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 estimated heterogeneity implies that the tax rebates added around 3.3% to aggregate non-durable consumption expenditure in the second half of 2001. The estimates of the homogeneous response model, in contrast, predict a 5% 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 aggregate implications of heterogeneous responses to stabilization policies have been

rigorously investigated in macroeconomic theory. 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 American families 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 (CE) 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 or 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 expenditure on non-durable goods and services 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, which is hard to summarize in few lines, has used exogenous variation in income 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 consumption non-durable 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 average and heterogeneous effects estimated with the two models. In section 4, we assess the role that 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.

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 response(s) to the income tax rebates. Following earlier contributions, the first model restricts the expenditure reaction to the refund to be constant across households, and therefore it can only be used to estimate the average effect. 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 average effect

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 modelled as function of time effects, individual controls and the variable meant to identify unanticipated changes in income. In this class of empirical models, it falls the identification strategy employed by Johnson, Parker and Souleles (2006), who propose the following specification:

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

The first difference of consumption expenditures of household i in quarter t is denoted by ΔC. M is a complete set of indicator variables for every period 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.

As the timing of 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 average causal effect of the rebate on expenditure.[1] Note that, in line with the most prominent studies in the field, the specification (1) assumes that there exists a single slope for the entire sample (of $13,066$ American households) and thus it can be estimated using least squares (LS). However, 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 as instrument for R_{it+1} an indicator function $I\left(R_{it+1} > 0\right)$ that takes value of one in the period when the rebate was received.

2.2 Estimating the quantile effect

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

[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.

of representative agent models. In an important theoretical work closely related to our empirical analysis, 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, access to the credit market, wealth or elasticity of intertemporal substitution are also likely to make the expenditure responses to a temporary tax cut heterogeneous across households.

To explore in the data the nonlinearity highlighted by the theory, we propose to use Quantile Regression (QR) methods which are designed to estimate unobserved heterogeneity models.[2] In particular, QR methods yield a family of estimated slopes which vary across the conditional distribution of the latent outcome variable. In our application, the outcome variable is consumption growth. This is treated as potentially latent because, given a received tax rebate and other observables 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, Q_τ, of the potential outcome distributions conditional on covariates are denoted by:

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

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:

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

[2] Another approach to estimate heterogonous slopes is to consider a least squares model with random coefficients. In this specification, however, a researcher must impose the distribution of the heterogeneity across units of observations. A main advantage of quantile regressions is that they allow us to estimate non-parametrically the extent of heterogeneity (see Koenker, 2005, chapter 2.6).

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 $q\left(R_{it+1}, X_{it}, M_s, \lambda_{it+1}\right) = Q_\tau\left(R_{it+1}|X_{it}, M_s, \lambda_{it+1}\right)$ and λ_{it+1} captures unobserved heterogeneity across individuals i with the same observed characteristics X_{it} and "treatment" R_{it+1}. The variable λ_{it} is usually referred to as the rank variable as it determines the relative ranking of individuals in terms of potential outcomes. To the extent that the timing of the receipt of the fiscal stimulus is independent from individual characteristics, QTE_τ measures the causal effect of the tax rebate on consumption growth, holding the unobserved characteristics driving heterogeneity fixed at $\lambda_{it+1} = \tau$.

Were the tax rebates R_{it+1} exogenous, 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 $\tau \in (0,1)$. The empirical specification of the conditional τ-th quantile distribution of consumption growth takes the following form:

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

for each $\tau \in (0,1)$, where the variables have been defined in the previous section.[3]

To the extent that the amount of the tax rebate is correlated with unobserved characteristics captured by λ_{it+1}, however, the moments restrictions above would be violated. To

[3]We obtain estimates similar to those reported in the next section by imposing that the coeffcients on the time dummies are fixed across quantiles.

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, this requires to 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 their IVQR estimator is rank similarity. In terms of our application, this requires that, conditional on covariates, the unobserved individual characteristics driving the rank variable λ_{it+1} do not vary systematically with the timing of the receipt of the tax rebates. The random variation (associated with the penultimate digit of the Social Security number) in the arrival of the rebate implies that the rank similarity condition is likely to hold in the data we use.

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 goods categories. The main results are that the evidence of heterogeneous behaviour is pervasive, in a way that it is significantly missed by the average effect.

3.1 The response of non-durable goods

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 CE survey 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 least squares (two stage least square) onto the specification (1). 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 on *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 average effects 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.[4] 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 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

[4]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 0.6.

expenditure with the possible exception of the tails where the instrumental variable estimates tend to be smaller in absolute value.[5]

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.[6]

In summary, the aggregated measures of non-durable consumption expenditure point towards significant heterogeneity in the responses of American households to the 2001 federal 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 implication of the estimated heterogeneity for the aggregate impact of the tax rebate plan on the U.S. economy (section 5).

