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FOUR LAWS OF CONSUMPTION

by

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Abstract

Scientific knowledge can be distilled into a set of laws that are sufficiently general and robust to be useful in describing and predicting behaviour – the behaviour of physical objects (the orbit of the planets, for example), invisible forces (electricity), economies (why some prosper and others languish) and people (education as deliberate investment in human capital). This paper identifies four empirical regularities in consumption behaviour that are sufficiently general and pervasive to qualify as "laws": Engel's law; the law of demand (the downward-sloping demand curve); quantities more dispersed than prices; and the "law" of -½ for price elasticities. In each case, I survey previous research; use international evidence to illustrate the workings of the laws; and demonstrate their practical use in applied economics.

[1] This paper is in part based on my Shann Memorial Lecture, UWA, September 2018. It draws on research I have undertaken over a lengthy period in collaboration with PhD students and others, including Dongling Chen, Grace Gao, Yihui Lan, Haiyan Liu, Antony Selvanathan, Saroja Selvanathan, and Jiawei Si. I have benefitted greatly from this productive collaboration. I also wish to acknowledge helpful comments from and discussions with Peter Hartley, Izan, Robert Leeson, Michael McLure, Tom Simpson, Jill Trinh, Long Vo and Juerg Weber, as well the feedback from participants at Vietnam's Business and Economics Research Conference (VBER2018), Ho Chi Minh City, July 2018, and those at the Shann Lecture. I appreciate the excellent research assistance of Jiawei Si, my long-time RA (of about 10 years) and co-author who sadly passed away in 2018; and Tom Simpson, Long Vo and Vu Vuong. Thanks also to the ARC and BHP for their long-term financial support.

I. INTRODUCTION

There are various types of laws, including:

- Physical laws: Earth orbits around the sun once every 365 days. And the earth's rotation takes 24 hours -- although it is reported the day is getting shorter as the moon is getting closer and the earth is speeding up its rotation.
- Law of the jungle: Kill or be killed. Examples are still observed today – cage fighting and economics seminars at some universities.
- Laws of good behavior: Treat people with respect. For example, pick up after your dog, don't walk on the grass and don't talk on your mobile phone at the gym.
- Legislated law: Drive on the left-hand side of the road (in Australia).
- Theological law: These laws are set out in the scriptures such as the Bible and the Koran. For example, don't work on the Sabbath.
- Parkinson's law: Work expands to fill up the time available.
- Murphy's law: Anything that can go wrong will go wrong.

In science, laws govern behavior – they provide some type of reliable guide to what might happen in the future. If economics is to qualify as a science, it should be useful in understanding how behavior responds under different economic circumstances. An example is by how much smoking would fall following a substantial increase in tobacco taxes. In other words, for it to be a science, economics should have its own laws. In this paper I demonstrate how important aspects of consumption behavior are now sufficiently well-understood that they can be summarised in the form of four laws.

Prior to turning to consumption economics, it is useful to briefly consider the broader perspective by discussing the views of the grand masters, who, understandably, differ considerably in their approach to the laws of economics. Adam Smith (1776) does not explicitly talk in terms of "laws", but the idea is arguably central to The Wealth of Nations. Take as an example the gains from trade, about which Smith writes: "Trade which… is naturally and regularly carried on between any two places is always advantageous, though not always equally so, to both." Mutual gain as the basis for trade could well be regarded as a type of law. There is also the famous pin factory example that demonstrates the powerful idea of the gains from specialisation, which can be interpreted as a "law of specialisation and productivity".

In Das Kapital, Karl Marx (1867) proposes the "laws of motion of capitalism" whereby the rate of profit falls and capitalism sows the seeds of its own demise. The downfall of capitalism is inevitable. Alfred Marshall (1920) has a chapter of Principles entitled "Economic Generalisations or Laws". He writes

> The laws of economics are to be compared with the laws of the tides, rather than with the simple and exact law of gravitation. … Economic laws [are] statements of economic tendencies.

As it deals with the behaviour of human being, perhaps Marshall felt economics was more difficult than physics, but nonetheless sufficiently scientific that there were well-defined laws.

Paul Samuelson (1947) introduces "meaningful theorems" – for theory to be useful, it must have implications that can be capable of being refuted by evidence. Examples are symmetry of the substitution effects, the correspondence principle (from comparative statics to dynamics) and so on. It is easy to imagine Samuelson wanting to endow his theorems with status of laws.

Milton Friedman likes to talk in terms of "positive economics", rather than the "laws of economics", but the two terms mean the same thing. For example, Friedman (1953) writes:

> Economics as a positive science is a body of tentatively accepted generalisations about economic phenomena that can be used to predict the consequences of changes in circumstances.

Thus, change X (by imposing a tax on a good, say) and behaviour can be expected to change to $Y + \Delta Y$ (consumption of the good, $\Delta Y < 0$). Friedman (1953) also notes the important distinction between the positive and the normative:

> Laypersons and experts alike are inevitably tempted to shape positive conclusions to fit strongly held normative preconceptions and to reject positive conclusions if their normative implications – or what is said to be their normative implications – are unpalatable.

The laws of economics deal with what is, not what ought to be.

As will become clear from what follows, my interpretation of the laws of consumption is that they have an important quantitative component, rather than being predominantly qualitative; theorems per se do not constitute laws. These laws embody theory, but also are supported by considerable accumulated experience and evidence. In other words, the laws of economics should be useful in understanding the way economies work, and useful in a way that can be expressed numerically, or quantitatively.[2] Four laws of consumption are discussed in this paper. The first, perhaps the most famous, is Engel's law regarding food consumption (Section II). Then comes in Section III the law that quantities tend to be more volatile than prices. It is demonstrated this well-established empirical regularity can be given an analytical foundation. The law of demand – demand curves slope down – is discussed in Section IV. The last "law" is that price elasticities are -½ (Section V). As indicated by the inverted comas, this is not really a law in the same sense that the other three are. Rather, it is a useful guide to the price sensitivity of goods that are broad aggregates without major substitutes. Again, this has

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[2] For related material, see Gabaix (2016), Klein (1983), Klein and Kosobud (1961) and Simon (1990).

analytical foundation, as discussed in this section. When presenting each laws, I include supporting evidence, where possible emphasising new cross-country findings. While Engel's law and the law of demand are, of course, well-known, here I provide a fresh – and, I hope, revealing – perspective. For these and the other laws, the treatment is part survey and part demonstration/application that throws new light on them and their uses in applied economics.[3] Section VI contains concluding comments that discusses the general nature of laws in economics and how they evolve over time.

II. LAW 1: ENGEL'S LAW

II.1 Food Consumption across Countries

Figure II.1 shows the weekly food consumption of two families of roughly the same size in a poor and a rich country, Chad and Norway. The contrast is extreme. Not only is there substantially more food in Norway, there is more variety, more colour and it looks more appetising. Although there is less food in Chad, its cost as a proportion of total consumption spending (51 percent) is much higher than that in Norway (11 percent). This vividly illustrates Engel's (1857) law that the share of spending on food declines as income rises. Of course, higher income means increased spending on food of superior quality that costs more, but this is unlikely to reverse the overall decline of the food share. Engel's law is possibly one of the strongest of all laws of economics.[4]

The decline in the food share means spending rises at a slower rate than income, that is, the income elasticity of food demand is less than unity. Thus, an equivalent way of stating Engel's law is that the food income elasticity, η, is less than unity, or that the good is a necessity. Numerous studies have found $\eta < 1$, the classic reference being Houthakker (1957). Table II.1 provides information on incomes and food in a large number of countries in 2005, from Gao (2012). As per capita income falls (as we go down the table) the food share has a strong tendency to rise, in agreement with Engel's law; and in the vast majority of cases, the food income elasticity is substantially less than unity. Figure II.2 shows a similar result with the more recent data from the 2011 round of the International Comparison Program (hereafter, ICP) of the World Bank (2015): In the poorest countries the food share is 50 percent or more, while in the richest it falls to around 10 percent.[5]

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[3] After commencing this paper, I found Kindleberger's (2009) book dealing with Engel's law, the iron law of wages, Gresham's law and the law of one price. This might seem to be similar to this paper, but there is a big difference. Kindleberger's approach is verbal and non-quantitative.

[4] For research related to Engel's law, see Chai and Moneta (2010), Chakrabarty and Hildenbrand (2011), Gao (2012), Houthakker (1987) and Ogaki (1992). Stigler (1954) discusses the history of Engel's law.

[5] Of the 182 ICP countries, we use 176. We omit (i) the duplicate entries for Russia, Sudan and Egypt; (ii) Cuba and Bonaire as they have incomplete data; and (iii) Algeria as there are issues its data. Note also that food is the

II.2 The Basis of Engel's Law

Some insight into Engel's law is given by the simple linear case. When prices are constant, food expenditure, e, depends on income, M, that is, $e = e(M)$. The food share is $w = \frac{e}{M}$ with $dw = (\eta - 1)w\frac{dM}{M}$, so that *w* falls with income growth when the elasticity $\eta < 1$. In the simplest possible case of proportionality, $e = \beta M,\ \beta > 0$, Engel's law is not satisfied as $\eta = 1$, and the food share is constant and equal to β. When some part of food expenditure is independent of income the elasticity is less than unity:

$$e = \alpha + \beta M,\ \ \alpha, \beta > 0, \qquad \eta = \frac{\beta}{\frac{\alpha}{M} + \beta}, \quad 0 < \eta < 1.$$

As income rises, so does spending on food, but not at the same rate as income and the food share falls. The α-part of food expenditure might be interpreted as the cost of "subsistence" consumption, perhaps something like the cost of 2,500 calories per day needed to sustain life, or the \$1.90-per-day poverty line of the World Bank. Roughly speaking, it is this subsistence food requirement, more or less independent of income, which is at the heart of Engel's law.

II.3 The Strong Version of the Law and its Reciprocal

Returning to the Chad-Norway comparison, the food share and income in the two countries are

	Food share (Percentage)	Income (\$US per capita)
Chad	51	2,000
Norway	11	62,000
Difference	-40	60,000
Ratio $\frac{\Delta share}{\Delta \log log\ (income)}$	$\frac{-40}{\log log\ 62{,}000 - \log log\ 2{,}000} =- 11.7$	

The difference in the share, relative to the logarithmic income difference, is -11.7. Interestingly, this is not too far from the mean this ratio for all possible pairs of the 176

combination of two ICP categories, (i) Food and nonalcoholic beverages; and (ii) Alcoholic beverages, tobacco, and narcotics.

countries of -11.9, as revealed in Figure II.3. Figure II.2 shows the food share declining arithmetically as income rises geometrically, that is

(II.1)
$$w = \alpha + \beta \log log\, M, \quad \beta <$$

This is Working's (1943) model, according to which if we compare a rich country *c,* with income M_c, to a poor one *d*, which is one-half as affluent, $M_d = \frac{1}{2} M_c$, the difference in the shares is

$$w_c - w_d = \beta\left(\log log\, M_c - \log log\, M_d\right) = \beta \log log\, 2.$$

For the value of the slope coefficient β, we shall use $-\ 15$, which is not too different from the mean ratio of Figure II.3. Thus, as $\log log\ 2 = 0.69$, $w_c - w_d = - 15 \times 0.69 \approx -\ 10$. In words, <u>a doubling of income leads to a 10-percentage-point decline in the food share</u>. This is the strong version of Engel's law due to Theil et al. (1989).

