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At the Origins of Engel Curves Estimation

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Abstract

This paper revisits Ernst Engel's (1857) original article in which he systematically investigated the relationship between consumption expenditure and income. While he is mainly remembered today for the discovery of Engel's law, we highlight how Engel addressed in a particular way the issue of the relation between statistical empirical analysis and economic theorizing. Inspired by an inductive methodology, Engel's method to infer empirical regularities made no *a priori* assumption on the estimated functional form and anticipates many aspects of current non-parametric regression methods. Furthermore, Engel devised a quasi-behavioral theory of consumption centered on the concept of wants to justify and explain his empirical results which he used to asses population living standards. Although incomplete, Engel's consumption theory tackles a much neglected issue in consumption theory: what accounts for the manner in which consumption patterns change as income rises.

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"*By his study on consumption alone Engel came to appreciate the modifiable nature of human beings. This is a central thought in modern economics which many students have only recently been coerced into accepting by the triumph of evolutionary philosophy*" (A. G. Warner, *Publications of the American Statistical Association*, 1896).

1 Introduction

Engel curves describe how household expenditure on particular goods or services relates to household income. Popularized by Houthakker (1952) and Prais (1952), this term is named after the German statistician Ernst Engel who was the first to systematically investigate this relationship in an article published 150 years ago (Engel 1857). Since then, Engel curves have become a significant part of empirical demand analysis and are used in many areas of economics, such as structural change analysis, growth theory, international trade studies, as well as in the measurement of inflation.

We revisit Engel's 1857 article. While it is still frequently cited today, most of the time this is done with reference to the "law" he discovered, which states that the poorer a household is, the larger is its budget share dedicated to nourishment (Engel 1857: 28-29). This has indeed been recognized as one of the most established empirical regularities in economics (Houthakker 1987). We argue that a more subtle but nevertheless noteworthy contribution consists of his inductive approach, which characterizes both his econometric method and the theoretical framework he used to interpret his results.

Concerning the former, his mode of estimating the expenditure-income relationship is nonparametric since no functional form is specified before the estimation. As such, it represents a salient example of an econometric method that is based on the premise that it is possible for researches to discover theoretical relationships directly from the data, and does not limit itself to the assessment of hypotheses exclusively derived from existing theories. Concerning the theoretical framework, in using his results to evaluate population living standards, Engel sought to *infer* rather than assume which types of consumption expenditures are necessities and thereby most relevant to measuring population living standards. He did so by devising a classification method wherein consumption expenditures were grouped according to the consumer's wants (*Bedürfnisse*) they satisfied. He also used the notion of wants to provide a preliminary theoretical account for the shape of the Engel curves, a task whose importance has been duly noted in the literature, but which has not received proper attention since Engel's time.

2 Engel's Inductive Approach

Ernst Engel's 1857 article, entitled the "The consumption-production relationships in the Kingdom of Saxony,"[1] had two ambitious goals: on the one hand, it tackled the longstanding

[1] *Die Productions- und Consumtionsverhältnisse des Königsreiches Sachsen* was published in the *Zeitschrift des Statistischen Büreaus des Königlich Sächischen Ministeriums des Innern*, No. 8 and 9, in 1857 and reprinted unchanged as an appendix of Engel (1895). Ernst Engel's (1821-1896) biographical details (see Houthakker 1968) demonstrate that he was a social scientist with a solid background in applied disciplines

debate concerning Malthus's conjecture that a population which does not encounter impediments to its reproduction increases more rapidly than the means for its subsistence (Engel 1857: 1). On the other hand, it sought to measure the living standards of a population by investigating their consumption patterns. Both reflected the fact that Engel was writing in a period in which the economy was undergoing a major transformation and the economic theory was being reinvented.

The goal of assessing living standards corresponded to an urgent need to evaluate how the industrial revolution and the social upheaval which accompanied it had changed the general welfare of the population. Engel's article was published less than a decade after the 1848 uprisings, which were in part triggered by the poor living conditions of newly urbanized workers throughout Europe and put pressure on governments to redress the conditions of the poor people. This had already given impetus to the first generation of studies on workers' consumption budgets, such as Le Play's study (1855). Moreover, an international congress on *bienfaisance* was held in Brussels 1856 that brought together statisticians (including Engel) to discuss methods for measuring the extent to which workers have attained "conditions essential for health and life" (Lumley 1856).

