Heterogeneous Responses and Aggregate Impact of the 2001 Income Tax Rebates*

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Abstract

This paper estimates the heterogeneous responses to the 2001 income tax rebates across endogenously determined groups of American households. Around 45% of the sample saved the entire value of the rebate. Another 20%, with low income and liquid wealth, spent a significant amount. The largest propensity to consume, however, was associated with the remaining 35% of households, with higher income or liquid wealth. The heterogeneous response model estimates that the income tax rebates added a 3.27% to aggregate non-durable consumption expenditure in the second half of 2001. The homogeneous response model, in contrast, predicts a 5.05% increase.

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1 Introduction

In the aftermath of the recent financial crisis, governments around the world have sought to support the economy through unprecedented fiscal interventions. Considerable uncertainty (and disagreement among economists) exists, however, around the impact of these policies. At the heart of this uncertainty lays the recognition that the effects of fiscal policies on the aggregate economy cannot be fully understood without explicit consideration of distributional dynamics. This important insight feeds into a growing macroeconomic literature which explicitly recognizes that consumers and entrepreneurs are inherently different in their access to financial markets, life-cycle positions, patience, risk propensity, earning ability and other individual characteristics.

Significant research efforts surveyed by Heathcote, Storesletten and Violante (2009) have forcefully made the case for the quantitative relevance of heterogeneous behaviour in terms of both social welfare and macroeconomic outcomes. Storesletten, Telmer and Yaron (2001), for instance, find that if some households are liquidity constrained the cross-sectional welfare costs of aggregate fluctuations can be substantially larger than the calculations á la Lucas (1987), which are based on complete markets and the representative agent paradigm. Closer to our work, Heathcote (2005) shows that temporary lump-sum tax cuts that would be neutral in a representative agent framework with complete markets may have large real effects in a model with heterogenous agents and borrowing constraints, even though approximate aggregation à la Krusell and Smith (1998) holds.

The macroeconomic implications of heterogeneous responses to stabilization policies have

been studied in the theory (Kaplan and Violante, 2011). Yet, their relevance for the transmission of fiscal policy remains relatively unexplored in the data. In this paper, we try to fill this important gap in the literature by revisiting the household responses to the 2001 income tax rebates. Unlike earlier studies, we allow for the possibility that the propensity to spend may vary across groups of households endogenously determined within the estimation method. To this end, we employ quantile regression techniques which are designed to deal with unobserved heterogeneity as well as possible endogeneity.

Our analysis on Consumer Expenditure Survey (CES) data leads to four main findings. First, there is strong and robust evidence in favor of heterogeneous responses to the 2001 income tax rebates. In particular, 45% of the sample conforms to Ricardian equivalence by saving the full value of the rebate. The rest of the sample spent a significant amount, with roughly one third of the non-Ricardian consumers increasing consumption by a value not statistically different from one. Second, the rebate spending was concentrated on 'health', 'gas, motor fuel, public transportation', 'food away from home' and to a lesser extent 'apparel'. Third, households with low income and low liquid wealth increased their expenditure by 10 to 40 *cents* for each dollar of rebate, consistent with the existence of liquidity constraints for 20% of the full sample. High income/high liquid wealth individuals, in contrast, spent either nothing or most of their rebate. Fourth, as for the aggregate impact on the U.S. economy in the second half of 2001, the estimates of the heterogeneous model suggest that the income tax rebates boosted aggregate non-durable consumption by a significant 3.27%. This should be compared with the 5.05% implied by the homogeneous model estimates, whose degree of uncertainty is three times larger than the uncertainty surrounding the estimates of the

heterogeneous response specification.

A vast empirical literature surveyed by Jappelli and Pistaferri (2010) has used exogenous variation in household income data to test for the permanent income hypothesis. Parker (1999), Souleles (1999), Shapiro and Slemrod (2003), Agarwal, Liu and Souleles (2007) and Krueger and Perri (2006 and 2010), among many others, have documented a positive association between income shocks and non-durable consumption expenditure. Our work is most closely related to the important study by Johnson, Parker and Souleles (2006), who evaluate the impact of the 2001 tax rebates by exploiting the randomized timing of disbursement. Depending on the specification, they find that American families spent 20% to 40% of their rebates during the quarter of arrival. A contribution of this paper is to compare the results based on the estimates of the homogeneous specification used in earlier contributions to the results obtained estimating a heterogeneous model in which households are allowed to respond differently to the arrival of the rebate.

The paper is organized as follows. Section 2 introduces the two empirical models. The first model restricts the responses of consumption to the tax rebate to be the same across households. The second model allows for slope heterogeneity. Section 3 reports our main findings by confronting the effects estimated by the homogeneous and heterogeneous response models. In section 4, we assess the role that age, income and liquid assets play in shaping our results. In section 5, we quantify the aggregate implications of the estimated heterogeneity by showing that the impact of the 2001 tax rebates is in fact smaller than the impact predicted by the homogeneous response model. Section 6 concludes. In Appendices A and B, we present further details on the estimation method and a sensitivity analysis.

2 Empirical models of household expenditure

In this section, we lay out the empirical models that will be used in section 3 to quantify the consumption responses to the income tax rebates. Following earlier contributions, the first model restricts the expenditure reaction to the refund to be constant across households. The second model relaxes the constancy assumption by allowing for slope heterogeneity across households at different points of the distribution of consumption conditional on covariates.

2.1 Estimating the homogeneous response model

A long standing tradition in micro econometrics has proposed alternative strategies to correlate exogenous variation in income to personal expenditure in an effort to quantify any departure from the permanent income hypothesis. In a typical formulation, the process of consumption growth has been modeled as function of time effects, individual controls and the variable meant to identify exogenous changes in income. Within this class of empirical models, Johnson, Parker and Souleles (2006) propose the following specification:

$$\Delta C_{it+1} = \sum_{s} \beta_{0s} * M_s + \beta_1' X_{it} + \beta_2 R_{it+1} + u_{it+1} \tag{1}$$

where ΔC is the first difference of consumption expenditure of household i in quarter t. The letter M denotes a complete set of indicator variables for every month s in the sample and it is meant to absorb seasonal variation in consumption as well as the impact of aggregate factors. Control variables are stacked in the matrix X and they include age, changes in family composition and, in our specification, their square values. As argued by Attanasio and Weber (1993 and 1995) and Fernandez-Villaverde and Krueger (2007) a nonlinear formulation for

demographics helps to control for differences in consumption driven by household-specific preferences. The key variable in specification (1) is R, which represents the amount of the rebate received by each household. Finally, u denotes unobserved shocks to consumption that are assumed to be drawn from an i.i.d. normal distribution.

As the mailing of the rebate was randomized according to the penultimate digit of the Social Security number of the tax filer, its arrival is independent from individual characteristics and therefore the coefficient β_2 can be interpreted as measuring the causal effect of the rebate on expenditure.[1] Note, however, that the specification (1) assumes implicitly that the parametric assumptions behind the linear regression model hold and, thus, the least squares (LS) estimate of β_2 represents an accurate measure of the *average treatment effect* of the rebate on expenditure across the 13,066 households in the sample.

While the randomized timing of the rebate receipt is uncorrelated to individual characteristics, the amount of the rebate is possibly not. To address this important concern, Johnson, Parker and Souleles (2006) estimate equation (1) with two stage least squares (TSLS) using the indicator function $I\left(R_{it+1} > 0\right)$, which takes value of one in the period when the rebate was received, as an instrument for R_{it+1}.

2.2 Estimating the heterogeneous response model

Several theoretical contributions have derived the conditions under which the aggregate implications of heterogeneous agent models may differ significantly from the predictions of

[1] As discussed by Johnson, Parker and Souleles (2006) at length, to interpret $\beta_2 = 0$ as a test of the permanent income hypothesis one has to rely also on the fact that the arrival of the rebates was preannounced. This implies that any resulting wealth effects should have arisen at the same time across households and therefore it would be captured by the time dummies.

representative agent models. In an important theoretical work, Heathcote (2005) builds a heterogenous agent model with borrowing constraints to show that temporary changes in the timing of taxes can have large real effects. Differences in the degree of impatience, illiquid wealth and elasticity of intertemporal substitution may also be associated with differences in the expenditure response to a temporary tax cut.

To explore in the data the heterogeneity highlighted by the theory, we propose to use Quantile Regression (QR) methods which are designed to estimate unobserved heterogeneity models. In particular, QR methods yield a family of estimated slopes which vary across the conditional distribution of the latent outcome variable. An additional important advantage of quantile regressions is that the estimates are robust to non-Gaussian distributions (e.g. fat tailed) of the error terms (Koenker, 2005).