The strong law can be used to infer differences in incomes from the food shares. This may be used in the realistic situation in which there is fairly reliable data on food consumption, such as that from a household survey, but lower-quality (or no) information on income. The fall in Norway's share relative to Chad's is 40 percentage points, which is a decline by 10 points four times over. If the strong law applies for each doubling of income, the implication is that Norway's true income is double Chad's four times over, or a multiple $2^4 = 16$. Contrast this with the income multiple based on market exchange rates of $\frac{62{,}000}{2{,}000} = 31$.

The above argument is illustrated in Figure II.4, where for countries other than Norway, food expenditure is governed by equation (II.1), as represented by the solid line. The point C represents the observed food share and income of Chad, while N is that of Norway. Bringing Norway onto the Engel curve by moving it from the point N to N' entails an almost 50-percent reduction in its measured income from \$62,000 to $\$2,000 \times 16 = \$32,000$ per capita. For Norway, the share is $\varepsilon > 0$ larger than predicted by (II.1), that is, $w = \alpha + \beta \log log\, M + \varepsilon$, so that relative to the Engel curve, Norway's income is overstated by a multiple $\exp exp\left(-\frac{\varepsilon}{\beta}\right) = \exp exp\left\{\log log\left(\frac{62{,}000}{32{,}000}\right)\right\} = 1.94$, or by 94 percent. Although this is only an illustrative example, the difference between Engel-adjusted and measured income represents in part the known characteristic of the currencies of rich countries like Norway to be overvalued, while those of poor countries tend to be undervalued (Balassa, 1964, Samuelson, 1964).

Engel's law can be used as a type of benchmark for the relationship between the food share and income. A substantial departure from the Engel curve can then be interpreted as saying "something else" is taking place. The approach described above identifies that "something else" as an overstatement of income caused by the use of market exchange rates to convert incomes in the two countries into a common currency. This is based on the reasonable assumption of no (or only modest) mismeasurement of the share relative to that of income. This approach can be extended to account for the influence of relative prices on the food share and the composition of the consumption basket, as in Chen and Clements (2010). In other research, the departure from the Engel curve is ascribed to mismeasurement of real income when using the CPI as the deflator. This is usually an understatement of real income as the CPI overstates the price level due to substitution and quality biases; see Costa (2001), Hamilton (2001) and Nakamura (1996).[6] Additionally, the food share itself has been used as an inverse measure of welfare; see, e. g., Orshansky (1965, 1969), Rao (1981) and Van Praag et al. (1982).

II.4 Food and the Cost of a Child

The forerunner to the above methods is the so-called Engel (1895) approach to measuring the cost of a child. To briefly explain the approach, let N_h be the number of children in household h and suppose the share of income devoted to food rises by $\gamma > 0$ percentage points when a child is added to the household. Thus, we extend model (II.1) by adding the number of children:

$$w_h = \alpha + \beta \log log\, M_h + \gamma N_h.$$

When the number of children in the household rises by 1 and income remains unchanged, the food share increases by $\Delta w_h = \gamma$. The cost of a child answers the question, What increase in income would be required to offset the higher spending on food by holding the share unchanged? This is M_h implied by $\Delta w_h = \beta M_h + \gamma = 0$, or $M_h = -\frac{\gamma}{\beta}$. For example, if the share rises by 1.5 percentage points per child and $\beta = -0.15$, then $M_h = \frac{0.015}{0.15} = 0.1$. Thus, the cost of the child is about 10 percent of income, which would seem not unreasonable.

While simple and still widely employed, the Engel approach is subject to some limitations, including the uncritical identification of the food share with welfare, the assumption that the coefficient of income, β, is the same for all households, and the assumed

[6] For related work, see Almås (2012), who uses Engel curves to analyse the bias in the estimates of income of the Penn World Table, and Nakamura et al. (2016).

identical cost for each additional child (no hand-me-downs). For references to the Engel approach, criticisms and alternatives, including the influential Barten (1964b) model, see Deaton (2016) and Deaton and Muellbauer (1986). As noted by Deaton and Muellbauer (1980b, p. 205), a general formulation of the cost of a child is via the cost function: If $C(u_0, p_0, N_0)$ is the cost function for some reference utility u_0, given the price vector p_0 and number of children N_0, then a constant-utility index of the cost of an additional child is $\frac{C(u_0, p_0, N_0+1)}{C(u_0, p_0, N_0)}$. If this index takes the value 1.075, for example, the cost of the $(N_0 + 1)^{th}$ child is 7.5 percent of income.

III. LAW 2: QUANTITIES ARE MORE VOLATILE THAN PRICES

III.1 Sticky Prices in Macroeconomics

An important stylized fact of macroeconomics is that prices are sluggish, or sticky – prices take time to adjust to shocks and so quantities do most of the adjusting.[7] This means the dispersion of quantities exceeds that of prices. The consequences of price stickiness are profound. Keynes argued in the General Theory that as wages are rigid downwards, increased spending by government would be unlikely to push up wages (and thus prices), but lead to additional output and employment. Sticky prices are the basis for a downward-sloping Phillips curve that is at the heart of most macro models used in policy-making today: Output responds positively in the short term to stimulus provided by, say, a larger budget deficit, while inflation remains more or less subdued. All this changes over the longer term as continued stimulus causes output to hit capacity constraints and inflation to take off, as discussed by Friedman (1968). This begs the question, how long is the long run? Following the global financial crisis in 2008, many countries have undertaken large-scale program of monetary and fiscal expansion. That subsequent inflation has been mostly subdued would seem to indicate the transition the long run can take a long time.

There are two main explanations of sticky prices. The first is the old-favourite "menu costs": Price are left unchanged for some finite period simply because changing them is costly -- new menus have to be printed in the case of a restaurant, an activity supposed to absorb time and money. Menu costs should not be interpreted literally and could include, for example, the difficulty of customers accepting/understanding the new pricing schedule, or informal pressures from regulators not to raise prices. In these situations, pricing involves an intertemporal optimisation problem: Only when the cost, in present-value terms, of foregone

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[7] For a survey of evidence regarding sticky prices, see Klenow and Malin (2010).

profit from not adjusting exceeds the menu costs, do prices get changed. The overall price level being an average of all prices -- some fixed, some not – is thus sticky.

The existence of contracts of finite length is a second reason for sticky prices. Many businesses negotiate with representatives of the workforce to set pay and conditions on a year-to-year basis. Any underseen circumstances arising during the currency of an agreement, such as a sudden surge in inflation, are absorbed by either/both parties until the next agreement. Firms and customers may have similar contractual arrangements for holding prices unchanged over the planning horizon. Obviously, not all prices in the economy are governed by these types of agreements, and not all contracts mature at the same time, but as before, the price level will be sticky as it is an average over all types of prices.[8]

III.2 <u>A Stochastic Commodity Market</u>

The higher volatility of quantities can also emerge in the case of a single commodity in a stochastic setting. For a certain commodity, consider a simple log-linear model of demand and supply:

$$\log log\, q^d = \alpha + \beta \log log\, p + \varepsilon, \quad \log log\, q^s = \gamma + \lambda \log log\, p + \eta,$$

where $\beta < 0$ is the demand elasticity of demand; $\lambda > 0$ the supply elasticity; and ε and η are independent, zero-mean disturbances with covariance matrix

$$var[\varepsilon\, \eta\,] = \left[\sigma_\varepsilon^2\; 0\; 0\; \sigma_\eta^2\right].$$

Let $\log log\, q^d = \log log\, q^s = \log log\, q$ and define $\theta = \frac{\lambda^2\sigma_\varepsilon^2}{(\beta-\lambda)^2} > 0$. The above model implies

$$var[\log log\, q\;\; \log log\, p\;] = \theta\left[\lambda^2 + \beta^2\psi\,\lambda + \beta\psi\,\lambda + \beta\psi\; 1 + \psi\,\right], \qquad \psi = \frac{\sigma_\eta^2}{\sigma_\varepsilon^2};$$

and so the dispersion of quantities relative to prices is

$$\frac{var(\log log\, q\,)}{var(\log log\, p\,)} = \frac{\lambda^2+\beta^2\psi}{1+\psi}.$$

When the supply shocks are small relative to those in the demand equation, the ratio of disturbance variances, ψ, is small and λ^2, the square of the supply elasticity. Thus, when the price sensitivity of supply is large ($\lambda > 1$), the ratio of the quantity variance to the price variance is similarly large in the situation in which demand shocks dominate.

Figure III.1 illustrates the case of a shifting demand curve with the supply curve unchanged, which agrees with the idea of more shocks hitting demand as compared to supply

[8] Prominent papers in the area of sticky prices include Calvo (1983), Fischer (1977), Mankiw and Reis (2002), Taylor (1980) and Rotemberg (1982).

shocks. When the supply curve is relatively flat (elastic supply), the shocks to the market give rise to a large quantity dispersion, while the price is more stable.

III.3 Divisia Moments of Prices and Quantities

The dispersion of consumer prices and quantities can be formulated elegantly in terms of index numbers as follows. Let p_i be the price of good i $(i = 1, ..., n)$ and q_i be the corresponding quantity demanded, so that $M = \sum_{i=1}^{n} p_i q_i$ is total expenditure and $\frac{w_i = p_i q_i}{M}$ is the budget share of i. The change in income is $dM = \sum_{i=1}^{n} p_i dq_i + \sum_{i=1}^{n} q_i dp_i$ or, using $d(\log log\, x) = \frac{dx}{x},\ x > 0,$

$$d(\log log\, M) = d(\log log\, P) + d(\log log\, Q), \qquad \text{(III.1)}$$

where

$$d(\log log\, P) = \sum_{i=1}^{n} w_i d\left(\log log\, p_i\right), \quad d(\log log\, Q) = \sum_{i=1}^{n} w_i d\left(\log log\, q_i\right), \qquad \text{(III.2)}$$

are Divisia (1926) price and volume indexes. These indexes weigh each price (quantity) change by its relative economic importance as measured by its budget share, so it contributes to the index in a representative manner. From equation (III.1), these indexes satisfy the factor reversal test that their (logarithmic) sum equals the change in income, so there is a clean split of the nominal change in income into price and volume components.