In relation to Malthus, Engel seeked to disprove his argument by showing that there was balanced growth between supply and demand. He affirmed Malthus's insight that there seemed to be no natural constraint on the population growth (Engel 1857: 2). However, Engel reasoned that this growth would only pose a threat if the number and type of producers in an economy would grow out of balance with the growth of consumer demand. To verify this, he matched the composition and size of consumption with the composition and size of production in Saxony (Engel 1857: 39). It was possible to address these two issues together in one article since both rested on statistical insights about how consumption expenditure changes with increasing income. These are used to both deduce population living standards and compare consumption trends to the composition of Saxony's production output.

In terms of its methodology, the article reflects Engel's belief in the possibility of uncovering via careful investigation new quantitative laws governing social phenomena. As Engel explicitly states, his approach is "inductive" (Engel 1857: 28). Induction is a mode of inference which, in contrast with deduction, is not necessarily truth-preserving. However, it is ampliative or knowledge-increasing, since the content of its conclusions extends the content of its premise (Niiniluoto 1998). Engel refers to induction in a more specific meaning: as the art of uncovering a law "from the assembly and classification (*Zusammenstellung*) of facts and observations," as it was suggested to him by the neo-Kantian philosopher Ernst Friedrich Apelt (1854). Engel distinguished this type of induction, from particulars to general, from the mode of reasoning by analogy (*Combination*) which moves from particulars to particulars. In this form of reasoning one infers from observing the attributes of a particular unit the attributes of another, similar unit. For example, if a doctor infers from the symptoms of a sick patient that another patient with similar symptoms has the same illness, this is combination. In contrast, if one learns from a population of patients who are exposed to the same (or randomly different) conditions that a particular illness is related to some symptom, this is what Engel refers to as induction.

At first sight, Engel's emphasis on induction appears to be in line with some influential philosophical and economic doctrines of his time. In economics, early exponents of the so-called historical school were quite influential in Germany in their objection to deductive reasoning.

and a foremost interest in practical activities (being trained as a mining engineer), although his knowledge came to span much of classical economics and philosophy.

On the philosophical side, in 1843 John Stuart Mill published his *System of Logic* which is an eulogy of the logic of induction as the central method of science. Yet upon a closer reading, Engel's concept of induction in economics is at odds both with the German historical school and Mill's philosophy.

There are two important differences between Engel and Mill. First, Mill considers induction primarily as the non-demonstrative rule through which we *confirm* theoretical hypotheses from the data, while for Engel induction is the mode wherein we *discover* from the data new theoretical relationships (laws). Second, Mill considers social science in general and economics in particular as disciplines in which induction should not be applied — not even for the sake of confirmation. This is because the theorized hypotheses always depend on *ceteris paribus* conditions that inexorably fail when the hypotheses are tested against empirical data, since data are the results of many composite forces beyond those isolated by economic theory.

While Mill's method to connecting theory and empirics gradually became authoritative in economics (De Marchi 1998), the emergence of econometrics in the 1930s did overcome Mill's view about the impossibility of empirically verifying economic-theoretical relationships. However, the position that theory comes before measurement remained dominant. In this sense, Engel's work anticipates a vision of econometrics in which statistics could be used to derive meaningful regularities directly from seemingly arbitrary observations. This style of doing empirical research has remained a minority in econometrics for many years, as the famous debate between Koopmans and Vining demonstrated (Koopmans 1947).

Engel's approach is also distinguishable from the doctrines of the German historical school. Scholars such as Schmoller came to emphasize the important of historical research and tended to shun formalism, which they associated to deductive logic (Pearson 1999). They also famously eschewed the search and formulation of general laws in economics, instead emphasizing the importance of case-by-case historical research. In contrast, Engel's agenda explicitly aimed to discover universal laws. Here, his position was more similar to Adolphe Quetelet's work, who influenced Engel's intellectual thinking during his formative years. In his *Essai de physique sociale* (1835) Quetelet called for employing probability and statistics to social sciences, in order for it to catch up with the natural sciences in terms of discovering important statistical laws that govern phenomena under investigation. In the following two sections we examine how Engel's inductivist style influenced both his use of statistics and the theoretical framework used to interpret results.