In our application, the outcome variable is consumption change. This is treated as potentially latent because, given a received tax rebate and other variables at both individual and macro levels, the observed outcome for each household is only one of the possible realizations in the admissible space of outcomes. The quantiles of the potential outcome distributions conditional on covariates are denoted by:

$$Q_{\Delta C_{it+1}|R_{it+1},X_{it},M_s}(\tau) \quad \text{with } \tau \in (0,1) \tag{2}$$

and the effect of the treatment, here the tax rebate, R_{it+1} on different points of the marginal distribution of the potential outcome is defined as:

$$QTE_\tau = \frac{\partial Q_{\Delta C_{it+1}|R_{it+1},X_{it},M_s}(\tau)}{\partial R} \tag{3}$$

The quantile treatment model can then be written as:

$$\Delta C_{it+1} = q\left(R_{it+1}, X_{it}, M_s, \lambda_{it+1}\right) \quad \text{with } \lambda_{it+1}|R_{it+1}, X_{it}, M_s \sim U\left(0,1\right) \tag{4}$$

where $q\left(R, X, M, \tau\right)$ is the conditional τ-th quantile of ΔC_{it+1} given $R = R_{it+1}$, $X = X_{it}$ and $M = M_s$. The term λ_{it+1} captures the unobserved heterogeneity across the households i having the same observed characteristics X_{it} and "treatment" R_{it+1}. This is usually referred to as the rank variable as λ_{it+1} determines the relative ranking of individuals in terms of potential outcomes.

For each $\tau \in (0,1)$, we specify a linear conditional quantile model of the form:

$$q\left(R_{it+1}, X_{it}, M_s, \tau\right) = Q_{\Delta C_{it+1}|\cdot}(\tau) = \sum_s \alpha_{0s}\left(\tau\right) * M_s + \alpha_1\left(\tau\right)' X_{it} + \alpha_2\left(\tau\right) R_{it+1} \tag{5}$$

where the parameters $\{\alpha_2\left(\tau\right), \tau \in (0,1)\}$ are the objects of main interest. To the extent that the variation in the refunds is exogenous, the quantile treatment effect $\alpha_2\left(\tau\right)$ measures the causal effect of the tax rebate on consumption change, holding the unobserved characteristics driving heterogeneity fixed at $\lambda_{it+1} = \tau$. Then, the methods outlined in Koenker and Bassett (1968) could be used to estimate quantile effects on the basis of the following conditional moment restrictions:

$$\mathbb{P}[\Delta C \leq q\left(R, X, M, \tau\right)|R, X, M] = \mathbb{P}[\lambda \leq \tau | R, X, M] = \tau$$

for each $\tau \in (0,1)$.

Were the amount of the tax rebates correlated with some unobserved characteristics captured by λ_{it+1}, however, the moments restrictions above would be violated. To address this issue, we follow Johnson, Parker and Souleles (2006) and use the indicator function

$I(R_{it+1} > 0)$ as instrument for R_{it+1}. In the Instrumental Variable Quantile Regression (IVQR) approach, we estimate the following model:

$$\Delta C_{it+1} = q\left(R_{it+1}, X_{it}, M_s, \lambda_{it+1}\right) \quad \text{with } \lambda_{it+1}|I(R_{it+1} > 0), X_{it}, M_s \sim U\left(0,1\right) \tag{6}$$

This deals with the endogeneity of the rebate amount via the conditional moment restrictions:

$$\mathbb{P}[\Delta C \leq q\left(R, X, M, \tau\right)|I(R > 0), X, M] = \mathbb{P}[\lambda \leq \tau | I(R > 0), X, M] = \tau$$

for each $\tau \in (0,1)$, where the randomized timing of the disbursement ensures that the instrument $I(R > 0)$ is independent of the rank variable λ.

Defining $H \equiv [R, X, M]$ and $Z \equiv I(R > 0)$, the parameters of the model (6) are estimated by solving the following optimisation problem:

$$\arg\min_{\Theta} \mathbb{E}\left[\rho_\tau\left(\Delta C_{t+1} - H_{t+1}\Theta\right) Z_{t+1}\right] \tag{7}$$

where $\rho_\tau\left(e\right) = \left(\tau - I\left(e < 0\right)\right)e$ and $e = \Delta C_{t+1} - H_{t+1}\Theta$. The objective function (7) is not straightforward to minimise because of the discontinuity introduced by the penalty function $\rho_\tau\left(e\right)$. Fortunately, Chernozhukov and Hansen (2005) propose a method to solve (7), which involves a grid search for the values of the vector Θ that minimize the QR projections of $(\Delta C_{t+1} - H_{t+1}\Theta)$ on Z_{t+1}.

A non-standard requirement for the IVQR estimator is rank invariance (rank similarity). In terms of our heterogeneous response model, this requires that, conditional on covariates, the individual characteristics driving the rank variable λ_{it+1} do not vary (systematically) with the receipt of the tax rebate. To the extent that the unobserved heterogeneity λ_{it+1}

reflects heterogeneity in the access to the credit market, degree of impatience, health status, housing tenure status, preferences, etc., this assumption is likely to hold in our application. In Appendix A, we discuss further the regularity conditions to identify the $QTEs$ in the context of our heterogeneous response model.

3 Evidence on spending heterogeneity

In this section, we present the main results of the paper, namely the large extent of heterogeneity in the household expenditure responses to the 2001 income tax refunds. We present results for the homogeneous response specification (1) and the heterogeneous response specification (5), first treating the tax rebate as exogenous and then instrumenting it with $I(R > 0)$. Finally, we assess the extent of heterogeneity across different expenditure categories. The main result is that the evidence of heterogeneous behaviour is pervasive, in a way that it is significantly missed by the homogeneous response model.

3.1 The response of non-durable expenditure

The data used in our investigation are from Johnson, Parker and Souleles (2006) who made them available at http://www.e-aer.org/data/dec06/20040878_data.zip. The data originate from CES questionnaires which, shortly after the passage of the 2001 Tax Act, were augmented with questions about the timing and the amount of each rebate check. A thoughtful discussion of the design of the 2001 income tax rebates is available in Johnson, Parker and Souleles (2006) and it will not be repeated here.

The dashed lines on the left (right) column of Figure 1 replicate Johnson, Parker and

Souleles' estimates and 95% confidence intervals fitting the specification (1) with least squares (two stage least square). Solid lines in the left (right) column, in contrast, refer to the QR (IVQR) estimates of the heterogeneous response specification (5), with the surrounding shaded areas representing 95% confidence intervals. In each panel, the horizontal axis indexes the τ-*th* quantile of the conditional distribution of consumption while the vertical axis reports the impact of the tax rebate on consumption associated with each quantile. In the rows of figure 1, we consider three aggregated measures of *non-durable* goods and services, *strictly non-durable*, which following Lusardi (1996) excludes 'apparel', 'health' and 'reading', and *food* expenditure respectively.

A few results from figure 1 are worth noticing. First, there is strong evidence in favor of heterogeneity with the effect implied by the homogeneous model overestimating (underestimating) significantly the household expenditure responses to the tax rebate at the lower (upper) end of the conditional consumption distribution relative to the QR estimates.[2] Second, for a large portion of the sample, the change in expenditure was not statistically different from zero. Coupled with the facts that the arrival of the rebates was preannounced and that the empirical specification includes time dummies, the latter finding may be interpreted as saying that it is not possible to reject the permanent income hypothesis for around 45% of American households. Third, for another 15% of consumers the response to the tax rebate

[2]Following Koenker and Machado (1999), we compute a measure of goodness-of-fit that is the quantile regression analogous of the R^2 statistics for least squares. Applied to the IVQR estimates for non-durable expenditure, the measures of goodness-of-fit in percent are: 1.59 (τ=.05), 1.23 (τ=.10), 1.01 (τ=.15), 0.86 (τ=.20), 0.80 (τ=.25), 0.67 (τ=.30), 0.52 (τ=.35), 0.36 (τ=.40), 0.32 (τ=.45), 0.33 (τ=.50), 0.40 (τ=.55), 0.54 (τ=.60), 0.69 (τ=.65), 0.85 (τ=.70), 0.98 (τ=.75), 1.14 (τ=.80), 1.32 (τ=.85), 1.94 (τ=.90) and 2.74 (τ=.95). The R^2 statistics in percent associated with the corresponding TSLS estimates is 0.60.

is not statistically different from one for non-durable expenditure. Fourth, the significant responses of strictly non-durable and food expenditures are significantly smaller than the responses of non-durable goods and services, with point estimates for the peak effect of 0.4 and 0.3 respectively. Fifth, the least square methods in the left column and the instrumental variable methods in the right columns produce similar results over most of the conditional distribution of the household expenditure, with the possible exception of the tails where the instrumental variable estimates tend to be smaller in absolute value.[3]

To test formally the null hypothesis of homogeneity in the response of American households to the income tax rebate, we follow the martingale approach proposed by Khmaladze (1981) and Koenker and Xiao (2002). This is based on the idea that the impact of a covariate in a homogeneous response model is a pure location shift, thereby making the coefficients constant across quantiles. The statistics of this test are 2.23, 2.65 and 1.96 for expenditure on non-durable, strictly non-durable and food expenditure respectively. As the empirical critical values at the 5% and 10% levels are 1.99 and 1.73 respectively (Koenker 2005, Appendix B), we can reject the null hypothesis of homogenous response.[4]

In summary, the aggregated measures of non-durable consumption expenditure point towards significant heterogeneity in the responses of American households to the 2001 federal

[3]Following Chernozhukov and Hansen (2006), we compute a measure of exogeneity for the amount of the rebate R_{t+1} that is the quantile regression analogous of the Hausman statistics for least squares. Applied to the IVQR estimates for the aggregated measures of expenditure, we cannot reject the null hypothesis of no endogeneity. The Hausman exogeneity test associated with the TSLS estimates also fails to reject the null hypothesis of no endogeneity.

