecasts are substantially more optimistic.

Figure 10 shows the forecasts for the four endogenous variables in each of the four models. The most pessimistic forecast (Forecast A) assumes both exogenous oil prices and that Lehman Brothers went bankrupt in September 2008. The reason that allowing oil prices to respond exogenously leads to a more pessimistic forecast is that the alternative model in which oil prices respond *endogenously* does not predict a rise in spring and summer 2008, but instead predicts a gentle drift down until they plummet after the bankruptcy of Lehman Brothers in September 2008. None of the forecasts hints at a V-shape path of consumption in 2008.

3 Macro Counterfactuals

In this section, we begin by constructing a medium-scale New Keynesian (NK) model that allows us to generate counterfactual paths of consumption expenditures that include general equilibrium feedbacks. We then simulate the response of consumer expenditures to rebates and apply the results to actual consumer expenditures to create counterfactual paths had there been no rebates.

3.1 Two-Good, Two-Agent New Keynesian Model with Hand-to-Mouth Consumers and Durable Goods

We construct a two-good, two-agent New Keynesian (TG-TANK) model, which features both nondurable and durable goods and both optimizing and hand-to-mouth agents. Most elements of our model are standard for a medium-scale New Keynesian

model. In particular, it builds on the model analyzed by Ramey (2021), which is an extension of Galí et al.'s (2007) fiscal NK model. The main addition to the model is a durable consumption good, which we interpret as motor vehicles. This part of the model builds on McKay and Wieland's (2021) recent analysis of durable goods expenditures.

We begin by describing the household's problem in more detail, since it is less standard than the other parts of the model. We then briefly summarize the other features, and refer interested readers to the appendix for more details.

Optimizing Households

A measure $1-\gamma$ of ex-ante identical households maximizes utility subject to their budget constraints. The utility function for these optimizing households is:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t^o)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} + \psi \frac{(D_t^o)^{1-\frac{1}{\sigma^d}}}{1-\frac{1}{\sigma^d}} - \nu \frac{(H_t^o)^{1+\phi}}{1+\phi} \right]$$

where C_t^o is nondurable consumption, D_t^o is the durable stock, and H_t^o is hours worked. The household budget constraint is

$$A_t^o = \frac{R_{t-1}}{\Pi_t} A_{t-1}^o - C_t^o + W_t H_t^o - X_t^o - \eta D_t^o - T_t^o + \text{Profits}_t^k + \text{Profits}_t^s$$

where R_t is the gross nominal interest rate, Π_t is the gross inflation rate measured in nondurable goods prices, A_t^o are holdings of the nominal bond, W_t is the real wage, X_t^o is durable expenditure denominated in nondurable goods, ηD_t^o are operating expenditures for the durable good (e.g., gasoline), T_t^o are net taxes (i.e. taxes less transfers), Profits^k are profits of the capital good producing firms, and Profits^s are profits of the sticky-price firms, which produce nondurable goods.

Durables follow a standard accumulation equation

$$D_t^o = (1-\delta^d) D_{t-1}^o + \frac{X_t^o}{p_t^d}$$

where δ^d is the depreciation rate of household durables and p_t^d is the relative price of durable goods.

Optimizing households pick an optimal plan $\{C_t^o, D_t^o, A_t^o, X_t^o\}_{t=0}^{\infty}$ to maximize utility. Labor supply is not chosen by the household, but instead by a union as discussed below. The first order conditions for the household problem are:

$$\begin{aligned}
\lambda_t &= (C_t^o)^{-\frac{1}{\sigma}} \\
\lambda_t &= \beta \frac{R_t}{\Pi_{t+1}} \lambda_{t+1} \\
p_t^d \lambda_t &= \mu_t \\
\mu_t &= -\nu \lambda_t + \beta(1-\delta^d)\mu_{t+1} + \psi (D_t^o)^{-\frac{1}{\sigma^d}}
\end{aligned}$$

where λ is the Lagrange multiplier on the household budget constraint and μ is the Lagrange multiplier on the durable accumulation equation.

Hand-to-Mouth Households

In order for lump-sum transfers to have general equilibrium effects, we require non-Ricardian households. We adopt Galí et al.'s (2007) assumption that a certain fraction γ of consumers neither borrow nor save and simply consume all of their current income,

$$\begin{aligned}
A_t^m &= 0 \\
C_t^m + \eta D_t^m + X_t^m &= W_t H_t^m - T_t^m
\end{aligned}$$

where variables superscripted by m denote the hand-to-mouth household.

We also assume that in steady state, hand-to-mouth households consume the same relative amount of durable and nondurable services,

$$\frac{C^m}{X^m} = \frac{C^o}{X^o}$$

Finally, we directly specify dynamic marginal propensities to consume for nondurable and durable expenditures to match both the allocation across goods and any lagged ef-

fects implied by the micro MPC estimates,

$$
\begin{aligned}
C_t^m - C^m + \eta(D_t^m - D^m) &= \sum_{l=0}^{L} mpc_l[W_{t-l}H_{t-l}^m - T_{t-l}^m - (WH^m - T^m)] \\
X_t^m - X^m &= \sum_{l=0}^{L} mpx_l[W_{t-l}H_t^m - T_{t-l}^m - (WH^m - T^m)] \\
1 &= \sum_{l=0}^{L} (mpc_l + mpx_l) \\
mpx_l &= \frac{\theta}{1-\theta} mpc_l, \qquad \forall l = 0, ..., L
\end{aligned}
$$

where mpc_l is the marginal propensity to spend on nondurable goods today out of income l periods ago, and mpx_l is the marginal propensity to spend on durable goods today out of income l periods ago.

Durable Goods Production

Durable goods are produced competitively using nondurables N_t as inputs,

$$
\frac{X_{it}}{p_t^d} = N_{it} \left(\frac{X_t}{\bar{X}} \frac{1}{p_t^d} \right)^{-\zeta}
$$

where $\frac{X_{it}}{p_t^d}$ is the real production of durable goods by firm i and ζ is a negative production externality.[6]

Real profits from the sale of durable goods are given by

$$
\max_{N_{it}} (X_{it} - N_{it}) = \max_{N_{it}} \left[p_t^d N_{it} \left(\frac{X_t}{\bar{X}} \frac{1}{p_t^d} \right)^{-\zeta} - N_{it} \right]
$$

Profit maximization yields an upward sloping supply curve,

$$
p_t^d = \left(\frac{X_t}{\bar{X}} \right)^{\frac{\zeta}{1+\zeta}}
$$

6. ζ could alternatively represent a fixed factor of production as in McKay and Wieland (2021).

where $\bar{X}$ is steady state durable expenditure, so the steady state relative durable price is normalized to 1. Since durable expenditure is denominated in units of nondurable consumption, the supply elasticity of real durable goods is given by $\frac{1}{\zeta}$.

Summary of the Model's Other Features

We summarize the other features of the model only briefly since they are standard. The market for nondurable goods features sticky prices and sticky wages and noncompetitive product and labor markets. Intermediate goods firms are monopolistically competitive and face a Calvo-style (1983) adjustment cost on prices. In labor markets, households mark up wages over the marginal rate of substitution and face Calvo-type (1983) adjustment costs. The result is that short-run employment fluctuations are driven more by labor demand than labor supply. Firms face an adjustment cost on capital investment. However, they can vary their utilization of capital, so capital services are more cyclical than the capital stock. The result is more elastic output supply since it mutes the diminishing returns to labor and prevents real marginal cost from increasing much when output rises. The monetary rule is inertial, with a coefficient of 1.5 on the inflation gap and 1 on the output gap. Lump-sum taxes respond to the deviation of government debt from its steady-state values but with a lag of one year A more complete description with equations is provided in the appendix.

Table 1. Baseline Calibration of the Model

Parameter	Value	Description
β	0.997	Subjective discount factor
ψ	1.435	Weight on durable service flow
σ	0.5	IES for nondurable consumption
σ_d	varies	Utility curvature on durable service flow
η	0.018	Durable operating cost
ν	70.956	Weight on disutility of labor
ϕ	1	Inverse of the Frisch elasticity of labor supply
γ	varies	Fraction of Hand-to-Mouth consumers
θ	0.83	Hand-to-Mouth fraction of MPC spent on durables
δ_d	0.015	Depreciation of durable consumption goods
α	0.36	Exponent on private capital in production function
δ	0.005	Depreciation of private capital
κ	40	Investment adjustment cost parameter
δ_1	0.008	Parameter on linear term of capital utilization cost
δ_2	0.017	Parameter on quadratic term of capital utilization cost
ζ	0	Inverse supply elasticity of durable goods
μ_p, μ_W	1.2	Steady-state price markup, wage markup
θ_p, θ_W	0.917	Calvo parameters on price and wage adjustment
ϵ_p, ϵ_W	6.0	Elasticities of substitution between types of goods and types of labor
gy	0.175	Steady-state share of total govt spending to GDP
ϕ_b	0.1	Debt feedback coefficient in fiscal rule
ρ_r	0.947	Monetary policy interest rate smoothing
ϕ_π	1.5	Monetary policy response to inflation
ϕ_{gap}	0.083	Monetary policy response to the output gap

3.2 Calibration

The calibrated parameters with their descriptions are shown in Table 1. Note that the model is calibrated to a monthly frequency. In addition to the calibrations shown in the table, we calibrate the steady-state transfers by type of household so that hand-to-mouth and life-cycle permanent income households consume the same amount in the steady state. We also calibrate the steady-state ratio of government purchases to GDP to equal 0.175 to match the U.S. economy average. The durable goods parameters are chosen to match the share of motor vehicle spending in PCE and its depreciation rate in the fixed asset table. Operating costs are based on PCE expenditures on motor vehicle fuels, lubricants, and fluids. The appendix shows more details of the model.

