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Is The Engel Curve Approach Viable in The Estimation of Alternative PPPs?

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Abstract Conventional estimates of purchasing power parities (PPP) rely on cross-country price data. Using Engel curves, Almås (2012) was able to show, however, that PPPs contain substantial bias. Since constructing conventional estimates is expensive and time-consuming, Almås' idea of employing Engel curves is welcome. This article examines the viability of the Engel curve approach to PPP and its sensitivity to differences in relative prices and preferences by estimating Engel curves not only between countries but also for regions within a given country. My empirical evidence from the United States and Norway suggests that the differences can be problematic, but not sufficiently to discredit the new methodology. A pragmatic approach to PPP estimation between countries that are different is to compute a PPP band, rather than a point estimate. I present a practical example of this using expenditure data from 2001, which yields a band for NOK and U.S. dollar.

Keywords: Engel curve, exchange rate, food share, material standard of living, purchasing power parity

JEL Classification: C20, D10, F31

1 Introduction

Estimating purchasing power parities (PPP) can be challenging, but because PPPs are so useful, the World Bank International Comparison Program (ICP) computes them today on a regular basis. The advantages of these parities are proportional to the disadvantages of using market exchange rates. For analyses of emerging economies, the need for PPPs is acute. However, conventional PPP computations consume vast resources; presuppose the existence of markets where markets may not exist; and can potentially be biased. In an important recent contribution, Ålmås (2012) shows that it is possible to examine PPP biases using Engel curves for food. These curves, which relate food shares to income levels, can be used to indicate the cost of achieving a material standard of living, add new functionality to the existing PPP toolbox. The approach has substantial potential. This article subjects the Engel curve method to close scrutiny. It inspects the sensitivity of the Engel curve methodology to two sources of disturbance, and argues that Engel curve PPPs can most usefully be employed to construct supplementary PPP bands, rather than competing point estimates.

The Engel curve approach is fascinatingly simple. It compares the monetary cost of acquiring a material standard of living in country A, measured in country A's currency, with the monetary cost of acquiring the same material standard of living in country B, measured in country B's currency. The PPP estimate is the ratio of the costs. The method uses spending on food as a percentage of the household budget or income as a proxy for material standard of living. Almås employs Hamilton's (2001) CPI bias idea and the use of Engel curves to estimate PPPs appears to rely on three underlying assumptions: 1. The Engel curves are monotonically related to material standard of living (or utility). 2. The relative price of food versus non-food is identical (or properly accounted for). 3. Preferences[1] are identical over food and non-food.. The first assumption is plausible and, indeed, widely used, not least in equivalence scale estimations. It is, moreover, intimately related to explanations of one of the most widely observed empirical regularities in economics, the data pattern known as “Engel’s Law”, according to which food shares fall with total expenditure or income.

Assumption two and three, however, are non-trivial and challengeable since relative prices and preferences both are functions of a number of variables in an economy.[2] However, conventional PPP computations also face the problem of varying preferences across countries since conventional PPP computations use a common set of weights. In that respect, Engel curve PPPs and conventional PPPs both face the same preference heterogeneity problem. Dealing with such heterogeneity requires careful modeling tailored to the particular case in question; see e.g. Crawford and Neary (2008).

The conventional PPP approach amounts to the collecting and weighting of prices. The Engel curve approach, on the other hand, is based on consumer behavior rather than prices. In the event of having to control for the effect of relative prices, the relevant information would have to be acquired from other sources. Almås’ Engel curve approach seeks to correct for relative price effects by including price

[1] By preferences I mean consumer preferences. However, in the “Discussion” below I explain why institutions may matter and how the definition of preferences could be broadened to include cultural and institutional factors and characteristics.

[2] Moreover, as Beatty and Crossley (2012) point out, the Engel curve methodology requires downward-sloping curves, i.e. non-homothetic preferences. At the same time, a single price index for all households implies homothetic preferences. This can occur if households are distributed in *finite mixtures* of preferences where preferences are homothetic within groups, but non-homothetic between them. This preference structure allows both Engel curve estimation and index computation for types.

observations. But as this article suggests, this may not be the optimal way forward for constructing an alternative or supplementary PPP methodology. There are two main reasons. First, it would seem counterproductive to use the same cumbersome method of acquiring price data as the very methodology one is seeking to correct or augment. It also makes the alternative method more resource-hungry than the original. The second, and more important, reason is that including price data renders the alternative methodology susceptible to the very biases the analyst is attempting to counteract. It would be preferable if it can be shown to be viable without price data acquisition, because then, after appeals to some level of pragmatism, one can supplement PPPs using only data on consumer behavior.

The structure of my argument, then, is this. I first examine empirically whether the potential disturbance from a *combined* effect of different relative prices and preferences is substantial in the Engel curve PPP-approach. I then inspect, in isolation, the preference effect by looking at different geographical regions and income strata in separate countries, one at a time, holding relative prices constant. I address such issues as functional form, choice of determinants, and estimation techniques with a battery of tests and inspection of both parametric and non-parametric results. This is useful information because we expect this effect to be larger between countries, adding to relative price differences. In other words, large within-country effects weaken the case for between-country Engel curve PPPs.

The results indicate that such effects may be disturbing, but not necessarily alarmingly so. Now, should the difference between two countries be wide enough to violate the preference homogeneity assumption, and/or if price data are simply not available, not all is lost. It should still be possible to say something of use about PPPs by accepting preference and price heterogeneity and using consumer behavior to construct a PPP band instead of a PPP point estimate.[3]

Following Hamilton's (2001) reasoning, I shall use Engel curves for food since food is a biological necessity for life. It is perishable and therefore avoids stock-flow problems. We can reasonably assume that utility functions are separable in food and non-food. I do, however, inspect potential sensitivity to different types of food by studying both energy-motivated food-at-home and the more socially motivated food-away-from-home. I also inspect issues arising from food stamps and free meals.

In its application of Engel curves to practical use, this article follows a venerable tradition. Because of its stability and universality, the Engel curve for food has attracted widespread use over many years and purposes; see Chai and Moneta (2010) for a history of Engel's work and examples of its applications. Hamilton (2001) was particularly innovative in using the drift in Engel curves to estimate CPI bias in domestic price data. He inspired Beatty and Røed Larsen (2005) and Røed Larsen (2007) to employ and refine the method on data from Canada and Norway. Gibson, Stillman, and Le (2008) use the Engel curve approach to examine Russian CPI bias and Barrett and Brzozowski (2010) use it to estimate the bias in Australian CPI. Costa (2001) applies Engel curves to estimate historical developments of real incomes. Charles, Hurst, and Roussanov (2009) employ them to describe differences in conspicuous consumption among groups

[3] In fact, building on Beatty and Crossley (2012), constructing different PPP-estimates for different household groups may be a preferable approach when preferences are homothetic within-group but not homothetic between groups.

of different ethnic origin. Lastly, Clements and Chen (2010) use Engel's Law to suggest a shortcut method of measuring real incomes across countries, an idea that is closely related to computing alternative PPPs.

This article's contribution is empirical, rather than theoretical. First, I inspect Almås' suggested use of Engel curves to construct PPPs by submitting it to sensitivity tests. Second, having examined sensitivity, I show how to construct a PPP band by observing the position and slope of the Engel curve. Third, I offer parametric (using specifications such as the "Almost Ideal Demand System" [AIDS], "Quadratic AIDS" [QUAIDS], and Two-Stage-Least-Squares [2SLS]) and non-parametric analysis.