3 Precursor of Nonparametric Statistics?

Writing in the middle of the 19th century, Engel completed his work in an era before the standard statistical techniques known today were systematically developed. In particular, the least squares estimation was not rigorously formalized before the work of Edgeworth (1885) and Galton (1888), although there were some previous anticipations (see Harter 1974). Had Engel known this method and applied it, he would have been forced to impose a linear function on the expenditure-income relationship he wanted to estimate. Indeed, least square analysis belongs to the class of parametric estimations which dominated econometrics for much of the 20th century and requires researchers to impose *a priori* assumptions on the functional form to be estimated. More recently, nonparametric techniques have been developed which permit the researcher to estimate the dependence of a variable Y on a variable X without imposing any pre-specified functional form. Statisticians who have contributed to the contemporaneous development of these techniques have occasionally referred to Engel as

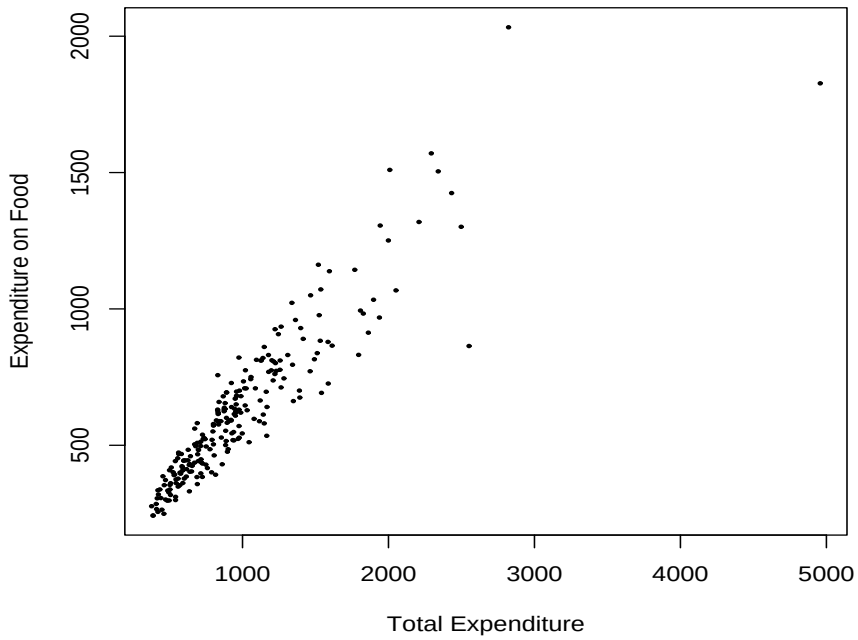

Figure 1: Le Play and Ductpetiaux data on food

a precursor of nonparametric regression method (Härdle 1990, Engel and Kneip 1997). With the aim of re-qualifying this statement, we revisit in this section Engel's estimation method. We find that he indeed came very close to developing a form of nonparametric regression.

Engel investigated the empirical relationship between some expenditure categories and total consumption using Ducpetiaux's (1855) 199 family budgets of Belgian families and Le Play's 36 budgets of workers from all over Europe (Le Play 1855). Figure 1 displays the scatter plot of the data for food expenditure. How did Engel estimate a curve from these data? The first thing to note is that Engel was not interested in graphically representing the data and examining functional relationships in term of curves. No diagram appears in his 1857 article, nor in the 1861 article on the law of demand, nor in the 1895 book. Although the method of representing data in a graph was known before Engel's time (Royston 1970), it was not yet an established tradition in research. Tabulated forms were preferred, probably because they appeared to be more precise. This seemingly inconspicuous aspect has important implications for the estimation of the relationship between expenditure and income. Specifically, using a table format forces the researcher to report the data on a discrete scale. Consequently, any estimation based on tabulated data must itself be discrete.

