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Erling Røed Larsen  
BI Norwegian Business School

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# THE ENGEL CURVE OF OWNER-OCCUPIED HOUSING CONSUMPTION

ERLING RØED LARSEN\*

*BI Norwegian Business School and Eiendomsverdi*

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Housing is a major component of aggregate demand, and understanding how the demand for housing co-varies with income is useful for analysis and policy. While estimating housing consumption for tenants amounts to observing rents, estimating housing consumption for owner-occupiers is challenging because it is not directly observable and interest payments vary with re-paid principals. In order to examine the housing consumption for owner-occupiers, this article combines micro data sets on income and imputed rents for owner-occupiers based on home attributes from a consumer expenditure survey and monthly rents in a rental survey. This allows estimation of an Engel curve of owner-occupied consumption, both parametrically and non-parametrically. Regression results demonstrate that the income share of owner-occupied housing consumption decreases with income, while the Engel elasticity computed at the mean is 0.32 and increasing in income.

*JEL classification codes:* C21, D12, D63, H23

*Key words:* consumption, Engel curve, Engel elasticity, housing, imputed rent, owner-occupier

## I. Introduction

Economists and policymakers have become increasingly interested in the mechanisms governing housing markets. This interest spans a range of topics, from the role housing plays in the macroeconomy (Leamer 2007) to the link between house prices and debt (Mian and Sufi 2011). A common factor appears to be the desire to establish empirical patterns that uncover consumer preferences for housing. Against this backdrop, Engel curves<sup>1</sup> for owner-occupied housing seem particularly well worth investigating since they map the relationship between owners' income and housing consumption, everything else being equal. In applied economics, they may serve several purposes. For example, since Engel curves inform us about partial income effects on demand they can serve as inputs in forecasting models. Moreover, they make it possible to assess whether housing taxes would be regressive or progressive, which is useful knowledge for policymakers. Since taxes are, or would be, levied on owners (Poterba and Sinai 2008 and Mirrlees 2010) and only owners have home equity relevant to macroeconomic performance, we are especially interested in the possibility of estimating Engel curves for owner-occupiers. However, estimating

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\* Professor, Dept. of Economics, BI Norwegian Business School and Head of Research, Eiendomsverdi. BI Norwegian Business School, N-0442 Oslo, Norway. E-mail: [erling.roed.larsen@bi.no](mailto:erling.roed.larsen@bi.no). Telephone: +47 46 41 06 93. Fax: +47 23 26 47 88. The author is grateful for financial support provided by the Research Council of Norway, projects no. 187392/S20 and no. 202364/S20 and is indebted to Erik Bjørn, Richard Blundell, Brita Bye, Ådne Cappelen, Vidar Christiansen, Hans Henrik Scheel, and Morten Skak for providing useful comments. Eiliv Mørk at Statistics Norway helped facilitate data acquisition, construction, and description.

<sup>1</sup> The term 'Engel curve' covers a broad class of relationships between expenditure on a given good and total consumption or gross/net income. The term also comprises relationships in which the dependent variable is a share of total consumption or income.

Engel curves for owners is more challenging than for tenants since an owner's housing consumption is not directly observable. An owner does not pay rent. An owner pays interest, but re-paid principal obscures the relationship between interest payments and housing consumption. The aim of this article is to meet this challenge and estimate Engel curves for owner-occupiers, employing the rental equivalence principle (Aaron 1970) to impute owner-occupied housing consumption.

I do this by accessing several data sets. First, I obtain estimates on imputed rent for owner-occupiers from a statistical agency that computes these estimates based on an empirical relationship between housing attributes and rent. The agency does this by estimating a hedonic regression of rent onto attributes of the rented unit using data from a rental survey. Subsequently, the agency uses the estimated function and inputs attributes of the owned home from owner-occupiers. Second, I employ income data from a tax register, which is advantageous because it ensures that information of income is of high-quality and not based on memory or self-reports and because it allows for controls of gross versus net income. Third, household size and composition is accounted for in the estimated Engel curve by employing household characteristics from the Consumer Expenditure Survey (CES). For cross-check purposes, I also access CES data on other expenditures, paid interest, and insurance.

I then estimate Engel curves of housing for owner-occupiers by regressing the income share of imputed rent onto a space spanned by gross income and household characteristics for owner-occupiers. Rarely does one find the possibility of combining CES information on housing attributes for owner-occupiers, partial rental prices estimated from rental surveys, and income data from tax records. Since Norway is a wealthy country it can afford the collection of high-quality data and since it is a small country it can offer an accurate overview of its consumers. Thus, this article's data set is a valuable source for housing analysis, and the Engel curve for housing may be representative for other modern high-income countries.

This article's contribution, then, is purely empirical. The value-added is the estimated Engel curves that result from the exploitation of rich micro datasets. The analysis may assist tax analyses, forecasts, and preference mapping elsewhere. I offer both parametric and non-parametrical estimation; in addition to estimated curves for several sub-segments of the population. My main findings are that the Engel elasticity of housing consumption for owner-occupiers is 0.32 for mean gross income levels and that it increases with gross income to 0.59 for households in the interval 80<sup>th</sup> to 90<sup>th</sup> percentile.

The article is organized as follows. Section II motivates the study and presents relevant literature. Section III introduces the empirical techniques of estimating Engel curves. Section IV describes the acquisition and combination of the required datasets. Section V presents empirical results and the subsequent section discusses their shortcomings. In the final section, I make concluding remarks and mention policy implications.

## **II. Literature**

The article stands in the confluence of three strains of literature on Engel curves, housing, and taxation. Among these fields of knowledge, the former is the oldest. Establishing empirical regularities in the form of Engel curves is one of the tasks to which applied economists and econometricians have allocated much effort. The reason is clear: Engel curves are useful. If we know the Engel curve of a given good, and policymakers consider levying a tax on it, an analysis of the distribution of the tax payments is feasible using the Engel curve; see, e.g., Aasness and Røed Larsen (2003). If we know the Engel curve for a given good and we think we have access to accurate predictions of income growth, then we can construct forecasts, *ceteris paribus*, for the long-term development of the demand for the good. Even if the forecasts necessarily must be based on the partial effect of income, other things being equal, such analyses can offer helpful insights into the structure of present versus future demand.

Moreover, the applicability of Engel curves is not limited to taxation and forecasts, but includes estimating CPI biases (Hamilton 2001 and Røed Larsen 2007), PPP biases (Almås 2012), and material standards of living (Røed Larsen 2009). Engel curves have also been the topic of other recent econometric research (Blundell, Browning, and Crawford 2003 and Blundell, Chen, and Kristensen 2007).