The timing of spending by hand-to-mouth households is important for constructing the counterfactual path of consumption. We assume that the hand-to-mouth households respond to a shock to their disposable income by spreading their spending over three months. Estimates from Broda and Parker (2014) using higher-frequency Nielsen data on nondurable expenditures suggest that two-thirds of expenditure occurs in the month of the rebate, and one-sixth each of the following two months. In our own investigation using CEX data, we find no evidence of additional expenditure after three months.[7] Unfortunately, the CEX does not lend itself to estimate monthly expenditure patterns as most household report expenditures divided equally across the three months within an interview. One exception to this limitation is reported car expenditure, which more precisely identifies the month of purchase. Appendix table C.1 shows that the car expenditure response occurs in the three months around the rebate. We conservatively choose an equal spread of expenditure since this minimizes the extent of V-shapes in our counterfactuals and is thus more consistent with larger MPCs.

A key distinction in both the estimates and in our model is the allocation of spending between nondurable goods and motor vehicles. We assume that hand-to-mouth households allocate 83% of their expenditure towards motor vehicles. This is based on our preferred estimated MPCs after implementing the Borusyak et al. (2021) method in the next section of this paper. The estimate for nondurable spending is 0.057 (table 8, panel B column 1) and for cars is 0.3 (table 7, panel B column 1).

We simulate several versions of the model, across a range of fractions of households who are hand to mouth. We set values for γ, and thus the overall quarterly MPC,

7. See the appendix table

equal to 0.3, 0.5, and 0.7. The lower value, 0.3, reflects our preferred estimate after implementing the Borusyak et al. (2021) method (table 5, panel B column 1). The other two values, 0.5 and 0.7, are the lower bound and mid-point for the MPC reported in Parker et al. (2013).

The supply and demand elasticities for durable goods are two important parameters for the general equilibrium outcomes of the model. We set the durable good supply elasticity $\zeta^{-1} = \infty$, implying perfectly elastic supply of durable goods. We calibrate the curvature of durable utility σ^d to match a motor vehicle demand elasticity of -0.87 estimated by McCarthy (1996). For example, when the fraction of hand-to-mouth households is $\gamma = 0.3$, targeting this value of the elasticity yields $\sigma^d = 0.25$.

3.3 Macro Counterfactuals

With the model constructed and calibrated, we now compute counterfactual paths of consumption that take into account the full dynamic general equilibrium effects. We start the economy in steady state in January 2008, and assume that households do not anticipate in advance the equilibrium path of prices resulting from the rebate until after the first rebate payments are made in April.[8] We feed a path of rebate shocks into the model that matches the relative size and timing of the actual rebate shown in figure 2.

We use first-order perturbation methods to solve for the general equilibrium impulse responses of the variables to the path of rebates. We then construct macro-counterfactuals by subtracting the model-implied impulse response functions for consumer expenditures from the observed consumer expenditure data.[9]

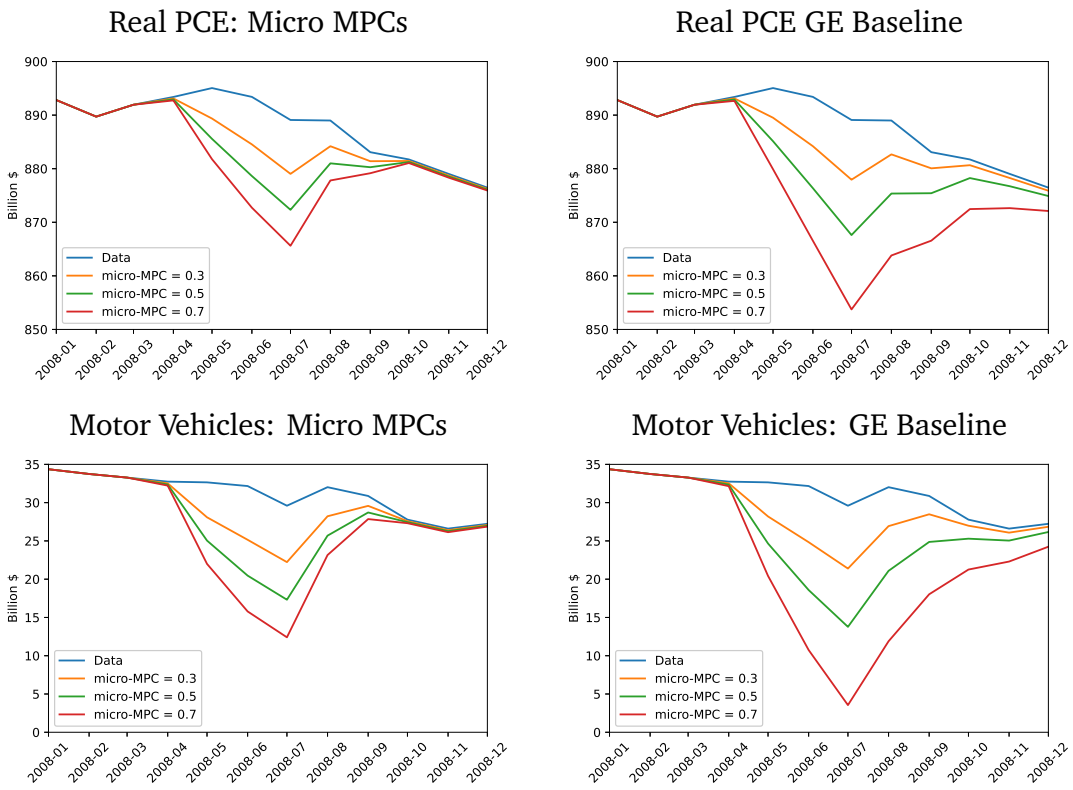
Figure 11 plots counterfactuals based on both the micro MPCs, excluding any general equilibrium effects, and on the GE-MPCs, which incorporate full dynamic general equilibrium feedbacks. The figure shows the results for both total consumer expenditure (real PCE) and motor vehicle expenditure. The micro counterfactual graphs in the left column are the analogs to the Sahm et al. (2012) counterfactual for motor vehicles, except that we assume that expenditure is equally spread over three months rather than over two months and we assume a greater fraction of the rebate is spent on motor vehicles. The figures show prominent, and we have argued implausible, V-shapes for

8. Without this assumption, optimizing households would foresee the future rise in motor vehicle prices and would increase their purchases immediately.

9. Because the model is linearized, the counterfactuals for the tax rebate would be identical if we also fed the model with other shocks that hit the economy at the time.

both total expenditure and motor vehicle expenditure, even for micro MPCs for total consumption expenditures as low as 0.3.

Figure 11. Counterfactual Consumption Expenditures: Baseline Model



Notes. Based on NK model simulations and actual data on rebates and consumption. The micro MPC value refers to the MPC for total consumption.

The graphs in the right column of Figure 11 plot the corresponding counterfactuals in general equilibrium. In this standard New Keynesian model, the general equilibrium forces amplify the effects, particularly as the micro MPCs become larger, so the counterfactual paths become even more V-shaped. For example, for a total micro MPC of 0.7, the implied counterfactual path of motor vehicles falls to $5 billion in the general equilibrium experiment rather than $13 billion in the experiment that neglects general equilibrium effects.

To quantify the total change in consumption following the rebate, we compute micro MPCs and GE-MPCs over a twelve month period in response to the rebate shock.[10]

10. GE-MPCs are computed in terms of real quantities.

Table 2 shows the correspondence between the micro MPCs (which equal the fraction of hand-to-mouth households) and general equilibrium MPCs. When the micro MPC is 0.3, the amplification is modest so that the GE-MPC for total consumption is only 24 percent higher (0.37) than the micro MPC. In contrast, when the micro MPC is 0.7, the GE-MPC is double the micro MPC.

Table 2. General Equilibrium Marginal Propensity to Consume: Baseline Model

PCE		Motor vehicles		Nondurable goods	
micro	GE	micro	GE	micro	GE
0.3	0.371	0.249	0.307	0.051	0.065
0.5	0.765	0.415	0.634	0.085	0.131
0.7	1.406	0.581	1.169	0.119	0.237

How do we reconcile the high micro MPCs with these implausible counterfactuals? To answer this question, we now explore modifications of the standard New Keynesian model that dampen rather than amplify the micro MPCs. In the next section, we re-examine the micro MPC estimates.

There are a number of ways to introduce dampening forces in general equilibrium that might help solve the puzzle of the implausible counterfactual. Possibilities include less accommodative monetary policy or lower elasticity of aggregate output.[11] We instead choose the most straightforward way to do this in our two-good model, which is to make the supply of durable goods more elastic. Our baseline calibration assumes a perfectly elastic supply of durable goods, which mimics the results one would obtain in a one-good model.[12] We thus calibrate the elastic supply of durable goods more realistically, by changing the supply elasticity of durable goods from $\zeta^{-1} = \infty$ to $\zeta^{-1} = 5$ which is midway between the elasticities reported in House and Shapiro (2008) and Goolsbee (1998).