Engel proceeded to construct a table displaying how three different groups of working-class families allocated, on average, their budget shares across nine categories of expenditures using Ducpetiaux's data (see table 1). However, these three groups of families do not coincide with perfectly separated classes of incomes, as one would expect. Instead, Engel used three socio-economic classes taken from the Ducptetiaux's (1855) study. Although the average income is increasing from the first to the third class, there is some overlap because the wealthiest members belonging to the middle socioeconomic class are not poorer than the poorest member of the upper socioeconomic class. The resulting overlap is clear when looking at the entries of

Table 1: Percentage Composition of Belgian Workmen's Family Budget

Category of Expenditure	Family Type		
	1. On Relief	2. Poor but Independent	3. Comfortable
Nourishment (*Nahrung*)	70.89	67.37	62.42
Clothing (*Kleidung*)	11.74	13.16	14.03
Housing (*Wohnung*)	8.72	8.33	9.04
Heating (*Heizung*) etc.	5.63	5.51	5.41
Tools (*Geräthe*) etc.	0.64	1.16	2.31
Education (*Erziehung*) etc.	0.36	1.06	1.21
Public Safety (*öffentliche Sicherheit*) etc.	0.15	0.47	0.88
Health (*Gesundheitspflege*) etc.	1.68	2.78	4.30
Services (*Dienstleistungen*)	0.19	0.16	0.40
Total (*Bedürfnisse zusammen*)	100	100	100
Average income (francs)	565	797	1198
Average expenditure (francs)	649	845	1214
Minimum expenditure (francs)	370	440	541
Maximum expenditure (francs)	1256	1769	2823

Source: lines 1-10: Table 6 in Engel (1857: 27); lines 11-14: Table 3 in Stigler (1954: 98)

the last two rows of table 1.

From these results, Engel noticed that the way in which households tend to allocate expenditure change when income increases. He came to state the following proposition: "The poorer a family is, the greater is the proportion of its total expenditure that is dedicated to the provision of food" (pp. 28-29). Engel claimed that this proposition should be considered as a "law" inferred from the data by induction. In a footnote he explains that induction permits us to derive meaningful relationships from the simple observation and gathering of data. In this particular case, induction simply consists in classifying observations on households expenditure according to income groups, calculating the average budget share for each group, and giving an interpretation to the resulting estimate.

For the modern reader, this approach has a distinct nonparametric flavor. Specifically, his exercise looks very similar to what is known today as a *regressogram* (Engel and Kneip 1996). The regressogram is a simple nonparametric technique for estimating a conditional expectation. Analogous to the histogram, it divides the X axis into a fixed number of bins, for each of which the local average is calculated. More formally, let $B(k) = [b_{k-1}, b_k)$ be the bins into which the X axis is divided, where $b_k = a + kh$, $k = 1, 2, \ldots$, and a denotes the origin and h the bin size. Let $g(x)$ be $E(Y|X = x)$. The estimation of $g(x)$ by a regressogram turns out to be:

$$\hat{g}(x) = \frac{1}{n_k} \sum_{i=1}^{n} Y_i \, I_{B(k)}(X_i), \tag{1}$$

where $I_{B(k)}(X_i) = 1$ if $X_i \in B(k)$ and $I_{B(k)}(X_i) = 0$ if $X_i \notin B(k)$, and $n_k = \sum_{i=1}^{n} I_{B(k)} X_i$ (i.e. n_k is the number of sample points belonging to bin $B(k)$).

Note that, given the above-mentioned overlap in the socio-economic classes, the manner

Table 2: Engel Curve for Nourishment in Tabulated Form

Annual Income (Francs)	Food Expenditure	
	In Percentage	In Francs
200	72.96	145.92
300	71.48	214.44
400	70.11	280.44
500	68.85	344.35
600	67.70	406.20
700	66.65	466.65
800	65.69	525.52
900	64.81	583.39
1000	64.00	640.00
1100	63.25	695.75
1200	62.55	750.60
1300	61.90	804.70
1400	61.30	858.20
1500	60.75	911.25
1600	60.25	964.00
1700	59.79	1016.43
1800	59.37	1068.66
1900	58.99	1120.81
2000	58.65	1173.00
2100	58.35	1225.35
2200	58.08	1277.76
2300	57.84	1330.32
2400	57.63	1383.12
2500	57.45	1436.25
2600	57.30	1489.80
2700	57.17	1543.59
2800	57.06	1597.68
2900	56.97	1652.13
3000	56.90	1707.00

Source: Col 1-2 are in Table 8 in Engel (1857: 30-31).

in which he chose the bins $B(k)$ does not strictly conform with the regressogram procedure. Another problem with this exercise is that it yields only three different estimations of budget shares across the entire spectrum of income: a rather thin empirical foundation upon which to build an argument about a so-called law.