Perhaps the single-most important reason for the popularity of Engel curves has come from the fact that they form the basis upon which one may compute Engel elasticities. Engel elasticities are useful because they are condensed statistics of consumer behavior and may function as easily accessed prisms into demand structures. For example, Fernández-Kranz and Hon (2006) present an application for housing consumption in Spain and use estimates on income elasticities to support the claim that Spanish house prices between 1998 and 2003 were above the equilibrium level. Piazzesi, Schneider, and Tuzel (2007) use expenditure shares of housing and non-housing to construct and calibrate a consumption-based asset pricing model to predict excess stock return. Zabel (2004) finds

Engel elasticities<sup>2</sup> on housing for the United States in 2001 ranging from 0.16 to 0.64.<sup>3</sup> Ioannides and Zabel (2008) estimate an elasticity of 0.21 on U.S. data. These are magnitudes that are comparable to the results in this article.

Poterba and Sinai (2008: 85) report that in the year 2003, households aged 35 to 50 with annual adjusted gross income between USD 75,000 and 125,000 typically owned a home of value USD 254,000. But households with incomes between USD 125,000 and 250,000 typically owned a home valued USD 422,000. Using the mid-points, we infer that an increase in income from USD 100,000 to 187,500; an 88 percent increase, is associated with an increase in the home value of 66 percent. In other words, the implicit income elasticity of housing consumption appears to be higher than the ones found by Ioannides and Zabel and this article. In comparison, Yates (1994), in an early paper, reports from Australia that a gross income increase of 221 percent<sup>4</sup> is associated with an increase in home value of 24 percent.

However, estimating Engel curves of housing consumption is not straightforward for owner-occupiers since their levels of housing consumption is latent and different from the directly observable expenditures on interest. Several approaches to deal with this challenge are possible. In addition to this article's method of estimating what an owner foregoes in rent, using data on rentals, one could take the above mentioned method used by Poterba and Sinai (2008) and estimate the value of each owner's house, using data on sales, and relate this to the owner's income. In a variant of this, one employs the interest payments of a new, no-equity purchase of an owner's home as a proxy for latent housing consumption (Beatty, Røed Larsen, and Sommervoll 2010). These approaches are not much different as long as the markets for owners and renters are comparable; a maintained assumption in this article. Interestingly, Hardman and Ioannides (2004) look at the income distribution within and across housing areas, instead of looking at housing distribution across income.

These results serve a need because tax regimes of housing have received much interest recently. There are several reasons why. First, such taxes could help stabilize economic development since they can be fashioned to work counter-cyclically and dampen pro-cyclical housing consumption; see e.g. Leung (2004); Davis and Heathcote (2005); Jud and Winkler (2002); and Leamer (2007). Røed Larsen and Weum (2008) show that such stabilization could be warranted given the substantial time structure and serial correlation in house prices. Second, a revenue-neutral substitution of a housing tax for a labor income tax could reduce deadweight losses and thus improve

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<sup>2</sup> The author uses the term 'income elasticities'. Engel and income curves are used interchangeably in the literature.

<sup>3</sup> Depending on where on the Engel curve the elasticities are computed.

<sup>4</sup> While gross income increases from 271 to 870, the value of dwellings increases from 82,193 to 102,262. Table 1, p. 54.

economic efficiency; see simulations on general equilibrium models by Nakagami and Pereira (1996) and Bye and Åvitsland (2003). However, such taxes are difficult to implement and reform, due to the contentious distribution of them. Poterba and Sinai (2008: 89) focus their attention on the burdens, and state: "... the distribution of burdens from eliminating the property tax deduction is closer to that associated with taxing imputed rent than to that for reducing the mortgage interest deduction..." Bowman and Bell (2008) demonstrate that overall a tax regime change towards property taxation would work progressively. Plummer (2010) finds that replacing a uniform property tax with a land value tax would entail a slightly more progressive tax system.

Today, the interest in housing taxes is considerable. The Mirrlees-Review<sup>5</sup> states that "housing is as important as an asset as all financial assets combined" (chapter 16.2.2) and argues: "VAT paid on the newly bought good is, in effect, a prepayment on the stream of services yielded. A natural starting point is that the same approach should be applied to housing" (chapter 16.2.1). Economists have for some time pointed out the positive arguments for implementing a housing tax reform, e.g., in response to recent concerns about housing inequity (Thalmann 2007), the preferential treatment of owner-occupied housing (Cremer and Gahvari 1998 and Gervais 2002), and the favorable treatment of housing overall (Hendershott and White 2000). This article's Engel curves can serve as input in analyses of how such taxes could be constructed.

### III. Empirical technique

I regress, parametrically, the ratio of imputed rent to gross income onto a space spanned by a second order polynomial of the logarithm of gross income. In order to control for household composition and size I include as regressors two preference-shifters, i.e., the number of adults and the number of children, as given in equation (1).

$$\omega_h = \alpha + \beta_1 \cdot \ln(GI_h) + \beta_2 \cdot (\ln(GI_h))^2 + \gamma_1 \cdot A_h + \gamma_2 \cdot C_h + \varepsilon_h, \quad h \in H, \quad (1)$$

where  $\omega_h$  is the (gross) income-share of housing consumption of household  $h$ ,  $GI_h$  denotes gross income of household  $h$ ,  $A_h$  and  $C_h$  represent the number of adults and children, respectively, in household  $h$  which is element in

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<sup>5</sup> See drafts on Tax by Design on-line: <http://www.ifs.org.uk/mirrleesReview.Chapter.16.2.1> deals with housing.

all households  $H$ , and  $\varepsilon$  is a zero-mean stochastic error variable.<sup>6</sup> This Engel curve specification is in line with the quadratic almost ideal demand system (QUAIDS) without price terms (Banks, Blundell, and Lewbel 1997 and Blundell and Stoker 2005) and functional form, robustness, and sensitivity are discussed below.

Housing consumption for owner-occupiers is estimated using the rental equivalence principle (Frick and Grabka 2003), i.e., by imputed rent. The imputation consists of a two-step procedure, which is explained in the Appendix. First, analysts at Statistics Norway collect observations from rental markets in an annual rental survey. This survey obtains information on market rent, attributes of the rental object, spatial coordinates, and other determinants of rent for several thousand rental objects; see Røed Larsen and Sommervoll (2009) for results on the first vintage of this survey. The survey itself is described in some detail below. The statistical agency regresses observed rent onto the relevant determinant space and obtains the partial rental price for each hedonic and spatial housing component; see Nesbakken (2008) for a detailed analysis of observed rent and imputed rent. Second, the agency conducts consumer expenditure surveys (CES) and collects information on similar hedonic and spatial housing components from owner-occupier households. This allows the statistical agency to impute what the households would have had to pay in rent had they rented their own home. To this end, the agency simply uses the hedonic regression model estimated from the rental survey and computes the imputed rent on the basis of the observed housing attributes for owner-occupiers.