The indexes (III.2) are formulated in continuous-change form and there are many ways of making discrete approximations to compare, say, prices of period *t* with those of *t-1*. A popular approach, advocated by Theil (1967) in particular, is to replace (i) budget shares with their arithmetic averages over the two periods, $\overline{w}_{it} = \frac{1}{2}\left(w_{it} + w_{i,t-1}\right)$; and (ii) infinitesimal changes in logarithms with log-changes, $\log log\, p_{it} - \log log\, p_{i,t-1} = \log log\, \frac{p_{it}}{p_{i,t-1}}$, and similarly for quantity changes. Defining the log-change operator $Dx_t = \log log\, \frac{x_t}{x_{t-1}}$, the finite-change indexes are then

$$DP_t = \sum_{i=1}^{n} \overline{w}_{it} Dp_{it} \quad and \quad DQ_t = \sum_{i=1}^{n} \overline{w}_{it} Dq_{it}. \qquad \text{(III.3)}$$

In an influential paper, Diewert (1976) shows that the price index DP is exact for the nonhomogeneous translog cost function evaluated at the geometric mean of utility in the two periods. As the translog is a second-order approximation to an arbitrary twice-differentiable cost function, Diewert terms the price index DP "superlative". The index DQ possesses analogous properties.[9]

A different interpretation/justification of the price index DP is along sampling lines (Theil, 1967, pp. 136-37). Consider a discrete random variable X_t which can take the n values $Dp_{1t}, \cdots, Dp_{nt}$. Suppose prices are drawn at random from this distribution such that each dollar of expenditure at a time mid-way between t and $t-1$ has an equal chance of being selected. This means that the probability of drawing Dp_{it} is $\overline{w}_{it}$, and so the expected value of X_t is $E(X_t) = \sum_{i=1}^{n} \overline{w}_{it} Dp_{it}$, which is the index DP. In words, the index has the interpretation as the expected value of the distribution of logarithmic price relatives. The quantity index DQ can also be given a similar interpretation.

The indexes (III.3) can be considered as weighted first-order moments of the distribution of price changes, $Dp_{1t}, \cdots, Dp_{nt}$, and quantity changes, $Dq_{1t}, \cdots, Dq_{nt}$. The corresponding second-order moments are

$$\sigma^2_{pt} = \sum_{i=1}^{n} \overline{w}_{it}\left(Dp_{it} - DP_t\right)^2 \quad and \quad \sigma^2_{qt} = \sum_{i=1}^{n} \overline{w}_{it}\left(Dq_{it} - DQ_t\right)^2. \tag{III.4}$$

When each price grows at the same rate, $Dp_{it} = DP_t$, $i = 1, \cdots, n$, and the variance $\sigma^2_{pt} = 0$; in all other cases $\sigma^2_{pt} > 0$. This σ^2_{pt} measures the cross-commodity dispersion of prices changes, or the degree to which they move disproportionately, and is known as the Divisia price variance.[10] Similarly, σ^2_{qt} is the Divisia quantity variance.

III.4 Cross-Country Evidence

The above indexes are expressed in terms of changes from one period to the next. But they can equally be applied to differences between countries. To compare consumption patterns in country c with some other country d, we could make this comparison from the point of view of either country. A choice that treats each country symmetrically is mid-way between the two in the sense of using in the indexes the weight $w_{i,cd} = \frac{1}{2}\left(w_{ic} + w_{id}\right)$, the average of the budget shares in c and d. Thus, the indexes (III.3) become

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[9] For related approximation results, see Kloek (1967) and Theil (1967, 1975/76). Diewert tends to refer to DP and DQ as Törnqvist-Theil indexes, after Törnqvist (1936) and Theil (1965, 1967). For more on Divisia indexes, see Balk (2005) and Hulten (1973).

[10] In the extensive literature on inflation and relative prices, starting with Parks (1978), t is a frequently used measure of relative price variability.

$$DP_{cd} = \sum_{i=1}^{n} w_{i,cd} Dp_{i,cd} \quad and \quad DQ_{cd} = \sum_{i=1}^{n} w_{i,cd} Dq_{i,cd},$$

where $Dp_{i,cd} = \log log\, p_{ic} - \log log\, p_{id}$ and $Dq_{i,cd} = \log log\, q_{ic} - \log log\, q_{id}$ are the price and quantity log-differences between the two countries. This DP_{cd} is an index of the overall level of prices in *c* as compared to those in *d*, while DQ_{cd} compares quantities in the two. The variances become

$$\sigma^2_{p,cd} = \sum_{i=1}^{n} w_{i,cd} \left(Dp_{i,cd} - DP_{cd}\right)^2 and \ \sigma^2_{q,cd} = \sum_{i=1}^{n} w_{i,cd} \left(Dq_{i,cd} - DQ_{cd}\right)^2. \quad \text{(III.5)}$$

which compare the dispersion of prices and quantities in *c* relative to *d*.

We implement the variances (III.5) with the same data from the 2011 round of the ICP (World Bank, 2015), referring to $n = 9$ goods in 176 countries.[11] Figure III.2 contains the results in the form of the standard deviations of quantities, $\sigma_{q,cd}$, on the vertical axis and that of prices, $\sigma_{p,cd}$, on the horizontal. As can be seen, in the vast majority of cases, the points lie above the 45°-degree line, implying that the dispersion of quantities exceeds that of prices.

Table III.1 presents a summary of the results with countries grouped into income quintiles. The element in the top left-hand corner of panel A refers to the average dispersion of quantities in countries belonging to the richest quintile, as compared to those in the second richest. Here, the logarithmic standard deviation ($\times 100$) is 56.06, or $100\left(e^{0.5606} - 1\right) = 75$ percent. As we move to the right across the first row and compare countries more distant apart on the income scale, dispersion increases, as is to be expected. As countries get poorer, there is a tendency for dispersion to also increase when countries in immediately neighbouring groups are compared (move down the sub-diagonals). Price dispersion is more stable across the income distribution, as revealed by panel B. Accordingly, the ratios of quantity to price dispersion, given in panel C, tend to reflect the pattern of quantity dispersion. Importantly, each of the ratios is well above unity and some exceed 2, which is another manifestation of the result that quantities are more volatile than prices. Panel D of this table will be discussed in the next section.

[11] The ICP identify 12 categories of consumption which we combine into 9, viz., (1) Food and alcohol (the combination of two ICP categories, as mentioned previously); (2) Clothing and footwear; (3) Housing and utilities; (4) Furnishings, equipment; (5) Health; (6) Recreation and culture; (7) Education; (8) Restaurants and hotels; and (9) Miscellaneous goods and services (which includes two ICP categories, Transport and Communications).

The greater volatility of quantities is not an isolated finding. A number of other studies have identified exactly the same result in both cross-country and time-series contexts.[12] The discussion at the start of this section in terms of relatively greater shocks to the demand side of the market, coupled with an elastic supply, provides an explanation for this finding. In view of the consistency of findings, it seems reasonable to endow the empirical regularity of more dispersed quantities with the status of a law of consumption economics.

IV. LAW 3: DEMAND CURVES SLOPE DOWN

IV.1 Why the Downward Slope?

When a good becomes relatively more expensive, consumers have an incentive to move away from the good and purchase substitutes in its place, as in Figure IV.1. The availability of substitutes is the fundamental reason for the downward-sloping demand curve when real income remains unchanged. If the consumer's money income remains unchanged, the price increase reduces real income, and for most goods ("normal" goods that have a positive income elasticity), consumption of the good falls further and the demand curve becomes flatter. The higher price reduces the consumer's feasible set, which usually results in a cut-back in consumption of the good.

The negative relation between the price and quantity demand is known as the law of demand, which has a long history going back at least as far as the late 1600s with the work of King and Davenant on the demand for wheat, as discussed by Evans (1967) and Stigler (1954, pp. 103-104); Stigler (1954, p. 105) also contains a brief review of the subsequent history of the law of demand. The well-known exception to the law is the case of the Giffen good, when the good is inferior and the income effect of a price increase is sufficiently strong to offset the substitution effect. This was once thought to fit the facts regarding potatoes in the 19th century Ireland, but the practical significance of Giffen goods is doubtful.[13] Of course, when *real*

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[12] See Chen (1999), Clements (1982), Clements and Selvanathan (1994), Finke (1985), Meisner (1979), Selvanathan (1993), Selvanathan and Selvanathan (2003), Theil (1967), Theil et al. (1981) and Wong et al. (2017), among others.

[13] It should be noted, however, Jensen and Miller (2008) find evidence of Giffen behaviour from a field experiment with rice consumption of poor households in Hunan, China. To emphasise the previous absence of convincing evidence of the existence of Giffen goods in practice, Jenson and Miller (2008) quote Stigler (1966) on the status of the law of demand: "If an economist were to *demonstrate* its failure in a particular market at a particular time, he would be assured of immortality, professionally speaking, and rapid promotion while still alive. Since most economists would not dislike either reward, we may assume that the total absence of exceptions is not from lack of trying to find them." (Stigler's emphasis.) In light of Jenson and Miller's finding regarding rice consumption, Stigler's skepticism of Giffen goods is probably too strong, but not totally without merit. For a further discussion of Giffen goods in theory and practice, see Dougan (1982), Dwyer and Lindsay (1984), Koenker (1977), McDonough and Eisenhauer (1995), Rosen (1999) and Stigler (1947).

income remains constant, there is only the substitution effect of a price change, which is always negative: The real-income-constant demand curve *always* slopes down.[14]

The material that follows provides some evidence on the law of demand with, first, an index-number approach, and then some simple price-quantity relationships, using cross-country data in both cases.