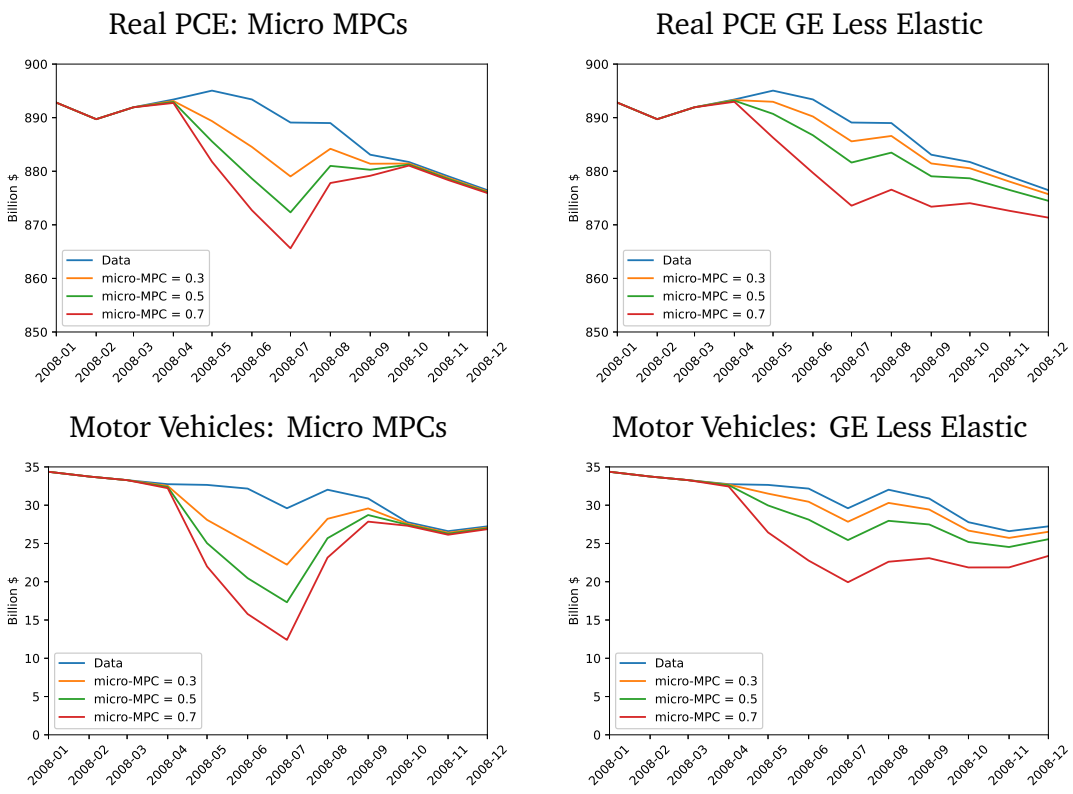
Figure 12 plots the corresponding counterfactuals for the revised model. The left column reports the same micro counterfactuals (which exclude general equilibrium effects) from the previous graph for comparison purposes and the right column reports the new general equilibrium counterfactuals based on less elastic durable goods supply.

11. The elasticity of aggregate output will be lower if prices and wages are more flexible, the labor supply elasticity is lower, or there is less scope for varying the utilization of capital.

12. Recall that in our model durable goods are produced competitively using nondurables as inputs, so a perfectly elastic supply means that the two goods are perfect substitutes in production.

For total PCE we no longer see evidence of V-shapes in the general equilibrium counterfactual. This change occurs because the general equilibrium response of motor vehicle expenditure to a tax rebate is much less than implied by the micro MPCs. With our preferred micro MPC of 0.3, real motor vehicle spending in general equilibrium falls from $33 billion in March 2008 to $28 billion July 2008, rather than from $33 billion to $22 billion based on the micro-MPCs. For higher micro MPCs these differences are even larger.

Figure 12. Counterfactual Consumption Expenditures: Less Elastic Durable Supply Model



Notes. Based on NK model simulations and actual data on rebates and consumption. The micro MPC value refers to the MPC for total consumption.

Our preferred micro MPC estimate also shows a continuous decline of the counterfactual consumer expenditure path for both total expenditure and motor vehicles. In particular, this estimate implies that motor vehicles decline further as Lehman Brother fails in September 2008. In contrast, with a micro MPC of 0.5 or 0.7, motor vehicle

expenditure in July 2008 is at or below the level of spending when Lehman Brothers fails.

Table 3. General Equilibrium Marginal Propensity to Consume: Model with less elastic Durable Supply

PCE		Motor vehicles		Nondurable goods	
micro	GE	micro	GE	micro	GE
0.3	0.155	0.249	0.12	0.051	0.035
0.5	0.36	0.415	0.286	0.085	0.074
0.7	0.831	0.581	0.67	0.119	0.161

Table 3 shows the correspondence between the micro MPCs and the GE-MPCs. When the micro MPC is 0.3, the GE-MPC is only half as large, 0.155. In this case, the general equilibrium forces of the model dampen the effect of the rebate on consumer expenditure. For a micro MPC of 0.5, this dampening is smaller and the GE-MPC is 0.36. For a micro MPC of 0.7, general equilibrium amplifies the initial partial equilibrium spending response resulting in a GE-MPC of 0.83. The general equilibrium spending response is non-linear in the micro MPC primarily because the Keyensian multiplier is also non-linear. For example, for a micro MPC of 0.3, the Keynesian multiplier is only 0.4; for a micro MPC of 0.7, the Keynesian multiplier is 2.3.[13]

The next four columns decompose the MPCs into durable expenditure (motor vehicles) and nondurable expenditure. By construction, the durable micro MPC accounts for 83% of the total expenditure micro MPC. The GE-MPCs show that the dampening in general equilibrium is concentrated in durable expenditure. For example, when the micro MPC on durables is 0.25, then the GE-MPC is less than half that magnitude. In contrast, the MPC on nondurables is only dampened by one third in general equilibrium.

The general equilibrium dampening of the consumption responses stems from the rise in relative durable goods prices. Optimizing households intertemporally substitute away from durable goods because their price is temporarily high; however, there is only a small amount of intratemporal substitution toward nondurable goods. Hand-to-mouth households also reduce their real expenditures on durable goods, but in their case, it is because their MPCs are fixed in nominal terms so the rise in relative prices

13. The simple Keynesian multiplier on rebates is mpc/(1-mpc).

of durable goods eats up part of their spending. Aggregate nondurable expenditure excluding operating costs is essentially invariant to changes in the relative price.[14]

These results have important implications for models with homogenous goods. While many models in the heterogenous agent literature are calibrated to match micro MPCs around 0.3, these models typically include only nondurable spending and therefore abstract from the stronger general equilibrium forces on durable expenditure.[15] Table 4 shows that a model that abstracts from durable goods features amplification in general equilibrium across the range of micro MPCs we consider.[16] For instance, a micro MPC of 0.3 translates into a GE-MPC of 0.41 in the model without durable goods. In our model with durable goods the GE-MPC is less than half as large as the micro MPC. This shows that it is not only important to match an overall micro MPC for consumer spending, but also its composition across nondurables and durables and their heterogeneous general equilibrium effects.

Table 4. General Equilibrium Marginal Propensity to Consume: Model without Durable Goods

PCE		Motor vehicles		Nondurable goods	
micro	GE	micro	GE	micro	GE
0.3	0.415	−0.0	−0.0	0.3	0.415
0.5	0.89	−0.0	−0.0	0.5	0.89
0.7	1.767	−0.0	0.0	0.7	1.767

4 The Micro MPC Estimates

We now reconsider the micro MPC estimates. We first summarize the latest developments in the estimation of treatment effects in the type of model used by Parker et al. (2013) on the CEX data. We then replicate the Parker et al. (2013) results using our

14. Nondurable expenditure excluding operating costs is also less responsive to changes in the real interest rate than durable expenditure. However, this difference is less important in our simulation because the change in the real interest rate peaks at only 10 basis points when the micro MPC is 0.3. This small response of the real interest rate reflects short-lived rebate, that prices are sticky, and that the nominal interest rates are inertial.

15. Notable exceptions include Berger and Vavra (2015), McKay and Wieland (2021), and McKay and Wieland (2022).

16. In this model we set the weight on the utility of durables stock $\psi = 0$, durable operating cost $\eta = 1$, and fraction of MPC that is allocated to durables $\theta = 0$.

version of the data and their methods and then apply some of the recently-developed econometric methods to generate new estimates of the micro MPCs. Our new estimates imply lower micro MPCs.

4.1 Estimation Strategy

The most widely cited micro MPC estimates, which range from 0.5 to 0.9, come from Parker et al. (2013). In a case of entrepreneurial data collection, the authors worked with the U.S. Bureau of Labor Statistics to add a question about the 2008 Tax Rebate receipt to the monthly Consumer Expenditure Survey (CEX). Since the CEX is a rotating panel survey of household expenditure, this allowed the authors to analyse consumption expenditure alongside rebate receipt in an already established survey. Furthermore, since rebate checks were sent to households based on the last two-digits of their social security number, the timing of treatment (i.e. distribution of the rebate) was effectively random.

Parker et al. (2013) leverage the variation in treatment time (i.e., the month in which the household received the rebate) and in some cases the treatment size (i.e. the dollar value of the rebate check) to estimate the causal impact of receiving a rebate on household spending using a standard difference-in-differences (DID) event-study methodology. We will focus on their specifications that leverage only the treatment timing, since the recently-developed method that we use does not allow for continuous treatment variables. For this specification, Parker et al. (2013) estimate the following regression,

$$C_{i,t+1} - C_{i,t} = \sum_{s} \beta_{0s} month_{s,i} + \beta_1' \mathbf{X}_{i,t} + \beta_2 I(ESP_{i,t+1}) + u_{i,t+1} \tag{1}$$

where t indexes the interview (performed once every three months), and i indexes individual households. The regression includes fixed effects for each month ($month_{s,i}$), household controls for age and change in household size $X_{i,t}$, and the main variable of interest, I(ESP), which is a dummy variable equal to one if the household received a rebate, i.e., an Economic Stimulus Payment (ESP).