In this framework, the Engel elasticity of housing ( $E_{HC,GI}$ ) is the ratio of the derivative of the Engel curve of owner-occupied housing consumption, i.e. imputed rent, with respect to income on the fraction of mean owner-occupied housing consumption out of mean gross income:

$$E_{HC,GI} = \frac{\partial HC(GI, A, C) / \partial GI}{\sum_h HC_h / \sum_h GI_h} , \quad (2)$$

where the Engel curve of housing consumption  $HC$  for this estimation is a second-order polynomial function of gross income with number of adults and children as preference-shifters.<sup>7</sup> Put differently, the Engel elasticity is simply the ratio of the derivative of housing consumption with respect to gross income and the income-share of housing consumption. I compute the Engel elasticity at several points on the estimated curve.

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<sup>6</sup>The reported t-statistics are heteroskedasticity-consistent.

<sup>7</sup>The Engel curve specification used to compute the Engel elasticity is a variation of equation (1) that avoids having gross income as denominator in the left-hand-side variable. Curvature is kept by employing a second-order polynomial. For robustness control, I also estimate the Engel elasticity using a log-log specification.

Even if the parametric specification includes a second order polynomial in gross income, and this typically captures most of the curvature, I test functional sensitivity by employing a non-parametric procedure. The relationship between the ratio of imputed rent on gross income and gross income itself is given by equation (3):

$$\omega_h = g(GI_h, D_h) + \mu_h , \quad (3)$$

in which  $g(\cdot)$  is an unspecified function, potentially non-monotonous, and the classically behaved error term  $\mu$  is uncorrelated with gross income,  $GI$ . The variable  $D$  denotes demographic variables such as size and composition. The local regression method fits a linear weighted regression line in a local neighborhood for each  $GI_h$ .<sup>8</sup> The linear regression weight assigned to an included observation  $GI_i$  around  $GI_h$ , for which the local line is fit, is given by equation (4):

$$W(GI_i, GI_h, b_h) = K_0(x) = K_0\left(\frac{GI_i - GI_h}{b_h}\right), \quad i \in I, \quad h \in H, \quad x \in X, \quad (4)$$

where  $GI_i$  is within the bandwidth set around  $GI_h$  such that the set that contains the observations used in the local regression  $I$  is a subset of  $H$ . The variable  $b_h$  is the bandwidth, and  $K_0(x)$  is a smooth weighting function. The variable  $x$  is an intermediary variable and element in the real-number set  $X$ . This article uses the Tri-Cube function for  $K_0(x)$ , given in equation (5):

$$K_0(x) = \begin{cases} (1 - |x|^3)^3, & \text{for } |x| \leq 1, \\ 0, & \text{otherwise.} \end{cases} \quad (5)$$

#### IV. Data

The analysis requires information on housing consumption of owner-occupiers. Since such information does not readily exist, this article estimates it by employing the rental equivalence principle. This estimation process requires

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<sup>8</sup> The neighborhood is chosen so as to contain a percentage of all available observations in the sample. These observations are weighted by a smooth, decreasing function of their distance for each center  $GI_h$ .



data on rent and attributes of rental objects to facilitate hedonic estimation of the partial prices of rental attributes and spatial qualities. It also requires data on owner-occupier dwellings in order to allow imputation of rent, in addition to demographic data for segmentation purposes and control of household size and composition. In order to estimate Engel curves it needs income data. For cross-check purposes on alternative proxies for owner-occupied housing consumption, such as paid interest and insurance, we need detailed CES data.

To do so, with the assistance of Statistics Norway, I was able to utilize information from the Norwegian Rental Survey (RS), the constructed imputed rent, the Norwegian Consumer Expenditure Survey (CES), and a tax register with income information for the year 2007.

#### **A. The rental survey and imputed rent for owner-occupiers**

In 2005, Statistics Norway launched its countrywide Rental Survey, an annual compilation of data from tenants on rental objects and characteristics of tenants, landlords, and their interaction. Røed Larsen and Sommervoll (2009) use the first vintage to estimate and compare the explanatory power in hedonic attributes, spatial qualities, and tenant-landlord characteristics.

The Norwegian Rental Survey of 2007 assembled 28,000 addresses in Norway as potential interview objects (IO); as documented by Høstmark (2009). The data acquisition field period extended from 25 November 2006 to 10 March 2007. From the set of addresses, a net sample of 13,008 interviews was collected (web, postal, telephone), and from this net sample, 7,681 IOs were identified (and interviewed) as tenants.

The statisticians used hedonic regression-techniques in order to estimate the function between observed rent and observed attributes and spatial coordinates; see Nesbakken (2008) for documentation on the analyses of the background material for constructing the algorithm. The resulting imputation scheme is a non-linear function of size of housing object; geographical location and city segmentation; population size of municipality; and degree of urbanization in the municipality. Employing the estimated rent function and inserting the observations on the attributes of the houses owner-occupiers own, yields the estimated rental value of owner-occupied housing consumption; i.e., imputed rent. These are the imputed rents this article accesses.

#### **B. Consumer Expenditure Survey (CES)**

Statistics Norway contact 1/26 of their household sample every two weeks and ask households to keep a diary where they note all expenditures over a fortnight. These households are subsequently interviewed for demographic variables, housing attributes, and other variables of interest. The CES data set includes, in addition to expenditures, household size and composition, age of household members, region of residence, vocation of main income earner, and number of hours worked for main income earner. CES sample sizes are typically around 1,000–1,200 households per year. The sampling scheme is a two-stage stratified random sample of the universe of Norwegian households. Response rates typically lie around 60 percent. Expenditures are annualized (by multiplying by 26). The demographic data include variables on number of children below 7, 16, and 20 years of age. My variable “No. of Children in household” denotes number of children below 16 years of age. I truncate the data in order to minimize outlier influence. I use expenditures on, e.g., housing insurance and paid interest as a way to check the validity of the results on imputed rent. Results on insurance are reported in the Appendix.

### **C. Income data**

Statistics Norway link, given proper authorization, Consumer Expenditure Survey datasets with datasets from income registers. These income registers are not surveys, but complete and exhaustive full-count registers compiled by the Norwegian Tax Administration (*Skattedirektoratet*, the Norwegian equivalent of the IRS) and National Insurance Administration (*Rikstrygdeverket*). The registers contain records of all Norwegian residents. I was able to access several income variables in these merged datasets, e.g., income before taxes (gross income) and income after taxes. Table 1 tabulates some summary statistics for my data.

**[INSERT TABLE 1]**

## **IV. Empirical results**

### **A. Parametric Engel curves**

Table 2 charts the results of a parametric regression of the share of imputed rent of gross income onto a space spanned by a second order polynomial of the logarithm of gross income with the two demographic shift variables: number of adults in the household and number of children in the household, following the QUAIDS-type specification introduced above. The main pattern is clear: the Engel curve is falling, i.e., the income share of imputed rent decreases with increases in  $\log(\text{gross income})$ . I include a second regression model with “Age of the main income earner” as a preference-shifter. We observe that the regression’s adjusted R-squared is 0.544, a high score in a cross-section of 941 observations. Most likely, however, some explanatory power is attributable to the use of imputed rent, which is an estimated and therefore constructed variable.