IV.2 <u>The Divisia Price-Quantity Correlation</u>

The previous section compared consumption patterns of 9 goods in 176 countries by considering the pairs of countries $\{c, d\},\ c < d,\ c, d = 1, \cdots, 176$. To briefly recap, the difference between the price level in countries *c* and *d* is $DP_{cd} = \sum_{i=1}^{9} w_{i,cd} Dp_{i,cd}$, where $w_{i,cd} = \frac{1}{2}\left(w_{ic} + w_{id}\right)$, the average of the budget share of good *i* in *c* and *d*; and $Dp_{i,cd} = \log log\, p_{ic} - \log log\, p_{id}$, the log-difference of the i^{th} price. An analogous measure is used for the comparison of quantities, $DQ_{cd} = \sum_{i=1}^{9} w_{i,cd} Dq_{i,cd}$, with $Dq_{i,cd} = \log log\, q_{ic} - \log log\, q_{id}$. The corresponding measures of dispersion of prices and quantities are the Divisia variances, $\sigma^2_{p,cd}$ and $\sigma^2_{q,cd}$, given in equation (III.5) with $n = 9$. There is also the Divisia price-quantity covariance and the correlation counterpart:

(IV.1) $$\sigma_{pq,cd} = \sum_{i=1}^{9} w_{i,cd}\left(Dp_{i,cd} - \log log\, P_{cd}\right)\left(Dq_{i,cd} - \log log\, Q_{cd}\right),\quad \frac{\sigma_{pq,cd}}{\sqrt{\sigma^2_{p,cd} \bullet \sigma^2_{q,cd}}}.$$

To interpret the measures in (IV.1), write the comparative price level explicitly as the difference between the price level in the two countries as $\log log\, P_{cd} = \log log\, P_c - \log log\, P_d$. The price term of the covariance can then be expressed as $Dp_{i,cd} - \log log\, P_{cd} = \log log\, \frac{p_{ic}}{P_c} - \log log\, \frac{p_{id}}{P_d}$, which is the difference in the relative price of the good in each country. Similarly, $Dq_{i,cd} - \log log\, Q_{cd} = \log log\, \frac{q_{ic}}{Q_c} - \log log\, \frac{q_{id}}{Q_d}$, the difference in the deflated quantity, where deflation can be interpreted as controlling for the impact of differing incomes in the

[14] Becker (1962) shows that a negatively sloped demand curve can -- and is even likely to -- emerge even if consumers are not a conventional utility-maximisers, but impulsive, inert or anywhere in between the two extremes. Becker's lucid demonstration revolves around the change in the opportunity set faced by all consumers when a price increases *and* when real income is held constant.

Following a price rise, demand may increase if future prices are expected to rise even more (think of housing booms). Does this violate the law of demand? For this to occur the good must be storable, that is, an asset. As the law of demand applies to nondurable commodities, not to assets, there is no violation.

form of $\log log\ Q_{cd} = \log log\ Q_c - \log log\ Q$. The law of demand says that a higher price usually leads to lower consumption of the good, which in a cross-commodity context, can be taken to mean those goods with higher relative prices usually experience lower consumption and vice versa.

In a cross-commodity, cross-country context, measures of the relative price of good *i* and its relative consumption in country *c* as compared to that in *d* are:

$$\log log\ \frac{p_{ic}}{P_c} - \log log\ \frac{p_{id}}{P_d} \quad and \quad \log log\ \frac{q_{ic}}{Q_c} - \log log\ \frac{q_{id}}{Q_d}. \tag{IV.2}$$

When the relative price of good i is more expensive in country *c* than in d, $\log log\ \frac{p_{ic}}{P_c} - \log log\ \frac{p_{id}}{P_d} > 0$, and according to the law of demand, relative consumption of the good usually will be lower in *c*, $\log log\ \frac{q_{ic}}{Q_c} - \log log\ \frac{q_{id}}{Q_d} < 0$. Thus, the prices and quantity measures of (IV.2) usually will be negatively correlated. Accordingly, crossing the elements of (IV.2), weighting by budget shares to recognise not all goods are equally important, and then summing over $i = 1, \cdots, 9$, yields the price-quantity covariance of (IV.1), which usually will be negative. The qualifier "usually" relates to the role of income. Deflating quantities by income amounts to taking the income elasticity to be unity. When there is a substantial departure from unity, it is possible for the covariance to be positive. But note that a "substantial departure" in this context refers to not only the size of the elasticity, also the difference in income, the difference in the relative price and the magnitude of the good's budget share.[15]

Panel D of Table III.1 contains averages by income quintiles of the price-quantity correlations obtained with the ICP data (World Bank, 2015). Comparing countries across the two highest quintiles, the average correlation is -0.46 and going down the main diagonal, in successive pairs of adjacent groups the values are -0.33, -0.31 and -0.24. For country groups with larger income differences, the correlations are lower in absolute value; and the correlation is positive (but small) in two instances for countries at opposite ends of the distribution. Figure IV.2 contains a histogram of the correlations for each of the 15,400 country pairs. As can be seen, the clear majority is negative, as expected, and the mean is -0.23 (median = -0.27). All in all, while the correlations are not huge, there is a robust negative relationship between consumption and prices, as predicted by the law of demand.

A final approach related to the Divisia correlation. As mentioned, the differences in the prices and quantities of equation (IV.2) should usually have opposite signs. Thus, if we

[15] See Appendix A1 for a discussion of regressions involving the relative prices and quantities of (IV.2).

tabulate the joint frequency of the price and quantity signs for all goods in the form of a 2×2 matrix, each off-diagonal element (representing opposite price-quantity signs) should dominate the corresponding diagonal (same signs). This approach is perused in Table IV.1 with the ICP data. For the 9 goods and the 15,400 pairs of the 176 countries, there are 138,600 price-quantity differences. From the first row of the table referring to negative price differences, about two-thirds of the quantity differences are positive, which is encouraging to the law of demand. But for the opposite case, the evidence is not so strong as only about 57 percent of higher prices are associated with lower quantities.

VI.3 Two Further Examples

We conclude this section with two further examples of the workings of the law of demand. If we plot the difference in the relative quantity of a good, $\log log \frac{q_{ic}}{Q_c} - \log log \frac{q_{id}}{Q_d}$, against its price difference, $\log log \frac{p_{ic}}{P_c} - \log log \frac{p_{id}}{P_d}$, the majority of points should be scattered around a downward-sloping line. In the case of food, deflating consumption by income would not be the ideal approach. As discussed above, Engel's law says food has an income elasticity of less than unity, but this would be contradicted by deflation by income since that implies a unity elasticity. Food consumption in a rich country would be over-predicted with a unity elasticity, and under-predicted in a poor one. If the income elasticity were, say, ½, a better measure of the difference in consumption would be $\log log \frac{q_{ic}}{Q_c} - ½\cdot \log log \frac{q_{id}}{Q_d}$. Using this income adjustment with the ICP data (World Bank, 2015), Figure IV.3 in a price-quantity scatter plot (in the form of a heat map) for food demand. (In comparison with Figure IV.1, the axes are interchanged here, but this is inconsequential.) While there is considerable dispersion, as is to be expected with countries with large income differences, the points tend to be scattered around a downward-sloping line, in agreement with the law of demand. This downward-sloping line is the regression line.

The second example is the demand for a more narrowly defined good, alcohol, comprising beer, wine and spirits (known as "liquor" in some countries). This good is very different in nature to food: Not only is alcohol narrower and more specific, there are many idiosyncrasies with drinking behaviour: Food is essential to sustain life and consumed by all. In contrast, there is much more heterogeneity with alcohol as some consumers drink heavily, some moderately and some not at all. Remarkably, a negatively sloped demand curve for alcohol still emerges from data for a number of countries. Panel A of Figure IV.4 (from Selvanathan and Selvanathan, 2007) is a scatter plot of alcohol consumption in Australian against its relative price. The data are time-series, so rather than the differences between countries, now it is changes from one year to the next. More precisely, the vertical axis is 100 times the annual logarithmic change in per capita consumption of alcohol relative to the change in income per capita, while the horizontal contains 100× the logarithmic change in the relative price. As can be seen, the points are negatively correlated and the regression line has a slope of -0.65, which can be interpreted as a rough estimate of the price elasticity of demand for alcohol.

Panel B of Figure IV.4 gives the same scatter plot for nine other countries, as well as reproducing the one for Australia. The slope coefficients of the 10 regression lines are:

1. Finland	-0.67	8. Canada	-0.33
2. Sweden	-0.66	9. US	-0.33
3. Australia	-0.65	10. France	-0.06
4. UK	-0.65		
5. NZ	-0.60	Mean	-0.48
6. Japan	-0.44	Median	-0.52
7. Norway	-0.43		

In all but one case (France), the regression lines have noticeable negative slopes: The demand curve for alcohol slopes down in 9 out of 10 countries, which again illustrates the law of demand.

V. LAW 4: PRICE ELASTICITIES ARE − ½

V.1 The Role of the Price Elasticity

It is no exaggeration to say that the price-sensitivity of demand for a good is at the heart of many, perhaps most, issues in applied microeconomics. To take a stylized example, consider the world market for cereals. Suppose the income elasticity of cereals demand is 0.5 and income grows at 6 percent per annum. Thus, the annual growth in consumption is $\frac{106}{100} + \eta\Delta \log log\, p,$ where is $\eta < 0$ is the price elasticity and $\Delta \log log\, p$ is the growth in the relative price. If, for simplicity, the supply of the good is fixed and the market clears each year, the change in the price, for various values of the price elasticity, is:

$$\Delta \log log\, p =- \frac{\frac{106}{100}}{\eta} =- \frac{0.029}{\eta} = \{0.039,\ if\ \eta =- 0.75\ \ 0.058,\ if\ \eta =- 0.50\ 0.117,\ if\ \eta =- 0.25.$$

The price change is inversely proportional to the value of $-\eta$, so that when the elasticity is -0.75, income growth causes the price to rise by about 4 percent, but when demand is more inelastic and $\eta =- 0.25$, the price rises by more than 12 percent. This underscores the importance of the numerical value of the price elasticity.

In addition to the prediction of likely price changes, two other major uses of price elasticities should be mentioned. First, CGE models involve the numerical modeling of the economy with considerable detail, with maybe more than 100 sectors. These models make extensive use of systems of demand equations with the values of the corresponding elasticities drawn from a number of sources.[16] A second major use of price elasticities is in the design of policy, from optimal taxation to those seeking to offset externalities and other distortions with commodity taxes. The original optimal tax formulation was due to Ramsey (1927) who studied how goods should be taxed in order to raise a given amount of revenue while minimising the deadweight loss. The solution involves an equi-proportional reduction in the consumption of each good, which, in the simplest case, is achieved by setting tax rates in inverse proportion to price elasticities.[17] Tobacco taxation to reduce smoking and fat taxes to reduce obesity are examples of policies designed to deal with external effects/distortions. If taxation is to be used to reduce consumption of a particular good by $\alpha > 0$ percent, the rate needs to be set such that the price rises by $-\frac{\alpha}{\eta} > 0$ percent, where η is the price elasticity, as before. If the elasticity is -½, the price needs to rise by 20 percent to achieve a 10-percent reduction in consumption.[18]

There have been many attempts to estimate demand equations that depend primarily on income and prices, but despite substantial progress, there are still substantial issues that remain unresolved.[19] An additional issue is that there are a number of demand models, each with its own strengths and weaknesses, and it is probably fair to say none clearly dominates.[20] As each model is likely to yield somewhat different elasticity estimates, the question is, which one should be relied upon?