[4]Results are robust to using the projection of the tax rebate on $I(R > 0)$ rather than the tax rebate to compute the test statistics. As a further sensitivity analysis, we confirmed our findings using the testing procedure described in Chernozhukov and Hansen (2006).

income tax refunds. In the next section, we will estimate the propensity to consume across several expenditure categories before turning to *(i)* identifying what are the characteristics that make a household more likely to spend the tax rebate (section 4) and (*ii*) assessing the implications of the estimated heterogeneous response model for the aggregate impact of the tax rebate plan on the U.S. economy (section 5).

3.2 The response across expenditure categories

In figure 2 (3), we present QR and LS (IVQR and TSLS) estimates for ten sub-components of non-durable consumption expenditure. The sub-component results provide important qualifications to the finding of heterogeneity in the previous section using the aggregated measures. First, the evidence of heterogeneity is stronger (according to both visual inspection and the Khmaladze test) for four categories: 'food away from home', 'gas, motor fuel, public transportation', 'health' and to a lesser extent 'apparel'. Altogether they account for an average share of non-durable goods expenditure of about 40%. Second, for other sub-components, including 'food at home' and 'utilities, household operations', there is little evidence of heterogeneity and, in line with Johnson, Parker and Souleles' evidence, the effects estimated using the homogeneous response model are typically not statistically different from zero. Third, the least square estimates in figure 2 and the instrumental variable estimates in figure 3 are now occasionally different from each other, but mostly at the left tail of the conditional distributions. This is the case, for instance, in the panels for 'utilities, household operations', 'apparel', 'health' and 'reading'. Fourth, for the bottom 30% of consumers the expenditure responses to the rebate on 'food away from home' and 'gas, mo-

tor fuel, public transportation' is significantly negative. While the latter finding may seem counter-intuitive, we will show in the next section that the negative coefficients are driven by households enjoying a relatively higher income. As the rebates came typically in the flat amount of $300 or $600 value per qualifying family, a possible interpretation consistent with Ricardian equivalence is that these high earners may have saved over and above the value of the rebate in anticipation of the relatively higher burden that a future income tax increase would place on them.

4 Who spent the tax rebate?

The evidence in favor of heterogeneity reported in section 3 raises an important issue about what factors may be driving the diverse responses to the tax rebate. The empirical literature emphasizes that age, income and liquid assets might bear some correlation with the unobserved characteristics that may trigger a violation of the permanent income hypothesis.[5] Figure 4 reports prima facie evidence along these lines. The top (bottom) panel reports the median value of income (liquid wealth) for each quantile of the estimated conditional distribution of non-durable consumption expenditure.

Two findings are worth emphasizing. First, both variables tend to have higher values at the tails. Bearing in mind the evidence of section 3, this implies that the behaviour at the left end is consistent with Ricardian equivalence as those families saved the full value of the rebate. On the other hand, households with a high propensity to spend at the right tail

[5]Note that because of data availability, the results of this section, and this section only, are based on restricted samples of $9,233$ observations for income and $5,951$ observations for liquid assets.

enjoyed higher income and liquid wealth.[6] Second, households with low income or low liquid wealth are concentrated in the 45 to 65 percentiles. According to the IVQR estimates of figure 1, these households spend a significant portion of the rebate, between 10% and 40%, and therefore their behaviour is consistent with the presence of liquidity constraints.

To provide formal evidence on the significant link between income, liquidity and heterogeneity in the propensity to consume, we perform two further analyses. First, we estimate a series of probit regressions for each quantile of the conditional distribution of non-durable consumption expenditure using either income or liquid assets as explanatory variable.[7] Second, we augment the specification in section 3 with an interaction term between the tax rebate and either age, income or liquid wealth.[8]

The findings of the first exercise are reported in table 1 and they corroborate the prima facie evidence of figure 4. Having higher income (liquid wealth) makes it more likely to belong to either the top or the bottom 15 (10) percentiles. As for the central part of the distribution, the sign switch on the estimated coefficients implies that lower income and lower liquid wealth increase the probability to belong to the groups of families who spent a significant amount of the rebate. The probit results are robust across sub-categories of non-durable expenditure, with the largest positive coefficients at the tails associated with

[6] A possible interpretation, not inconsistent with rational behaviour, is that the cost of processing information may make it optimal to revise consumption plans only if the unanticipated amount is large enough relative to income or wealth. To the extent that for some inattentive consumers the value of the refund was relatively small, high income or wealth might be associated with high spending propensity (Reis, 2006).

[7] For each quantile τ, the dependent variable of the probit model takes value of 1 if $[y - X\alpha(\tau)] \leq 0$ and $[y - X\alpha(\tau - 0.05)] > 0$.

[8] In both exercises, we obtain similar results using all variables simultaneously. Their joint inclusion, however, comes at the cost of less precise estimates as the sample reduces to $5,951$ observations.

'food away from home' and 'gas, motor fuel, public transportation' and the largest negative coefficients at the center of the distribution associated with 'health'.

While the coefficient on income is significant in more quantiles than the coefficient on liquid wealth in table 1, for 20% of the sample both low income and low liquid wealth help to predict which households are most likely to have a propensity to consume statistically larger than zero. This number is consistent with the fraction of liquidity constrained American families estimated by Jappelli (1990), Jappelli, Pischke and Souleles (1998) and Dogra and Gorbachev (2010) using independent data from the Survey of Consumer Finance.

As for the second analysis, the estimates associated with the specifications including the interaction term with age, income and liquid assets are reported in the first, second and third row respectively of figure 5.[9] The coefficients on the tax rebate in the first column display a similar extent of heterogeneity relative to the estimates in figure 1, with the possible exception of the specification in the second row. The latter finding appears explained by the variation in the coefficients on the interaction term between tax rebate and income in the second column: households with higher income tend to spend significantly less (more) than average at the left (right) tail of the conditional distribution of non-durable expenditure. The visual impression in favor of heterogeneous behaviour is confirmed by the Khmaladze statistics, which are 2.60 for the estimated coefficients on the tax rebate and 2.67 for the

[9]In each augmented specification, we include as additional instrument the interaction of $I(R > 0)$ with either age, income or liquid wealth. The interaction term is constructed as $R * \tilde{s}$, where $\tilde{s} = (s/\bar{s}) - 1$ and $\bar{s}$ is the average across households of the variable $s = age$, $income$, $liquid\ wealth$. This implies that in each row/specification the overall impact of the rebate for the quantile τ is the sum of the coefficient for τ in the first column and the product between the corresponding coefficient in the second column and the percentage deviation of the variable s in quantile τ from the mean.

estimated coefficients on the interaction term.

The latter result can also provide a rationale for one of the findings in Johnson, Parker and Souleles (2006). In table 5 of their paper, the sample is split in three exogenous groups according to the income level. They find that the response of the high income group is larger but statistically insignificant. Our results, based on groups endogenously determined within the estimation method, reveal that, in fact, for a significant fraction of high income households the marginal propensity to consume is significantly larger than the average while for some other high income families it is significantly smaller.

As for the unobserved characteristics proxied by age and liquid wealth, the evidence from the first and third rows suggests that they tend to contribute less to the heterogeneous responses. The coefficients on the interaction term display little significance and variation across households, with the possible exception of the coefficients on the interaction term with age at the top quantiles. The test statistics are now 2.32 (2.23) for the estimates of the impact of the level of the rebate and 0.96 (1.02) for the estimates of the impact of the interaction term between rebate and age (liquid wealth)[10].

In summary, the evidence of this section is suggestive of a significant association between the heterogeneous responses to the 2001 tax rebates and unobserved characteristics correlated with income and, to a lesser extent, liquidity and age. Americans earning relatively higher income or having relatively higher liquid wealth tend to spend either nothing or most of the rebate. Household with low income and low liquid assets, which represent a 20% of the full sample, appear to have a propensity to consume between 10% and 40%.

[10]This may also reflect, however, poor measurement of liquid assets in the CES.