[5] 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.

[6] 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).

3.2 The response across goods 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 estimated average effects 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, motor 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, an interpretation consistent with Ricardian equivalence is that these high earners 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. Two variables, emphasized by the empirical literature on testing for the permanent income hypothesis, stand up as natural candidates: income and liquid assets.[7] Figure 4 reports prima facie evidence in favor of a role for these two variables. 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 enjoyed higher income and liquid wealth. An interpretation consistent with rational behaviour is that the cost of processing information makes it optimal for some households to revise their 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 could also be associated with high spending propensity (Reis, 2006). Second, households with low income and 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

[7] 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.

their behaviour is consistent with the presence of liquidity constraints.

To provide formal evidence on the empirical relevance of income and liquidity considerations for the heterogeneous responses, 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.[8] Second, we augment the specification in section 3 with an interaction term between the tax rebate and either income or liquid wealth.[9]

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

It is interesting to note that 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 propen-

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

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

sity to consume statistically larger than zero. This number is very close to 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 specification including the interaction term with income (liquid assets) are reported in the first (second) column of figure 5.[10] The coefficients on the tax rebate in the first column specification display a lesser extent of heterogeneity than in figure 1. This is explained by the variation in the coefficients on the interaction term in the bottom-left panel: households with higher income 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 estimated coefficients on the interaction term.

The evidence from the second column suggests that the contribution of liquid wealth to the heterogeneous responses is more muted as the coefficients on the interaction term display little variation across households. In particular, the test statistics are now 2.23 for the estimates of the impact of the rebate and 1.02 for the estimates of the impact of the interaction term between rebate and liquid wealth.

In summary, the evidence of this section is suggestive of a significant and highly non-monotonic association between the heterogeneous responses to the 2001 tax rebates, income

[10] In the augmented specifications, we include as additional instrument the interaction of $I(R > 0)$ with either income or liquid wealth.

and to a lesser extent liquidity. 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, have a propensity to consume between 10% and 40%.

5 The aggregate impact of the tax rebates

In the previous sections, we have shown strong evidence of heterogeneous responses to the 2001 income tax rebates. A natural question at this point is whether such heterogeneity implies a different aggregate effect on the U.S. economy relative to the prediction of a specification that imposes the same propensity to spend across American households. 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) expenditure. For the sake of brevity, in this section we only report instrumental variable results.

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 across quantiles which, together with the coefficients on R_{t+1}, map into a significantly heterogeneous cumulative impact. The estimates in the third row corroborates the earlier finding that the response of around 45% of households is not statistically different from zero. The rest of the sample, however, spends a significant amount of the tax rebate

in the period following its arrival and for individuals in the top 15% of the conditional distribution of non-durable (strictly non-durable) good 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 are now ready to 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 billion, 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 response specifications in figure 5 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.

According to table 2, the heterogeneous response model implies estimates of the aggregate impact of the rebates that are systematically lower (by 36% on average) than the estimates implied by the specification that imposes slope homogeneity. Based on the latter, for instance, the cumulative effect is found to be just above 5%, with a large standard error. The $IVQR$ method, in contrast, implies a smaller cumulative effect of 3.27%, which is also more accurately estimated. 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%.

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 heterogeneous responses. 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 on liquidity constraints, we have explored the

link between income, liquid wealth and heterogeneous responses, finding that this is highly non-monotonic. Households enjoying relatively higher income or liquid wealth spent either nothing or most of the tax rebate. While the behaviour of the former is consistent with Ricardian equivalence, the behaviour of the latter is consistent with rule-of-thumb or inattentive consumers. On the other hand, Americans with low income or liquid wealth spent between 10 and 40 *cents* for each dollar of the tax rebate, consistent with the existence of liquidity constraints for about 20% of the full sample.

The estimated heterogeneity implies 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 all American families 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 accounting for heterogeneous responses can 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 * denotes 1%, 5% and 10% significance level. The dependent variable takes value of one if $[y\text{-}X\alpha(\tau) \leq 0]$ and $[y\text{-}X\alpha(\tau\text{-}0.05)] > 0$.

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

	effect in 2001Q3	*effect in 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. TSLS (IVQR) refers to the aggregate impact of the tax rebate (as share of aggregate non-durable consumption expenditure) implied by the two stage least square (instrumental variable quantile regression) estimation method assuming that the total amount of the tax rebate was 7.5% of non-durable consumption in Q3 (and the consumption share was the same across deciles). The 'difference' between IVQR and TSLS point estimates is reported as % of the TSLS entries.