When we cannot place sufficient confidence in the available elasticity estimates, what value should be used? Or what if there are no data, so it is simply impossible to estimate the elasticity, as in the case of the demand for an illegal good such as marijuana in many jurisdictions? A popular approach is to use a Cobb-Douglas utility function, which implies

[16] For a survey of CGE, see Dixon and Jorgenson (2012). For a recent comparison of the impact of difference demand systems on CGE results, see Boysen (2019).
[17] Stiglitz (2015) gives an account of developments in the theory of optimal taxation following Ramsay.
[18] For examples of this research, see Powell et al. (2013) and Zhen et al. (2013).
[19] A partial listing of the major studies on the income and price sensitivity of demand, each dealing with a large number of countries, includes Chen (1999), Gao (2012), Goldberger and Gamaletsos (1970), Houthakker (1957), Liu (2018), Lluch and Powell (1975), Lluch et al. (1977), Muhammad et al. (2011), Regmi and Seale (2010), Rimmer and Powell (1992), Seale and Regmi (2006), Seale et al. (2003), Selvanathan (1993), Selvanathan and Selvanathan (2003), Theil and Clements (1987), Theil et al. (1989) and Theil et al. (1981).
[20] Popular demand models are the linear expenditure system (Stone, 1954), the Rotterdam model (Barten, 1964a, Theil, 1965), the almost ideal model and its quadratic extension (Deaton and Muellbauer, 1980a, Banks et al., 1997) and the translog (Christensen et al., 1975). For major reviews, see Bewley (1986), Deaton (1986), Deaton and Muellbauer (1980b), Goldberger (1987), Pollak and Wales (1992), Powell (1974), Theil (1975/76) and Theil (1980).

price elasticities of -1. For many broad aggregates (such as food, clothing, housing, etc.) this is likely to overstate the degree of substitution. As the price elasticity reflects the availability of substitutes, it would seem likely for goods that are not too finely defined, substitution is limited and the elasticity low. In what follows, we show for these goods, a case can be made to set the price elasticity to − ½, which we call the law of ½. This case rests on the evidence from prior estimates and analytical considerations. The next subsection discusses the evidence, from Clements (2008), while the subsequent subsections, drawing on and extending Clements (2006, 2008), present elements of consumption theory that point to the law of ½.[21] It is to be emphasised this rule is applicable to broad aggregates only, not to more finely defined products.

V.2 Evidence on Price Elasticities

The price sensitivity of certain goods has been studied extensively in the literature and meta-studies aggregate the findings. These studies are available for those goods listed in column 1 of Table V.1. Cigarettes, for example, are highly addictive with few other goods that are directly competing, and so smoking is unlikely to be highly responsive to higher prices. The first row panel 4 of the table summarises the meta study carried out by Gallet and List (2003) regarding estimates of the price elasticity of demand for cigarettes. This confirms prior expectation of a low price-sensitivity as the mean of more than 500 estimates of the elasticity is -0.48. The other panels of the table, with the exception of the final one, reveal a similar result for other goods: The demand for beer, wine and spirits, water, petrol and electricity is price inelastic, at least on average.

Not only is consumption of these goods price inelastic, but as Figure V.1 clearly shows the elasticities are clustered around − ½.[22] The only major exception is for branded products, where the mean elasticity is -1.76, so demand is highly elastic. The reason is that a good of a certain brand would in many cases face substantial competition from other brands of the same good. In other words, there are many substitutes available for banded goods, leading to elastic demands. Where there is a distinction between the long- and the short-run elasticity, the means of the former are higher, which makes good economic sense as consumers can take some time to adjust to price changes.

What are the common features of these goods? Take beer as an example: Some beer drinkers might be induced to switch to wine following a rise of the price of beer. But the popular and realistic idea of the "hard-core" beer drinker (at least in Australia!) means that the price rise would most likely need to be large in order to bring about a substantial conversion

[21] There are several typographical errors in Clements (2008) that are corrected here.
[22] The elasticities for alcohol of the previous section are also clustered around this value.

of beer drinkers to wine. That is, beer is likely to have only limited substitutes and a low elasticity. On the other hand, different brands of beer are good substitutes for one another and price discounting of one brand would be likely to cause some to switch from one brand to another, so the inter-brand elasticities would be large. This outcome would be consistent with elasticity of $-\ 1.76$ in panel 8 of Table V.1 for branded goods in general. By contrast, the goods in the first 7 panels of the table are all fairly broad aggregates with few substitutes. As for beer, most of the substitution that does take place is likely to be vis-à-vis members of the same group, and so confined to within the aggregated good. Generally speaking, broad aggregates tend to have few substitutes.

V.3 Preferences and the Budget Constraint

Denote by q_i the quantity consumed of good *i* ($i\ =\ 1, \cdots, n$) and the utility function by $u\left(q_i, \cdots, q_n\right)$. If tastes can be characterised by an additive utility function, we have

$$u\left(q_1, \cdots, q_n\right) = \sum_{i=1}^{n} u_i\left(q_i\right), \quad \text{(V.1)}$$

where $u_i(\bullet)$ is the *i^th^* sub-utility function which only depends on consumption of good *i*. Accordingly, $\frac{\partial u}{\partial q_i} = \frac{du_i}{dq_i}$, and so the marginal utility of good *i* depends only on the consumption of that good and the utility function (V.1) is described as of the preference independence form. The consumer's budget constraint is

$$\sum_{i=1}^{n} p_i q_i\ =\ M, \quad (V.2)$$

where p_i is the price of *i* and *M* is total expenditure (to be referred to as "income" for short).

There are two implications of the budget constraint. The first is obtained by differentiating both sides of equation (V.2) with respect to M gives $\sum_{i=1}^{n} \frac{\partial\left(p_i q_i\right)}{\partial M}\ =\ 1$, or

$$\sum_{i=1}^{n} w_i \eta_i\ =\ 1, \quad \text{(V.3)}$$

where $w_i\ =\ \frac{p_i q_i}{M}$ is the budget share of good *i* and $\eta_i\ =\ \frac{\frac{\partial\left(p_i q_i\right)}{\partial M}}{w_i}\ =\ \frac{\partial \log log\ q_i}{\partial \log log\ M}$ is the corresponding income elasticity. As a budget-share weighted average of the income elasticities is unity, not all goods can be necessities, nor can they all be luxuries. For the second implication, we differentiate (V.2) with respect to the price of good *j* to give

$q_j + \sum_{i=1}^{n} \frac{p_i \partial q_i}{\partial p_j} = 0$, or, multiplying by $\frac{p_j}{M,}$

(V.4)

$$w_j + \sum_{i=1}^{n} w_i \eta_{ij} = 0,$$

where $\eta_{ij} = \frac{\partial q_i}{\partial p_j}\frac{p_j}{q_i} = \frac{\partial \log log\, q_i}{\partial \log log\, p_j}$ is the $(i, j)^{th}$ price elasticity.

The choice faced by the consumer is how much to spend on each of the *n* goods with total expenditure constrained to be fixed. Thus, the consumer faces an allocation problem. Equations (V.3) and (V.4) are aggregation constraints on how income is reshuffled following changes in income and prices.

V.4 Marginal Utility

The marginal utility of good i is $\frac{\partial u}{\partial q_i}$. How does this change following an increase in one of the prices? In the general case in which utility is not additive, the effect of a change in the *j*th price on the marginal utility of *i* is, in logarithmic terms, $\sum_{k=1}^{n} \frac{\partial \log log\left(\frac{\partial u}{\partial q_i}\right)}{\partial \log log\, q_k}\eta_{kj}$. But as from equation (V.1) all cross effects in utility vanish under preference independence, and only the *i*th term in the summation is non-zero: $\sum_{k=1}^{n} \frac{\partial \log log\left(\frac{\partial u}{\partial q_i}\right)}{\partial \log log\, q_k}\eta_{kj} = \frac{\partial \log log\left(\frac{\partial u}{\partial q_i}\right)}{\partial \log log\, q_i}\eta_{ij}$.

Denoting by λ the marginal utility of income, the *i*th first-order condition for a budget-constrained utility maximum is $\frac{\partial u}{\partial q_i} = \lambda p_i$, or

(V.5)

$$\log log\, \frac{\partial u}{\partial q_i} = \log log\, \lambda +]$$

Under preference independence, the derivative of this equation with respect to $\log log\, p_j$ is

(V.6)

$$\frac{\partial \log log\left(\frac{\partial u}{\partial q_i}\right)}{\partial \log log\, q_i}\eta_{ij} = \frac{\partial \log log\, \lambda}{\partial \log log\, p_j} + \delta_{ij},$$

where δ_{ij} is the Kronecker delta $\left(\delta_{ij} = 1\ if\ i = j,\ 0\ otherwise\right)$. Differentiating equation (V.5) with respect to $\log log\, M$ gives

(V.7)

$$\frac{\partial \log log\left(\frac{\partial u}{\partial q_i}\right)}{\partial \log log\, q_i}\eta_i = \frac{1}{\phi} \quad or \quad \frac{\partial \log log\left(\frac{\partial u}{\partial q_i}\right)}{\partial \log log\, q_i} = \frac{1}{\phi\eta_i},$$

where $\frac{1}{\phi} = \frac{\partial \log log\, \lambda}{\partial \log log\, M} < 0$ is the income elasticity of the marginal utility of income. The reciprocal of this elasticity, ϕ, is known as the income flexibility.