5 The aggregate impact of the tax rebates

In the previous sections, we have shown strong evidence of heterogeneous responses to the 2001 tax rebates. A natural question at this point is how does relaxing the assumptions behind the homogeneous response model affect the estimated aggregate impact on the US economy. To address this issue, we follow Johnson, Parker and Souleles (2006) and augment our model specifications with the lagged value of the tax rebate, R_t. Results are reported in figure 6, which displays the response to the tax rebate at time $t+1$ (t) in the first (second) row and the cumulative impact in the third row. The left (right) column refers to non-durable (strictly non-durable) consumption expenditure. For the sake of brevity, in this section we only report results based on the instrumental variable method.

The first row reveals that the estimates of $\alpha_2(\tau)$ in figure 1 are robust to adding a lag of the tax rebate. The coefficients on R_t in the second row are also characterized by significant variation which, together with the coefficients on R_{t+1}, map into a significantly heterogeneous cumulative impact. The estimates in the third row corroborates the finding that the response of around 45% of families is not statistically different from zero. The rest of the sample spent a significant amount of the rebate in the period following its arrival. For individuals in the top 15% of the conditional distribution of non-durable (strictly non-durable) expenditure, the cumulative response is (not) statistically larger than one.

In figure 7, we assess the sensitivity of the finding on the cumulative effects at the top end of the distribution by replacing the income tax rebate variables R_{t+1} and R_t with their first difference, ΔR_{t+1}. In other words, we impose the restriction that the effect of the rebate on

spending occurs entirely in the period of the check arrival. The left (right) column reports estimates for the aggregated measures (disaggregated measures associated with the largest heterogeneity). Under the restricted specification, for each dollar of refund the top 15% of the distribution spends overall an amount which is not statistically larger (is significantly smaller) than \$1 on non-durables (strictly non-durables and food) in the first row (second and third rows). The results for the other quantiles confirm, by and large, the estimates reported in the previous figures.

Endowed with estimates for the long-run responses, we can compute the aggregate impact of the 2001 tax rebate along the lines of Johnson, Parker and Souleles (2006). As the total amount of the rebate disbursement, \$38 billions, represented 7.5% of the aggregate non-durable consumption in the third quarter of 2001, we can use the propensities to spend estimated with the homogeneous and heterogeneous models in figure 6 to express the aggregate impact of the fiscal stimulus as a percentage of the aggregate non-durable expenditure. The results for the $IVQR$ ($TSLS$) model are reported in the first (second) row of table 2. For closer comparability with the estimates in Johnson, Parker and Souleles (2006), in the bottom panel we repeat the calculations using specifications which do not include squared values of the demographic variables. In table 3, we report the aggregate propensity to consume implied by the estimates of the two models.

According to table 2, the heterogeneous response model implies estimates of the aggregate impact of the rebates which are systematically lower –by 36% on average– than the estimates implied by the specification that imposes homogeneity in the marginal propensity to consume. Based on the latter, for instance, the cumulative effect in table 2 is found to

be just above 5%. The $IVQR$ method, in contrast, implies a smaller and more accurate estimate of the cumulative effect, 3.27%, corresponding to a difference of $9 billions relative to the prediction of the homogeneous response model.[11] While the $TSLS$ point estimates are surrounded by large uncertainty, we note that the aggregate impact implied by the heterogeneous response model is statistically lower than 5%.[12]

As for the aggregate propensity to consume in table 3, the heterogeneous response model implies an estimate of 0.256 (0.436) for the third quarter (second half) of 2001. This should be compared with the estimate of 0.391 (0.673) implied by the homogeneous response model. In Appendix B, we show that the finding of heterogeneous responses to the 2001 income tax rebates is robust to using the log difference of non-durable consumption expenditure. Furthermore, the aggregate propensity to consume implied by the log difference specification is not statistically different from the aggregate propensity to consume implied by the specification using the first difference of the level of expenditure.

6 Conclusions

This paper has revisited the response of the U.S. economy to the 2001 income tax rebates using an empirical model in which the propensity to spend is allowed to vary across a large sample of American households. Our results point toward significant evidence of hetero-

[11] A possible explanation for the difference in accuracy between the estimates of the homogeneous response model and the estimates of the heterogeneous response model may be fat tails in the distribution of the error terms of equation (1). To investigate this in the data, we run the test of Kurtosis proposed by D'Agostino, Belanger and D'Agostino Jr. (1990). The Kurtosis measure is 95 (as opposed to 3 in a Gaussian distribution) and the test statistic is 71, which rejects the null hypothesis of normality at a 0.01% level.

[12] Our estimates are robust to restricting $\alpha_2(\tau)$ to be between zero and one in each quantile τ.

geneous responses to the fiscal stimulus. For each dollar of tax rebate, 45% of consumers spent on non-durable goods and services an amount that is not statistically different from zero, consistent with the permanent income hypothesis. For another 15% of households, in contrast, the response to the rebate was not statistically different from one, with the rest of the sample associated with significant values somewhere in between. Furthermore, the rebate spending was concentrated on 'health', 'gas, motor fuel, public transportation', 'food away from home' and to a lesser extent 'apparel'.

Motivated by a large empirical literature, we have explored the link between the heterogeneous responses and unobserved characteristics correlated with age, income and liquid wealth. Households enjoying relatively higher income and liquid wealth spent either nothing or most of the tax rebate. On the other hand, American families with low income and low liquid wealth spent between 10 and 40 *cents* for each dollar of rebate, consistent with the existence of liquidity constraints for about 20% of the sample.

The estimated heterogeneous response model indicates that the 2001 income tax refunds directly boosted the aggregate demand for non-durable goods and services by a significant 3.27%. This should be compared with the 5.05% based on the restriction of the empirical model that American households shared the same propensity to spend. Furthermore, the estimates of the homogeneous response specification are surrounded by a degree of uncertainty which is three times larger than the uncertainty around the estimates of the heterogeneous model. Our findings suggest that the heterogeneous response model may be important for an accurate evaluation of the impact of large public programmes on different groups of the society as well as on the aggregate economy.

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Table 1: Probit estimates for different quantiles of the conditional distribution of non-durable expenditure

quantile	*coefficient on income*	*coefficient on liquid assets*
0.05	0.27*** (0.02)	0.06*** (0.01)
0.10	0.15*** (0.03)	0.03*** (0.01)
0.15	0.07*** (0.03)	0.01 (0.01)
0.20	0.02 (0.03)	-0.01 (0.01)
0.25	-0.02 (0.03)	-0.01 (0.01)
0.30	-0.03 (0.03)	-0.01 (0.01)
0.35	-0.13*** (0.03)	-0.01 (0.01)
0.40	-0.15*** (0.03)	-0.03*** (0.01)
0.45	-0.14*** (0.03)	-0.03*** (0.01)
0.50	-0.19*** (0.03)	-0.03* (0.02)
0.55	-0.20*** (0.03)	-0.02 (0.01)
0.60	-0.19*** (0.03)	-0.03 (0.01)
0.65	-0.11*** (0.03)	-0.04** (0.02)
0.70	-0.09*** (0.03)	-0.01 (0.01)
0.75	-0.08*** (0.03)	-0.04** (0.02)
0.80	0.00 (0.03)	0.00 (0.01)
0.85	0.02 (0.03)	0.01 (0.01)
0.90	0.07*** (0.03)	0.01 (0.01)
0.95	0.20*** (0.03)	0.04*** (0.01)
1.00	0.24*** (0.03)	0.04*** (0.01)
observations	*9,233*	*5,951*

Notes: standard errors in parenthesis. ***, ** and * denote 1%, 5% and 10% significance level. For each quantile τ, the dependent variable of the probit model takes value of 1 if $[y - X\alpha(\tau)] \leq 0$ and $[y - X\alpha(\tau - 0.05)] > 0$.

Table 2: Aggregate impact of the 2001 tax rebates as % of aggregate non-durable consumption expenditure

	2001Q3	*2001Q4*	*cumulative*
method			
$IVQR$	1.93***	1.34***	3.27***
	(0.30)	(0.44)	(0.69)
$TSLS$	2.94***	2.11***	5.05***
	(0.91)	(0.92)	(2.08)
difference	-34%	-37%	-35%
	without squared demographic variables		
$IVQR$	1.83***	1.26***	3.09***
	(0.30)	(0.43)	(0.68)
$TSLS$	2.89***	2.05***	4.94***
	(0.90)	(0.92)	(2.05)
difference	-37%	-39%	-37%

Notes: standard errors in parenthesis. *** denotes 1% significance level. IVQR (TSLS) refers to the aggregate impact of the tax rebate (as share of aggregate non-durable consumption expenditure) implied by the instrumental variable quantile regression (two stage least square) estimation method based on the total amount of the tax rebate being 7.5% of non-durable consumption in Q3. The 'difference' between IVQR and TSLS point estimates is reported as % of the TSLS entries.