In the last few years, the literature on staggered event-studies and two-way fixed effect models has made significant progress, first by uncovering problems with standard OLS estimators, and second by developing new estimators appropriate for this context

(see e.g., Borusyak and Jaravel, 2017; De Chaisemartin and d'Haultfoeuille, 2020; Sun and Abraham, 2020; Borusyak et al., 2021). The problems arise in the weights that are used by standard methods. The standard OLS estimators implicitly adopt the assumption that the treatment effect β_2 is homogeneous in the population. To maximize efficiency in this context, OLS assigns a large weight (relative to population size) to certain treatment effects and a negative weight to other treatment effects (see e.g., De Chaisemartin and d'Haultfoeuille, 2015; Sun and Abraham, 2020; Borusyak et al., 2021). But this weighting scheme is inappropriate when treatment effects are heterogenous and the object of interest is the average effect of treatment on the treated (ATT) in the population.

Misra and Surico (2014) were the first to note the heterogeneity across households in the responses to the rebates in 2001 and 2008 and worried that heterogeneity might affect the estimates produced by standard methods that assume homogeneity. They used quantile regression methods to estimate the distribution of MPCs across categories of households, and found that the heterogeneous MPC model produced average estimates that were lower than Johnson et al.'s (2006) and Parker et al.'s (2013) estimates.

We instead focus on the issue of weights that arises from heterogeneous treatment effects and therefore use one of the more recently-developed methods. Our goal is to estimate the average MPC in the population of households treated by the rebate. For this purpose we adopt the method in Borusyak et al. (2021). Their method consists of imputing a counterfactual spending path based on untreated and non-yet-treated households, and then aggregating the implied treatment effects among the treated population using equal weights. The identifying assumptions are that there are no anticipation effects and that the untreated households are on parallel trends with the treated households.[17]

We estimate the following regression on the sample of untreated observations, which consists of all observations on households that never received a rebate and observations on households prior to their receiving a rebate, i.e. the "untreated." The estimating equation is:

17. We adopt the weaker parallel trends rather than the random treatment assignment for the following reasons: (1) The actual rebate timing is not fully random because households received the rebate sooner if they filed taxes via EFT. (2) The reported rebate dates appear non-random as households are more likely to report receiving a rebate in the month before the interview compared to the previous two months. (3) We prefer to use the never-treated group as a control group because the OLS weighting problems are more severe when no never-treated group exists.

$$Y_{i,t+1} \equiv C_{i,t+1} - C_{i,t} = \sum_s \beta_{0s} month_{s,i} + \beta_1' \mathbf{X}_{i,t} + \tilde{u}_{i,t+1}, \qquad \forall (i, t+1) \in \{\text{Untreated}\}$$

Because these observations are untreated, this equation omits $ESP_{i,t+1}$ in contrast to equation (1). We use the estimated coefficients from this equation to "impute" the change in spending for all observations as if they had never received a rebate check as:

$$Y_{i,t+1}(0) = \sum_s \hat{\beta}_{0s} month_{s,i} + \hat{\beta}_1' \mathbf{X}_{i,t}, \qquad \forall (i, t+1) \in \{\text{Full Sample}\}$$

where $Y_{i,t+1}(0)$ is the imputed change in expenditure of household i if it is never treated. We then create the difference between the actual change in expenditures and the imputed change as:

$$\tau_{i,t+1} = Y_{i,t+1} - Y_{i,t+1}(0), \qquad \forall (i, t+1) \in \{\text{Treated in t+1}\}.$$

The average treatment effect of receiving the rebate on spending by households that received a rebate in the last interview period is then just:

$$\tau = \sum_{i,t+1 \in I(ESP_{i,t+1})=1} \omega_{i,t+1} \tau_{i,t+1},$$

where the weights $\omega_{i,t+1}$ are chosen so that τ is the sample average given the CEX survey weights (ATT).[18]

4.2 Results

We first report the results for the version of equation (1) that uses the change in total consumer expenditure as the dependent variable. These results are reported in Table 5. Panel A reports the estimates the treatment effects using standard OLS as in (1). Column (1) is a replication of Parker et al. (2011) (the detailed working paper version of (Parker et al., 2013)) estimates in Table 4, column 8. While the samples

18. We use Borusyak et al. (2021)'s **did_imputation** STATA command to construct point estimates and standard errors.

Table 5. Contemporaneous Household Expenditure Response to Rebate

Panel A: OLS				
	Full Sample		Rebate Only Sample	
	(1)	(2)	(3)	(4)
Rebate Indicator	483.2**	325.7*	779.2**	593.6**
	(209.9)	(178.2)	(310.2)	(238.8)
Implied MPC	0.52	0.35	0.86	0.65
Extra Controls	No	Yes	No	Yes
Observations	17,229	17,229	10,343	10,343

Panel B: DID Imputation				
	Full Sample		Rebate Only Sample	
	(1)	(2)	(3)	(4)
Rebate Indicator	287.0	116.2	984.4	−64.3
	(216.0)	(191.4)	(665.6)	(579.0)
Implied MPC	0.30	0.12	1.03	-0.07
Extra Controls	No	Yes	No	Yes
Observations	12,499	12,499	5,585	5,585

Notes: The dependent variable is the change in Expenditure from the previous interview. Standard errors, in parentheses, are clustered at the household level. Significance is indicated by: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. All regressions include interview (time) fixed effects, as well as household level controls for age, change in number of adults, and change in number of children. Extra controls refer to additional controls for household income decile and lagged total spending. Rebate sample includes only households that receieve a rebate at some point during our sample period.

are not exactly identical,[19] the estimates—$483.2 in our sample, $494.5 in theirs—are extremely close. We construct an implied MPC by dividing this estimate by an estimate of the rebate received for each household. We obtain the rebate amount estimate by regressing the rebate amount on the rebate indicator and the other control variables in shown in (1). These results are tabulated in Table 6. The ratio yields an MPC of $\frac{483.2}{930.5} = 0.519$, very close to the value of 0.523 reported in Parker et al. (2011), Table 4, column 16. Column (3) of Table 5 repeats the same analysis in the sub-sample of

19. We were unable to create the exact same dataset as in (Parker et al., 2013) based on the replication instructions provided by (Johnson et al., 2006; Parker et al., 2011, 2013). But the difference appear to be very small in the vast majority of cases.

Table 6. First Stage: Rebate Amount Conditional on Rebate Receipt

Panel A: OLS				
	Full Sample		Rebate Only Sample	
	(1)	(2)	(3)	(4)
Rebate Indicator	930.5***	926.6***	905.5***	907.5***
	(10.2)	(10.1)	(12.9)	(12.8)
Extra controls	No	Yes	No	Yes
Observations	17,229	17,229	10,343	10,343

Panel B: DID Imputation				
	Full Sample		Rebate Only Sample	
	(1)	(2)	(3)	(4)
Rebate Indicator	952.4***	952.4***	954.1***	954.1***
	(9.62)	(9.62)	(9.69)	(9.69)
Extra controls	No	Yes	No	Yes
Observations	12,499	12,499	5,585	5,585

Notes: The dependent variable is the dollar value of Econoimic Stimulus Payments (ESP) received by the household. Standard errors, in parentheses, are clustered at the household level. Significance is indicated by: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. All regressions include interview (time) fixed effects, as well as household level controls for age, change in number of adults, and change in number of children. Extra controls refer to additional controls for household income decile and lagged total spending. Rebate sample includes only households that receieve a rebate at some point during our sample period.

households that report receiving a rebate. Our implied MPC, $\frac{779.2}{905.5} = 0.861$ is again very close to the estimate of 0.866 reported in Parker et al. (2011), Table 4, panel B, column 12.

In columns (2) and (4) of Table 5, Panel A, we include additional controls for household income decile and lagged spending. These controls are not included in the original Parker et al. (2011) specifications, but we do find that they reduce the implied MPCs relative to the baseline specifications. This suggests that the rebate timing is not fully orthogonal to household characteristics. Nevertheless, the two-way fixed effects estimates for the MPC remain statistically significant, and remain large in the rebate-only sub-sample.