Engel, perhaps sensing this, presented another table in which the food budget share is shown for 29 — in this case clearly separated — classes of income (see table 2). Engel did not precisely state how he attained these numbers. Indeed, there has been some debate about how exactly Engel derived this new table. Some have understood it as an estimated regression reported in tabular form (van der Wijk 1939; cited in Perthel 1975). However, this is hardly the case, because four of these classes are out of sample: two on the lower end, and two at the higher end. This point was definitively clarified by Perthel (1975), who demonstrated how Engel took two points from the previous estimations belonging to two different and non-adjacent bins. He then calculated the first difference between these two points and divided it

Table 3: Budget shares from Engel (1895).

Category of Expenditure	income 0-80 m.	income 80-100 marks	income 100-120 marks	income 120-200 marks
Nourishment (*Nahrung*)	66.28	66.27	65.80	64.90
Clothing (*Kleidung*)	12.19	14.07	14.96	15.66
Housing (*Wohnung*)	11.51	10.09	8.92	8.79
Heating and Lighting (*Heizung u. Beleuchtung*)	5.07	5.03	5.37	4.59
Health (*Gesundheitspflege*)	0.82	1.03	1.56	1.26
Others	3.54	2.61	3.39	4.77
Total	100	100	100	100

Source: Table 10 in Engel (1895: 96)

into three parts following a geometric rate. In this manner, he attained the estimation of two bins situated between the original points. Having derived estimation for four adjacent bins in this manner, Engel went on to derive the other twenty five estimates by projecting the second difference of the the four estimated points across the spectrum of income in a relatively *ad hoc* fashion. Specifically, the manner in which this projection is made does not seem to adhere to any mathematical formula. The result is a curve which comes to close to being a straight line. This peculiarity may explain why Engel stated that his law "cannot be brought into a precise mathematical formulation" (Engel 1857: 30).

As such, it is true that the method he used in deriving the two points which formed the bases of his table 2 estimations is nonparametric, since he did not impose a functional form to the relationship between food and total expenditure. In particular he did not assume that this relationship should be represented by a straight line. Unfortunately, the manner in which Engel derived the rest of the observations present in this table does not conform to any rigorous (parametric or nonparametric) regression method at all. In particular, it diverges from the regressogram in the arbitrary choice of $g(x)$ for most of the bins $B(k)$. Thus no fully fledged regressogram is present in Engel's original 1857 article.

However, in the later 1895 book where Engel revisits some the results in his original article, a fully fledged regressogram is indeed present. Engel reworked table 2 and made two important changes, one of which is relevant to the regressogram. First, he used an equivalence scale to weigh different families in order to achieve some form of general comparability (originally developed in his 1866 article *Der Preis der Arbeit*). However, this is only relevant for international comparisons of family budgets he made, because every family in the same country has the same weighting. The basic unit by which all families should be measured was called by Engel "Quet" (dedicated to Quetelet). He calculated that the typical Belgian family, consisting of parents and four children, measured 14.10 Quets. The second important change that Engel introduced, in constructing table 3, was that he used income classes rather than social economic classes. This was probably due to Carroll Wright's (1875) approximate translation of his 1857 article (Stigler 1954) in which he reported the socio-economic classes as if they were non-overlapping income classes. Perhaps acting on this misinterpretation, Engel set out to re-estimate the original table 2 with income classes. Hence in this new version, we have a regressogram in which $B(1)$ is composed by families between 0-80 marks of income, $B(2)$ by families between 80-100 marks, $B(3)$ by families between 100-120 marks, $B(4)$ by families between 120-200 marks.

The resulting image of Engel as precursor of nonparametric statistics is quite mixed. As

we have shown, he did eventually use a method that coincides with what is known today as a regressogram. However, this was not in his 1857 article but rather in his 1895 book. Moreover, even in his later work, Engel only used four bins, one more than in the original article. This casts a further shadow on the claim that he was the first in using a form of nonparametric regression, since a rigorously estimated regressogram, given his data, would require a higher number of bins.[2]

What does clearly emerge from Engel's work is a data-driven approach to empirical economics, in which the form of a functional dependence should be inferred from the data and not imposed to the data. This is well in tune, at least in the methodological spirit, with much of the recent nonparametric approaches to the estimation of Engel curves (Engel and Kneip 1996). Thus, the praising remark of Houthakker fifty years ago remains actual: Engel's "successful attempt to derive meaningful regularities from seemingly arbitrary observations will always be an inspiring example to [econometrics] the more so because in his day economic theory and statistical techniques were of little assistance in such an attempt" (Houthakker 1957: 532). Looking at Engel's work and 150-years developments with hindsight, the fact that he could not be assisted by linear-regression methods elaborated some decades after was not a real handicap. He could anticipate, although more in the methodological spirit than in effective techniques, developments in curve estimation that transcended linear regression.