Table 3: Aggregate propensity to spend the 2001 tax rebates on non-durable consumption expenditure

	2001Q3	*2001Q4*	*cumulative*
method			
$IVQR$	0.257***	0.178***	0.436***
	(0.04)	(0.06)	(0.09)
$TSLS$	0.391***	0.281***	0.673***
	(0.12)	(0.12)	(0.28)
	without squared demographic variables		
$IVQR$	0.244***	0.168***	0.412***
	(0.04)	(0.06)	(0.09)
$TSLS$	0.386***	0.273***	0.659***
	(0.12)	(0.12)	(0.27)

Notes: standard errors in parenthesis. *** denotes 1% significance level. IVQR (TSLS) refers to the aggregate propensity to spend the tax rebates on non-durable consumption expenditure implied by the instrumental variable quantile regression (two stage least square) estimation method.

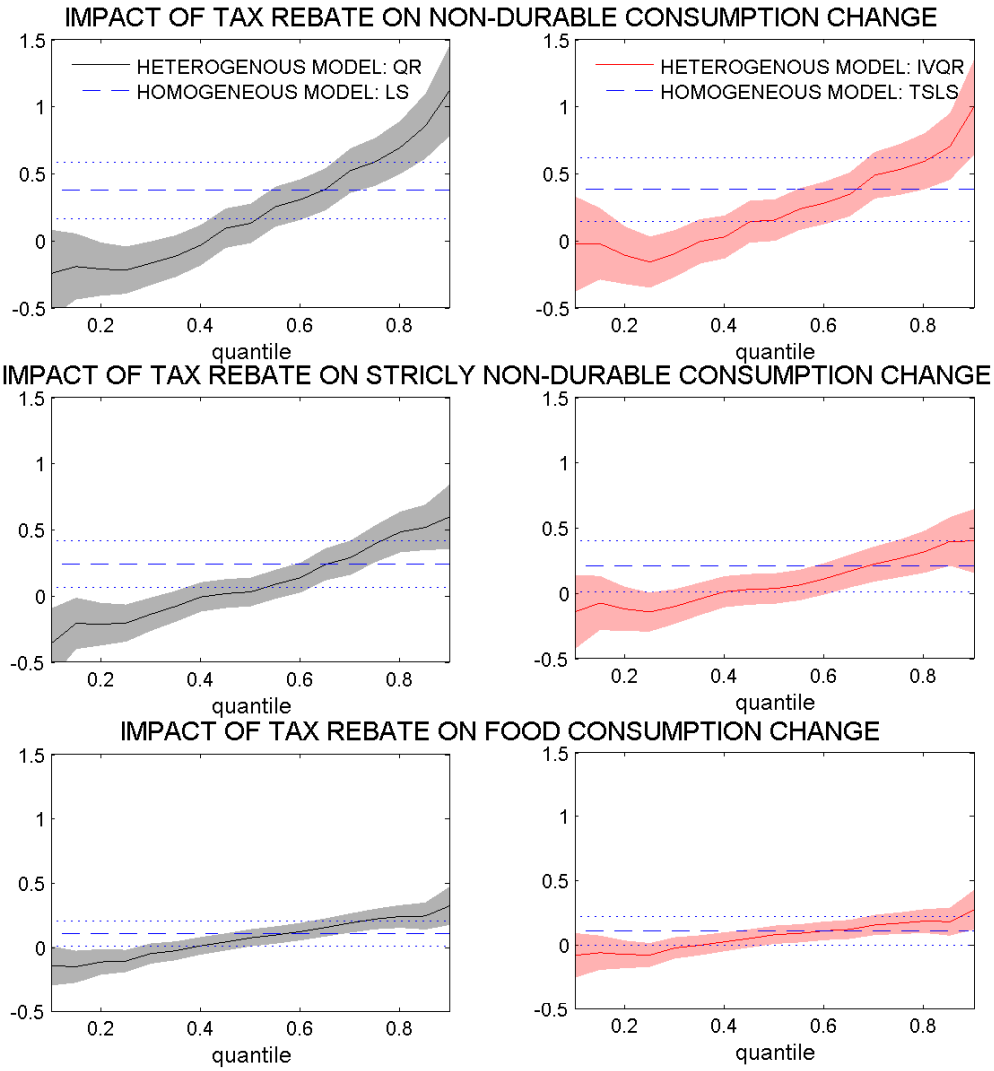

Figure 1: The figure shows the coefficient on tax rebate from regressions of consumption change on age, change in the number of kids and the number of adults, their square values and monthly dummies. In the instrumental variable regression, tax rebate is instrumented with the dummy variable $I(R > 0)$ which takes value of one if a household received a tax rebate and zero otherwise. In the left [right] column, QR (LS) [IVQR (TSLS)] estimates in black (blue) [red (blue)] refer to quantile (least squares) [instrumental variable quantile (two stage least squares)] regressions. Shaded areas (dotted lines) are 95% confidence intervals obtained using heteroscedasticity robust standard errors. Estimates are reported for $\tau \in [0.1, 0.9]$ at 0.05 unit intervals. The first, second and third rows refer to specifications in which the dependent variable is non-durable, strictly non-durable and food consumption change, respectively. Sample: N=13,066.

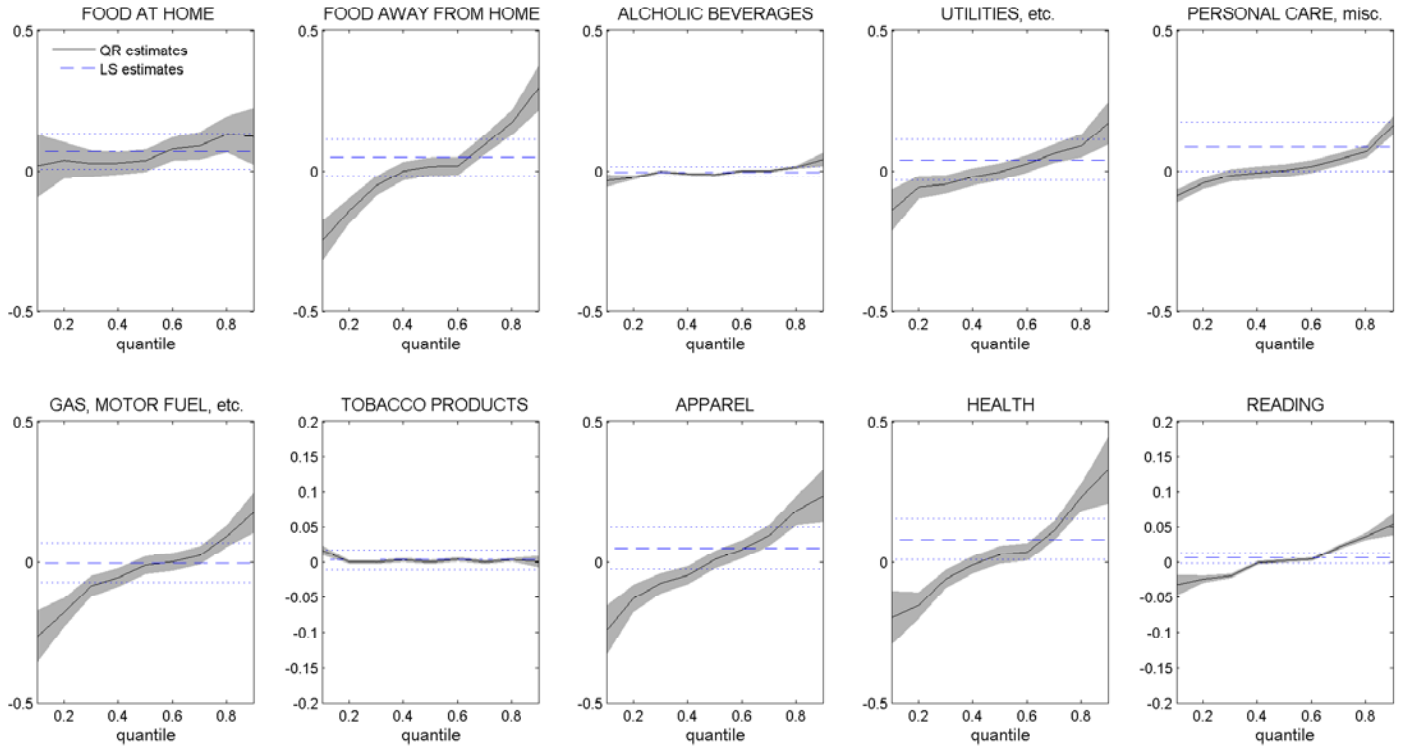

Figure 2: The figure shows the coefficient on tax rebate from regressions of consumption change on age, change in the number of kids and the number of adults, their square values and monthly dummies.QR (LS) estimates in black (blue) refer to quantile (least squares) regressions. Shaded areas (dotted lines) are 95% confidence intervals obtained using heteroscedasticity robust standard errors. Estimates are reported for $\tau \in [0.1, 0.9]$ at 0.1 unit intervals. Each panel refers to a specification in which the dependent variable is a different sub-component of household expenditure. Sample: N=12,730.