Substituting the second member of equation (V.7) into (V.6) yields

(V.8)
$$\eta_{ij} = \phi \frac{\partial \log log\ \lambda}{\partial \log log\ p_j} \eta_i + \phi \delta_{ij} \eta_i.$$

Multiply both sides of this equation by w_i and then sum over $i = 1, \cdots, n$:

$$\sum_{i=1}^{n} w_i \eta_{ij} = \phi \left(\frac{\partial \log log\ \lambda}{\partial \log log\ p_j} + w_j \eta_j \right),$$

where we have used constraint (V.3) and $\sum_{i=1}^{n} w_i \phi \delta_{ij} \eta_i = \phi w_j \eta_j$. As, from (V.4), the left side of the above is $-\ w_j$, we have $\frac{\partial \log log\ \lambda}{\partial \log log\ p_j} = -\ w_j \left(\eta_j + \phi^{-1} \right)$. Substitute this back into equation (V.8) to give

(V.9)
$$\eta_{ij} = \phi \eta_i \left(\delta_{ij} - w_j \eta_j \right) - \eta_i w_j.$$

V.5 <u>A Key Proportionality Relationship</u>

In the above, money income is held constant when computing the effects of a price change, and so the price elasticities include both income and substitution effects. The last term on the right of equation (V.9) is the income effect and the term immediately to the right of the equals sign is the compensated (or Slutsky) price elasticity. Denote this by $\eta'_{ij} = \phi \eta_i \left(\delta_{ij} - w_j \eta_j \right)$. As w_j is a positive fraction and as the income flexibility ϕ tends to lie in the range $[-\ 1,\ 0]$, it follows that $\phi \eta_i w_j \eta_j \approx 0$. Thus, for $i = j$, the compensated own-price elasticities are

(V.10)
$$\eta'_{ii} \approx \phi \eta_i, \quad i = 1, \cdots, n.$$

In words, (compensated) price elasticities are proportional to income elasticities, so luxuries (goods with $\eta_i > 1$) are more price elastic than necessities $\left(\eta_i < 1 \right)$, a result known as Pigou's (1910) law (Deaton, 1974). The factor of proportionality is the income flexibility, $\phi < 0$. Note also that as an approximation, cross-price elasticities vanish, something that is not implausible for broad aggregates with little or no interactions in generating utility. [23]

The value of the price elasticity reflects the availability of substitutes -- it is low when there are few alternatives and high when there are many. The income elasticity is a measure of

[23] Friedman's (1935) first publication was an early contribution to this topic. For a generalisation of Pigou's law, see Snow and Warren (2015).

luxuriousness. Engel's law states that food is a necessity, that is, it is an essential, not a luxury, and its income elasticity is less than unity. High-fashion handbags are a strong luxury and so their $\eta_i > 1$. As the price and income elasticity would seem to reflect distinct properties of the good, it might come as a surprise that equation (V.10) links them together. But there is really no contradiction as the proportionality relationship (V.10) agrees with common usage of the terms "essential" and "luxury". Take salt as an example. This is an "essential" that humans cannot do without – that is, consumption cannot be postponed or replaced with something else, so it has few substitutes and a low price elasticity. The reverse is true of, say, a foreign vacation, which is likely to have a high income elasticity, and usually can be cancelled or delayed. This is a luxury with a high price elasticity. The same applies for handbags.

Equation (V.8) refers to the effect on consumption of good i of a change in the price of j. A price increase $dp_j > 0$ makes the consumer worse off, so in view of diminishing marginal utility, we would expect the marginal utility of income λ to increase. If the consumer were compensated for the price increase such that λ remains unchanged, the first term on the right of (V.8) involving $\frac{\partial \log log\, \lambda}{\partial \log log\, p_j}$ vanishes and the proportionality relation becomes exact, $\eta'_{ii} = \phi\eta_i$, and now η'_{ii} is interpreted as the marginal-utility-constant, or Frisch, price elasticity. Note also multiplying both sides of the i^{th} equation in (V.10) by w_i and then summing gives $\sum_{i=1}^{n} w_i\eta'_{ii} \approx \phi \sum_{i=1}^{n} w_i\eta_i = \phi$, where the second step is based on equation (V.3). This shows that under preference independence, the income flexibility is also interpreted as approximately a budget-share weighted average price elasticity.[24] A further implication is that all Frisch cross-price elasticities are zero.[25]

V.6 <u>The Law of</u> ½

According to equation (V.10), price elasticities are proportional to income elasticities, with the income flexibility ϕ the (negative) proportionality factor. We use in this relationship the following two values:

[24] This interpretation is exact for Frisch price elasticities. Relatedly, Powell (1992) shows that under preference independence, the average elasticity of substitution $\sigma=-\phi$.

[25] What is the evidence on the hypothesis of preference independence? In the past, preference independence has been regarded by many as too strong even for broad aggregates, but more recent research reaches a more positive conclusion. While it is not possible to give iron-clad guarantees, it now seems preference independence is a not an unreasonable hypothesis for broad aggregates. See Appendix A2 for details.

1. $\eta_i = 1$. As indicated by equation (V.3), on average income elasticities are unity; so, if nothing is known about the nature of the good, it is not unreasonable to set its income elasticity equal to 1.
2. $\phi = -\frac{1}{2}$. As discussed in Appendix A3, -½ is a frequent centre-of-gravity of estimates of ϕ.

With these values, equation (V.10) leads to the rule of (minus) one half:

$$\eta'_{ii} \approx -\frac{1}{2}. \tag{V.11}$$

In words, price elasticities are approximately minus one-half.

To summarise, there is both empirical and analytical support for the rule of thumb (V.11) for broad aggregates. Meta-studies have been carried out of econometric estimates of the price elasticity of beer, wine, spirits, water, petrol, cigarettes and electricity. While there is obviously dispersion among the individual estimates, these meta-studies all point to $-\frac{1}{2}$ as a centre-of-gravity value of the price elasticity. Regarding the theory, there are four steps:

1. The starting point is preference independence, whereby the marginal utility of each good is unaffected by variations in the consumption of all others.
2. Preference independence implies price elasticities are approximately proportional to the corresponding income elasticities. The factor of proportionality (denoted by ϕ) is the inverse of the income elasticity of the marginal utility of income, which is known as the "income flexibility".
3. As income elasticities are unity on average, the proportionality relationship means that as an approximation, the average commodity has a price elasticity equal to the income flexibility ϕ.
4. As the bulk of the empirical evidence points to $\phi = -\frac{1}{2}$, it follows that price elasticities are approximately $-\frac{1}{2}$.

Broadly defined commodities such as food, clothing, housing, etc. are consumed in one way or another by all consumers. It is not too difficult to imagine utility as being derived from the consumption of food and clothing and housing and so on, where the underscoring of the word "and" emphasises the additive nature of the manner in which these goods are combined. In all probability, there would be limited scope for substituting one good for another, which can be taken to mean each marginal utility is more or less independent of the consumption of the other goods, consistent with the additive form of the utility function under preference independence. These considerations are consistent with the rule $\eta'_{ii} \approx - \frac{1}{2}$ for broad aggregates.[26]

The rule of ½ is a useful rule of thumb with some empirical and theoretic support. However, as should be clear from the above discussion, the rule is a broad guideline for elasticity of demand for a certain type of good. It is not a "law" in the same sense as the three other laws of consumption.

VI. CONCLUDING COMMENTS

The laws of consumption dealt with in this paper are Engel's law, that food absorbs a declining proportion of the budget as consumers become richer; quantities consumed have a strong tendency to be more volatile than prices, in agreement with the "sticky price" assumption popular in macroeconomics; demand curves slope down, a simple idea with major implications and uses; and the "law" of ½, that price elasticities of demand for "interesting products" are minus one-half. Strictly speaking, the last of these is not really a law at all, but can be used as a guideline for practitioners wanting a numerical value for the elasticity of a broad aggregate, such as alcoholic beverages. The emphasis of the paper has been on quantification, surveying evidence, presenting new empirical results based on cross-country data, and illustrating the usefulness of studying the laws of consumption.

The paper has been deliberately detailed in its treatment of the laws of consumption. The cost of this specificity is the exclusion of related phenomenon that could also be termed "laws of consumption". In this category would be Bennett's (1941) law that the share of cereals in calories falls with increasing income; Houthakker's law that the cost of food increases with higher incomes as superior-quality foodstuffs are consumed (Timmer et al., 1983, p. 58); and Schwabe's (1868) law regarding the higher rent-to-income ratio for the poor. These can probably be regarded as secondary to my four laws of consumption, however There are, of course, broader laws of economics -- in addition to that of Marx regarding the dismal future of capitalism mentioned at the start of the paper, these might include Wagner's law (as economies grow, the share of the public sector increases); the link between money and prices of the quantity theory; and the tendency for currencies of high-inflation countries to depreciate, according to purchasing power parity principle.

How do the laws of economics come about? How are they enforced? Importantly, how are new ones identified and propagated? How long does this typically take? Is the process

[26] Appendix A4 demonstrates the wider applicability of the above approach by starting with finely defined goods that are not additive in the utility function. Under certain conditions, these can be aggregated into groups of goods that are additive, so that the rule of ½ applies to such groups.

cumulative with new ones building on old, or do the new destroy the old? There are no direct answers of course, but these questions are closely related to the issue of how economics progresses over time. Stigler (1983) believes there is little or no impact of current events on developments of economic theory. Overstating slightly, he writes: "The scholars who create economic theory do not read the newspapers regularly or carefully during working hours" (Stigler, 1983, p. 535). Stigler also has some pertinent views regarding the apparent slowness of progress in science that probably apply equally to the pace of change in economics:

> Gary Becker has suggested that a substantial resistance to the acceptance of new ideas by scientists can be explained by two familiar economic concepts. One is the concept of specific human capital: the established scholar possesses a valuable capital asset in his command over a particular body of knowledge. That capital would be reduced if his knowledge were made obsolete by the general acceptance of a new theory. Hence, established scholars should, in their own self-interest, attack new theories, possibly even more than they do in the absence of joint action. The second concept is risk aversion, which leads young scholars to prefer mastery of established theories to seeking radically different theories. Scientific innovators, like adventurers in general, are probably not averse to risk, but for the mass of scholars in a discipline, risk aversion is a strong basis for scientific conservatism… (Stigler, 1983, p. 538).

In principle, econometric testing would appear to be the obvious way in which economic knowledge is advanced by testing the laws, rejecting the deficient and discovering new ones. In reality, this is seldom the case and econometrics evidence never seems decisive in determining debate and progress; see, e. g., Lucas (2013, pp. 247-248) and Summers (1991). Perhaps we can do no better than describe the process of the advancement of economics as osmosis. However, the nature of the path of economics has been carefully considered by Niehans (1993). On the basis of an analysis of six episodes previously described as "revolutionary", he concludes economics advances in a continuous, evolutionary process, not by leaps and bounds in a revolutionary manner. Revolution comes about by a growing disparity between accepted theory and the facts. The episodes analysed are marginalism of the late 19th century; development of monopolistic competition by Chamberlin and Robinson in the 1930s; Keynesian economics; game theory; monetarism; and rational expectation. Only Keynesism comes close to being truly revolutionary and even then there is suspicion that its prominence may have been more the result of clever marketing, in Niehans' view. When presenting an earlier version of his paper as the Bateman Memorial Lecture at The University of Western Australia in October 1992, Niehans described the process in vivid terms as amounting to a mundane "turning-up-at-the-office-each-day" activity. Clearly, again there is exaggeration (of an understated form), but the description is evocative of the absence of discrete, major breakthroughs and slowness of the acceptance of new ideas. Economics is essentially non-revolutionary as it deal with basic aspects of human behavior such as preferences and self-interest that are more or less permanent features of the species and not subject to change (part of our DNA?). Thus, Niehans' rejection of the idea that economics advances in the revolutionary fashion associated with Hegel, Marx, Schumpeter and Kuhn. This is a persuasive argument.