4 The Theoretical Framework

Complementing his empirical method, the theoretical framework Engel constructed around his statistical analysis was also inductive in nature. Specifically, both the method by which he classified the expenditure data for estimation as well as the manner in which he interpreted the results from the estimation are relevant here. A central goal of his work was to measure population living standards (*Volkswohlfahrt*, i.e. public welfare) using consumption data. The main problem he faced in undertaking this task was to discern which types of consumption expenditure, from a very diverse set, may be used to measure individual welfare. That is, given observation of the individuals expenditure on such things as food, accommodation and skiing holidays, which of these should one use to estimate their living conditions? This problem was not negligible given that he undertook this task several decades before income was systematically analyzed in economic theory (Stigler 1954: 102). Moreover, there existed no established method for measuring the welfare level of population in general, let alone doing so via examining consumption patterns. While some crude attempts were made using income as a direct measure of welfare (see Sen 1979), this option would have been self-defeating in Engel's case given that Engel focused on analyzing the conditions of poor workers.

Previously, some headway had been made in developing a distinction between basic and luxury goods contributions (e.g. Cantillon 1755, Smith 1776, Senior 1836). This was done via theoretical conjectures about which goods and services made essential contribution to individual welfare. Adam Smith defined necessities as "food, clothing and lodging, and household furniture,"(Smith 1776: 178). Luxuries, on the other hand, were those good which "nature does not render them necessary for the support of life, and custom nowhere renders it indecent to live without them" (Smith 1776: 869). Hence, if one accepts these fundamental assumption about which goods are vital to the sustenance of life, it is possible to discern whether

[2]The number of bins used in table 2 (29) is the number of bins one should expect in a regressogram with 299 data. But table 2, as shown above, is not a regressogram because it contains only a few bins that reflect local averages.

consumers have attained some critical level of welfare by examining the absolute amount of necessities individuals consume.

Engel had difficulties with these broad statements about which goods are and are not luxuries. He argued that "luxury" is a relative term, and is thus present amongst all types of goods. "The difficulty is in understanding where useful consumption ends and the luxury begins, since there is no such thing as absolute luxury, only relative luxury. It would be a grave mistake to define luxury as only the unproductive use of material goods. Luxury is possible in all spheres of consumption,"(Engel 1857: 5). Thus drawing conclusions about the welfare of consumers from the types of goods they consume is flawed since there will always be certain goods in every category that are luxurious relative to other goods in the same category.

As an alternative, Engel shifted the focus of research away from examining how expenditure is distributes across individual goods consumed, towards focusing on how it is distributed across the consumer's wants (*Bedürfnisse*), which goods ultimates satisfy. These are innate behavioral tendencies, such as hunger, thirst and status seeking, that motivate consumption (Witt 2001). While wants are discussed by a wide range of scholars, such as Menger (1871) and Alfred Marshall (1890: Book III), most of the time they are seen as non-observable entities which play a minor role in consumer theory by accounting for the origins of demand. However, since they represent the fundamental "ends" of consumption, Engel co-opted these into his work via the Smithian notion that the degree to which these wants are satisfied is the ultimate measure of populations welfare. This is evident in how he defines public welfare, where he quoted the German economist Josef Lang: "Every individual is most interested (urged by his inner drive (*Trieb*)) in continuously satisfying those wants that stem immediately from the human nature, in widening them more and more, and in being able to obtain the necessary means for the satisfaction of the wants that are higher expanded. The condition that makes this possible for the inhabitants of a country is the national or public welfare, and the wider the set of opportunities becomes for all the inhabitants, the greater is the welfare"(Lang 1811, cited by Engel 1895: 1).