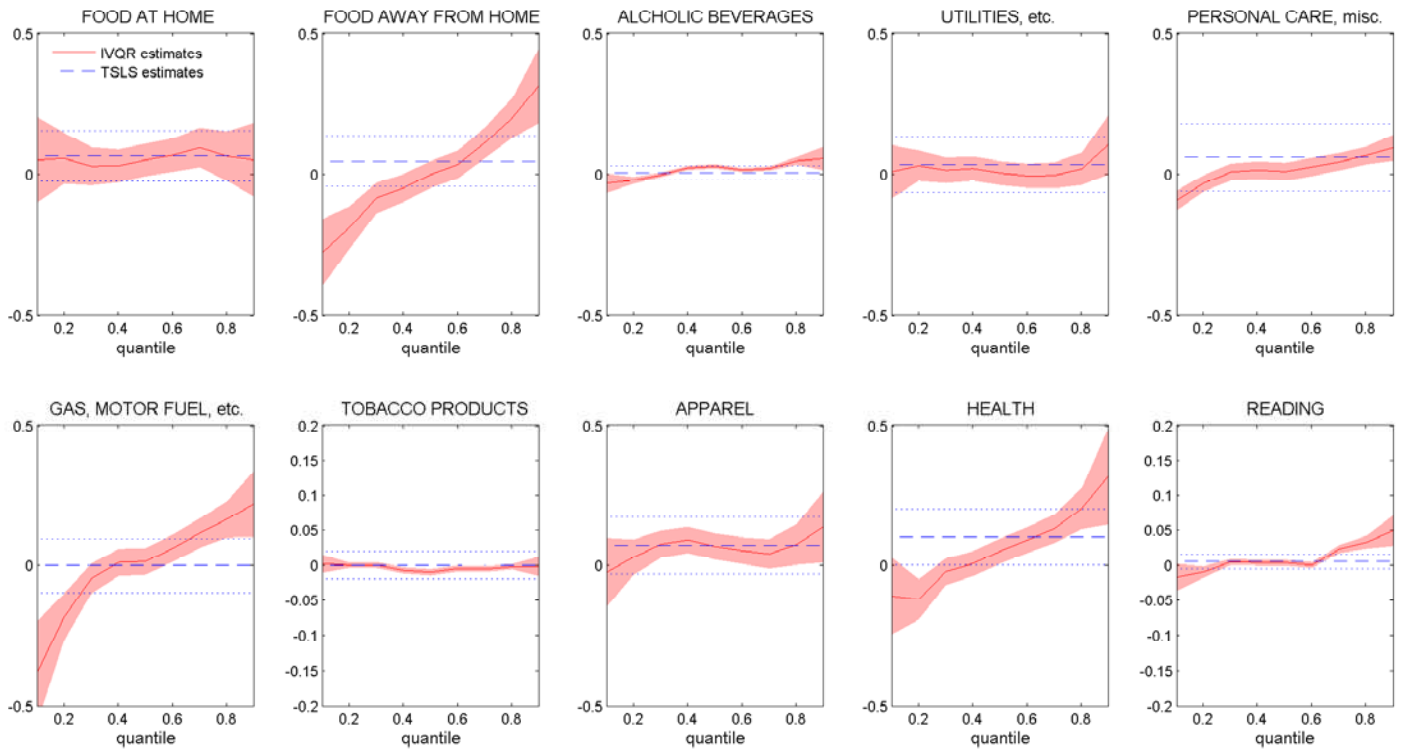

Figure 3: The figure shows the coefficient on tax rebate from instrumental variable regressions of consumption change on age, change in the number of kids and the number of adults, their square values and monthly dummies. The instrument for tax rebate is a dummy variable $I(R > 0)$ which takes value of one if a household receive the tax rebate and zero otherwise. IVQR (TSLS) estimates in red (blue) refer to instrumental variable quantile (two stage least squares) regressions. Shaded areas (dotted lines) are 95% confidence intervals obtained using heteroscedasticity robust standard errors. Estimates are reported for $\tau \epsilon$ [0.1, 0.9] at 0.1 unit intervals. Each panel refers to a specification in which the dependent variable is a different sub-component of household expenditure. Sample: N=12,730.

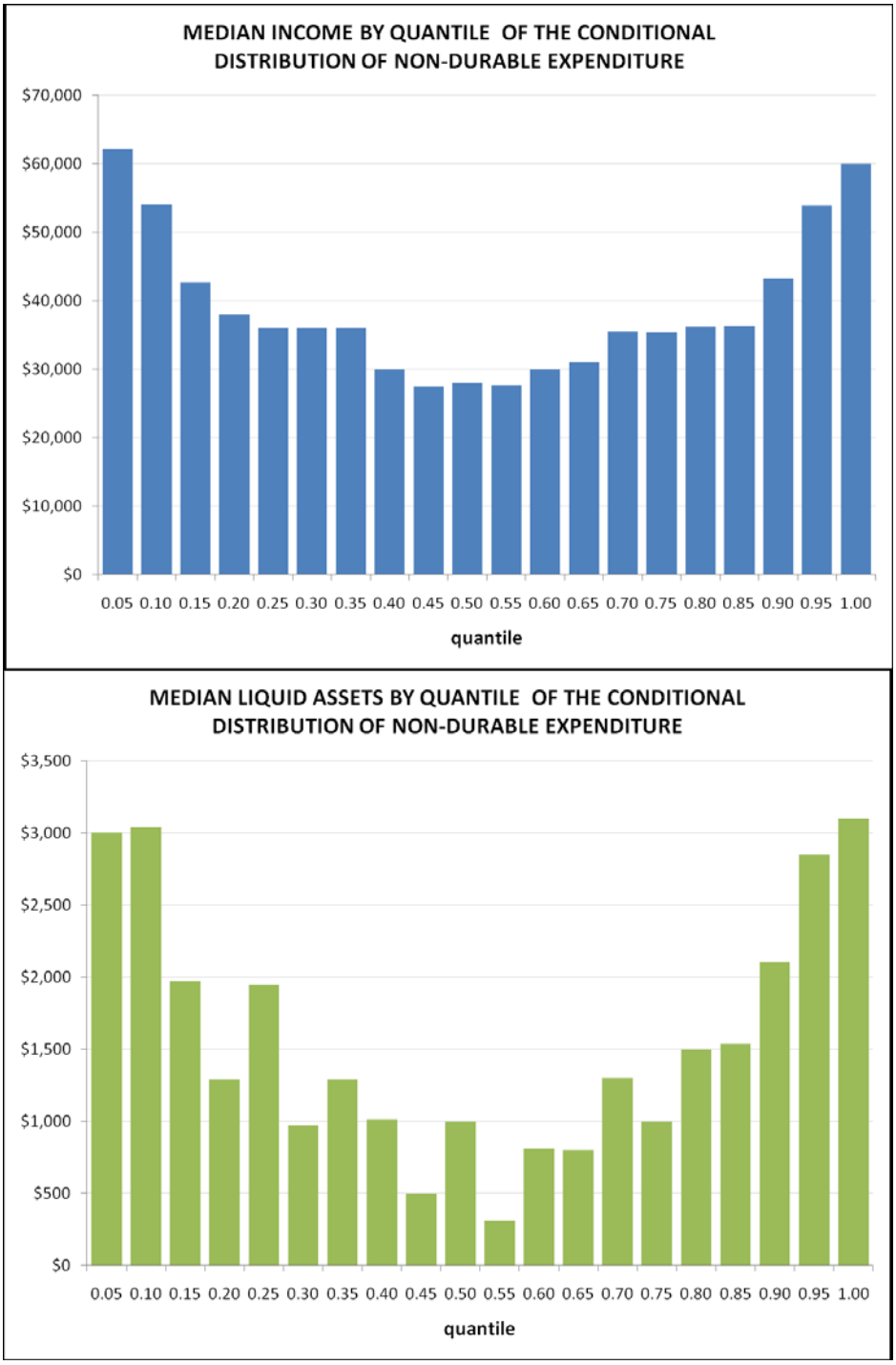

Figure 4: Median income and median liquid assets by rank-score quantile of the conditional distribution of non-durable consumption expenditure. For each quantile τ, we include households for which $[y - X\alpha(\tau)] \leq 0$ and $[y - X\alpha(\tau - 0.05)] > 0$.