The article proceeds as follows. In the next section, I introduce the theoretical requirements for the empirical tests and statistical inferences. The section presents the empirical strategy, the estimation methodology, and I add some words on specification. Section three describes my data sources. In section four, I present the empirical results and in section five I discuss the severity of the shortcomings. Section six concludes and offers policy implications. Additional results are included in the Appendix

2 Theory and Empirical Techniques

2.1 General Approach and Empirical Strategy

The implicit idea underlying the use of Engel curves to estimate PPP is that an Engel curve for food, ω, is a monotonic function of material standard of living, S, that maps from S to ω via preferences. The material standard of living, S, is latent and unobservable, but its empirical counterpart, the share ω of food expenditures on income I (or total expenditure) is observable. Equal food shares ω imply equal standards of living S, even when the same standard of living is associated with two different income levels, I_N and I_{US}, in the two countries Norway and the United States, respectively. In equation (1), the PPP-estimate is simply the factor R that equalizes the two income levels.

$$\omega_N(RI_N, P_N, S) = \omega_{US}(I_{US}, P_{US}, S), \tag{1}$$

in which P_r, r = N, US, is the price vector in country r and is included as a determinant of the food share. This article uses food share of income before taxes in the baseline model, but also includes food share of total expenditure for robustness checks.

The first aim is to test the sensitivity of the Engel curve mapping function ω. The second aim is to construct an Engel curve approach which practitioners should find easy to implement. Distinguishing between differences in preferences and relative prices, however, is challenging. My plan is to inspect between-country and within-country regressions and use such comparison as a platform for assessments. Below, I explain in some detail how I attempt to go about it and the usefulness of the exercise. In the discussion section I examine in more detail the maintained assumptions and differences between the two countries' institutions and cultures.[4]

[4] Notice that my PPP estimates for households of different material standards of living may serve several purposes. First, they capture possible differences in institutions and relative prices between countries. Second,

2.2 Functional Form and Model Selection

My approach entails a *model selection* process. I use and compare three specifications, AIDS, QUAIDS, and linear 2SLS with income variables as instruments. Contributors to the Engel curve literature make frequent use of the AIDS-type modelling set-ups, and they are well known. These approaches relate food share to exogenous income linearly, as given in equation (2). More recently, the advantages of QUAIDS-type models have made these somewhat more complex set-ups the more frequent choice; see Blundell and Stoker (2005). They are given generally in equation (3).

$$\omega_{h,r} = a + b(\ln(P_{f,r} / P_{n,r}) + c(\ln(I_{h,r})) + \sum_J \theta_j D_{j,h,r} + u_{h,r}, \qquad (2)$$

$$\omega_{h,r} = d + e(\ln(P_{f,r} / P_{n,r}) + f(.)\ln(I_{h,r}) + g(.)(\ln(I_{h,r}))^2 + \sum_J \varphi_j D_{j,h,r} + u_{h,r}, \qquad (3)$$

where observed income before taxes is denoted I, prices P, and demographical characteristics of households D from a set J. Subscripts *h, r, j, f,* and *n* refer to household, country, characteristics of household, food, and non-food. The functions f(.) and g(.) can be general functions, but I use them solely as coefficients f and g.[5] The error term u captures omitted structure and stochastic elements. It is assumed to behave classically; in that its distribution has zero mean

they allow for non-homothetic preferences within-countries; see Beatty and Crossley (2012). I do not, however, estimate the number of groups in the finite mixture of preferences.

[5] The coefficients c and f are typically negative since Engel-curves slope downward.

and constant variance.[6] Food is defined as food consumed at home, food consumed away from home, or both. The category food contains non-alcoholic beverages.

It is also possible to employ total expenditure as a determinant in a simpler linear set-up, as given in equation (4):

$$\omega_{h,r} = l + m(P_{f,r} / P_{n,r}) + n\xi_{h,r} + \sum_{J} \delta_j D_{j,h,r} + u_{h,r}, \tag{4}$$

in which total expenditure ξ contains a measurement error element that is the sum of all measurement errors in expenditure sub-categories, e.g. food. Linearity has the advantage of simplicity and interpretability. The measurement error, however, implies an endogeneity problem; see Kay, Keen, and Morris (1984) and Røed Larsen (2009). Basically, total expenditure contains measurement errors not orthogonal to the error term. This can be resolved by using 2SLS techniques, with exogenous variables as instruments for total expenditure. This article makes use of all three specifications (2) – (4) to ensure that misspecification does not drive the results nor limit the interpretability.

2.3 The Partial Preference Effect

Let me explain the details of the plan to use model selection and estimation results to look for a combined price-and-preference effect and partial effects in the Engel

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[6] Thus, I report classical t-values. I have computed, but do not report, heteroskedasticity-consistent t-values. The differences between the two are small.

curve PPP methodology. It is possible to deduce ex ante how a simple variable-transformation affects coefficient estimates, and I do so below in Table 1. The first step is to estimate two Engel curves, one for each country, and examine the evidence that indicates that only a variable-transformation of the monetary unit has taken place. The second step is to examine the importance of differences in preferences. The hypothesis is that preferences *between* countries may vary more than preferences *within* countries. If preferences vary much within a country, this will be revealed by a segmented regression set-up. That being the case, preference-variation will clearly represent a challenge to Engel curve PPPs since any within-country disturbance would likely be magnified between-countries. Conversely, if preferences do not appear to vary much within a country, the case for Engel curve PPPs will be correspondingly strengthened. The empirical strategy involves estimating four Engel curves for the United States and two for Norway. Conveniently, since a country's regions all have the same monetary unit there will be no variable transformation involved. This allows us to isolate the preference effect, if there is one. The question is which model specification is adequate to the test.

An AIDS-type specification involves a function that is linear in the logarithm of a relative price ratio and the logarithm of income while a QUAIDS-type specification involves a function that is quadratic in the logarithm of income and may involve price terms both in intercept and slope, as indicated by the general functions f(.) and g(.). I make use of the AIDS-type specification in the attempt to isolate the preference effect under a constant price ratio since the price term vanishes in first-differences between two food-share functions. Put differently, country-specific regional differences in food share functions, where regions have a similar ratio of food-to-non-food prices, given that the AIDS-specification captures the broad patterns, will be due to preference differences.

Table 1 tabulates combinations of the price and preference effects. The outcome of the no price and no preference effect is given by the top left cell, in which the only difference between the two Engel curves is obtained from the variable-transformation that results from estimating Engel curves for two countries with different currencies. The estimated PPP will be unbiased and show up as a difference in the intercept as a vertical shift. Engel curves for country-specific regions should not display coefficient differences when there is no price or preference effect. The combined price-and-preference effect is given by the bottom right cell, in which the Engel curves have shifts in position and slope.

Table 1 Implications for position and slope from variable-transformation of monetary unit and differences in relative prices and preferences. AIDS-specification

Preferences	Price ratio P_f/P_n	
	Identical	Different
Identical	Diff. vertical position by $c\ln(1/R)$ same slope	Diff. vertical position by $c\ln(1/R)$ + $b(\ln(P_{fN}/P_{nN}) - \ln(P_{fUS}/P_{nUS}))$, same slope
Different	Diff. vertical position by $a_N - a_{US} + \Delta b + \Delta c$, different slopes, c_N and c_{US}	Different vertical position, $a_N - a_{US} + \Delta c + b_N\ln(P_{fN}/P_{nN}) - b_{US}\ln(P_{fUS}/P_{nUS})$, different slopes, c_N and c_{US}

Notes: The table tabulates the share difference $\omega_N - \omega_{US}$ by letting $I_{US} = RI_N$. The term $\Delta b = (b_N - b_{US})\ln(P_f/P_n)$ is zero when $b_N = b_{US}$ and $\Delta c = c_N\ln(I_N) - c_{US}\ln(RI_N) = (c_N - c_{US})\ln(I_N) + c_{US}\ln(1/R)$ simplifies to $c_{US}\ln(1/R)$ when $c_N = c_{US}$.