Alternatively, it could indicate outlier influence, but my truncation scheme with cut-off points at NOK 100,000 and NOK 2,000,000 prevents tail influencers. In fact, Table 1 tabulates the 10<sup>th</sup> and 90<sup>th</sup> percentile of the share of imputed rent in 2007 as 0.0566 and 0.208, which indicates a substantial compression in the distribution of income-shares. Thus, I interpret the high R-squared as at least consistent with the idea that we discover a pattern of consumer behavior with acceptable model fit. The estimated coefficient of  $\log(\text{gross income})$  is clearly negative, -2.11, and highly statistically significant with an absolute robust t-value of 6.4.

The estimated Engel curve for imputed rent’s share shows curvature since the estimated coefficient of squared  $\log(\text{gross income})$  is positive, 0.0755, and highly statistically significant. The number of adults and the number of children are not particularly important determinants of the share of imputed rent, since the estimates are small and not statistically significant, a finding that is somewhat surprising. The age of the main income earner does not affect results much, as can be seen in Table 2’s right column. The estimated coefficient is small and its t-value is 1.0.

## **[INSERT TABLE 2]**

To check sensitivity, in an alternative specification of the Engel curve, I use the level of imputed rent itself (not the income share of imputed rent) regressed on a polynomial in gross income (not the logarithm of gross income). Table 2 also reports estimation results for such a model specification. The specifications have different properties and one advantage of a logarithmic transformation is the reduction of the influence of outliers. However, from the results of the level specification one may directly compute levels of housing consumption. Moreover, it has the advantage that we easily and transparently can find the Engel elasticity of owner-occupied housing by computing the

ratio of the derivative of owner-occupied housing with respect to income on the fraction of mean owner-occupied housing out of mean gross income; i.e. the definition given in equation (2). This yields an overall elasticity of 0.32; i.e. a one percent increase in gross income is associated with 0.32 percent increase in owner-occupied housing.<sup>9</sup> This is comparable to Zabel (2004), but considerably smaller than Røed Larsen (2010).<sup>10</sup>

Zabel (2004) uncovers substantial differences between elasticities across the income spectrum. So does this article. Table 3 tabulates the gross income share of imputed rent for households in different percentile intervals. We observe that for households with gross income between the 10<sup>th</sup> and 20<sup>th</sup> percentile the ratio of mean imputed rent (for all households in interval) and mean gross income<sup>11</sup> is 0.18. For this segment, the estimated elasticity is small, 0.10. On the other hand, for households between the 80<sup>th</sup> and the 90<sup>th</sup> percentile the ratio is 0.078 and the estimated elasticity higher, 0.59. The right-most column in Table 3 presents estimates without the statistically insignificant coefficient. In Table A2, I tabulate the results from performing a log-log regression by regressing the logarithm of imputed rent onto a space spanned by the logarithm of gross income, household size and composition, and the age of the main income earner.<sup>12</sup> The log-income coefficient is 0.281, consistent with an elasticity of order 0.3 computed in Table 3 on the basis of the linear-polynomial specification in Table 2.<sup>13</sup>

### [INSERT TABLE 3]

#### B. Non-parametric Engel curves

I also employ a non-parametric regression of the proportion of imputed rent onto gross income. In this non-parametric regression type, I control for household type, composition, and size by segmentation. I divide the sample into different segments: Figure 1 shows the results for households with 2 adults, with or without children of any age and the results from single households.

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<sup>9</sup> This computation uses all observations, which of course makes it different from the computation in Table 3 based only on observations between the 50<sup>th</sup> and 60<sup>th</sup> percentile.

<sup>10</sup> Røed Larsen (2010) computes the elasticity of observable total housing expenditures with respect to total expenditures for Norway in the period 1986-1998 using a 2SLS errors-in-variables approach. However, he computes the elasticity for the large category “Housing, Fuel, and Power”, which includes but is not limited to expenditures as paid interest, insurance, maintenance, and electricity. Moreover, total expenditure differs from gross income by savings and taxes, and while mean gross income in 2007 is NOK 727,638, mean total expenditure is NOK 445,577.

<sup>11</sup> This ratio is different from mean gross income share of imputed rent. It is used to smooth out influence from households with unusual shares.

<sup>12</sup> In the Appendix, I include Table A2 for control purposes. It reports results from the log-log regression. The basic pattern is intact.

<sup>13</sup> The estimated log-log income coefficient originates in a specification including age of main income earner while elasticities in Table 3 are based on a specification excluding age. This serves as a sensitivity control.

## [INSERT FIGURE 1]

Indeed, as we see from Figure 1, although functional form is always contentious in Engel curve studies, the non-parametric regressions demonstrate the ability of a parametric model consisting of second order polynomial (in logs or not) to capture the essence of curvature. The impression of a downward-sloping curve of the income-share of imputed rent is supported as the share of imputed rent by visual inspection clearly falls with gross income, although at a decreasing rate.

There is at least one noteworthy finding to be drawn from Figure 1. There is a substantial difference in the proportion of imputed rents at the end points of the income spectrum. While households with two adults with low gross income may consume housing at a level as much as 25 percent of gross income, the same type of households with high gross income consume as little as 7 percent. Thus, the income curve slopes downward relatively sharply and the downward slope is most pronounced from lower levels of gross income. Notice in the same figure that single households with low gross income consume housing of a magnitude up to half of gross income.

## **VI. Discussion**

### **A. Housing consumption and the rental equivalence principle**

In order to examine Engel curves empirically, several serious obstacles must be overcome. First, the definition of housing consumption is non-trivial and controversial. This article employs the rental equivalence principle and defines an owner-occupier's unobserved housing consumption to be equal to, and estimated by, the opportunity cost; i.e., rental value of the home or the imputed rent. This is a widely used and broadly established method (Frick and Grabka 2003), even if it is challenging to bridge the differences between renting and owning.

The rental equivalence principle rests on the theoretical foundation that owner-occupied housing consumption can be estimated using foregone rent and on the empirical regularity that there is a robust and mean-reverting relationship between a transaction price for a house and its annual rent, i.e., the P/E-rate for housing. From this we

realize that an alternative method of estimating owner-occupied housing is to substitute estimated market value<sup>14</sup> of the home for imputed rent. It would require transaction data for homes instead of rental surveys from tenants. However, given the rental equivalence principle and the mean-reverting tendency of the P/E-rate, the difference between the two methods would mostly be the quality of the data. One advantage of rental data is the relatively stable composition of different types of rented objects. Transaction data for owner-occupied dwellings reportedly show volatility in the composition of which type of objects are sold – and the composition may vary with the business cycle.