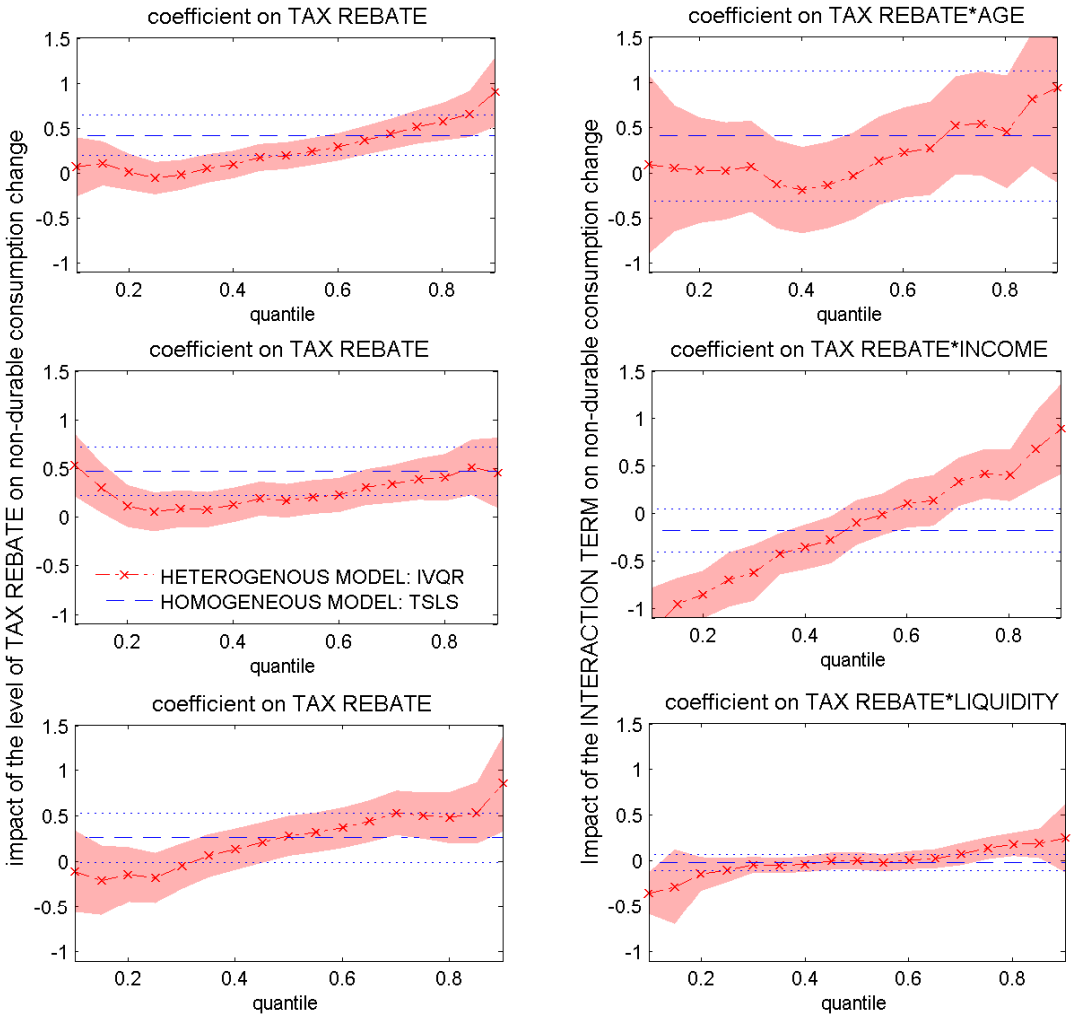

Figure 5: The figure shows in the first column the coefficient on tax rebate and in the second column the coefficient on tax rebate interacted with either age (first row), income (second row) or liquid assets (third row) from regressions of non-durable consumption change on age, change in the number of kids and the number of adults, their square values and monthly dummies. In the instrumental variable regression, tax rebate is instrumented with the dummy variable $I(R > 0)$ which takes value of one if a household received a tax rebate and zero otherwise. The interaction between tax rebate and each variable is instrumented with the interaction between $I(R > 0)$ and that variable. IVQR (TSLS) estimates in red (blue) refer to instrumental variable quantile (two stage least squares) regressions. Shaded areas (dotted lines) are 95% confidence intervals obtained using heteroscedasticity robust standard errors. Estimates are reported for $tau \in [0.1, 0.9]$ at 0.05 unit intervals. Samples are N=13,066, N=9,233 and N=5,951 for the specification including the interaction with age, income and liquid assets respectively. In each augmented specification, age, income and liquid assets enter as deviations from the mean over the mean.

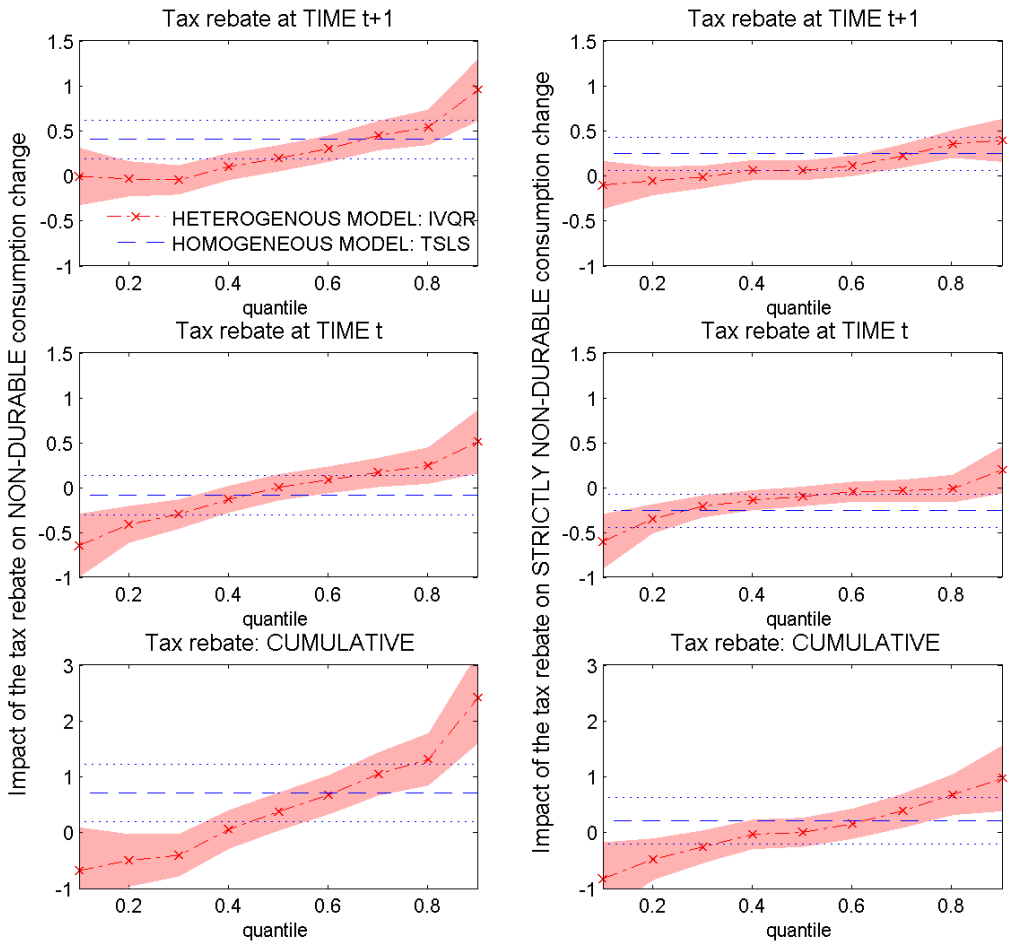

Figure 6: The figure shows the coefficient on tax rebate at time t+1 (first row), tax rebate at time t (second row) and the cumulative effect of the tax rebate (third row) from regressions of consumption change on age, change in the number of kids and the number of adults, their square values and monthly dummies. In the instrumental variable regression, tax rebate at time t+1 and t are instrumented with the dummy variable $I(R > 0)$ at time t+1 and t, which takes value of one if a household received a tax rebate and zero otherwise. IVQR (TSLS) estimates in red (blue) refer to quantile instrumental variable quantile (two stage least squares) regressions. Shaded areas (dotted lines) are 95% confidence intervals obtained using heteroscedasticity robust standard errors. The first (second) column refer to non-durable (strictly non-durable) consumption expenditure change as dependent variable. Sample: N=12,730.