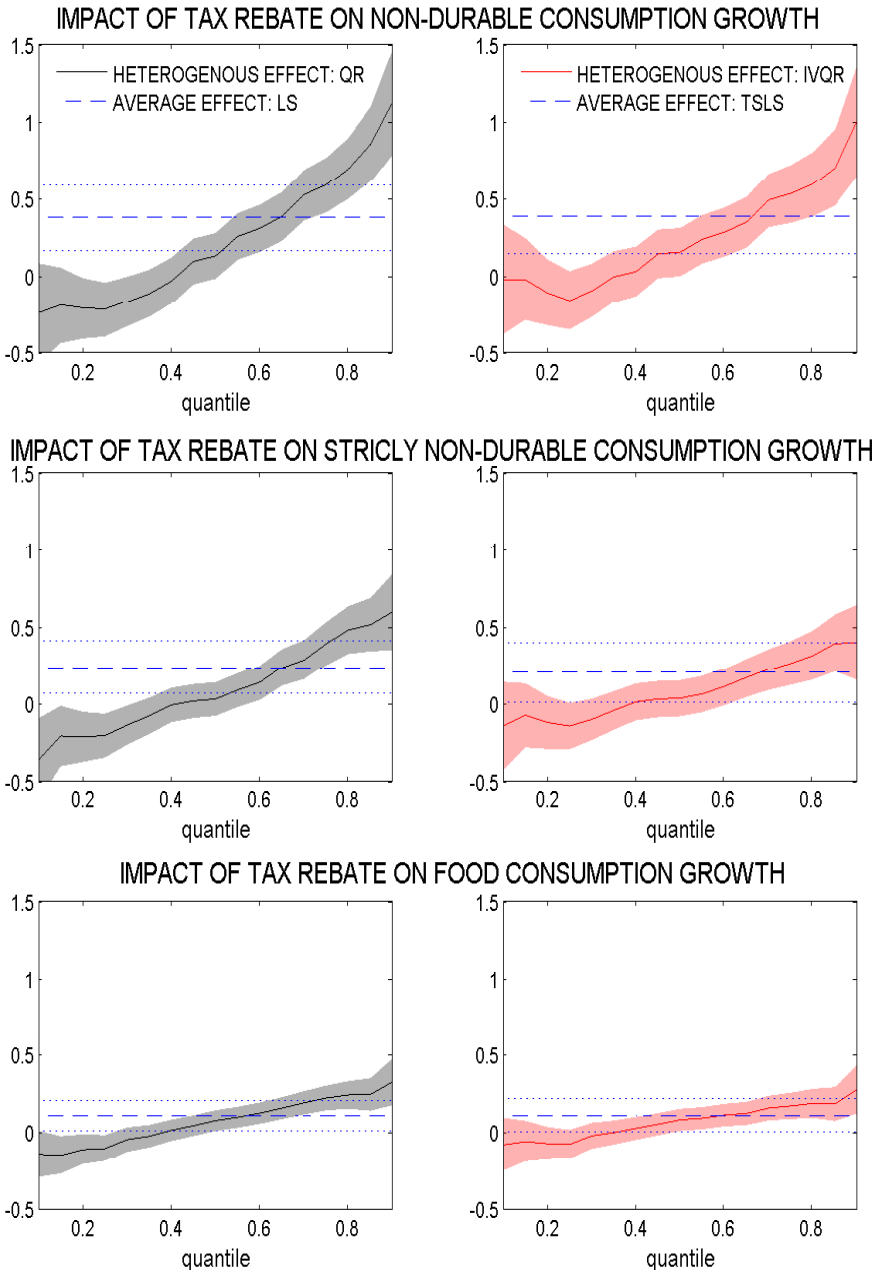

Figure 1: The figure shows the coefficient on tax rebate from regressions of the first difference of consumption on age, changes in the number of kids and the number of adults, their square values and monthly dummies. In the instrumental variable regression, tax rebate is instrumented with the dummy variable $I(R>0)$ which takes value of zero 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 growth, respectively. Sample: N=13,066.