There are, however, some indications that owning and renting are not perfect substitutes. Røed Larsen and Sommervoll (2009) point to the important fact that transferring ownership involves a one-shot interaction between a seller and a buyer while renting involves an inter-temporal interaction between a tenant and a landlord. Since the quality of the interaction affects observed market rents it may also affect imputed rent, and then imply an estimation bias because such relationships do not apply for owners. Moreover, Thalman (2007) suggests that market rent may not constitute an entirely appropriate basis for computation since rent may include some mark-up to take into account landlords' tax payments. One could instead apply a housing income concept, the available income *after* housing costs, by keeping track of, e.g., production costs and capital gains, he suggests.

Moreover, imputed rents may involve out-of-sample predictions if the objects comprising the rental sector is different from the objects owner-occupiers own. In the analysis of the imputation algorithm, Nesbakken (2008) documents systematic differences between owner-occupiers and renters in terms of household gross income, household size, and house size. However, the statisticians at Statistics Norway employ the hedonic estimation model in the attempt of using partial prices of object attributes in the rental sector to estimate the implicit partial prices of object attributes in the owner-occupier sector. Obviously, one could worry about the possibility that imputations are more accurate for households in some segments along the income-dimension than others. In order to obtain sensitivity tests of the imputation technique I cross-check the Engel curve of imputed rent with Engel curves for directly observed variables, such as paid interest and insurance. I do not report all of these control exercises, but include results from analysis on insurance in Figure A2. The patterns are intact.

We cannot, however, overlook the possibility that the accuracy of imputed rents is not well known. At worst, imputing rent risks involving biased estimators. If the market for owner-occupied units and the rental market

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<sup>14</sup> And define housing consumption as a fraction of house value.

function differently, the partial prices obtained in the latter are not fully indicative of the ones in the former. The same applies if preferences between tenants and owners are different, i.e., if the rental equivalence principle is violated. If so, tenants and owners would self-select into groups and potentially pay different partial prices for attributes. Notice, however, that should tenants and owners differ on dimensions such as age, income, household size and composition, occupation, or sex the estimators would still be unbiased as long as preferences were shared. To see this, it suffices to visually imagine the two groups located at different points on the same curve. In this article, I take as a maintained assumption the legitimacy of the rental equivalence principle and do not test it.

In the analysis, I do not adjust imputed rent by allowances for maintenance expenditures since such outlays imply, with a substantial frequency, home improvement. One could, of course, consider applying a uniform rate of house depreciation for all owner-occupiers; e.g., of the order 2.5 percentage as estimated by Harding, Rosenthal, and Sirmans (2005). I did experiment with schemes of subtracting maintenance expenditures and the main pattern was intact. This is not surprising since the exercise essentially amounts to a mark-down.

## **B. Income or total expenditure**

Whether to use total expenditures or gross income when mapping the distribution depends on the purpose. Total expenditure is a good measure of material standard of living and reflects what the household believes about its economic future. However, measurement of total expenditure is challenging in itself since no household is observed for a full year and the short observation period creates possible biases that leads to endogeneity problems when employing total expenditure in Engel curve estimation; see Røed Larsen (2007: 182-183) and Røed Larsen (2010). Moreover, given the relevance to taxation; after all taxes are levied on gross income; gross income has an advantage.

## **C. Functional form and omitted variables**

There is an on-going debate in the literature on optimal estimation of non-linear Engel curves with unknown functional form; see Banks, Blundell, and Lewbel (1997) for non-linearity, Blundell, Browning, and Crawford (2003) for non-parametric versions, and Lewbel (1998) for the semi-parametric variety. In order to allow for

curvature, to inspect functional form, and to avoid the endogeneity problem that arises if total expenditure is used as regressor (and then co-varies with the error term), I chose to use gross income and polynomial specifications.

It is non-obvious whether to choose to use a reduced form approach or a structural model. Moreover, whether preferences are homothetic or non-homothetic can be debated. Suffice it to say that sensitivity tests appear to indicate that this article's model apparatus may allow the interpretations presented since the patterns are intact over different model specifications, population segments, income groups, and household composition and size.

Omitted variables may matter. The most important could be the age of the main income earner since one could fathom a mechanism where the needs and behavior of a young household differ from those of an older one. If so, an age effect could appear as an income effect if age was not properly controlled for since age and income may co-vary. I counteract this possibility in two ways. First, I perform specification tests of the regression models by including, parametrically, age as a preference shifter. Second, I segment the samples into several sub-groups of different ages and estimate curves for each non-parametrically. I do not include wealth as preference-shifter due to data limitations, but I admit that including it could have improved the precision; see Ogaki and Atkeson (1997) for the quite interesting result that wealthy households tend to have more volatile consumption growth than do less wealthy households.

Inspecting the parametric results carefully we do obtain an indication that confounders from the life-cycle stage are not influential. Age does not appear to be an important determinant of the income-share of owner-occupied housing. Including it in the model does not improve explanatory power much. Moreover, after segmenting for age groups the non-parametric approach reveals only slightly different curves. In the Appendix, Figure A1 shows that for households where the main income earner is above 50 years of age the Engel curve falls gradually from 0.2 to 0.05, while the one for 35-to-50 year-olds first falls from 0.25 and then flattens out at around 0.07.

There exists a possible confounder in relative price. It is, however, conventional in cross-sectional analyses to assume that consumers face the same relative prices at a given point in time. This is not an implausible assumption; especially not for a small country like Norway; and this article makes the same assumption. Since this article does *not* estimate a demand curve, but a cross-sectional Engel curve, there is no explicit price term in the model and as long as the assumption holds, there is no need to identify the effects from different relative prices.

#### **D. Estimation**



In terms of empirical estimation, several additional points can be made. I did experiment with several model specifications, and varied functional choice, types of determinants, and estimation methodology. I checked not only functional form (linear, polynomial, linear-log, linear-polynomial log, log-log), but also variables (levels or income shares as dependent variable and total expenditure as independent variable) and techniques (linear-polynomial log in income or 2SLS with income as instrument for total expenditure). I do not report these results since they were in line with the presented findings. Tables 2 and A2 report results from different specifications.

Some analysts would have preferred employing a linear 2SLS method with total expenditure as regressor and gross and net income as instruments, and such a specification was one of the varieties I examined. However, I ended up emphasizing measures of curvature, which entails higher-order polynomials, and I put weight on retaining well-known properties of estimators. Thus, I introduced logarithms and a second order polynomial of exogenous gross income. At the end, this choice reflects an emphasis on the kinship with the QUAIDS-specification; see, e.g., Banks, Blundell, and Lewbel (1997) and Blundell and Stoker (2005).

Household size and composition turned out less important than one would expect, but I kept the specification because they are standard in household analysis. I also investigated results from the period 2004-2006, but did not include them because the rent imputation technique in those three years is inferior to the one used in 2007. (Basically, these imputations use averages for zones, size, and type, not hedonic regressions.) The overall picture, however, was intact.