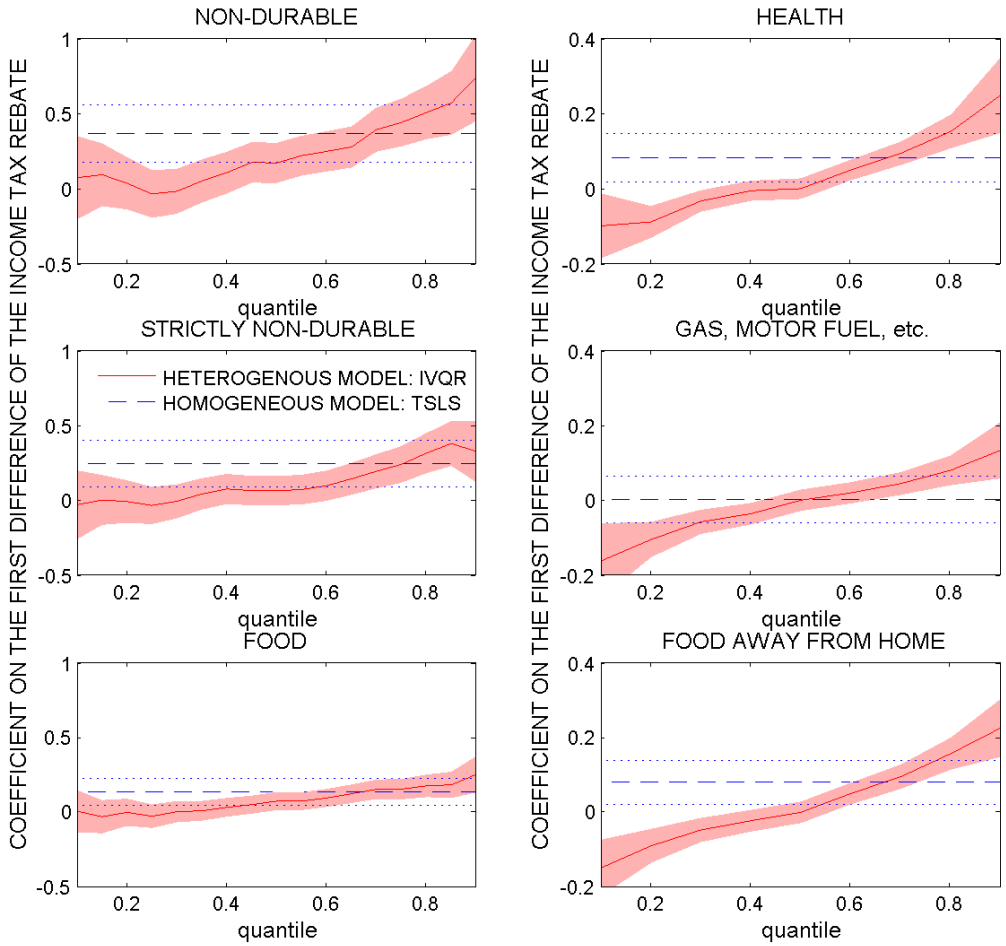

Figure 7: The figure shows the coefficient on the first difference of the tax rebate from regressions of consumption change on age, change in the number of kids and the number of adults, their square values and monthly dummies. In the instrumental variable regression, tax rebate is instrumented with the dummy variable$I(R > 0)$ which takes value of one if a household received a tax rebate and zero otherwise. IVQR (TSLS) estimates in red (blue) refer to quantile instrumental variable quantile (two stage least squares) regressions. Shaded areas (dotted lines) are 95% confidence intervals obtained using heteroscedasticity robust standard errors. Estimates are reported for $\tau \in [0.1, 0.9]$ at 0.05 unit intervals. The first, second and third rows of the left (right) column refer to specifications in which the dependent variable is non-durable, strictly non-durable and food consumption change ('health', 'gas, motor fuel, etc.' and ' food away from home'), respectively. Sample: N=12,730.

Appendix A: Regularity conditions for the IVQR model

In this appendix, we discuss the extent to which the five conditions to identify the quantile treatment effect of the heterogeneous response model described in Chernozhukov and Hansen (2005) are likely to hold in the context of our application.

- **A1 Potential outcome.** Conditional on demographics and time dummies, and for every possible treatment (rebate), $Q_{\Delta C_{it+1}|\cdot}(\tau)$ must be strictly increasing in λ_{it+1}. In our application, the linearity of the specification for consumption expenditure implies that the relationship between $Q_{\Delta C_{it+1}|\cdot}(\tau)$ and λ_{it+1} is increasing. Furthermore, this must be *strictly* increasing as the dependent variable ΔC_{it+1} is continuous with full support on the real line.[13]

- **A2 Independence.** Conditional on demographics and time dummies, the unobserved heterogeneity λ_{it+1} must be independent of the timing of the arrival of the rebate $(I(R_{it+1} > 0))$ for consumers who received the *same level* of treatment (rebate). As in Johnson, Parker and Souleles (2006), we rely on the fact that the timing of the rebate mailing was randomized according to the penultimate digit of the Social Security number and therefore is independent from individual characteristics.

- **A3 Selection.** There must exist an unknown function δ such that $R_{it+1} \equiv \delta(I(R_{it+1} > 0), X_{it}, M_s, V)$ for some random vector V. In our application, the amount of the rebate (typically \$300 or \$600) is based on household demographics (per US Tax rules), while the timing of the check arrival is captured by the instrument. Accordingly, we assume

[13] If ΔC_{it+1} could only take discrete outcomes, then $Q_\tau(\Delta C_{it+1}|\cdot)$ would be *weakly* increasing in λ_{it+1}.

that δ is a function that captures both the amount of the rebate (through X and V) and the timing of the check arrival (through the instrument $I(R > 0)$).

- **A4 Rank invariance (rank similarity).** In its stronger (weaker) form of rank invariance (rank similarity), this says that conditional on demographics, time dummies and the arrival of the rebate $I(R_{it+1} > 0)$, the ranking described by λ_{it+1} does not vary (systematically) with the amount of the rebate R_{it+1}. This assumption requires, for instance, that the consumers who are associated with a large increase in expenditure without a tax rebate would remain large increase consumers if they were granted with a refund. In our application, we interpret the unobserved heterogeneity λ_{it+1} as capturing individual characteristics such as access to the credit market, health status, housing tenure status, preferences, etc., which are unlikely to be influenced by either the arrival or the amount of the rebate. As emphasized by Chernozhukov and Hansen (2005), the plausibility of the assumption of rank invariance (rank similarity) can be corroborated by using appropriate controls for other factors which could influence the left hand side variable. In our application, we control for individual fixed effects by taking first differences of consumption and we include age, changes in family composition (both number of adults and number of kids) and their square values to control for demographic characteristics. Furthermore, as discussed in the main text, the timing of the arrival of the tax rebate check is uncorrelated with household characteristics.

- **A5 Observations.** As required by this condition, we observe the outcome variable (ΔC_{it+1}), the endogenous variable (R_{it+1}), the instrument ($I(R_{it+1} > 0)$) and all other

exogenous variable (X_{it}, M_s).

Appendix B: Sensitivity analysis

In this appendix, we present the results of a specification which is alike the benchmark IVQR model with the exception that the measure of consumption change is now log-difference (as opposed to difference-in-level). To make the results in this section comparable to the estimates of the heterogeneous model in the main text, we map the estimated semi-elasticity of consumption to the tax rebate into the marginal propensity to spend using the formula for the semi-elasticity.

Results are reported in figure 8 and they suggest that the finding of heterogeneous responses to the 2001 income tax rebates is robust to measuring consumption change in percent. While in no quantile the propensity to consume estimated with the log-difference specification is statistically different from the propensity to consume estimated using differences in levels, at higher quantiles the point estimates in figure 8 tend to be smaller than the point estimates in the main text. It should be noted, however, that according to the log-difference specification the aggregate propensity to spend the 2001 income tax rebates was 0.227. This number is not statistically different from the prediction of 0.257 for the difference-in-level specification.

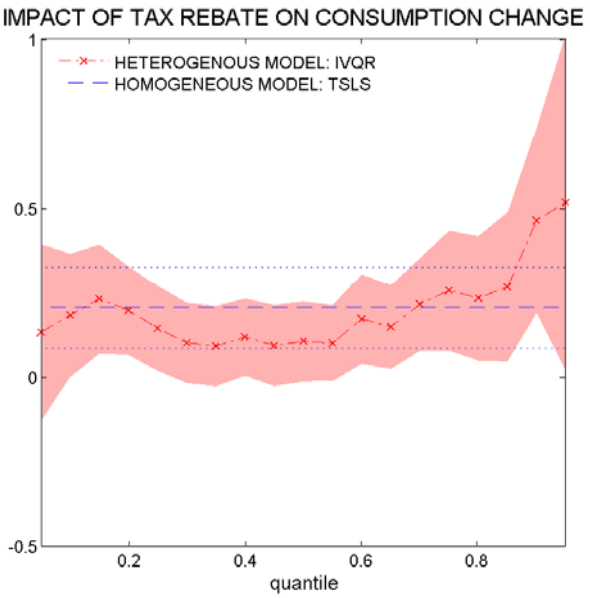

Figure 8: The figure shows the propensity to spend the tax rebate from regressions of non-durable consumption percent change on age, change in the number of kids and the number of adults, their square values and monthly dummies. In the instrumental variable regression, tax rebate is instrumented with the dummy variable $I(R > 0)$ which takes value of one if a household received a tax rebate and zero otherwise. IVQR (TSLS) estimates in red (blue) refer to instrumental variable quantile (two stage least squares) regressions. Shaded areas (dotted lines) are 95% confidence intervals obtained using heteroscedasticity robust standard errors. Estimates are reported for $\tau \in [0.1, 0.9]$ at 0.05 unit intervals.