Essentially, the empirical strategy amounts to a three-stage plan:

1. Examination of price-and-preference sensitivity by comparing Engel curves, estimated for one country at the time.

2. Examination of partial preference-sensitivity by comparing several within-country regional Engel curves.
3. Demonstration of how to construct a PPP band that allows for price-and-preference heterogeneity.

Observe, however, that step two relies on the maintained hypothesis of similar ratio of food-to-non-food prices within a geographical stratum, e.g. a country. It is no innocuous assumption, but may be legitimate; see Deaton (1987) for more on spatial price variation. While this assumption is something that the Engel curve methodology shares with the conventional PPP methodology, it may be more plausible in a small and homogeneous country than in a large and heterogeneous country. This is a possibility this article investigates by dividing Norway into two strata and the United States into four. In order to allow us to inspect the validity of the hypothesis of spatially homogeneous relative prices, I also segment along social strata; i.e. material standards of living, where consumers with low standards of living face the same relative prices as consumers with higher standards of living.

2.4 Using the QUAIDS specification

If the Engel curve PPP methodology does prove sensitive to preferences and prices this article proposes a pragmatic way forward that satisfies some of the need for a PPP-supplement. If relative preferences affect Engel curves in ways we cannot control for, and if attempting to control for relative prices replicates the effort we seek to avoid, we are left with accepting their presence. This article suggests an addition to the conventional PPP *scalar*, an Engel curve PPP *band*, the boundaries of which are computed for different material standards of living. I employ a QUAIDS-type specification in order to capture potential curvature.

The rationale behind this pragmatic approach is as follows. In the QUAIDS-type model in equation (3) there would be three sources that contribute to cross-country Engel curve differences: a) different monetary units; b) an unaccounted-for difference in relative prices; and c) unaccounted-for difference in preferences. A point estimate requires us to disentangle all three and control for the last two, a band estimate does not.[7]

2.5 Parametric and Non-Parametric Estimation

In order to estimate a PPP band parametrically this article builds on Banks et al. (1997), Lewbel (1998), and Blundell and Stoker (2005). I therefore choose a QUAIDS-type specification, both with and without a vector of preference-shifters. In the most parsimonious form, the parametric specification's preference-shifters are limited to household size and composition, i.e. number of children, C, and number of adults, A. The importance of controlling for size and composition is demonstrated e.g. by Logan (2008) who shows that Engel curve estimates of CPI biases may themselves be biased over time unless they account properly for demographic composition and size.

[7] Again, the idea of a PPP-band is supported by the findings in Beatty and Crossley (2012) since a band allows for different estimates for households at different income levels.

I also use non-parametric estimation; see e.g. Blundell et al. (2003) for a discussion and Blundell et al. (2007) for a useful demonstration of semi-parametric instrumental variable estimation. Generally, the relationship between food share of income and income is given by a non-specified relationship Γ(.) in equation (5):

$$\omega_h = \Gamma(I_h, D_h) + \mu_h, \tag{5}$$

where Γ potentially is non-monotonic. The classically behaved error term μ is assumed to be uncorrelated with income before taxes, I. The local regression method used here fits a linear weighted regression line in a local neighborhood for each I_h. The linear regression weight assigned to an included observation I_i around I_h, for which the local line is fit, is given by equation (6):

$$W(I_i, I_h, b_i) = K_0\left(\frac{I_i - I_h}{b_h}\right); \qquad i \in IH, h \in H, \tag{6}$$

where I_i is member of the bandwidth set around I_h, where b_h specifies the bandwidth, and where $K_0(x)$ is a smooth weighting function. The bandwidth b_h is constructed around each I_h so that for each local regression a pre-specified fraction[8] of the data are included. For the weighting function, this article uses the traditional Tri-Cube function, given by equation (7). The closer the observation I_i is to the I_h, the more weight it is given.

[8] This fraction is controlled by the smoothing parameter, which is set by the analyst. I use a smoothing parameter of 0.6. in the procedure PROC LOESS of the software package SAS. For technical details on and examples of code for such non-parametric regressions, see SAS/STAT® 9.2 User's Guide, 2nd. Ed. Online: http://support.sas.com/documentation/.

$$K_0(x) = \begin{cases} (1-|x|^3)^3, & |x| \le 1, \\ 0, & otherwise. \end{cases} \qquad (7)$$

Let us provide some further details. For an observation h with income I_h, a neighborhood set IH around the level I_h is chosen according to the inputted smoothing parameter (controlling the bandwidth). The set IH has fewer than n observations, e.g. 0.6n. For each observation within the neighborhood IH a weight is computed using equations (6) and (7) and a local regression is run. This yields a predicted share associated with I_h. This type of regression is repeated for all n observations. The analyst may then construct a figure consisting of the pairs of observed I_h and their associated fitted shares. This constitutes the non-parametric Engel curve.

3 Data

The information I use on consumer expenditure comes from the United States and Norway. The U.S. data were compiled by the Bureau of Labor Statistics; see Bureau of Labor Statistics (2002); the Norwegian data were acquired by Statistics Norway.[9]

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[9] Statistics Norway has constructed a special internet site in English on CES, sampling, weights, and latest developments. Use: http://www.ssb.no/english/subjects/05/02/forbruk_en/.

3.1 The Norwegian Data

Every fortnight, Statistics Norway asks 1/26 of their household sample to make a complete inventory (a “diary”) of all expenditures over a 14-day period. The households are subsequently interviewed to obtain information on demographic variables, housing arrangements and attributes, and other variables of interest. Sample sizes are typically around 1200 households per year. The sampling scheme is a two-stage stratified random sample of the universe of Norwegian households. Response rates are approximately 60 percent. Expenditures are annualized (by multiplying with 26). My variable “No. of Children in household” is the number of children under 16. I use information on a total of 999 households, after removing some due to missing values, truncation, and data cleansing.

Statistics Norway link Consumer Expenditure Surveys data sets with data sets from income registers, which contain records of all Norwegian residents. I was able to access several income variables from this combined resource, e.g. income before taxes and income after taxes. Income data maintain a high standard since employers are required by law to file information on employees, for example pay and salary, with the authorities.

3.2 U.S. data

The U.S. consumer expenditure data were obtained from the Bureau of Labor Statistics as described in U. S. Dept. of Labor, Bureau of Labor Statistics, 2002[10], (documentation available online at http://www.bls.gov) for the four quarters of 2001 and the first quarter of 2002. The data were downloaded from the ICPSR-site at the University of Michigan, Ann Arbor (available online at http://www.icpsr.umich.edu). The data are in the public domain, and can be accessed to cross-check the results and examine sensitivity to specifications. The CES interview data comprise five datasets of the fmly-type: da3674.fmly011 through da3674.fmly014, and da3674.fmly021.[11] Although all the main results rely on these interview data sets, I also accessed the diary data[12]. Regression results based on diary data are included in Table A3 in the appendix.