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Table II.1
Income and Food Consumption in 138 Countries, 2005

Country	Incom e	Food		Country	Income	Food		Country	Income	Food	
		Budge t share	Income elasticity			Budge t share	Income elasticit y			Budge t share	Income elasticity
1. U.S.	100.0	6.2	0.23	47. Belarus	27.3	34.7	0.53	93. Kyrgyz	8.0	40.8	0.79
2. Luxembourg	92.2	6.9	0.25	48. Kazakhstan	26.5	18.6	0.53	94. Sri Lanka	7.9	36.4	0.79
3. Iceland	80.7	8.9	0.27	49. Mauritius	26.3	23.4	0.54	95. Iraq	7.8	32.1	0.80
4. Norway	77.7	9.7	0.28	50. Russia	26.3	25.5	0.54	96. Mongolia	7.7	35.9	0.80
5. U.K.	76.9	7.1	0.28	51. Bulgaria	26.1	19.5	0.54	97. Tajikistan	7.7	55.0	0.80
6. Austria	76.4	8.7	0.28	52. Iran	25.2	23.4	0.55	98. Philippines	7.5	43.9	0.80
7. Switzerland	74.6	9.3	0.29	53. Romania	24.4	25.0	0.55	99. Indonesia	7.4	41.6	0.80
8. Canada	74.4	7.7	0.29	54. Oman	24.2	22.1	0.56	100. Pakistan	7.3	48.8	0.81
9. Netherlands	72.4	8.2	0.29	55. Argentina	24.0	22.5	0.56	101. Morocco	7.2	31.1	0.81
10. Sweden	72.0	8.3	0.30	56. Serbia	23.7	25.6	0.56	102. Lesotho	7.1	35.5	0.81
11. France	71.5	10.6	0.30	57. Saudi Arabia	23.6	18.5	0.56	103. China	7.0	24.1	0.81
12. Australia	70.6	8.5	0.30	58. Chile	23.3	16.2	0.56	104. Vietnam	6.8	31.3	0.82
13. Denmark	69.8	8.1	0.30	59. Uruguay	22.1	19.0	0.58	105. India	5.5	33.7	0.85
14. Belgium	68.4	10.3	0.31	60. Bosnia Herz.	21.9	28.5	0.58	106. Cambodia	5.3	47.2	0.85
15. Germany	67.5	9.1	0.31	61. Macedonia	20.5	30.9	0.60	107. Yemen	5.2	41.1	0.85
16. Hong Kong	66.3	8.9	0.31	62. Ukraine	19.8	32.1	0.60	108. Sudan	4.5	55.6	0.87
17. Ireland	66.2	4.6	0.31	63. South Africa	19.3	17.6	0.61	109. Lao P.D.R.	4.4	47.3	0.87
18. Japan	66.0	12.3	0.31	64. Malaysia	19.3	17.3	0.61	110. Djibouti	4.4	33.6	0.87
19. Taiwan	64.5	14.8	0.32	65. Turkey	18.9	23.1	0.62	111. Kenya	4.3	33.3	0.88
20. Cyprus	63.4	13.7	0.32	66. Montenegro	18.7	32.2	0.62	112. Sao Tome P.	4.3	53.7	0.88
21. Finland	63.0	9.3	0.32	67. Brazil	18.7	15.5	0.62	113. Congo, R.	4.1	37.5	0.88
22. Spain	61.9	11.8	0.33	68. Venezuela	17.1	26.1	0.64	114. Cameroon	4.0	43.4	0.88
23. Italy	61.6	12.3	0.33	69. Thailand	16.1	15.9	0.65	115. Nigeria	4.0	56.7	0.88
24. Greece	59.4	13.8	0.34	70. Albania	14.6	24.6	0.67	116. Senegal	3.9	48.9	0.89
25. N.Z.	57.7	11.5	0.34	71. Colombia	14.5	24.3	0.68	117. Chad	3.5	55.0	0.90
26. Israel	54.7	12.9	0.36	72. Ecuador	13.7	25.9	0.69	118. Mauritania	3.4	63.6	0.90
27. Malta	54.3	13.9	0.36	73. Jordan	13.7	28.9	0.69	119. Nepal	3.4	48.7	0.90
28. Singapore	53.6	8.2	0.36	74. Tunisia	13.7	24.8	0.69	120. Bangladesh	3.3	49.9	0.90
29. Qatar	50.5	13.6	0.37	75. Peru	13.6	29.2	0.69	121. Benin	3.3	43.6	0.90

(Continued next page)

Table II.1 (continued)
Income and Food Consumption in 138 Countries, 2005

Country	Income	Food Budget share	Food Income elasticity	Country	Income	Food Budget share	Food Income elasticity	Country	Income	Food Budget share	Food Income elasticity
30. Slovenia	50.0	11.9	0.38	76. Egypt	13.5	41.6	0.69	122. Ghana	3.3	49.2	0.90
31. Portugal	49.0	13.1	0.38	77. Armenia	13.1	65.1	0.70	123. Coted 'Ivoire	3.1	43.3	0.91
32. Brunei	48.7	18.4	0.38	78. Moldova	13.0	24.2	0.70	124. S. Leone	3.1	42.4	0.91
33. Kuwait	47.0	14.8	0.39	79. Maldives	12.9	22.9	0.70	125. M'gascar	3.0	57.0	0.91
34. Czech	46.3	13.1	0.40	80. Gabon	12.7	36.3	0.70	126. Togo	2.7	48.6	0.92
35. Hungary	42.6	13.3	0.42	81. Fiji	12.6	26.3	0.71	127. Burkina Faso	2.5	42.0	0.93
36. Bahrain	41.6	19.0	0.42	82. Georgia	12.1	36.7	0.71	128. Guinea	2.4	44.0	0.93
37. Korea	40.4	13.7	0.43	83. Botswana	11.9	21.9	0.72	129. Mali	2.3	46.7	0.93
38. Estonia	39.4	15.4	0.43	84. Namibia	10.9	26.0	0.74	130. Angola	2.3	40.7	0.93
39. Slovak	38.8	15.7	0.44	85. Swaziland	10.8	41.9	0.74	131. Malawi	2.1	23.3	0.93
40. Lithuania	38.3	22.9	0.44	86. Azerbaijan	10.5	57.9	0.74	132. Rwanda	2.1	42.7	0.94
41. Poland	36.7	17.8	0.45	87. Syrian Arab	10.5	41.7	0.74	133. C. Africa	1.9	56.8	0.94
42. Croatia	36.1	19.3	0.46	88. Bolivia	10.2	27.8	0.75	134. M'bique	1.7	60.1	0.95
43. Macao	36.1	13.3	0.46	89. Equat. Guinea	10.1	39.5	0.75	135. Liberia	1.3	25.8	0.96
44. Latvia	33.4	19.2	0.48	90. Paraguay	9.9	32.3	0.75	136. Niger	1.3	46.4	0.96
45. Lebanon	32.0	27.8	0.49	91. Cape Verde	8.8	28.8	0.77	137. G-Bissau	1.2	52.3	0.96
46. Mexico	28.7	22.0	0.51	92. Bhutan	8.0	34.5	0.79	138. Congo, D. R.	0.4	62.2	0.99

Note: Income is real total consumption per capita with US = 100. Food budget shares are percentages.
Source: Gao (2012).

Table III.1

Volatilities of Quantities and Prices, and Correlations,

Five Income Groups of 176 Countries, 2011

		□ Richer			Poorer □
		Group 2	Group 3	Group 4	Group 5
		A. <u>Quantity dispersion</u> (SD of log-differences × 100)			
Richer	Group 1	56.06	64.28	84.87	105.22
	Group 2		52.35	66.01	85.05
	Group 3			60.73	77.44
Poorer	Group 4				62.51
		B. <u>Price dispersion</u> (SD of log-differences × 100)			
Richer	Group 1	32.97	41.25	42.82	41.04
	Group 2		30.66	32.18	29.35
	Group 3			31.51	28.37
Poorer	Group 4				26.17
		C. <u>Ratios of quantity to price dispersion</u>			
Richer	Group 1	1.70	1.56	1.98	2.56
	Group 2		1.71	2.05	2.90
	Group 3			1.93	2.73
Poorer	Group 4				2.39
		D. <u>Price-quantity correlations</u>			
Richer	Group 1	-0.46	-0.36	-0.12	0.11
	Group 2		-0.33	-0.16	0.04
	Group 3			-0.31	-0.17
Poorer	Group 4				-0.24

Notes:

1. Countries are ranked by income per capita and divided into income quintiles. Income of country *c* is real total consumption, defined as $\sum_{i=1}^{9} q_{ic}$, where q_{ic} is per capita consumption of item *i* measured in \$US.
2. <u>Panel A</u>. For 9 goods, the weighted variance of quantity differences between countries *c* and *d* is $\sigma^2_{q,cd} = \sum_{i=1}^{9} w_{i,cd}\left(Dq_{i,cd} - DQ_{cd}\right)^2$, where $w_{i,cd} = \frac{1}{2}\left(w_{ic} + w_{id}\right)$ is the average of the budget shares in *c* and *d;* $Dq_{i,cd} = \log log\, q_{ic} - \log log\, q_{id}$ is the log-difference between per capita consumption of good *i* in *c* and *d*; and $DQ_{cd} = \sum_{i=1}^{9} w_{i,cd} Dq_{i,cd}$ is the Divisia volume index for *c* relative to *d*. As $\sigma^2_{q,cd} = \sigma^2_{q,dc}$, $c, d = 1, \cdots, 176$ and $\sigma^2_{q,cc} = 0$, $c = 1, \cdots, 176$, we confine attention to the "upper triangle" comparisons involving the country pairs $\{c, d\}$ for $d > c$, and $c, d = 1, \cdots, 176$. The square roots of $\sigma^2_{q,cd}$, averaged over countries in the relevant income quintiles, form a symmetric 5×5 matrix and this panel contains the upper triangle of this matrix.
3. <u>Panel B</u>. This contains average price dispersion across countries, defined similarly to the quantity counterparts of panel A.
4. <u>Panel C</u>. The entries are ratios of the corresponding elements of panels A and B.