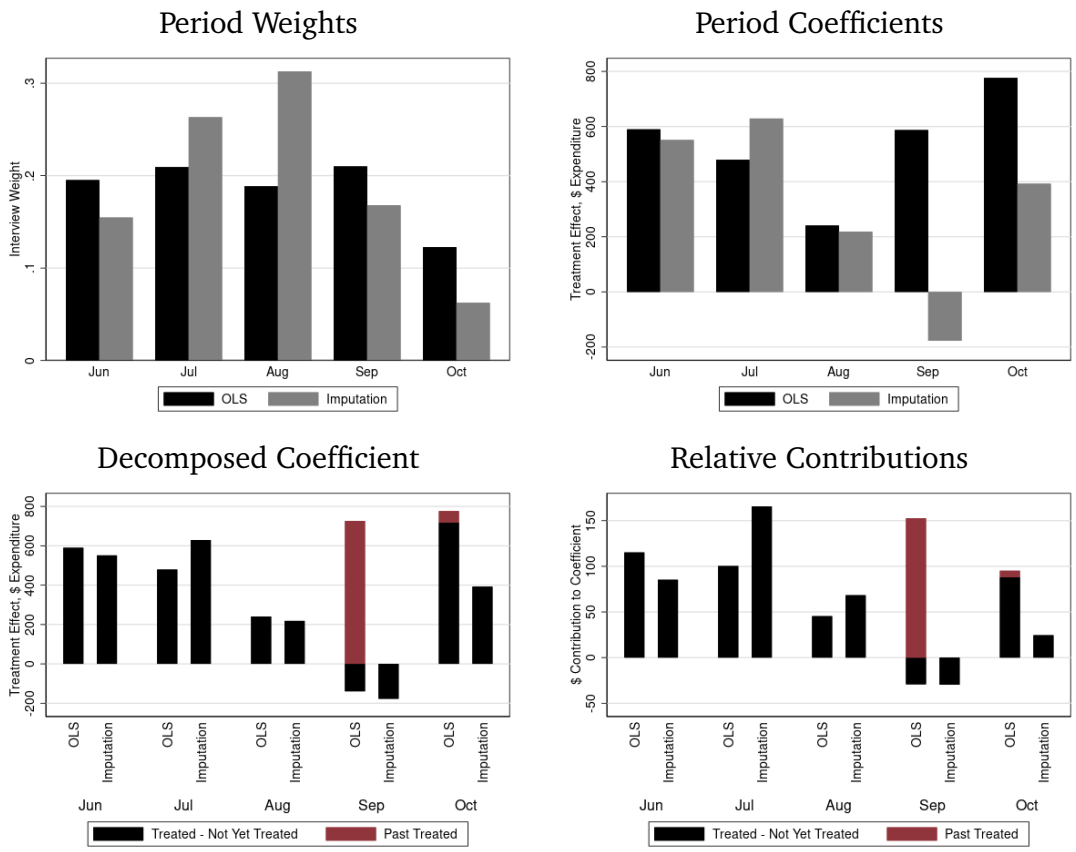
In Panel B of Table 5 we instead apply the Borusyak et al. (2021) imputation estimator. Column (1) shows that average rebate spending is only $287.0, compared to the OLS estimate of $483.2 in column (5). The implied MPC in column (15) is 0.3. Note that while the point estimate drops by almost half, the standard errors are almost unchanged. This is also the case once we include extra household controls in column (2), which only further depress the estimate for the MPC.

In columns (3) and (4) of Panel B of Table 5 we restrict the estimation to the rebate-only sample, which results in much noisier and statistically insignificant estimates. The noiser estimates reflect the fact that the imputed part of the dependent variable $Y_{i,t+1}(0)$ is calculated using a shrinking sample of not-yet-treated observations. Most households receive their rebate in May or June 2008, which means that a very small number of households are used to calculate the time fixed effects for the imputed dependent variable for the majority of the sample. The higher precision of the estimates in panel A columns (3) and (4) suggests that OLS heavily leverages comparisons with previously treated units. Borusyak et al. (2021) call these "forbidden comparisons" because they may result in negative weighting of treated observations, which in turn yields misleading estimates of the ATT when treatment effects are not homogeneous. For this reason, we believe the full sample estimates yield more reliable estimates of the aggregate MPC.

In Figure 13 we decompose the OLS coefficient in column (1) of Panel A and the imputation estimator in column (2) Panel B into weights (top left panel) and their treatment effects (top right panel). The headline coefficients in Table 5 are simply the weighted sum of the period treatment effects (see appendix C for details). The top right panel shows that the imputation estimator applies more weight to periods with more treated households, consistent with its interpretation as an average treatment effect. The top right panel show that the imputation estimator and OLS estimator largely agree on the treatment effects from rebates reported in June through August, but they imply very different treatment effect for rebates reported in the months of September and October.

To understand why the period treatment effects are different in OLS and the imputation method, the bottom left-panel shows the decomposition of the period coefficients into contributions from currently treated households compared to not-yet treated households and households that received their rebate in the past. For September, almost all the difference in the treatment effect between the DID imputation estimator and OLS comes from the comparison with the previously treated group. Put another way, OLS

Figure 13. Decomposing the OLS and DID Imputation Coefficients



Notes. The dependent variable is the change in total expenditure. Based on estimations of equation 1 via OLS and the DID imputation method described in section 4. Periods after October, 2008, also receive positive weight, however, these weights are quite small and are not shown here.

sees that households that report receiving their rebate in June display substantial negative consumption growth in the following interview (September); OLS then uses the sizeable negative consumption growth for past-treated units as a counterfactual for the treated group.[20] Borusyak et al. (2021) call these "forbidden comparisons" and remove them from their imputation estimator by dropping previously treated observations.

Previously treated households are unlikely to form a valid control group: expenditure growth in the September interview month is likely relatively low if the rebate

20. Recall the the June interview captures expenditures from February through May, and the September interview captures expenditures from June through August.

Table 7. Contemporaneous Household New Vehicle Expenditure Response to Rebate

Panel A: OLS

	Full Sample		Rebate Only Sample	
	(1)	(2)	(3)	(4)
Rebate Indicator	301.2**	231.4*	310.8	245.2
	(128.7)	(121.4)	(192.2)	(176.8)
Implied MPC	0.32	0.25	0.34	0.27
Extra Controls	No	Yes	No	Yes
Observations	17,229	17,229	10,343	10,343

Panel B: DID Imputation

	Full Sample		Rebate Only Sample	
	(1)	(2)	(3)	(4)
Rebate Indicator	301.3**	235.8*	539.0*	173.7
	(126.8)	(121.2)	(309.8)	(299.2)
Implied MPC	0.32	0.25	0.56	0.18
Extra Controls	No	Yes	No	Yes
Observations	12,499	12,499	5,585	5,585

Notes: The dependent variable is the change in New Vehicle Expenditure from the previous interview. Standard errors, in parentheses, are clustered at the household level. Significance is indicated by: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. All regressions include interview (time) fixed effects, as well as household level controls for age, change in number of adults, and change in number of children. Extra controls refer to additional controls for household income decile and lagged total spending. Rebate sample includes only households that receieve a rebate at some point during our sample period.

did raise reported expenditures in the previous interview in June.[21] For this reason we prefer the imputation estimator. The bottom right panel shows the contribution the decomposed period treatment effect to the overall estimate in Table 5. It shows that comparison with the previously treated group in September accounts almost all of the difference between the imputation and the OLS estimator.

Table 7 displays the same analysis with new vehicle expenditure as outcome variables. We find that the MPCs for new vehicles in the full sample are quite similar using

21. Controls for lagged spending or lagged rebate do not solve the "forbidden comparison" problem: the comparison will remain invalid if treatment effects are heterogeneous across rebate cohorts.

Table 8. Contemporaneous Household Non-Durable Expenditure Response to Rebate

Panel A: OLS

	Full Sample		Rebate Only Sample	
	(1)	(2)	(3)	(4)
Rebate Indicator	126.4*	116.2*	262.9***	241.5***
	(67.2)	(66.8)	(94.8)	(91.2)
Implied MPC	0.14	0.13	0.29	0.27
Extra Controls	No	Yes	No	Yes
Observations	17,229	17,229	10,343	10,343

Panel B: DID Imputation

	Full Sample		Rebate Only Sample	
	(1)	(2)	(3)	(4)
Rebate Indicator	57.0	44.8	175.2	42.8
	(68.9)	(70.5)	(212.5)	(203.2)
Implied MPC	0.06	0.05	0.18	0.04
Extra Controls	No	Yes	No	Yes
Observations	12,499	12,499	5,585	5,585

Notes: The dependent variable is the change in Non-Durable Expenditure from the previous interview. Standard errors, in parentheses, are clustered at the household level. Significance is indicated by: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. All regressions include interview (time) fixed effects, as well as household level controls for age, change in number of adults, and change in number of children. Extra controls refer to additional controls for household income decile and lagged total spending. Rebate sample includes only households that receieve a rebate at some point during our sample period.

OLS and the imputation estimator. This suggests that the instability of the MPCs for total expenditure reflects other components of spending. Indeed, Table 8 shows that the MPC estimates for non-durable expenditure are only half as large when estimated using imputation rather than OLS.

In short, we find that household MPC estimates are substantially smaller when we employ additional household controls or use an estimation method that is robust to "forbidden comparisons." Our preferred estimates indicate an MPC for total consumer spending of 0.3 or below, with all of it accounted for by durable goods expenditures.

5 Conclusion

In this paper, we have argued that a standard New Keynesian model calibrated with the leading micro estimates of the marginal propensity to consume out of temporary stimulus payments implies counterfactual paths of consumption that are implausible. Using the 2008 tax rebate as a case study, we presented narrative and forecasting evidence that no events in late spring and summer 2008 should have caused aggregate consumption expenditures to plummet and then recover in August and September 2008. Using a two-good, two-agent New Keynesian model with standard amplification and high MPCs, we simulate the effect of the 2008 tax rebates and apply the simulated responses to actual aggregate consumption to create counterfactual paths of consumption had there been no rebate. The resulting counterfactual paths imply that consumption would have exhibited a sharp V-shape in late spring and summer 2008 if there had been no tax rebates. We argue that this counterfactual path is implausible.