The interview component of the CES-system consists of data on major items of expenses, household characteristics, and income in a continuous flow of surveys. Each consumer unit is interviewed every three months over a 15-month period, and each reports expenditures for the past three months prior to the interview. Households recollect these expenditures as they were made, and they are not annualized (p. 99,). It is estimated that the interview covers 90 to 95 percent of all expenditures, but first quarter interview expenditure data are not reported (p. 321) because they are collected for bounding purposes only. Each quarter sample is designed to be representative of the United States population, and the response rate of the 2001 survey was 78 percent (p. 326). The results in this article are

[10] The producer and distributor of the U.S. data files are: U.S. Dept. of Labor, Bureau of Labor Statistics. Consumer expenditure survey, 2001: Interview survey and detailed expenditure file [Computer file]. Washington, DC: U.S. Dept. of Labor, Bureau of Labor Statistics [producer], 2002. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2003.

[11] The last digit in the ID represents the interview-quarter, the other the unique household.

[12] I use fmly-files from diary data (da3675.fmly011-da3675.fmly014) and detailed expenditure files (da3675.expn011-da3675.expn014).

based on the reports from the five-quarter period starting with January 2001 and ending with March 2002, but are limited to expenditures reported in the calendar year 2001 only. I use income before taxes as defined by BLS (p 66), but have experimented with other income definitions and total expenditure.

Reported expenditures in 2001 for all reporting households are transformed to an annual basis by dividing by number of reporting months and multiplying by 12. I truncated the data by requiring at least 6 months of observed expenditures. Some variables, including income and demographics, vary over the observation period. I use the latest available. Children are defined as household members below 18 years of age. The variable "Adults" is defined as family size less number of children. After removing households for missing values, truncation, and data cleansing, the remaining households numbered 5,391.

3.3 Comparing U.S. and Norwegian data

There are differences between the U.S. and Norwegian classification systems; see Bureau of Labor Statistics (2002), p. 100) for the content of total expenditures in the U.S. data. For the headline comparison I use the U.S. definition of food, including non-alcoholic beverages and food away from home. Below, I discuss sensitivity analyses on alternative definitions of food, most notably by excluding food away from home. Table 2 tabulates the summary statistics of households in the two country samples.

Table 2 Summary statistics of data. United States (in nominal USD) and Norway (in nominal NOK). 2001

Variable	10th Percentile	50th Percentile	Mean	90th Percentile
Norway N = 999 obs.				
Food[a]	21,625	52,441	56,579	93,130
Total Expenditure	128,066	295,768	347,862	729,924
Income before taxes	243, 263	502,227	528,051	817,676
No. of children	0	1	1.06	3
No. of adults	1	2	2.10	3
Age[b]	29	43	44.8	64
Mortgage[c]	0	270,000	380,944	960,000
Sex[d]	0	1	0.734	1
United States N = 5, 391 obs.				
Food	2,590	5,319	5,926	9,856
Total Expenditure	17,524	37,210	44,671	81,439
Income before taxes	20,400	47,400	59,150	142,600
No. of children	0	0	0.76	2
No. of adults	1	2	2.02	3
Age	29	46	47.8	71
Tenure[e]	0	1	0.97	2
Sex	0	1	0.57	1

[a] Food is defined as food-at-home (including non-alcoholic beverages) and food-away-from home

[b] Age is defined as age of main income earner

[c] Mortgage is reported outstanding debt on owner-occupied house

[d] Sex is sex of main income earner in Norway and reference person in U.S. It is unity if male and zero if female

[e] Tenure is defined as the household's type of tenure. There are six categories: owned with mortgage, owned without mortgage, owned with mortgage not reported, rented, occupied without payment of cash rent, and student housing

4 Empirical Results

4.1 Engel Curves for both the United States and Norway

First, I estimate Engel curves for each country. The null hypothesis states that Engel curves between U.S. and Norway are not affected by differences in relative prices and preferences and that the only difference between the two Engel curves results from the variable-transformation of the monetary unit. The null implies that in an AIDS-type specification a variable-transformation yields a Norwegian intercept that is larger than the U.S. intercept by a term consisting of the absolute value of the U.S. slope coefficient multiplied by the log-variable-transformation factor. In a linear 2SLS set-up, on the other hand, a variable transformation would only show up in the slope.

Table 3 reports the results of estimating one Engel curve for each country using both the AIDS-specification and the 2SLS-regression with income variables as instruments. At first glance, the results appear to be consistent with the null: the slope estimates in the AIDS specification are highly similar while the intercepts differ; in the 2SLS specification the slope estimates differ while the intercepts are at least relatively similar.

Table 3 2SLS and AIDS regressions[a] of food[b] Share on determinants. United States and Norway. 2001

Model	**2SLS**		**AIDS**	
Variable	**Norway**	**U.S.**	**Norway**	**U.S.**
Intercept	0.199 (19.7)	0.167 (60.9)	1.0937 (18.6)	0.947 (63.3)
Tot. Exp.	$-2.74*10^{-7}$ (-8.8)	$-1.17*10^{-6}$ (-22.8)		
Log(Inc. b. tax)			-0.0798 (-16.8)	-0.0809 (-56.9)
No. of Childr.	0.0166 (6.0)	0.00953 (11.5)	0.0199 (11.8)	0.0130 (16.4)
No. of Adults	0.0326 (7.1)	0.0150 (13.2)	0.0221 (7.2)	0.0211 (19.7)
Adj. R-sq.	0.0822	0.1043	0.273	0.392
RSS	8.20175	23.72946	3.61636	22.20512
No. of obs.	999	5,391	999	5,391

Notes: U. S. CES data were truncated at income before tax equal to $15,000 and $300,000. Only households reporting expenditures for at least 6 months in 2001 were included. (Before truncation the data comprised 17,690 observations over 5 quarters.) Norwegian CES data were truncated at income before taxes equal to NOK 135,000 and 2,700,000. All households reported for a 14-day period in 2001. All expenditures were annualized. U.S. food is defined as food at home (which includes non-alcoholic beverages) + food away from home (which includes non-alcoholic beverages). Norwegian food is defined as food at home + sub-category food away from home + sub-category non-alcoholic beverages

[a] The 2SLS regression was performed in two stages. First, I regressed Norwegian total expenditures onto a space spanned by income before taxes, income after taxes, no. of children, no. of adults, age of main income earner, mortgage, and sex. Second, I used the predicted values as determinant in the last stage where food's share was regressed onto its determinant space. The U.S. regression was performed similarly, except that total expenditures in the first stage were regressed onto a space spanned by income before taxes, income after taxes, no. of children, no. of adults, age, tenure, sex, and race

[b] Food share in 2SLS is defined as food's share of total expenditures. Food share in AIDS-regression is defined as food's share of income before taxes

A closer inspection leads to some modifications. The estimated slope coefficients from the AIDS-specification, found in the right-most column of Table 3, are remarkably similar. They are both estimated to be -0.08, which supports the null. With a variable-transformation factor R equal to 7, the null implies an intercept-difference of 0.157[13] compared to the actual difference of 1.0937 – 0.947 = 0.147, consistent with the null. We do not reject.[14]

[13] The result of 0.0809ln(7); see Theory.

[14] The t-values of the intercept estimates are 18.6 and 63.3 indicate small estimated standard deviations (0.0588 and 0.0150, respectively). The estimated standard deviation of the intercept difference becomes 0.060674. Thus, the t-value of testing the intercept difference is 0.16.

However, we do observe that Engel curve estimation using a 2SLS linear set-up yields both differences in intercept and slope. The Norwegian slope estimate is $-2.74*10^{-7}$ while the U.S. is $-1.17*10^{-6}$; the value of the former is 0.23 of the latter. This is larger than a mere variable transformation would have produced. If we use variable transformations with factors of 5, 6, and 7, the Norwegian slopes, under the null, would be 0.2, 0.17, and 0.14 times the U.S. one, while the 0.23 ratio obtained imply a variable transformation of 4.25, unrealistically low. However, this conversion is only meaningful under the null, and under the null the difference in intercept would be zero. It is not. The observed difference between intercept estimates is 0.199 – 0.167 = 0.032. A t-test yields a t-value of 3.05[15]. Thus, the 2SLS set-up rejects the null. However, keep in mind that if the true specification is AIDS, then the 2SLS is in fact mis-specified, which would imply rejection.