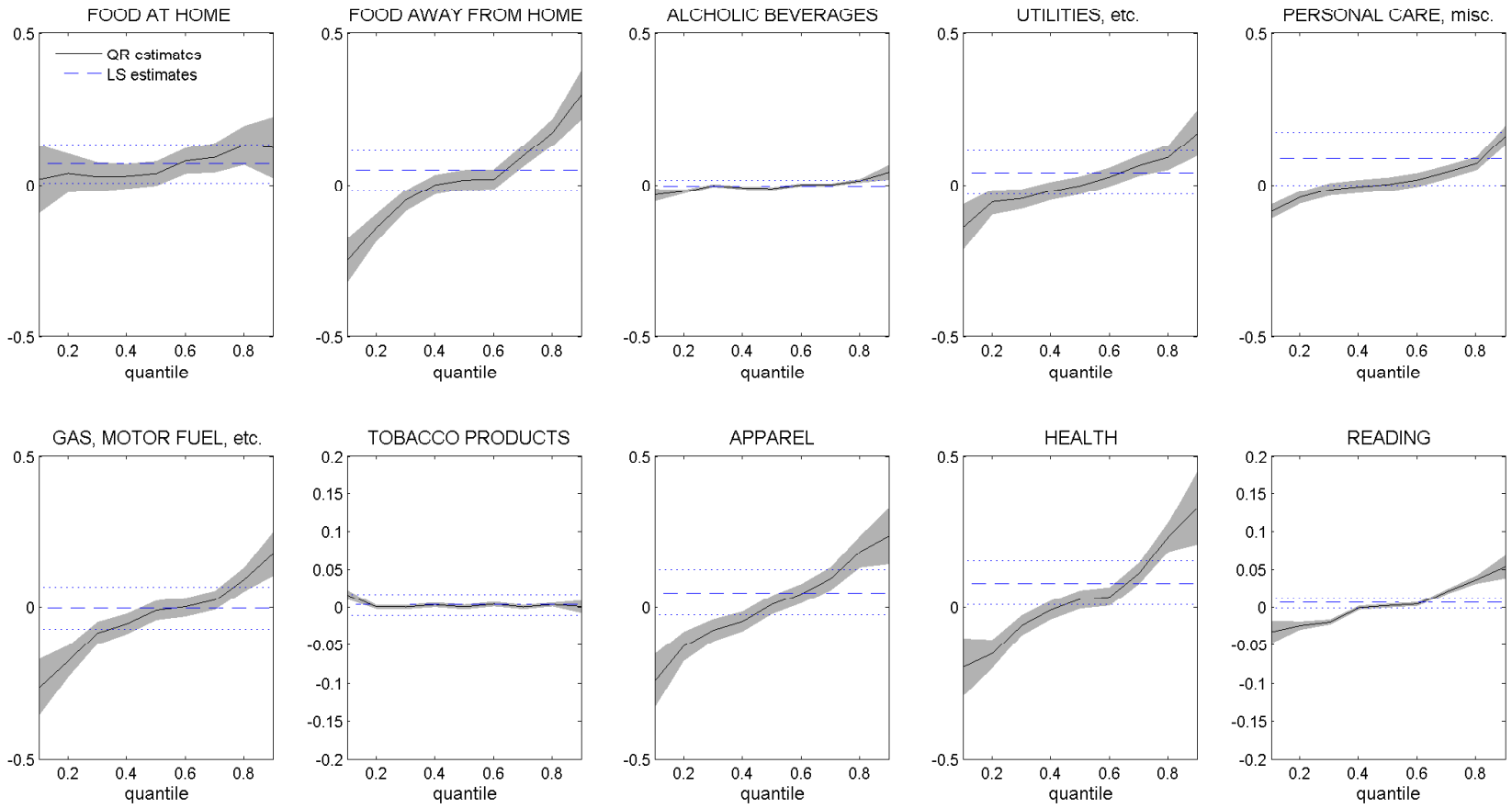

Figure 2: The figure shows the coefficient on tax rebate from regressions of the first difference of consumption on age, changes in the number of kids and the number of adults, their square values and monthly dummies.QR (LS) estimates in black (blue) refer to quantile (least squares) regressions. Shaded areas (dotted lines) are 95% confidence intervals obtained using heteroscedasticity robust standard errors. Estimates are reported for $\tau \epsilon$ [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.