We have reconciled the implausible counterfactual with the micro MPC estimates in two ways. First, we modified our two-good model, which features nondurable consumption goods and durable consumption goods (interpreted as motor vehicles), to allow more realistic supply elasticities of durable goods. This modification goes far to creating counterfactual consumption paths that are more plausible. Second, we re-estimated the micro MPCs in the CEX data using new methods that overcome problems with standard OLS estimates of treatment effects. The new method results in estimated MPCs that are noticeably lower than those in the literature. The combination of the modified model and lower micro MPC estimates results in counterfactual paths that are no longer implausible. However, they imply that the general equilibrium consumption multiplier on the 2008 tax rebates was below 0.2.

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A Model

A.1 Households

A continuum of identical households maximizes utility subject to their budget constraints. The utility function for the representative household is:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} + \psi \frac{D_t^{1-\sigma^d}}{1-\sigma^d} - \nu \frac{H_t^{1+\phi}}{1+\phi} - \frac{\xi}{2} A_t^2 \right]$$

where C_t is nondurable consumption, D_t is the durable stock, H_t is hours worked, and A_t are household holdings of nominal bonds. We allow the curvature of nondurable consumption utility σ and the durable service flow σ^d to differ. We include bonds in the utility function to generate empirically estimated patterns of MPCs and intertemporal MPCs (**?**). The magnitude of MPCs in the model are determined by the parameter ξ.

The household budget constraint is

$$A_t = \frac{R_{t-1}}{\Pi_t} A_{t-1} - C_t + W_t H_t \ - X_t - T_t + \text{Profits}_t^k + \text{Profits}_t^s$$

where R_t is the gross nominal interest rate, Π_t is the gross inflation rate, W_t is the real wage, X_t is durable expenditure denominated in nondurable goods, T_t are transfers, Profits^k are profits of the capital good producing firms, and Profits^s are profits of the sticky-price firms.

Durables follow a standard accumulation equation

$$D_t = (1-\delta^d) D_{t-1} + \frac{X_t}{p_t^d}$$

where δ^d is the depreciation rate of household durables and p_t^d is the relative price of durable goods.

Households pick an optimal plan $\{C_t, D_t, A_t, X_t\}_{t=0}^{\infty}$ to maximize utility. Labor supply is not chosen by the household, but instead by a union as shown below. The first order conditions for the household problem are:

$$\begin{aligned}
\lambda_t &= (C_t)^{-\sigma} \\
\lambda_t &= \beta \frac{R_t}{\Pi_{t+1}} \lambda_{t+1} - \xi A_t \\
p_t^d \lambda_t &= \mu_t \\
\mu_t &= \beta(1-\delta^d)\mu_{t+1} + \psi (D_t)^{-\sigma^d}
\end{aligned}$$

A.2 Wages

The union problem follows XXXXX. A continuum of unions indexed by j provide differentiated labor services to the final good firm that are subsitutable with elasticity ϵ^w. Each period there is a iid probability θ^w that the union cannot adjust the contract wage. In this case, wages will adjust by a fraction χ^w of last periods inflation.

The demand for hours from union j at time $t+s$ conditional on having last reset wages at time t is

$$H^d_{t+s}(j) = H^d_{t+s}\left(\frac{W_t(j)(\frac{P_{t+s-1}}{P_{t-1}})^{\chi^w}(\frac{P_t}{P_{t+s}})}{W_{t+s}}\right)^{-\epsilon^w} = H^d_{t+s}W^{\epsilon^w}_{t+s}\left(\frac{P_{t+s}}{P_t}\right)^{\epsilon^w}\left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{-\epsilon^w\chi^w}W_t(j)^{-\epsilon^w}$$

where P_t is the price level at time t.

If the union can adjust its wage at time t it picks the optimal wage to maximize the expected discounted utility of the representative household while this wage prevails:

$$\max_{w^*_t}\sum_{s=0}^{\infty}(\beta\theta^w)^s H^d_{t+s}W^{\epsilon^w}_{t+s}\left(\frac{P_{t+s}}{P_t}\right)^{\epsilon^w}\left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{-\epsilon^w\chi^w}\left[\tilde{\lambda}_{t+s}\left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{\chi^w}\left(\frac{P_{t+s}}{P_t}\right)^{-1}(W^*_t)^{1-\epsilon^w} - \nu H^{\phi}_{t+s}(W^*_t)^{-\epsilon^w}\right]$$

where $\tilde{\lambda} = (1-\gamma)\lambda^o_t + \gamma\lambda^r_t$

The first order condition for the union is:

$$\begin{aligned}
&(\epsilon^w-1)\sum_{s=0}^{\infty}(\beta\theta^w)^s H^d_{t+s}W^{\epsilon^w}_{t+s}\left(\frac{P_{t+s}}{P_t}\right)^{\epsilon^w-1}\left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{-\chi^w(\epsilon^w-1)}\tilde{\lambda}_{t+s}(W^*_t)^{1-\epsilon^w}\\
&= \epsilon^w\nu\sum_{s=0}^{\infty}(\beta\theta^w)^s H^d_{t+s}H^{\phi}_{t+s}W^{\epsilon^w}_{t+s}\left(\frac{P_{t+s}}{P_t}\right)^{\epsilon^w}\left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{-\epsilon^w\chi^w}(W^*_t)^{-\epsilon^w}
\end{aligned}$$

We write it recursively using

$$\begin{aligned}
F_{1t} &= \nu H^d_t H^{\phi}_t W^{\epsilon^w}_t (W^*_t)^{-\epsilon^w} + \beta\theta^w\Pi^{\epsilon^w}_{t+1}\Pi_t^{-\chi^w\epsilon^w}\left(\frac{W^*_t}{W^*_{t+1}}\right)^{-\epsilon^w}F_{1,t+1}\\
F_{2t} &= H^d_t W^{\epsilon^w}_t\tilde{\lambda}_t(W^*_t)^{1-\epsilon^w} + \beta\theta^w\Pi^{\epsilon^w-1}_{t+1}\Pi_t^{-\chi^w(\epsilon^w-1)}\left(\frac{W^*_t}{W^*_{t+1}}\right)^{1-\epsilon^w}F_{2,t+1}\\
\epsilon^w F_{1t} &= (\epsilon^w-1)F_{2t}
\end{aligned}$$

Wage dispersion across unions lead to inefficiency in the labor types used by firms. This creates a wedge between hours worked H_t and effective hours worked H^d_t, which we denote by s^w_t,

$$H_t = s^w_t H^d_t,$$

and which evolves according to,

$$s_t^w = (1-\theta^w)\left(\frac{W_t^*}{W_t}\right)^{-\epsilon^w} + \theta\left(\frac{W_{t-1}}{W_t}\right)^{-\epsilon^w}\Pi_t^{\epsilon^w} s_{t-1}^w$$

A.3 Production of capital goods

The representative capital goods firm chooses investment I_t, the capital stock K_t, and the utilization rate u_t to maximize profits,

$$\begin{aligned}
&\max_{\{K_{t+s},I_{t+s},u_{t+s}\}} \sum_{s=0}^{\infty} \beta^s \lambda_{t+s}^o \text{Profits}_t^k \\
&\text{s.t. Profits}_t^k = R_{t+s}^k u_{t+s} K_{t+s-1} - I_t \\
&\qquad K_t = (1-\delta(u_t))K_{t-1} + I_t\left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right]
\end{aligned}$$

where R_{t+s}^k is the rental rate of capital paid by the final goods firm, $S\left(\frac{I_t}{I_{t-1}}\right)$ is an investment adjustment cost, and $\delta(u)$ is the depreciation rate of capital which is increasing in utilization.

Let ζ_t be the Lagrange multiplier on the capital accumulation equation and define Tobin's q as the relative value of capital to nondurable consumption,

$$q_t = \frac{\zeta_t}{\lambda_t^o}.$$

Then the first order conditions for the representative capital producing firms are,

$$\begin{aligned}
1 &= q_t\left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - \left(\frac{I_t}{I_{t-1}}\right)S'\left(\frac{I_t}{I_{t-1}}\right)\right] + \beta\frac{\lambda_{t+1}^o}{\lambda_t^o} q_{t+1}\left(\frac{I_{t+1}}{I_t}\right)^2 S'\left(\frac{I_{t+1}}{I_t}\right) \\
q_t &= \beta\frac{\lambda_{t+1}^o}{\lambda_t^o} R_{t+1}^k u_{t+1} + \beta(1-\delta(u_{t+1}))\frac{\lambda_{t+1}^o}{\lambda_t^o} q_{t+1} \\
R_t^k &= \delta'(u_t) q_t
\end{aligned}$$

A.4 Production of final goods

Final output Y_t is produced using a Cobb-Douglas production function with capital share α,

$$s_t Y_t = Z_t (u_t K_{t-1})^\alpha (H_t^d)^{1-\alpha}$$

where Z_t is aggregate TFP. The wedge s_t captures a distortion from price dispersion, which is described below.

The cost minimization for the representative final goods firm is

$$\begin{aligned} &\min R_t^k u_t K_{t-1} + W_t H_t^d \\ &\text{s.t. } Z_t (u_t K_{t-1})^{\alpha} (H_t^d)^{1-\alpha} = s_t Y_t \end{aligned}$$

which yields the following first order conditions for capital and labor,

$$\begin{aligned} R_t^k &= \xi_t \alpha \frac{s_t Y_t}{u_t K_{t-1}} \\ W_t &= \xi_t (1-\alpha) \frac{s_t Y_t}{H_t^d} \end{aligned}$$

where ξ_t is the Lagrange multiplier on the production function. Dividing the two first order conditions yields the optimal capital-labor ratio,

$$\frac{u_t K_{t-1}}{H_t^d} = \frac{\alpha}{1-\alpha} \frac{W_t}{R_t^k},$$

which in turn yields the marginal cost of output is,

$$MC_t = \alpha^{-\alpha} (1-\alpha)^{-(1-\alpha)} (R_t^k)^{\alpha} W_t^{1-\alpha} \frac{1}{Z_t}$$

With perfect competition among final goods firms, the real final goods price is equal to marginal cost,

$$p_t^f = MC_t,$$

and final good firms make zero profits.