Insurance payments and paid interest are related to the value of the house and housing consumption is related to the value of the home, so potentially one could estimate owner-occupied consumption using such variables as proxies. Perhaps insurance payments are superior to paid interest since they do not change with payments on the principal and may be less sensitive to the business cycle. Figure A2 in the Appendix shows the results of a non-parametric regression of the share of insurance premiums onto gross income.

The Engel curve in Figure A2 is nicely shaped across the income spectrum. However, the insurance value of a house is the rebuilding cost, which may not accurately reflect the value of the home since the physical building could be of an impractical type or located at a low-value site. The latter is important since a key component of the value of a home is the value of its spatial coordinates. Housing consumption may be more than the consumption of hedonic, physical house attributes; households may of course also extract utility from the enjoyment of spatial coordinates,

i.e., neighborhood location and geographical position. Households have a willingness to pay for proximity to urban centers and area amenities, and it is this willingness that may represent the immobile and immutable core of housing demand that makes it attractive for tax purposes. This consumption of spatial coordinates is included in imputed rent since geographical location is a variable in the algorithm.

## **E. Future research**

The Engel elasticity increases with income, and it doubles from the fourth decile to the eighth decile. My hypothesis is that this has to do with housing as a bundled good. A house serves multiple purposes. First, it serves as shelter against weather and it is a home to which to retreat. These components are necessary goods. Second, a house functions as a social meeting place and even represents a positional signal of status. These components are luxury goods. The relative strengths of these effects are most likely multifactorial, but the presence of luxury elements may explain why the elasticity is increasing in income; see Witt (2001) for a perspective on the development of wants.

## **VII. Concluding remarks and policy implications**

Housing consumption is a major part of an economy's aggregate demand. It is of substantial interest to know how it is distributed along the income spectrum since, if we do, we may construct useful indicators of consumption-to-income ratios and inspect the distributional consequences of housing taxes. We may also construct forecasts of housing consumption on the basis of predictions of income growth. This explains the old interest into Engel curves in economics and why it would be useful to have one for owner-occupied housing consumption.

However, housing consumption among owner-occupiers is a latent and unobservable variable. It must be estimated. To that end, this article employs the rental equivalence principle and imputes rents for owner occupiers. Thus, in order to estimate Engel curves of housing consumption for owner-occupiers, analysts need to combine data from three sources, household income, home attributes, and rents for rental units with known attributes. This is a challenge. This article demonstrates, however, that it is possible to locate such data sources and combine them. In the resulting Engel curve, we see that the gross income share of owner-occupied housing consumption decreases with gross income. One finding in this article can be summarized in a single, useful statistic: The estimated Engel

elasticity of housing consumption is 0.32, computed at the mean. The interpretation is that a one percent increase in gross income is associated with an increase in estimated owner-occupied housing consumption of 0.32 percent. Another finding is that this elasticity increases with income.

These findings have implications for the potential implementation of a housing taxation scheme, which is policy-relevant given the fact that housing is increasingly seen as an attractive object for tax purposes. The reason why is that housing demand is universal, quite immobile, and relatively immutable. Houses are visible, so the taxes are less avoidable than other taxes. Houses continue to render their services, even if they are taxed, so the dead-weight loss may be smaller than for other taxes. In fact, it is possible to conceive of a housing tax as one with several dividends. However, it is an empirical question who would bear the burden of a housing tax and this is a question economists, households, and policymakers are keen to have answered. This article's answer is that if a housing tax is constructed to be similar to the flat-rate tax on financial income it would function regressively. For a housing tax to function progressively, given the demonstration that the gross income share of imputed rent decreases with gross income, a housing tax rate would have to be an increasing function of gross income.

## Appendix

### A. The imputation method

The estimation of imputed rent involves a two-step procedure. First, the statistical agency collects observations from rental markets on vectors containing market rent, hedonic attributes, spatial coordinates, and other determinants. The agency then regresses observed rent,  $R$ , onto the relevant space spanned by rent determinants and obtains the partial rental price for each hedonic and spatial housing components, as given in equation (A1):

$$R_{te} = k + a.A_{te} + s.S_{te} + o.O_{te} + u_{Rte}, \quad te \in TE, \quad (A1)$$

where  $R$  is observed rent for tenant  $te$  in the tenant sample  $TE$ , and  $A$ ,  $S$ , and  $O$  are hedonic attributes, spatial coordinates, and other determinants of the object the tenant rents. Second, the agency obtains from consumer expenditure surveys vectors of similar housing components ( $A$ ,  $S$ , and  $O$ ) from owner-occupier households, and

estimate what the households would have paid in rent had they rented their own home. To this end, imputed rent functions as an estimator of latent housing consumption expenditure for owner-occupiers,  $y$ , in equation (A2):

$$\hat{y}_{ih} = \hat{R}_h = \hat{k} + \hat{a}.A_h + \hat{s}.S_h + \hat{o}.O_h , \quad (A2)$$

where  $i$  is the housing category among consumption categories; the estimated parameters  $k$ ,  $a$ ,  $s$ , and  $o$  are used in combination with the hedonic attributes, spatial coordinates, and other determinants of the housing object owned by the owner-occupier  $h$  to compute the estimate on latent housing consumption expenditure for the owner-occupier  $h$ .

The algorithm for computing monthly imputed rent (MIR) for owner-occupiers was constructed by statisticians at Statistics Norway from an analysis of the rental survey that determined optimal segmentation into areas based on urbanity and population size and from using the most-accessible salient hedonic feature, size of the home; see Nesbakken (2008) for more. The algorithm is presented in Table A1 below, without specification of each of the 12 estimated coefficients. In essence, it is based on a hedonic regression of monthly imputed rent on a non-linear function of size; segmented on five regions. Even if this is a simple set-up, it captures the key elements, and can explain a substantial amount of the variation in rent. Additionally, it satisfies the necessary requirement that the observed rental characteristics also can be traced out of the housing attributes listed in the Consumer Expenditure Survey (CES), which of course is a strict constraint.

**[INSERT TABLE A1]**

## **B. Supplementary tables and figures**

**[INSERT TABLE A2]**

**[INSERT FIGURE A1]**

**[INSERT FIGURE A2]**

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**Table 1. Data characteristics from the Rental Survey, the Consumer Expenditure Survey, and the Income Register (Norway 2007)<sup>1</sup>**

Variable	N <sup>2</sup>	10 <sup>th</sup> Percentile	Median	Mean	90 <sup>th</sup> Percentile
Share of Imputed Rent <sup>3</sup>	941	0.0566	0.101	0.123	0.208
Share of Paid Interest	941	0.000	0.0244	0.0421	0.112
Gross Income	941	344,966	692,773	727,638	1,157,158
No. of Adults <sup>4</sup>	941	1	2	2.155	3
No. of Children <sup>5</sup>	941	0	1	1.0255	3

Notes: Income in NOK. <sup>1</sup> Truncation at NOK 100,000 and 2,000,000 and positive imputed rent. <sup>2</sup> Only observations with positive imputed rent are kept in this analysis. <sup>3</sup> Share of imputed rent is the ratio of imputed rent on gross income. <sup>4</sup> An adult is a household member above 16 years of age. <sup>5</sup> A child is a household member below 16 years of age.