Consequently, by utilizing the concept of wants, Engel devised a classification method that enabled him to empirically measuring the impact that particular wants have on consumption over a range of observed income. He did so by classifying expenditures into the want for nourishment, clothing, accommodation, heating and light, household goods, spiritual education (education and entertainment), public safety, health and recreation and personal services (Engel 1857: 6). Engel did not create a separate category for travel and trade, reasoning that these type of expenditures are not end purposes in themselves, but that they were done for other purposes, e.g. expenditure on travel contributed to either work or pleasure. As shown in table 4 below, the resulting taxonomy of consumption expenditure was far more detailed relative to standard expenditure taxonomies of the time, where goods were divided into three very broad categories: physical and material expenses, religious and intellectual expenses, luxury and unforseen expenses.[3]

The main theoretical result of his work is thus the fact that it yields evidence about which wants are most relevant to measuring the welfare of consumers (table 4). This was the essential point of devising his famous law. For him, these results revealed a hierarchy amongst wants, where the want for nourishment was the most important want, followed by clothing, accommodation and the want for heating and lighting (Engel 1857: 27).[4] He noted

[3] "Dépense de l'ordre physique et matériel, Dépenses de l'ordre réligieux moral et intélectuel, Dépenses de luxe ou résultant de l'imprévoyance" (Engel 1895: 9).

[4] "...so ist nun eine Scala der Bedürfnisse des Lebens zu Tage gefördert."

Table 4: Classification of Expenditure Categories According to the Wants They Serve

Wants (*Bedürfnisse*)	**Relevant Expenditures**
1. Nourishment (*Nahrung*)	Daily nourishment from meals and beverages, spices, stimulants (e.g. alcohol, coffee), tobacco, occasional dining out, etc.
2. Clothing, Linen, and Toiletries	Clothing and shoes of all kinds; underwear, jewelry and toiletries; clothing accessories.
3. Housing	Shelter, furniture, household appliances; beds and bedding; insurance for housing and furniture.
4. Heating and Lighting	Wood, coal and gas heating; lighting via candles, oil and gas.
5. Appliances and Means for Work	Tools, machines, mechanical instruments; crockery and vessels etc.; all kinds of metal, earths, stones, glass, porcelain, leather, pulp, rubber, etc.; wagons, boats, saddles and equipment etc.; means of communications, etc.
6. Intellectual Education	Education, tuition; church; tools for education, tuition and worship; scientific equipment, literary and artistic production; intellectual rejuvenation and educations, music, theater, etc.; musical instruments .
7. Public Safety	Legal protection; administration; police; state defence; care for the poor etc.
8. Health, Recreation, Self-Maintenance	Medical treatment and pharmaceutical expenses, bathing; outdoor recreation, play, recreational travel.- Life insurance.
9. Personal Service	Personal services attained from use of domestic servants of all kinds.

Source: Engel (1857: 5-6).

that the observed hierarchy is in line with what one typically observes to happen in families experiencing a decline in income levels: When a family can not properly satisfy all their existing wants, they tend to sacrifice the satisfaction of higher order wants in order to satisfy more basic wants. In his thinking, the lowering of income essentially acts like a litmus test on the consumer's priorities, in that it crowds out expenditures related to wants that are less basic, and leaves those expenditures related to more fundamental wants. Therefore, those wants whose expenditure are left at the lowest level of observable income can be understood to be the most urgent. In turn, he reasoned that a rough approximation for public welfare can be attained by investigating how much of the consumer budget is dedicated the want for nourishment, which appeared to be the most basic want (Engel 1857: 50). As a rule of thumb, Engel concluded that the less individuals tended to spend on it, the better off they tended to be.

In his 1895 book, Engel further developed his theory of how wants drove structural change in consumption expenditure. He argued that the origins of wants was linked to the biological evolution of humans in that the same wants seemed to be present amongst all living beings, not

just humans(Engel 1895: 8). A commentator noted that "by his study on consumption alone Engel came to appreciate the modifiable nature of human beings. This is a central thought in modern economics which many students have only recently been coerced into accepting by the triumph of evolutionary philosophy" (Warner 1896). Thus this aspect of Engel's theory can be viewed as an early hint of an attempt to naturalize consumer theory by grounding it in positive scientific knowledge provided by biological science.