Together, the two initial tests appear to lend support to the Engel curve approach even if they are not definitively conclusive. In short, the Engel curve approach does appear to yield sensible results. However, these initial tests include both a relative price effect and a preference effect which leaves open the possibility that both effects are present, but with opposite signs. If so, they could cancel each other out, leading interpreters to see support for the Engel curve approach where there is none. A more thorough examination keeps one factor constant while varying the other. In the next section, preference differences are tested, while holding relative prices constant.

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[15] See e.g. Rice (1995, p. 515). The estimated standard variation of the estimated intercept difference is $(0.010102^2 + 0.00275^2)^{0.5} = 0.010467$.

4.2 Within-Country Tests of Sensitivity to Preference Differences

When we compare Engel curves for regions within a given country, the maintained assumption is that the price ratio is constant across regions.That being the case, we may usefully employ the more advanced specification in a QUAIDS-type set-up and examine potential curvature.[16] Table 4 presents results of separate price-homogeneous QUAIDS-type regressions on four U.S. geographical strata, the Northeast, the Midwest, the South, and the West. We observe that results from the Midwest and the South are quite similar, both have estimated log-income coefficients of -0.63. The estimates of the Northeast and West are also quite similar, with estimated squared log-income coefficients of -0.74 and -0.73. In order to test most conveniently whether preferences are identical under the assumption of price homogeneity, this article runs a pooled regression with dummies for the Northeast and the West. In addition, interaction variables between the dummy and log-income and the dummy and squared log-income are inserted. Table 5 tabulates the results. We observe that neither the estimates of the dummy nor the estimates of the interaction variables are statistically significant. However, using an F-test to compare the unconstrained specification versus a constrained specification with three linear restrictions requiring the coefficients of the dummy and the interaction variables to be zero, we obtain an F-statistic of 7.4. This rejects the null of no preference differences.

[16] I employ different specifications as part of a broader model selection process. If the QUAIDS-specification is true to the underlying structure, then the linear AIDS-specification is an approximation. In that case, the latter may still be quite accurate in the most interesting income interval.

Table 4 Estimating Engel curves for food for U.S. regions: Food's share of income before tax on determinants. United States. 2001

Variable	Northeast	Midwest	South	West
Constant	4.491 (8.7)	3.916 (9.5)	3.904 (11.1)	4.468 (11.1)
Log(Inc.b.tax)	-0.735 (-7.7)	-0.631 (-8.3)	-0.630 (-9.7)	-0.726 (-9.8)
Sq.Log(Inc.b.tax)	0.0299 (6.8)	0.0253 (7.3)	0.0254 (8.5)	0.0300 (8.7)
No. of Children	0.0144 (6.9)	0.0166 (10.5)	0.0145 (11.0)	0.00913 (6.4)
No. of Adults	0.0300 (10.5)	0.0233 (10.4)	0.0194 (11.0)	0.0186 (9.9)
R^2 Adj.	0.4165	0.4107	0.4355	0.422
No. of obs.	942	1265	1703	1481

Note: See Tables 2 and 3

Table 5 Engel Curves for food for U.S. West and Northeast versus Midwest and South: Food’s share of income before tax on determinants. United States. 2001

Variable	With Dummies	Without Dummies
Constant	3.907 (13.8)	4.201 (20.4)
West and North East (dummy)	0.595 (1.5)	
Log(Inc. b. Tax)	-0.631 (-12.1)	-0.682 (-18.0)
Log(Inc. b. Tax)*West and North East	-0.104 (-1.4)	
Sq. Log(Inc. b. Tax)	0.0254 (10.6)	0.0277 (15.9)
Sq. Log(Inc. b. Tax)*West and North East	0.00452 (1.3)	
No. of Children	0.0132 (17.1)	0.0132 (17.1)
No. of Adults	0.0214 (20.5)	0.0217 (20.7)
R^2 Adj.	0.421	0.419
No. of obs.	5,391	5,391
RSS	21.12624	21.21334

Note: See Tables 2 and 3

An augmentation of the investigation of sensitivity to preference differences within a country involves examining different socioeconomic strata.Partitioning along socioeconomic lines involves no spatial partitioning.[17] Under the null, agents share the same functional form and coefficients, but position themselves differently along the curves. Put differently, the null hypothesis implies that if household A enjoyed the same income as household B, it would also behave like

[17] Moreover, it allows smaller segments to have within-group homothetic preferences even if there are between-group differences; see Beatty and Crossley (2012).

B. Table A1 in the appendix tabulates results from regressions on households from strata with different levels of material standard of living. Clearly, coefficient estimates differ substantially between within-country segments, suggesting that Engel curve estimation may indeed be sensitive to preferences.

It would be a formidable challenge for the Engel curve approach if, after partitioning a small area within the same labor market, language, and culture proved sensitive to preferences. This brings us to the final test. We divide the small, culturally homogeneous country of Norway into two geographical strata: 1. Oslo and the Eastern Norway region and 2. the rest of the country. The results are reported in Table 6. We do detect some differences. The triplets of intercept, log-income coefficient, and squared log-income coefficients are (4.04, -0.54, 0.018) and (5.13,-0.70, 0.024), respectively. In order to test for differences, I ran an unconstrained regression with a dummy and interaction variables for log-income and squared log-income and a constrained regression without dummies and interaction variables. The F-test yields a statistic of 1.8; we can therefore not reject the null.[18] Put differently, there is support for the Engel curve approach, whichcould usefully be applied on fairly homogeneous geographical areas.

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[18] The sums of squared errors were 3.54985 for the unconstrained and 3.56906 for the constrained. There were 999 observations, 8 parameters in the unconstrained regression and 3 linear restrictions in the constrained.

Table 6 Estimating Engel curves for food for regions: Food's share of income before tax on determinants. Norway. 2001

Variable	**Oslo and Eastern Norway**	**Rest of Norway**
Constant	4.0379 (2.8)	5.133 (3.7)
Log(Inc. b. tax)	-0.538 (-2.4)	-0.696 (-3.3)
Sq. Log(Inc. b. tax)	0.0178 (2.1)	0.0235 (2.9)
No. of Children	0.0210 (8.1)	0.0207 (9.4)
No. of Adults	0.0246 (5.6)	0.0215 (5.1)
R^2 Adj.	0.243	0.327
No. of obs.	502	497

Note: See Tables 2 and 3

4.3 Constructing a PPP-band

In total, however, the Engel curve estimation appears, to be sensitive to differences in relative prices and preferences, especially over larger geographical areas. Now, it is reasonable to assume that the more countries differ along dimensions such as institutions, population, ethnicity, geographical extent, and stage of development, the more they will differ with respect to prices and preferences. As Blundell and Stoker (2005) say: “Different people do, in fact, behave differently” (p. 347). They urge analysts to realize that in empirical economics one must accept the presence of heterogeneity and attempt to approach it optimally when aggregating. This article suggests that instead of trying to solve the insoluble, i.e. to control for differences in relative prices and preferences, rather than computing a PPP scalar, analysts should compute a PPP band. I employ a QUAIDS-type regression of food shares on income in the following PPP band estimation, even if though, as has ben argued (Meyer and Sullivan (2011)), a 2SLS type with total expenditure as endogenous and income as instrument may be preferable at times. The QUAIDS type goes back to Banks et al. (1997)[19] and has since become a work-horse in the field of parametric Engel curve estimation. I employ a price-homogeneous QUAIDS-specification in two versions: one parsimonious and one augmented. The latter includes standard preference shifters. I use the parsimonious version to construct a PPP band from parametric Engel curves since this version contains identical determinants for both countries.