A.5 Prices

A continuum of retailers purchases final goods at price p_t^f and differentiates these goods with elasticity of substitution ϵ. Retailers can only reset their price with probability θ. The profit maximization problem for setting the reset price is

$$\max_{p_t^*} \sum_{s=0}^{\infty} \beta^s \left(\frac{\lambda_{t+s}^o}{\lambda_t^o} \right) \theta^s Y_{t+s} \left[(p_t^*)^{1-\epsilon} \left(\frac{P_{t+s}}{P_t} \right)^{\epsilon-1} - (p_t^*)^{-\epsilon} \left(\frac{P_{t+s}}{P_t} \right)^{\epsilon} p_{t+s}^f \right]$$

The first order condition for the optimal reset price is

$$\epsilon \sum_{s=0}^{\infty} \beta^s \left(\frac{\lambda^o_{t+s}}{\lambda^o_t} \right) \theta^s Y_{t+s} \left(\frac{P_{t+s}}{P_t} \right)^{\epsilon} (p^*_t)^{-\epsilon-1} p^f_{t+s} = (\epsilon - 1) \sum_{s=0}^{\infty} \beta^s \left(\frac{\lambda_{t+s}}{\lambda_t} \right) \theta^s Y_{t+s} \left(\frac{P_{t+s}}{P_t} \right)^{\epsilon-1} (p^*_t)^{-\epsilon}$$

which we write recursively as

$$\begin{aligned}
X_{1t} &= Y_t p^f_t (p^*_t)^{-\epsilon-1} + \beta\theta \left(\frac{\lambda^o_{t+1}}{\lambda^o_t} \right) \left(\frac{P_{t+1}}{P_t} \right)^{\epsilon} \left(\frac{p^*_t}{p^*_{t+1}} \right)^{-\epsilon-1} X_{1,t+1} \\
X_{2t} &= Y_t (p^*_t)^{-\epsilon} + \beta\theta \left(\frac{\lambda^o_{t+1}}{\lambda^o_t} \right) \left(\frac{P_{t+1}}{P_t} \right)^{\epsilon-1} \left(\frac{p^*_t}{p^*_{t+1}} \right)^{-\epsilon} X_{2,t+1} \\
\epsilon X_{1t} &= (\epsilon - 1) X_{2t}
\end{aligned}$$

The optimal reset price determines aggregate inflation

$$1 = (1-\theta)(p^*_t)^{1-\epsilon} + \theta \Pi_t^{-(1-\epsilon)}$$

as well as the relative price distortion

$$\begin{aligned}
s_t &= \int_0^1 \left(\frac{P_t(i)}{P_t} \right)^{-\epsilon} di \\
&= (1-\theta)(p^*_t)^{-\epsilon} + \theta \int_0^1 \left(\frac{P_{t-1}(i)}{P_t} \right)^{-\epsilon} di \\
&= (1-\theta)(p^*_t)^{-\epsilon} + \theta \Pi^{\epsilon}_t s_{t-1}
\end{aligned}$$

Due to monopoly power, the sticky-price firms make non-zero profits in equilibrium equal to

$$\text{Profits}^s_t = Y_t (1 - p^f_t)$$

A.6 Government

The central bank sets the gross nominal interest rate according to the following interest rate rule,

$$R_t = (1-\rho_r) R_{t-1} + \rho_r \left[R + \phi_\pi (\Pi_t - \bar{\Pi}) + \phi_y \left(\frac{Y_t}{\bar{Y}} - 1 \right) \right]$$

where ρ_r determines the degree of interest rate smoothing, ϕ_π the response to deviations of inflation from target, and ϕ_y the response to deviations of output from target.

The government issues one-period nominal bonds at gross interest R_t to cover debt repayment and any fiscal deficit.

$$B_t = \frac{R_{t-1}}{\Pi_t} B_{t-1} + G_t - T_t$$

To balance the budget over time, taxes are an increasing function of the debt level,

$$T_t = T + \phi_b (B_{t-k} - \bar{B}) - \epsilon_t.$$

We allow for a lag of k periods in the response of taxes to debt. The shock ϵ_t represents a one-time deficit financed transfer from the government to households.

A.7 Durable Goods Production

Durable goods are produced competitively using nondurables N_t as inputs,

$$\frac{X_{it}}{p_t^d} = N_{it} \left(\frac{X_t}{\bar{X}} \frac{1}{p_t^d} \right)^{-\zeta}$$

where $\frac{X_{it}}{p_t^d}$ is the real production of durable goods by firm i and ζ is a negative production externality.[22]

Real profits from the sale of durable goods are

$$\max_{N_{it}} X_{it} - N_{it} = \max_{N_{it}} p_t^d N_{it} \left(\frac{X_t}{\bar{X}} \frac{1}{p_t^d} \right)^{-\zeta} - N_{it}$$

Profit maximization yields an upward sloping supply curve,

$$p_t^d = \left(\frac{X_t}{\bar{X}} \right)^{\frac{\zeta}{1+\zeta}}$$

where $\bar{X}$ is steady state durable expenditure, so the steady relative durable price is normalized to 1. Since durable expenditure is denominated in units of nondurable consumption, the supply elasticity of real durable goods is given by $\frac{1}{\zeta}$.

A.8 Market Clearing

The goods market clears if total expenditure equals output.

$$Y_t = C_t + I_t + X_t + G_t$$

22. ζ could alternatively represent a fixed factor of production as in McKay and Wieland (2021).

The bond market clears of bonds supplied by the government equal bonds held by households,

$$B_t = A_t \tag{2}$$

A.9 Functional Forms

We assume the following functional forms:

$$\delta(u_t) = \delta_0 + \delta_1(u_t - 1) + \delta_2(u_t - 1)^2$$
$$S\left(\frac{I_t}{I_{t-1}}\right) = \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$$

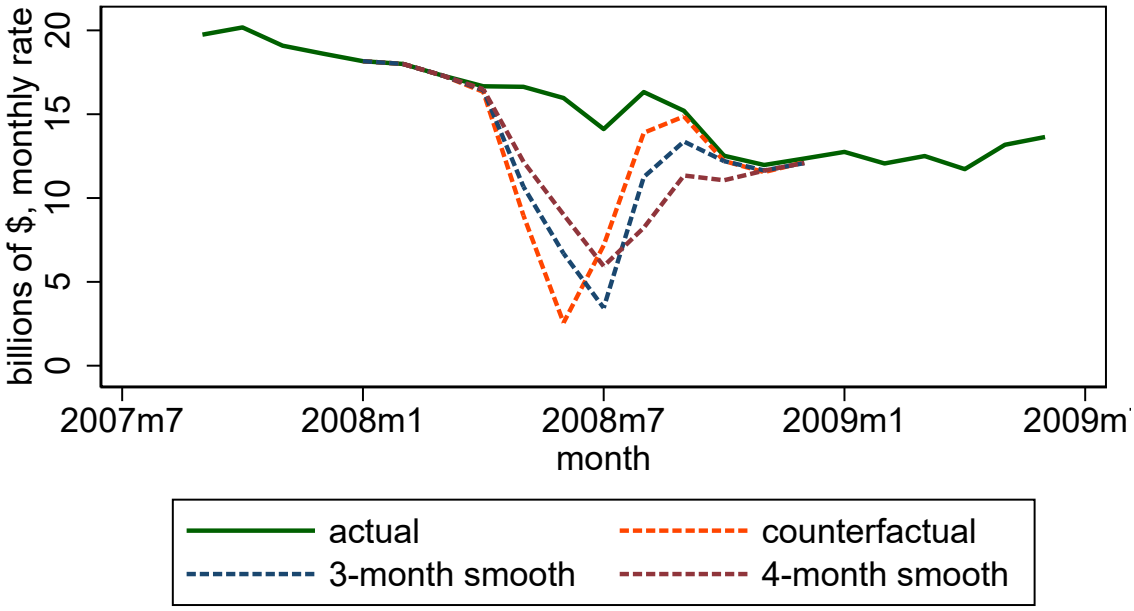
B Data Appendix

B.1 Details for Figure 1

The following are details of the Sahm et al. (2012) calculation and our update. Sahm et al. (2012) use Parker et al.'s (2013) estimate of a marginal propensity to spend on new motor vehicles of 0.357 (from Table 7 of Parker et al. (2013)) to calculate induced spending. Following Parker et al. (2013), they assume that the spending is evenly distributed between the current and the next month. They use seasonal factors to seasonally adjust the induced spending. We follow the same procedure to calculate induced spending and then subtract it from actual spending to create the implied counterfactual, which does not account for partial or general equilibrium effects.

The following graph shows counterfactuals from the motor vehicle accounting exercise for different assumptions of how much the spending is smoothed.

Figure B.1. Expenditures on New Motor Vehicles:Alternative Counterfactuals



Note. The baseline counterfactual assumes that rebate-induced spending is spread over two months. The two alternatives show the counterfactual with the induced spending spread over three or four months.