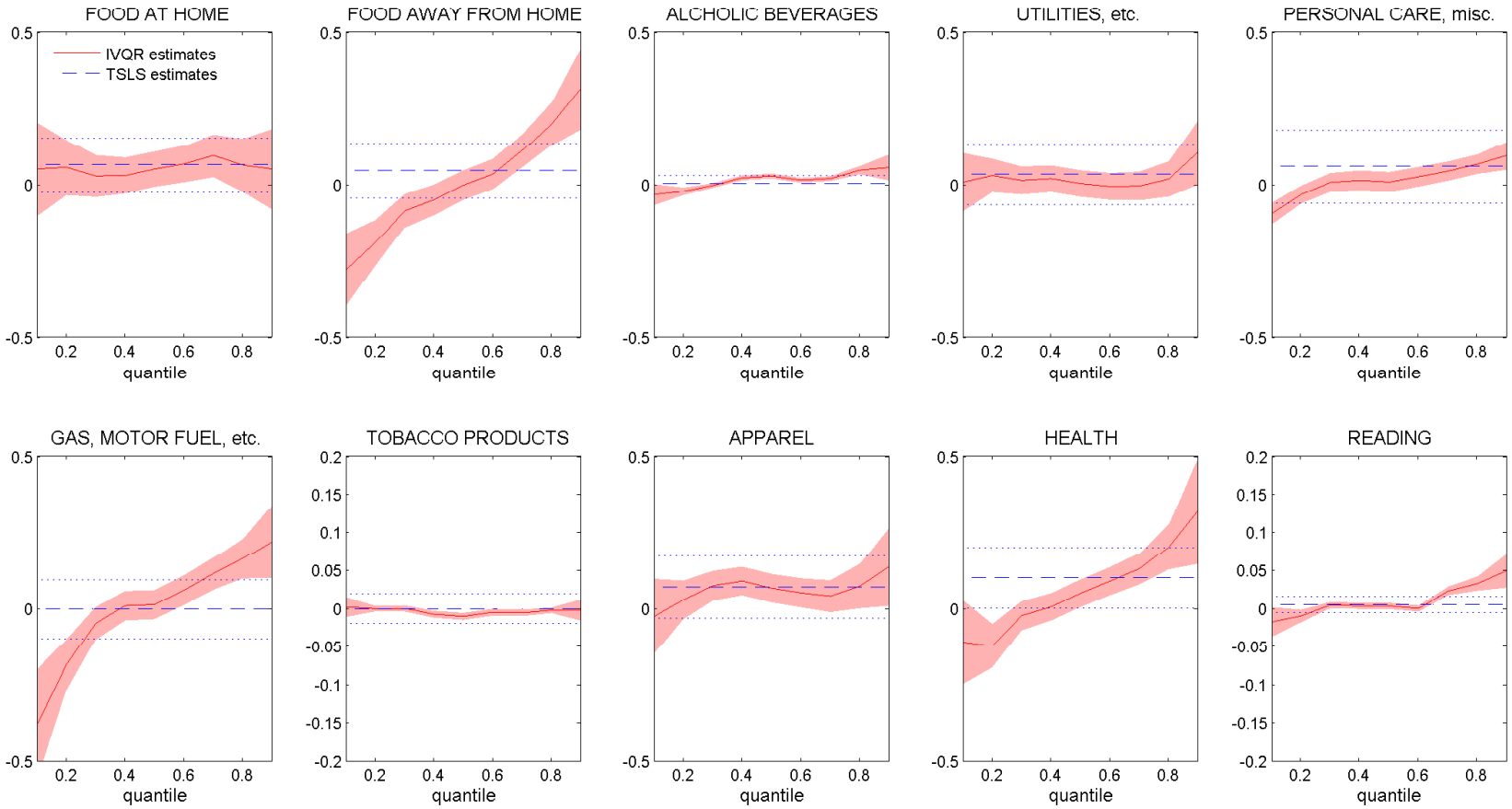

Figure 3: The figure shows the coefficient on tax rebate from instrumental variable regressions of the first difference of consumption on age, changes in the number of kids and the number of adults, their square values and monthly dummies. The instrument for tax rebate is a dummy variable $I(R>0)$ which takes value zero 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 $\tau \in [0.1, 0.9]$ 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.