Table 7 QUAIDS-type regression. Food's share of income before taxes on determinants. Norway. 2001

Variable	**Norway I**	**Norway II**	**U.S. I**	**U.S. II**
Const.	4.701 (4.7)	5.104 (5.1)	4.201 (20.4)	4.309 (20.8)
Log(Inc.b. tax)	-0.635 (-4.2)	-0.696 (-4.5)	-0.682 (-18.0)	-0.710 (-18.6)
Sq(Log(Inc. b.tax))	0.0213 (3.6)	0.0234 (4.0)	0.0277 (15.9)	0.0288 (16.4)
No. Childr.	0.0205 (12.2)	0.0178 (9.4)	0.0132 (17.1)	0.0135 (16.3)
No. Adults	0.0229 (7.6)	0.0229 (7.4)	0.0217 (20.7)	0.0208 (19.7)
Age		0.00202 (2.0)		0.00242 (7.4)
Age Sq.		$-2.48*10^{-5}$ (2.4)		$-2.33*10^{-5}$ (-7.4)
Mortgage		$2.36*10^{-9}$ (0.5)		
Tenure				0.00181 (1.3)
Sex		0.00221 (0.5)		0.00448 (2.6)
R^2 Adj.	0.282	0.287	0.419	0.426
No. of obs.	999	999	5,391	5,391

Notes: See Tables 2 and 3.Food is defined as food-at-home (including non-alcoholic beverages) and food-away-from home

Table 7 presents this article’s main empirical findings. The estimated coefficients in the table are statistically significant and economically important. The negative estimate of the coefficient of the logarithm of income before taxes indicates the inverse relationship between food share and income, and the positive estimate of

[19] Blundell et al. (1993) also study quadratic curves.

coefficient of the squared logarithm of income demonstrate the curvature of the Engel relationship.

I use the estimated Engel curves from Table 7 to compute the inputs to the PPP band, and these inputs are then used to tabulate the PPPs in Table 8. For example, a U.S. income before taxes of 36,500 dollars is associated with a 15 percent food share for a family of two adults and one child. In comparison, 290,500 Norwegian kroner (NOK) are needed to achieve the same material standard of living, measured as the material standard of living consistent with 15 percent food share. A Norwegian household will need 7.96 times more units of their domestic currency to purchase the same material standard of living; the estimated purchasing power parity is therefore 7.96 NOK per USD. For a more luxurious standard, e.g. for an 8 percent standard, the estimated PPP-rate is 7.33 NOK per USD.

For an American single-person household, an income before taxes of 42,800 U.S. dollars is associated with a material standard of living commensurate with a 10 percent food share. The similar association for Norwegian single-person households occurs at NOK 310,500. This gives an estimated PPP for the 10 percent standard single-person-household of 7.25 NOK per USD.

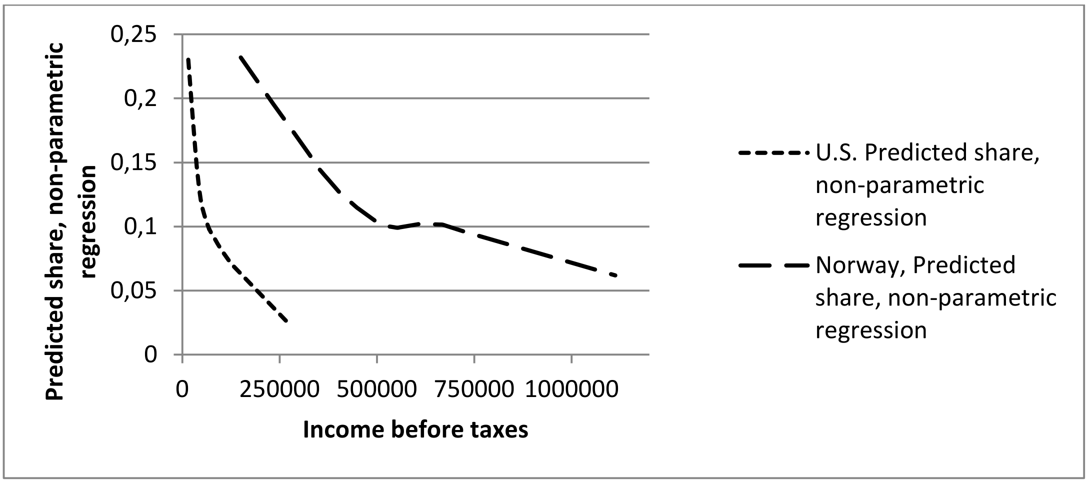
Table 8 Engel Curve PPP estimates. U.S. and Norway. Household of 3 (2 adults, 1 child) and single-person household. 2001

Standard of Living (Inverse of food share)	Norwegian Income Required, in NOK	U.S. Income Required, in USD	Estimated R_{PPP} = NOK inc./USD inc.
Family of 3 (2 Adults, 1 Child)			
0.08	691,500	94,400	7.33
0.10	516,000	66,500	7.76
0.12	401,500	50,800	7.90
0.15	290,500	36,500	7.96
0.20	183,500	23,400	7.84
Single Person Household			
0.08	386,500	54,100	7.14
0.10	310,500	42,800	7.25
0.12	254,500	34,800	7.31
0.15	194,000	26,500	7.32

As Table 8 shows, we get a high PPP estimate for a household of three members with a low material standard of living (15 percent food share). For this demographic type and this standard of living, the PPP estimate is 7.96. Conversely, single-person households with a high material standard of living (8 percent food share) have a PPP estimate of 7.14. Together, these estimates function as lower- and upper-bounds of effects that encompass relative prices and preferences, and result in a PPP band spanning from 7.14 to 7.96.

4.4 Non-parametric estimation

In the estimation of non-parametric regressions, I make use of a two-stage method. First, I segment for demographic type in order to avoid confounding effects from household size and composition, before computing the non-parametric regressions. Figure 1 depicts the results from employing the non-parametric technique of a local, weighted regression on households of two adults and one child.



Notes: The non-parametric regression line for households of 2 adults and 1 child in the United States was based on 467 observations. It had 17 fitting points and the smoothing parameter was 0.60. Points in local neighborhood: 280. Residual sum of squares: 1.314. Equivalent number of parameters: 3.99. The non-parametric regression line for households of 2 adults and 1 child in Norway was based on 101 observations. It had 14 fitting points and the smoothing parameter was 0.60. Points in local neighborhood: 60. Residual sum of squares: 0.324. Equivalent number of parameters: 3.79

Fig. 1 Non-parametric regression. Food share on income before taxes. Household of 3 members (2 adults, 1 child). United States and Norway. 2001

Visual inspection reveals that the choice of parametric model with curvature is warranted. For households of two adults and one child, the computed PPP at 15 percent food share standard from the non-parametric estimates is 9.49 NOK per USD. For singles the computed PPP at an 8 percent food-share standard is 6.38 NOK per USD. Appendix Table A2 includes a table equivalent to Table 8 based on the results from the non-parametric, segmented regressions. We observe that the PPP band for a 3-person household is 8.70-9.49 NOK/USD and 6.38-7.59

NOK/USD for singles. Thus, the non-parametric PPP bands are comparable to the parametric ones, but wider and somewhat differently positioned. I suggest the following interpretation of this finding. Making parametric choices allows one to deploy larger funds of data at the same time, combining income and demographics in *one* regression instead of running segmented regressions on household types. Parameterization may compress information into fewer scalars, use preference-shifters, and narrow the band around the most interesting demographic types, but at the cost of smoothing out interesting kinks (e.g. at the 10 percent share for 3-person households and at the 7 percent share for singles) and differences between population segments in how they optimize purchases given prices. An important lesson to be drawn from both parametric and non-parametric analyses is that constructing PPPs at different levels of material standard of living has several advantages, consistent with the message in Beatty and Crossley (2012).