C Decomposing the Difference Between OLS and DID Imputation

In section 4, our implementation of Borusyak et al. (2021) DID imputation method yields a much smaller MPC for total expenditure (.3) compared to our OLS replication of Parker et al. (2013) (0.52). We use Sun and Abraham (2020) method to decompose OLS event studies and show that the difference between the OLS and DID imputation coefficients can be explained by OLS applying negative weights to past-treated units.

We first apply Sun and Abraham (2020) to decompose the differences and differences coefficient (β_2 from 1) as a linear combination of cohort average treatment effects on the treated (CATT) from the period households receive the rebate and from other periods. Where the CATT from each period ($\gamma_{e,h}$) are estimated in the following saturated regression:

$$
\begin{aligned}
C_{i,t+1} - C_{i,t} = & \sum_s \beta_{0s} month_{s,i} + \beta_1' \mathbf{X}_{i,t} \\
& + \sum_e \gamma_{e,0} \left(I(ESP_{i,t+1}) \times I(t+1=e) \right) \\
& + \sum_{h \neq 0} \sum_e \gamma_{e,h} \left(I(ESP_{i,t+1+h}) \times I(t+1+h=e) \right) \\
& + \varepsilon_{i,t+1}.
\end{aligned} \tag{3}
$$

In the above expression, $\gamma_{e,0}$, represents the contemporaneous treatment effect for households that report receiving their rebate in interview e.[23] Each $\gamma_{e,h}$ represent separate CATT for different horizons around the treatment date. For example, if $h = 1$ then $\gamma_{e,h}$ would be the estimated impact of treatment on the period after receiving the rebate. We could also estimate separate effects for the never-treated units in each interview, however, in practice these would be collinear with the interview-month fixed effects, so we treat the never-treated households as the excluded category. Hence, $\gamma_{e,\infty} = 0 \ \forall e$.

We can express the original OLS coefficient, β_2, as a linear combination of these $\gamma_{e,h}$ (Sun and Abraham, 2020):

$$
\beta_2 = \sum_h \sum_e \omega_{e,h} \gamma_{e,h}
$$

Where the weights, $\omega_{e,h}$, are the coefficients in the following series of regressions:

$$
\begin{aligned}
\left(I(ESP_{i,t+1+h}) \times I(t+1+h=e) \right) = & \sum_s \tilde{\beta}_{0s} month_{s,i} + \tilde{\beta}_1' \mathbf{X}_{i,t} \\
& + \omega_{e,h} \left(I(ESP_{i,t+1}) \times I(t+1=e) \right) + \varepsilon_{i,t+1}.
\end{aligned}
$$

The weights on the period the rebate is received sum to 1, $\sum_e \omega_{e,0} = 1$, while the weights on the other sum to -1, $\sum_e \sum_{\neq 0} \gamma_{e,h} = -1$. In each period, the treatment weights and the other period weights are symmetric i.e. $\omega_{e,0} = -\sum_{h \neq 0} \omega_{e,h}$. [24]

In the right panel of figure C.1 we plot the estimated weights ($\omega_{e,h}$), separately for each period. Where:

23. In keeping with the notation in Sun and Abraham (2020), e could also represent the household's rebate cohort. This results in a similar decomposition, but figure 13 would then represent treatment cohorts rather than interview dates. We find that the decomposition via interview date is more intuitive for our application.

24. The never treated units are included in the weights for the other periods.

$$\text{Weight Treated} = \omega_{e,0}$$
$$\text{Weight Not-yet Treated} := \omega_{e,h<0} = \omega_{e,\infty} + \sum_{h<0} \omega_{e,h}$$
$$\text{Weight Past Treated} := \omega_{e,h>0} = \sum_{h>0} \omega_{e,h}$$

The treated weight each period is symmetric with the non-treated and past-treated weights: $\omega_{e,0} = -(\omega_{e,h<0} + \omega_{e,h>0})$. Since these weights are symmetric, in figure 13 in the main text, we show only the per-period treatment weights in the upper-left panel.

With our estimated weights ($\omega_{e,h}$) and CATT ($\gamma_{e,h}$) we can decompose the relative contribution of each period and horizon of treatment to the final OLS DID coefficient (β_2). We can also estimate average coefficients for past-treated, not-yet treated, and treated units in each period:

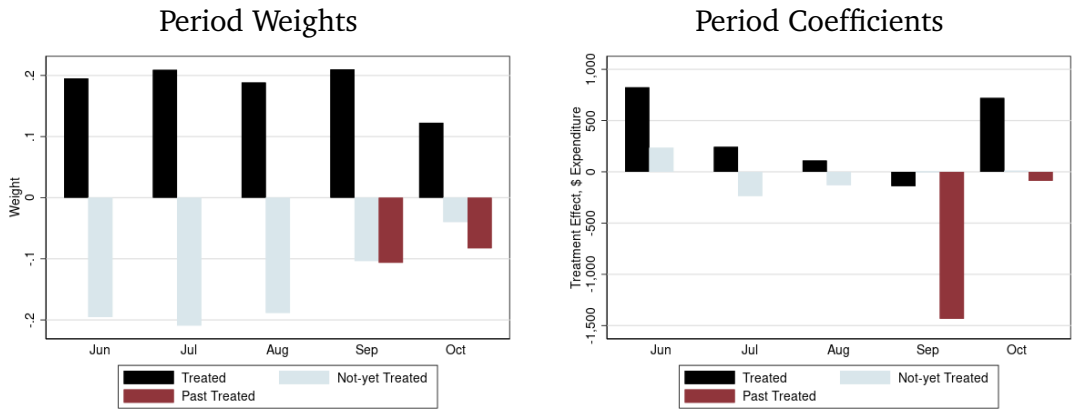
$$\text{Coefficient Treated} = \gamma_{e,0}$$
$$\text{Coefficient Not-yet Treated} := \gamma_{e,h<0} = \frac{\sum_{h<0} \omega_{e,h}\gamma_{e,h}}{\sum_{h<0} \omega_{e,h}}$$
$$\text{Coefficient Treated} - \text{Not Yet Treated} = \gamma_{e,0} - \frac{\omega_{e,h<0}\gamma_{e,h<0}}{\omega_{e,h<0} + \omega_{e,h>0}}$$
$$\text{Coefficient Past Treated} := \gamma_{e,h<0} = \frac{\sum_{h>0} \omega_{e,h}\gamma_{e,h}}{\sum_{h>0} \omega_{e,h}}$$
$$\text{Average Coefficient} := \gamma_e = \gamma_{e,0} - \frac{\omega_{e,h<0}\gamma_{e,h<0} + \omega_{e,h>0}\gamma_{e,h>0}}{\omega_{e,h<0} + \omega_{e,h>0}}$$

The right panel of figure C.1 shows the estimated coefficients at each horizon as described above, while the upper-right panel in the main text (figure 13 shows the average period-coefficients (γ_e). The main text also shows the relative contribution to the average coefficient coming from the difference between the treated and the not-yet treated and the past treated in the bottom right panel of figure **??**. The relative contributions from each period and horizon (bottom panel in figure 13 in the main text) are simply the period weights multiplied by the period coefficients.

The reason why the past-treated units in September had such a large contribution to the overall OLS coefficient (see figure 13) is because the past treated units receive a sizable negative weight and because these past treated units have such a large negative average coefficient ($\gamma_{e,h>0}$). Part of this negative coefficient could be explained by households that report receiving their rebate in the June interview reverting back to regular spending over the next interview. What is really interesting is that even the treated units have a negative estimated coefficient in September, while its the non-treated units

that have a positive coefficient (although this is very small). For these two reasons, we do not believe that the past-treated units serve as valid controls for the treated units.

Figure C.1. OLS: Weights and CATT



Notes. The dependent variable is the change in total expenditure. Based on estimations of equation 1 via OLS.

C.1 Additional Regression Table

Table C.1. Expenditure Response to Rebate: Full Sample (monthly frequency)

	FOOD	SND	ND	EXP	CAR	ln(FOOD)	ln(SND)	ln(ND)	ln(EXP)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Right hand side variables:									
Lead 1 Rebate Amount	0.00040	0.013	0.032**	0.14**	0.11**				
	(0.0052)	(0.011)	(0.014)	(0.062)	(0.045)				
Rebate Amount	0.013*	0.035**	0.054***	0.13*	0.081*				
	(0.0067)	(0.014)	(0.018)	(0.067)	(0.048)				
Lag 1 Rebate Amount	0.0095	0.035**	0.038**	0.079	0.039				
	(0.0074)	(0.015)	(0.019)	(0.065)	(0.039)				
Lag 2 Rebate Amount	−0.00065	0.020	0.025	0.16*	0.055				
	(0.0066)	(0.014)	(0.018)	(0.084)	(0.058)				
Lead 1 Rebate Indicator						0.0036	0.0067	0.015**	0.023***
						(0.0068)	(0.0056)	(0.0060)	(0.0079)
Rebate Indicator						0.013*	0.017**	0.025***	0.039***
						(0.0080)	(0.0066)	(0.0068)	(0.0084)
Lag 1 Rebate Indicator						0.0078	0.018***	0.019***	0.034***
						(0.0084)	(0.0067)	(0.0072)	(0.0092)
Lag 2 Rebate Indicator						−0.0023	0.0077	0.0074	0.033***
						(0.0075)	(0.0063)	(0.0066)	(0.0096)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Observations	66,394	66,394	66,394	66,394	66,394	66,391	66,394	66,386	66,393

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$