**Table 2. Regression results (t-values). Two model specifications (Norway 2007)**

<i>Model 1: IR/GI = a + b*log(GI) + c*Sq(log(GI)) + preference shifters + stochastic element</i>		
	Model 1a	Model 1b
Intercept	14.856(6.7)	14.775 (6.7)
Log(Gross Income)	-2.113 (-6.4)	-2.103 (-6.4)
Sq(Log((Gross Income))	0.0755 (6.2)	0.0752 (6.2)
No. Of Children	0.00132 (0.9)	0.0027 (1.5)
No. Of Adults	-0.0020 (-0.9)	-0.0022 (-1.0)
Age of Main Inc. Earner		0.00024 (1.0)
No of obs.	941	941
Adj.R <sup>2</sup>	0.554	0.555
<i>Model 2: IR = a + b*GI + c*Sq(GI) + preference shifters + stochastic element</i>		
	Model 2a	Model 2b
Intercept	64,238 (14.5)	53,424 (8.5)
Gross Income	-0.000510 (-0.04)	0.00142 (0.1)
Sq(Gross Income)	2.208*10 <sup>-8</sup> (2.9)	2.113*10 <sup>-8</sup> (2.7)
No. of Children	1,066 (1.2)	2,190 (2.2)
No. of Adults	-2,280 (-1.5)	-2,406 (-1.5)
Age of Main Inc. Earner		193 (2.2)
No of obs.	941	941
Adj. R <sup>2</sup>	0.164	0.167

Note: Average imputed rent (IR) is 74,279. Average gross income (GI) is 727,638 (in NOK). Truncation at NOK 100,000 (lost no observations) and 2,000,000 (lost 22 observations) in household gross income based on the Consumer Expenditure Survey, 2007. Includes only households with positive imputed rent. Children are defined as household members below 16 years of age. Sq is short notation for squared. No of obs. is the number of observations with positive imputed rent, i.e., owner-occupiers.

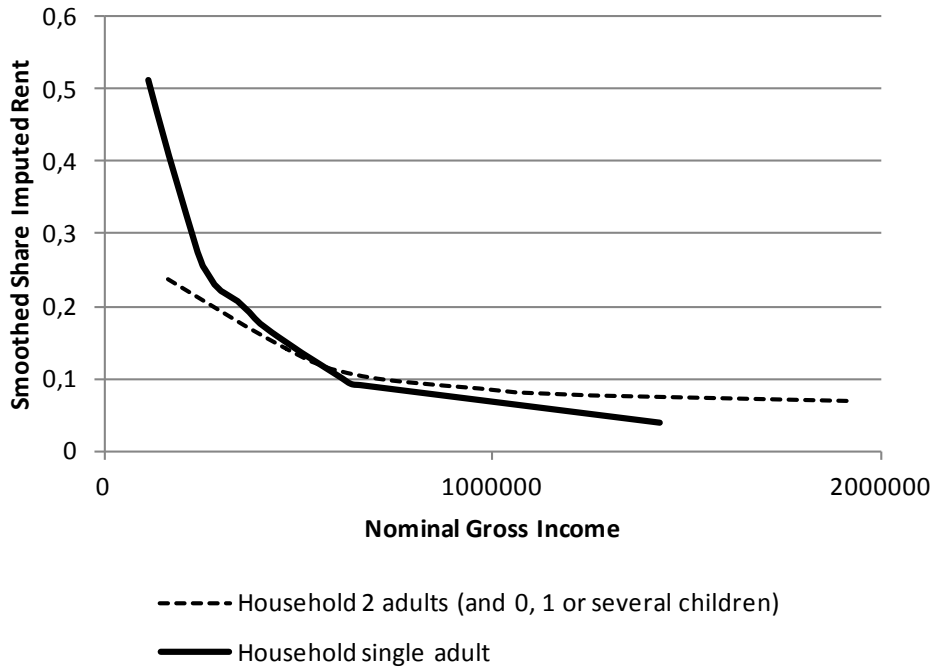
**Table 3. Engel elasticities of owner-occupied housing consumption (Norway 2007)**

Percentile Gross Inc. <sup>1</sup>	Mean Gross Income	Mean Imputed Rent	Ratio Rent-to-income	Estimated elasticity	Alternative elasticity w/o 1 <sup>st</sup> order element <sup>2</sup>
10 <sup>th</sup> – 20 <sup>th</sup>	380,879	67,126	0.18	0.10	0.09
20 <sup>th</sup> – 30 <sup>th</sup>	477,580	62,776	0.13	0.16	0.15
30 <sup>th</sup> – 40 <sup>th</sup>	576,195	68,118	0.12	0.22	0.20
40 <sup>th</sup> – 50 <sup>th</sup>	658,628	66,305	0.10	0.29	0.27
50 <sup>th</sup> – 60 <sup>th</sup>	730,010	71,830	0.098	0.33	0.31
60 <sup>th</sup> – 70 <sup>th</sup>	801,755	76,613	0.096	0.37	0.35
70 <sup>th</sup> – 80 <sup>th</sup>	901,754	80,908	0.090	0.44	0.42
80 <sup>th</sup> – 90 <sup>th</sup>	1,047,161	81,740	0.078	0.59	0.56

Notes: Income in NOK. <sup>1</sup> I included in each segment observations with gross income above the lower threshold and below the upper threshold. <sup>2</sup> In computing this elasticity, I included only the second-order element of gross income coefficients since the estimated first-order coefficient is not statistically significant. Keep in mind, however, that given that the true model contains both first-order and second-order elements, the first-order estimator is still unbiased and because statistical significance is a function of sample size, it could be warranted to include it.



**Figure 1. Non-parametric local regression of imputed rent's share of gross income on gross income (Norway 2007)**



Notes: Nominal Gross Income (in NOK) does not include imputed rent. I truncate the dataset by requiring gross income to be more than 100,000 NOK per household and less than 2,000,000 NOK per household. The non-parametric regression line for households of 2 adults and an unspecified number of children in the year 2007 included 584 observations while, for singles, it included 97 observations. For the former, the regression had 17 fitting points and the smoothing parameter was 0.60 (points in local neighborhood: 350; residual sum of squares: 1.034; equivalent number of parameters: 3.99). For the latter, the regression line had 17 fitting points and the smoothing parameter was 0.60 (points in local neighborhood: 58; residual sum of squares: 1.287; and equivalent number of parameters: 4.37).