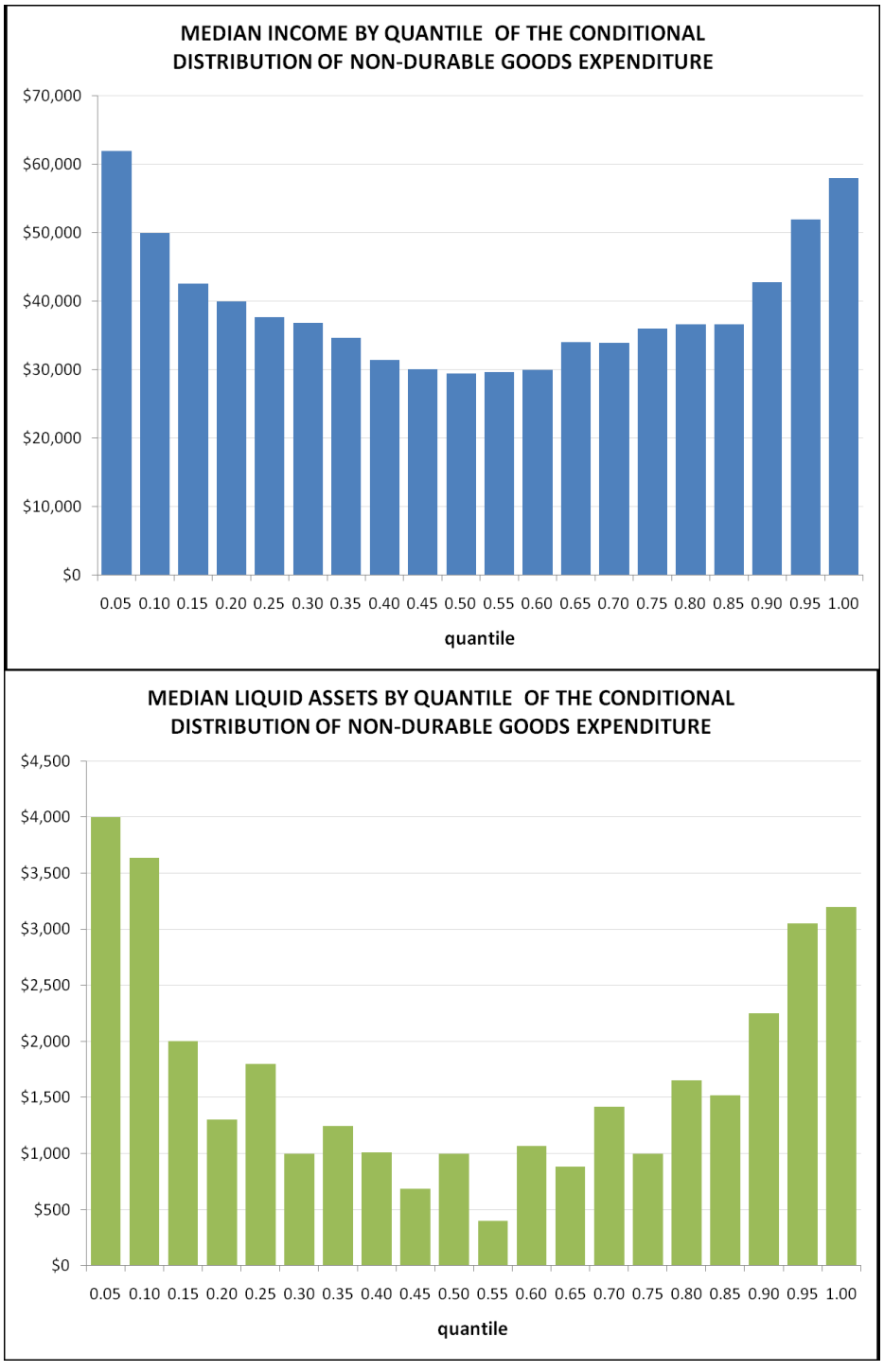

Figure 4: median income and median liquid assets by rank-score quantile of the conditional distribution of non-durable goods expenditure.