4.5 Comparison with market exchange rates and other PPPs

In Figure 2, I plot upper and lower bounds for my parametric PPP estimates compared with historical market exchange rates. The upper bound of 7.96 NOK per USD results from the computation of a low (15 percent food share) material standard of living for households of two adults and one child. The lower bound of 7.14 NOK per USD is obtained by using a high (8 percent food share) material standard of living for singles. The PPP-band lies in the middle range of historical exchange rates. The non-parametric band of 6.38-9.49 is wider but also appears to be aligned with historical rates.

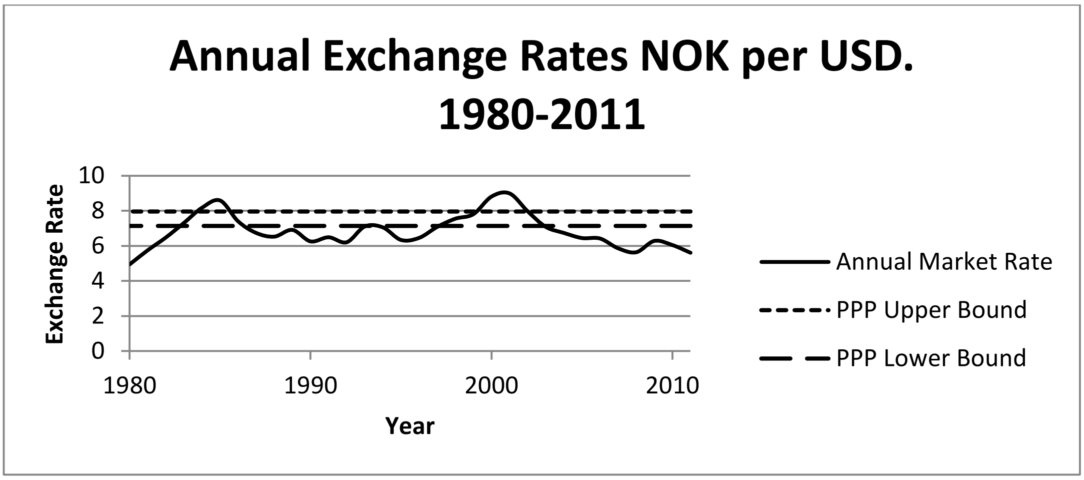


Fig. 2 Market exchange rates and 2001 Band of estimated PPP-levels. NOK per USD. 1980-2011

Table 9 Other PPP point estimates.

Source	Time Frame	Method	PPP-estimate
The Economist	April 25 2002	Big Mac Index[a]	14.06
OECD[b]	2001	Representative Basket[c]	9.18
BLS[d]	1999	Representative Basket[e]	9.25
World Bank[f]	2005	Broad Basket[g]	8.84

[a] Prices quoted for Big Macs in April 2002 were USD 2.49 in the United States and NOK 35.00 in Norway

[b] Available online: http://www.oecd.org/std/ppp

[c] Representative basket of consumer goods and services

[d] Bureau of Labor Statistics. Current data available online: http://www.bls.gov/fls

[e] See Bureau of Labor Statistics (2003)

[f] International Comparison Program. See World Bank online for details on methodology and scope: http://www.world . For a general outline and technical details see International Bank for Reconstruction and Development/The World Bank (2008).Available online: http://siteresources.worldbank.org/ICPINT/Resources/icp-final.pdf . The USD-NOK estimate can be found on page 26 under Tables of Results from the 2005 round, see: http://siteresources.worldbank.org/ICPINT/Resources/icp-final-tables.pdf

[g] The ICP seeks to produce PPPs that take into account prices for a broad range of goods and services, not only consumer goods and services, but also capital and government expenditures

Table 9 lists other estimates of PPP from the same time period. For example, *The Economist*'s Big Mac Index estimates the PPP between the USD and NOK at 14.06 since a Big Mac was priced at USD 2.49 in the U.S. and NOK 35.00 in Norway. In comparison, PPP estimates from OECD, Bureau of Labor Statistics, and World Bank range from 8.84 to 9.25 NOK per USD, also clearly above this article's band. We do notice, however, that the Engel curve estimates are closer to historical exchange rates than conventional PPP estimates.

5 Discussion

The Engel curve PPP approach relies on maintained assumptions, which it cannot test. The key assumption is that an x percent food share in the United States involves a material standard of living comparable, if not identical, to the material standard of living associated with x percent food share in Norway. It is a plausible assumption, but may be contentious. Its plausibility is related to *which* economies are compared; and consequently to cultural similarities, institutional correspondences, and the comparability of levels of economic development. The United States and Norway are excellent candidates in terms of comparability because both are rich, market-based economies. Similarities notwithstanding, cultural and political differences do advise a measure of caution when interpreting the results.

To take an example, the third assumption of identical preferences could and perhaps should include institutions. In fact, Tables 4, 5, and 6 above do allow for an extended interpretation where not only relative prices are constant for within-country regressions, but also institutions. Nevertheless, it might be a concern that between-country differences in social policy could function as confounders. As a case in mind, poor households in the U.S. receive some of their support in the form of food stamps and free meals. In Appendix Table A3, I present regression results after having accessed the diary data of the CES. I ran such regressions to examine the sensitivity of my results to including or excluding such types of support. The overall pattern is similar to the one reported above. Additionally, U.S. households typically acquire private insurance schemes either from insurers directly or through their employers. Norway has a state insurance scheme, to which households contribute in the form of taxation. I have tried various adjustments for medical expenditures, and run regressions using after-tax income and even savings. Space does not allow me to report all of the results. While the main pattern is intact, there can be no doubt that careful analysis, application, and interpretation of the Engel curve methodology require well-designed definitions of food expenditure and income.

In fact, while the Norwegian income data are of exceptional quality having been sourced from tax records at the Norwegian IRS, doubts have been raised about the quality of U.S. CES income data. Meyer and Sullivan (2011) document disturbing under-reporting in U.S. CES data, findings corroborated by Brzozowski and Crossley (2011). U.S. data quality appears to be lower than Canadian data. Moreover, Bee, Meyer, and Sullivan (2012) document under-representation at the top of the income distribution and under-reporting of both expenditures and incomes at the top. Ahmed, Brzozowski, and Crossley (2006) find, using a data set where households both recall and record expenditures, that recall data have substantial measurement errors and that diary data are not accurate reflections of expenditure. Taken together, these findings make us wonder whether we legitimately can use expenditure and/or income data. If expenditure records are better than income records, it might be possible to use total expenditure as denominator in the food share and as determinant. Again, the problem with using total expenditure is that of endogeneity associated with common measurement errors in food expenditures and total expenditure. However, a linear specification of an errors-in-variable 2SLS approach using total expenditure does yield sensible results. Nevertheless, uncertain estimator properties in specifications of higher order polynomials make the exogenous variable Income before Taxes preferable. I have, however, experimented both with the inclusion of more preference shifters in linear errors-in-variable 2SLS approaches and with using food's share of total expenditure regressed on polynomials of the logarithm of income before taxes. I do not report these results, except to mention that the former yields a PPP band that ranges from 6.29 to 9.87 NOK /USD.