From this perspective, it is interesting to note that in spite of how well received Engel's work was in economics and the multitude of work that has since examined Engel curves, very little progress has been made in theoretically accounting for certain properties of the Engel curve such as their shape. Many distinguished scholars have noted the ability of standard theory to account for the shape of the Engel curve (Houthakker 1952: 2, Prais 1952: 88, Aitchison and Brown 1954). Here Engel's use of the notion of wants to explain his findings may yet to prove a significant contribution to economics. His theory suggests that investigating the specific nature of consumer's wants may provide a proper behavioral foundation for understanding the nature of income-expenditure relationships. Since his contribution, various authors have argued that goods and services related to particular wants display distinctive income expenditure patterns: e.g. goods and services related to the want for status (Hirsch 1976, Frank 1999), as well as goods and services related to the want for arousal (Scitovsky 1976). Unfortunately, this work has not yet been developed to stage where their implications for Engel curves have been drawn out.[5] In this sense, returning to a proper consideration of the wants that motivate consumption and of how available goods and services satisfy these wants, one may provide a proper account of how consumption behavior systematically changes over large intervals of income (see e.g. Pasinetti 1981, Witt 2001).

All in all, Engel's approach to empirically measuring individual welfare via expenditure patterns was original not only for the fact that those types of consumption expenditure that were fundamental to welfare were not theoretically derived but were actually inferred from empirical results. Rather, his approach should also be noted for the fact that it contains a classification method, based on the concept of wants, wherein different types of consumption expenditures are aggregated into theoretically significant meta-categories. Although today not much attention is given to classification and aggregation methods, these methods are crucial if scholars are interested, as Engel was, in uncovering empirical regularities directly in the data. The validity of any such uncovered regularities ultimately always rests on the validity of the manner in which scholars classify their data. Indeed, especially with consumption expenditure data where a very large number of categories are involved, the aggregation methods may themselves impose a significant bias on results.[6]

5 Engel's legacy

Given that Engel completed his work some decades before income was systematically analyzed in economic theory and before the linear regression method was established, one could consider the timing of work in some sense 'cursed'. However, we showed how certain aspects of his estimation techniques and theoretical framework that were inspired by his inductive approach turned out to be very original.

In relation to statistical method, parametric techniques became since the first decades

[5] An exception is Heffetz (2008).

[6] Hildenbrand (1994) made clear the idea that aggregation may destroy or create properties that do not necessarily correspond to the disaggregate variables.

of the twentieth century the predominant econometric method for Engel curve estimation. Interestingly, they turned out to have major difficulties in dealing with the heterogeneity of household expenditure patterns across categories of goods, time and geographic locations (Härdle and Jerison 1991, Engel and Kneip 1996). Moreover, it was not clear how the correct functional form required in parametric estimations could be derived from standard consumer theory. Since the 1980s, it was increasingly recognized that nonparametric methods, by not requiring researchers to impose a priori a functional form on the estimates, are more flexible in tackling both heterogeneity and the lack of information about the correct functional form. Hence, Engel's original method is closer in spirit to current nonparametric techniques rather than parametric methods which predominated the twentieth century.

In terms of the twentieth century developments in consumer theory, here again there is little to support the idea that Engel's work would have benefited from the emergence of standard microeconomic consumer theory. Its main focus on how consumer demand reacts to marginal price changes is not relevant for the analysis of Engel curves, which is concerned with how consumption changes with very large changes in income (Prais 1952). To account for the shape of Engel curves, one requires a deeper comprehension of the manner in which consumer tastes vary with income levels. In this task, Engel's own use of the concept of wants may well yet turn out to be a salient precursor to a theory of consumption that can in future deliver a proper theoretical account for the shape of Engel curves.

All in all, Engel's article is an artifact of the dawn of an era in which economic analysis matured significantly and gritty, hard-nosed empirical research become almost as important as deductive armchair theorizing. Nevertheless, this emerging union between theory and data was couched solely in an *apriorist* approach: scholars were first required to devise a theory before doing any testing. In this sense, Engel's work went beyond an as-yet-to-be established tradition to show how this union may look like in an inductive approach. Hence Engel did not only discover one of the most robust empirical regularity ever found in the modern economics: he also devised an empirical method and theoretical framework wherein unique synergies between inductive logic, empirical data and economic theory were created.

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