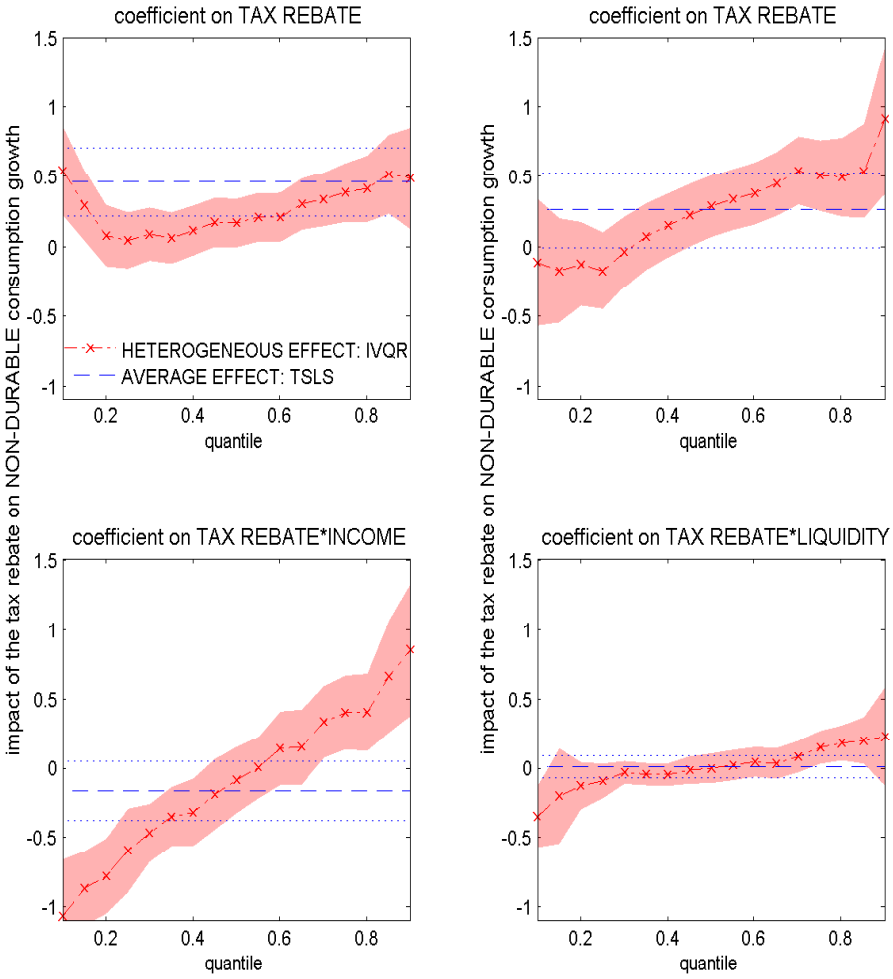

Figure 5: The figure shows the coefficient on tax rebate and the coefficient on tax rebate interacted with either income (first column) or liquid assets (second column) from regressions of the first difference of non-durable consumption on age, changes in the number of kids and the number of adults, 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 zero if a household received a tax rebate and zero otherwise. The interaction between tax rebate and income (liquid assets) is instrumented with the interaction between $I(R>0)$ and income (liquid assets). 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=9,233 for the specification including the interaction with income and N=5,951 for the specification including the interaction with liquid assets. To ensure comparability among the magnitude of the coefficients, income and liquid assets enter each specification as deviation from the mean divided by the mean.