**Table A1. The Statistics Norway algorithm for computing monthly imputed rent (MIR)**


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Zone 1. Oslo:

$$MIR_{1h} = a_1 + b_1 S_h + c_1 D_h + d_1 D_h S_h, \quad h \in H \text{ households in Oslo.}$$

$S_h$  is size of owner-occupier h's home,  $D_h$  is unity if size  $S_h$  is above 100 m<sup>2</sup>

Zone 2. Large Metropolitan Areas: Akershus, Bergen, Trondheim, Stavanger, and Tromsø

Zone 3. Cities and urban areas with population of more than 20 000 inhabitants (except households included in zone 1 and 2).

Zone 4. Small towns and urban areas with population in interval 2 000 – 19 999 inhabitants.

Zone 5. Urban areas with population in interval 200 – 1999 inhabitants.

$$MIR_{ik} = a_i + b_i S_k, \quad k = \text{zones } 2, \dots, 5; k \in K \text{ households in zones 2 through 5.}$$


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**Table A2. Regression results (t-values). Log-log specification (Norway 2007)**


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Model:  $\text{Log}(IR) = a + b \cdot \text{Log}(GI) + \text{preference shifters} + \text{stochastic element}$

Intercept	7.351 (18.5)
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Log(Gross Income)	0.281 (9.2)
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No. of Children	0.0198 (1.6)
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No. of Adults	-0.0437 (-2.4)
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Age of Main Income Earner	0.00196 (1.8)
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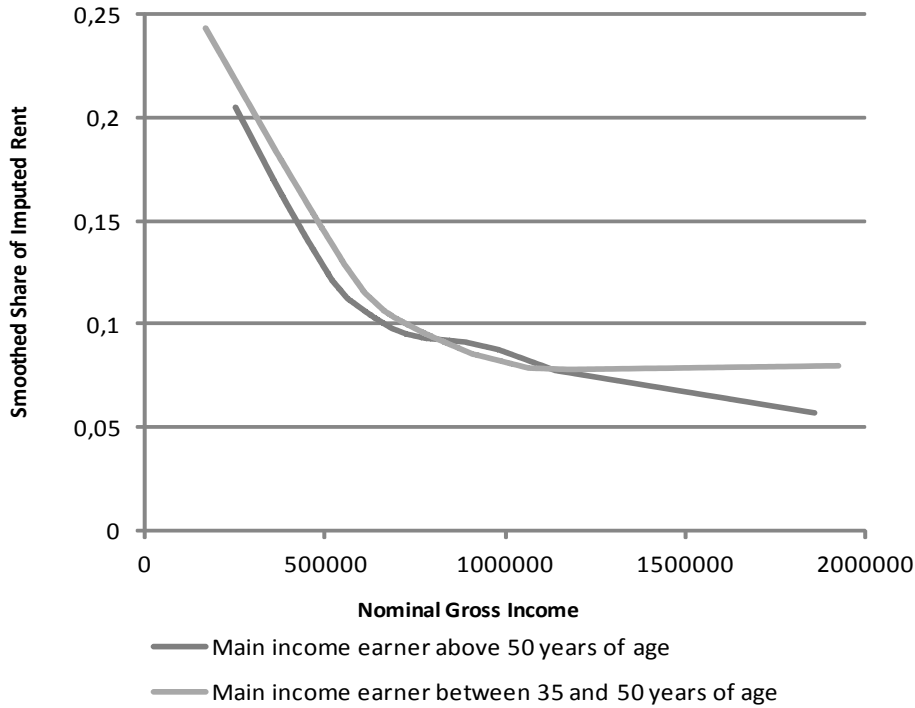
Adj. R <sup>2</sup>	0.107
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N	941
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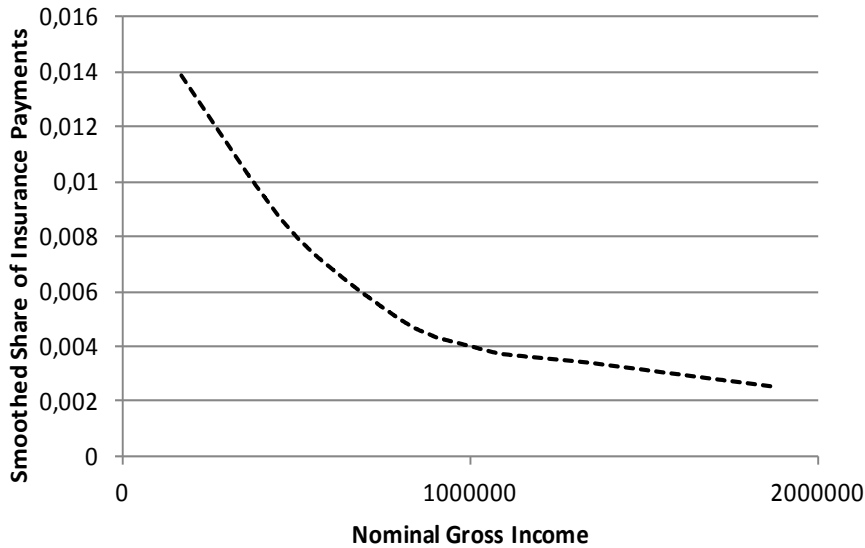
Notes: See Table 2. *IR* is imputed rent, and *GI* is gross income.

**Figure A1. Non-parametric local regression of imputed rent's share of gross income on gross income (Households of 2 adults, Norway 2007)**



Notes: Nominal Gross Income (in NOK) does not include imputed rent. I truncate all datasets by requiring gross income to be more than 100,000 NOK per household and less than 2,000,000 NOK per household. The non-parametric regression line for households of 2 adults (and an unspecified number of children) in the year 2007 where main income earner was above 50 years of age included 199 observations. It had 17 fitting points and the smoothing parameter was 0.60. Points in local neighborhood: 119. Residual sum of squares: 0.360. Equivalent number of parameters: 3.93. Where main income earner was above 35 and below or equal to 50 years of age, it included 256 observations. It had 17 fitting points and the smoothing parameter was 0.60. Points in local neighborhood: 153. Residual sum of squares: 0.469. Equivalent number of parameters: 4.05.

**Figure A2. Non-parametric local regression of proportion of housing insurance expenditures of gross income on gross income (Households of 2 adults, Norway 2007)**



Notes: Income in NOK. I truncated on positive expenditures on housing insurance. I also truncated all datasets by requiring gross income to be more than 100,000 NOK per household and less than 2,000,000 NOK per household. I also required positive entries on the variable interest payment. The non-parametric regression line for households of 2 adults (and an unspecified number of children) in the year 200 included 445 observations. It had 17 fitting points and the smoothing parameter was 0.60. Points in local neighborhood: 263. Residual sum of squares: 0.00352. Equivalent number of parameters: 4.00.