This article suggests that we avoid a doctrinaire defense or dismissal of the Engel curve method and instead appeals to practicality. The assumption of a link between food share and standard of living is strong, and the use of a strong non-tested hypothesis is disadvantageous in any method. But the conventional PPP estimate is derived from the prices of identical baskets across different economies, and it too relies on the maintained hypothesis of preference-homogeneity. In addition, analysts performing conventional PPP estimates may be unable to obtain quoted prices in a given developing country, and baskets available in one country may not be available anywhere else. In fact, in the absence of markets and prices, the Engel curve approach may prove to be more, not less, useful.

The definition of *food* is contentious. However, even though two baskets consist of different goods they may arguably serve the same end. For example, a 1500 calorie basket consisting of meat, bread, and pineapples is arguably comparable to a 1500 calorie basket consisting of fish, oatmeal, and apples as far as nutritional needs are concerned; see Witt (2001) for a consumption framework. On the other hand, while food consumed at home provides necessary calories and nourishment, food consumed away from home comes with an element of sociality. The production function used by households may rely on food-away-from-home in a different way than food-at-home. Nevertheless, we see from Table 10 that the exclusion of food-away-from-home does not seem to affect the structural findings substantially.

Table 10 Estimating Engel curves for food: Food-at-home's share of income before tax on determinants, United States and Norway, 2001

Variable	U.S., 2001	Norway, 2001
Constant	3.636 (22.2)	3.901 (4.73)
Log(Inc. b. tax)	-0.593 (-19.6)	-0.519 (-4.1)
Sq. Log(Inc. b. tax)	0.0240 (17.3)	0.0170 (3.5)
No. of Children	0.0136 (22.1)	0.0207 (14.8)
No. of Adults	0.0217 (26.1)	0.0254 (10.1)
R^2 Adj.	0.481	0.348
No. of obs.	5,391	999

Note: See Tables 2 and 3

6 Concluding Remarks and Policy Implications

This article asks whether the method suggested by Ålmås (2012), which uses Engel curves to compute PPP estimates, is viable. The empirical strategy set out here first examines the results of estimating Engel curves on each country, then of Engel curves on within-country regions. It turns out that Engel curve estimation does appear to be sensitive to differences in relative prices and preferences, but not alarmingly so. Overall, the method seems to have promise.

This is welcome news. Trying to control for relative prices is counterproductive since it means that Engel curve PPP estimation is more cumbersome than the method it seeks to augment. It also makes the Engel curve PPPs prone to the same biases. While controlling for differences in preferences may never truly succeed, this article suggests that the Engel curve method could usefully augment conventional PPP estimates by estimating PPP bands. Even if the non-parametric band is wider, my parametric PPP band of NOK per USD ranges from 7.14 to 7.96, perhaps sufficiently narrow to be of practical use.

Where conventional PPP methods compare prices of presumably identical baskets of goods and services, the Engel curve method compares the cost of purchasing presumably identical material standards of living. Standard is measured as the proportion of pre-tax income spent on food. For example, it turns out that a U.S. household of two adults and one child that spends 10 percent of its pre-tax income on food typically has a pre-tax income of USD 66,500. In Norway, regression analysis reveals that the association with a 10 percent food share occurs when pre-tax income equals NOK 516,000. Assuming that the Engel curve discloses the cost of material standard of living, the PPP estimate becomes 7.76 NOK per USD.

While the conventional PPP approach employed by the World Bank and OECD yields estimates of 8.84 and 9.18 NOK per USD, the Engel curve approach yields a band of 7.14-7.96 NOK per USD. Comparing these numbers with 31 years of market exchange rates, the conventional estimates lie near the top of the spectrum while the Engel curve band contains most of the core market amplitudes. This, of course, does not necessarily increase its credibility, especially so if the purpose of constructing PPPs is different from trying to understand the market; but it does lend some credibility to the method all the same.

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Appendix

Table A1 Estimating Engel curves for food for Norwegian and U.S. income groups: Food's share of income before tax on determinants. United States. 2001

Variable	**Norway above Median**	**Norway below or Equal to Median**	**U.S. above Median**	**U.S. below or Equal to Median**
Constant	1.181 (0.3)	5.082 (1.3)	2.0364 (4.2)	8.745 (5.3)
Log(Inc. b. tax)	-0.107 (-0.2)	-0.682 (-1.1)	-0.299 (-3.5)	-1.564
Sq(Log(Inc. b. tax))	0.00170 (0.1)	0.0225 (0.9)	0.0109 (3.0)	0.0702
No. of Children	0.0111 (5.7)	0.0284 (10.4)	0.00825 (12.3)	0.0178
No. of Adults	0.0145 (4.7)	0.0306 (5.1)	0.00939 (10.0)	0.0321
R^2 Adj.	0.1490	0.298	0.2328	0.3144
No. of obs.	499	500	2,695	2,696

Notes: See Tables 2 and 3. Q1, Q2, and Q3 are 29,300; 47,400; 75,000. Different quartile sizes due to multiple counts around cut-off points. First quartile included 29,300, second quartile included 47,400 etc

Table A2 Non-parametric and segmented Engel curve PPP estimates. U.S. and Norway. Households of 3 (2 adults, 1 child) and single-person household. 2001

Standard of Living (Inverse of food share)	Norwegian Income Required, in NOK	U.S. Income Required, in USD	Estimated R_{PPP} = NOK inc./USD inc.
Family of 3 (2 Adults, 1 Child)			
0.08	907,100	104,200	8.70
0.10	533,700	66,200	8.06
0.12	429,200	47,600	9.02
0.15	340,600	35,900	9.49
Single Person Household			
0.08	344,500	54,000	6.38
0.10	245,100	35,800	6.84
0.12	206,200	27,800	7.42
0.15	154,000	20,300	7.59

Table A3 Linear-log[a] regressions using different definitions of food and income (t-values). United States and Norway, 2001

Model	**I**	**II**	**III**	**IV**
Data Source	U.S. Diary	U.S. Diary	U.S. Diary	U.S. Interview
Income Definition[b]	Inc.b.t. – food stamps[c]	Inc.b.t. – food stamps	Inc.b.t + free meals[c]	Inc.b.t.
Food Definition	Total food	Total food + free meals	Total food + free meals	Total food
Intercept	0.983 (36.3)	0.853 (4.0)	0.743 (4.4)	0.947 (63.3)
Log(Inc. b. t.)				-0.0809 (-56.9)
Log(Inc.b.t-food stamps)	-0.0854 (-33.1)	-0.0734 (-3.6)	-0.0622 (-3.9)	
No. of Children	0.0153 (11.0)	0.00952 (0.9)	0.00589 (0.7)	0.0130 (16.4)
No. of Adults	0.0284 (14.1)	0.0505 (3.4)	0.0420 (3.6)	0.0211 (19.7)
Adj. R-sq.	0.225	0.121	0.136	0.392
No. of obs.	4,354	4,354	4,354	5,391

Note: U.S. diary-sourced expenditure data were truncated at same levels as interview-sourced data. Observations with only one week of recorded expenditures were deleted, a truncation that led to a loss of 458 households. Diary data are labeled da3675.fmly011-da3675.fmly014 and da3675.expn011-da3675.expn014

[a] The specification is food share regressed on log(income) plus children and adults

[b] Income occurs both as denominator in food share and determinant in the regression

[c] Foodstamps are registered by BLS as part of income before taxes; free meals are not