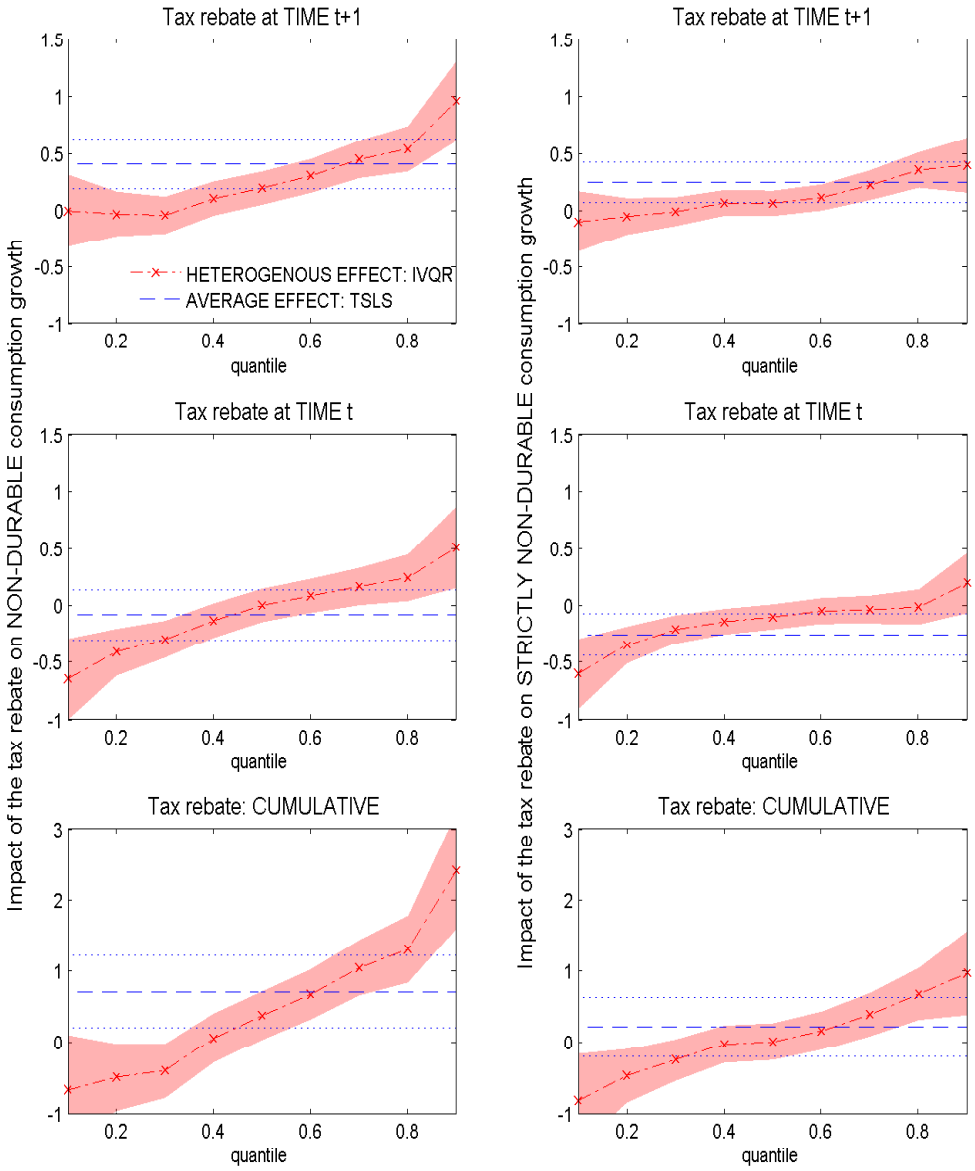

Figure 6: The figure shows the coefficient on tax rebate at time t+1 (first row), tax rebate at time t (second row) and the cumulative effect of the tax rebate (third row) from regressions of the first difference of consumption on age, changes in the number of kids and the number of adults, their square 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 zero 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 growth as dependent variable. Sample: N=12,730.

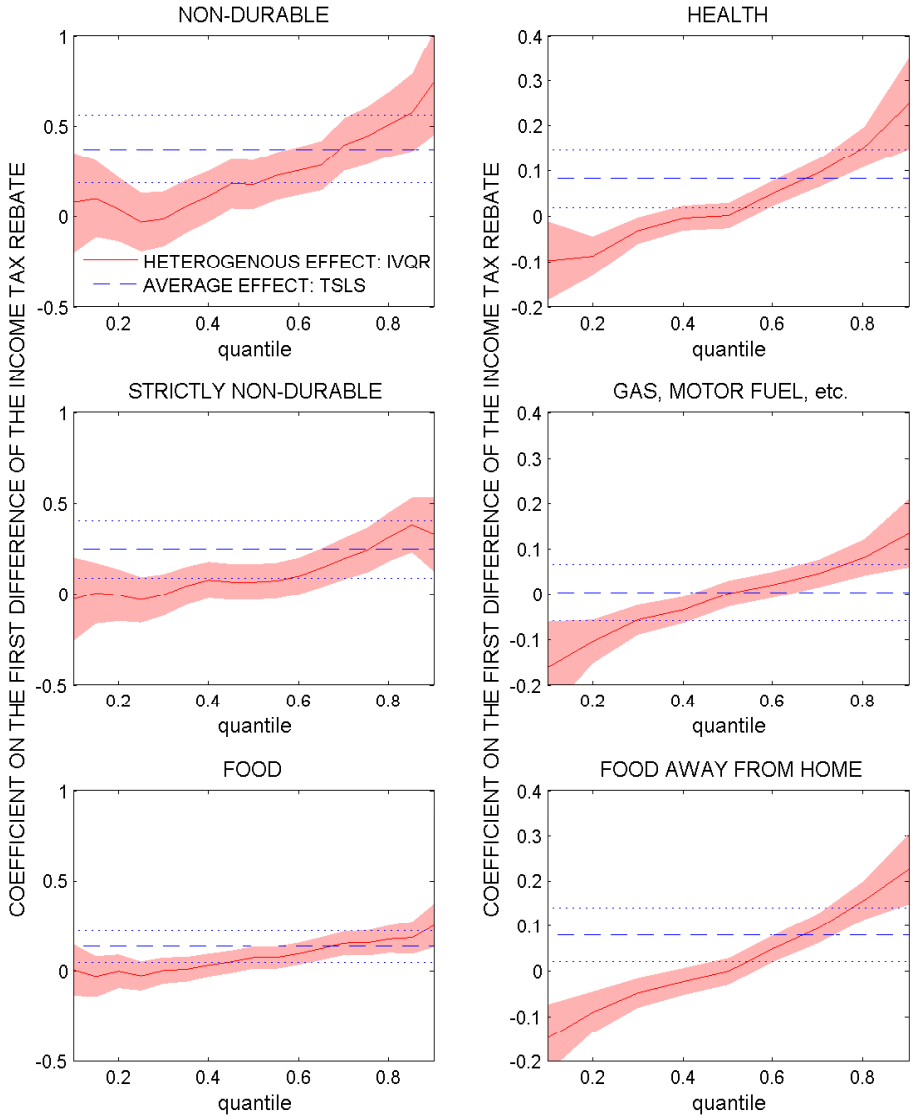

Figure 7: The figure shows the coefficient on the first difference of the tax rebate from regressions of the first difference of consumption on age, changes in the number of kids and the number of adults, their square values and monthly dummies. In the instrumental variable regression, tax rebate is instrumented with the dummy variable $I(R>0)$ which takes value of zero 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 left (right) column refer to specifications in which the dependent variable is non-durable, strictly non-durable and food consumption growth ('health', 'gas, motor fuel, etc.' and ' food away from home'), respectively. Sample: N=12,730.