5. Panel D. The price-quantity correlation for country c relative to d is $\frac{\sigma_{pq,cd}}{\left(\sigma^2_{p,cd}\cdot\sigma^2_{q,cd}\right)^{\frac{1}{2}}}$, where $\sigma_{pq,cd} = \sum_{i=1}^{9} w_{i,cd}\left(Dp_{i,cd} - \log log\, P_{cd}\right)\left(Dq_{i,cd} - \log log\, Q_{cd}\right)$ is the covariance; $\sigma^2_{q,cd}$ is the quantity variance defined above; and $\sigma^2_{p,cd} = \sum_{i=1}^{9} w_{i,cd}\left(Dp_{i,cd} - DP_{cd}\right)^2$ is the price variance. For the country pairs $\{c, d\}, c, d = 1, \cdots, 176,\ d > c,$ this panel contains the correlations averaged over countries in different income quintiles.
6. See text for details of the data.

Table IV.1

Price and Quantity Differences,

176 Countries, 2011

(Number of occurrences)

Price difference	Quantity difference (Percent of row total)		Total
	Negative	Positive	
Negative	34.0	66.0	69,465
Positive	56.6	43.4	69,135
Total	62,752	75,848	138,600

Notes:

1. Interpretation: This table contains the number of observations for each of the four possible configurations of the joint signs of the price and quantity differences across pairs of countries, as well as the marginals (the row and column totals). There are 15,400 distinct pairs among the 176 countries; with 9 commodities the total number of observations is, therefore, $15,400\times 9 = 138,600$, the grand total in the table. For example, the second element of the top row, 66.0, means that of the instances when goods are cheaper in one country than another, the quantities consumed of those goods are higher in 66 percent of the cases.
2. Price and quantity differences: Define the difference in the price level between countries c and d as $DP_{cd} = \sum_{i=1}^{9} w_{i,cd} Dp_{i,cd}$, where $w_{i,cd} = \frac{1}{2}\left(w_{ic} + w_{id}\right)$, the average of the budget share of good i in c and d; and $Dp_{i,cd} = \log log\, p_{ic} - \log log\, p_{id}$, the log-difference of the i^{th} price. The difference of the relative price of i in the two countries is $Dp_{i,cd} - \log log\, P_{cd} = \log log\, \frac{p_{ic}}{P_c} - \log log\, \frac{p_{id}}{P_d}$, where $\log log\, P_c - \log log\, P_d = DP_{cd}$. This difference of the relative price is the "Price difference" of the row labels in the table. Similarly, the difference in the relative quantity of i is $Dq_{i,cd} - \log log\, Q_{cd} = \log log\, \frac{q_{ic}}{Q_c} - \log log\, \frac{q_{id}}{Q_d}$, where $DQ_{cd} = \sum_{i=1}^{9} w_{i,cd} Dq_{i,cd}$, $Dq_{i,cd} = \log log\, q_{ic} - \log log\, q_{id}$ and q_{ic} is per capita consumption of i in c. This measure is the "Quantity difference" of the column labels.
3. Data: See text for details.

Table V.1

Price Elasticities of Demand for Selected Products

	Product	Mean	Median	Number of observations	Length of run	Source
	(1)	(2)	(3)	(4)	(5)	(6)
1.	Beer	-0.46	-0.35	139		Fogarty (2005, Chapter 2)
		-0.37		10		Selvanathan and Selvanathan (2005, p. 232)
2.	Wine	-0.72	-0.58	141		Fogarty (2005, Chapter 2)
		-0.46		10		Selvanathan and Selvanathan (2005, p. 232)
3.	Spirits	-0.74	-0.68	136		Fogarty (2005, Chapter 2)
		-0.57		10		Selvanathan and Selvanathan (2005, p. 232)
4.	Cigarettes	-0.48		523		Gallet and List (2003)
			-0.40	368	Short run	Gallet and List (2003)
			-0.44	155	Long run	Gallet and List (2003)
5.	Residential water	-0.41	-0.35	314		Dalhuisen et al. (2003)
		-0.51		124		Espey et al. (1997)
			-0.38		Short run	Espey et al. (1997)
			-0.64		Long run	Espey et al. (1997)
6.	Petrol	-0.26	-0.23	363	Short run	Espey (1998)
		-0.25		46	Short run	Goodwin et al. (2004)
		-0.25	-0.21	387	Short run	Graham and Glaister (2002, p. 48)
		-0.58	-0.43	277	Long run	Espey (1998)
		-0.64		51	Long run	Goodwin et al. (2004)
		-0.53		70		Espey (1996)
		-0.77	-0.55	213	Long run	Graham and Glaister (2002, p. 48)
		-0.35	-0.35	52	Intermediate	Graham and Glaister (2002, p. 54)
7.	Residential electricity	-0.35	-0.28	123	Short run	Espey and Espey (2004)
		-0.85	-0.81	125	Long run	Espey and Espey (2004)
8.	Branded products	-1.76		337		Tellis (1988)

Notes:

1. The other average elasticities of road traffic and fuel consumption reported in Goodwin et al. (2004) and Graham and Glaister (2002) are excluded as they are not confined to the demand by final consumers.
2. Although the elasticities reported by Goodwin et al. (2004) and Graham and Glaister (2002) refer to "fuel" used by motor vehicles, which is broader than "petrol" ("gasoline"), for simplicity of presentation of the table we list these under the product "petrol".

Figure II.1

Food Consumption in Chad and Norway

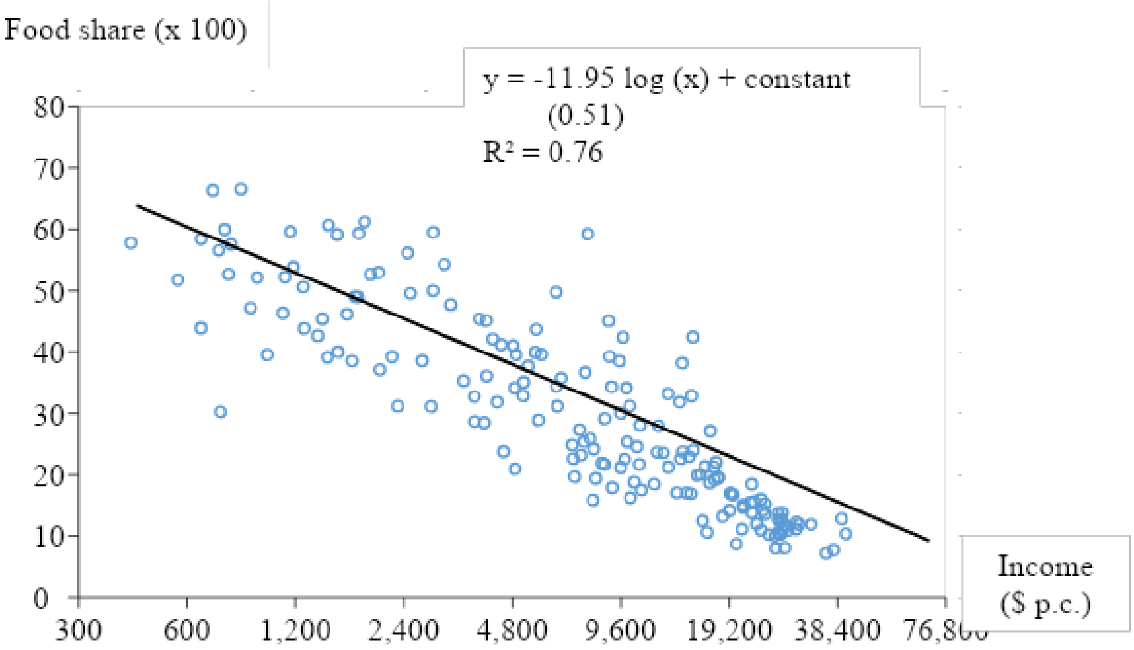
2011 GDP p.c. = $2,000
Food share = 51%

2011 GDP p.c. = $61,900
Food share = 11%

Note: GDP p.c. is in US dollars using market exchange rates.
Sources: World Bank (2015); Hungry Planet (http://world.time.com/2013/09/20/hungry-planet-what-the-world-eats).

Figure II.2

Food and Income, 176 Countries, 2011

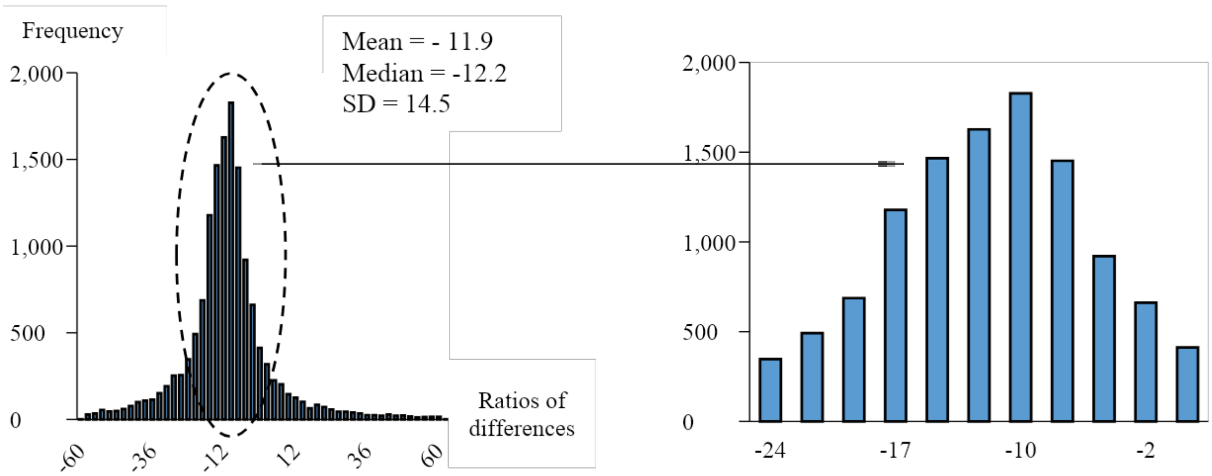


Note: Income is real total consumption per capita in $US, using PPP exchange rates, from World Bank (2015). See text for details of the data.

Figure II.3

Ratios of Differences in Food Shares to Income Differences,

Pairs of 176 Countries, 2011



Note: For $country\ c\ (c = 1, \cdots, 176)$, $let\ w_c$ be the food share and M_c be real income per capita. Countries are ranked according to decreasing income, so country c is richer than d for $d > c$. This frequency distribution refers to the ratios $\frac{w_c - w_d}{\mathrm{loglog}\ M_c - \mathrm{loglog}\ M_d}$, $c, d = 1, \cdots, 176,\ d > c$. There are

$176C_2 = ½176·(176 - 1) = 15,400$ such ratios, but values are truncated to [-60, 60]. See text for details of the data.

Figure II.4
Food and Income Mismeasurement

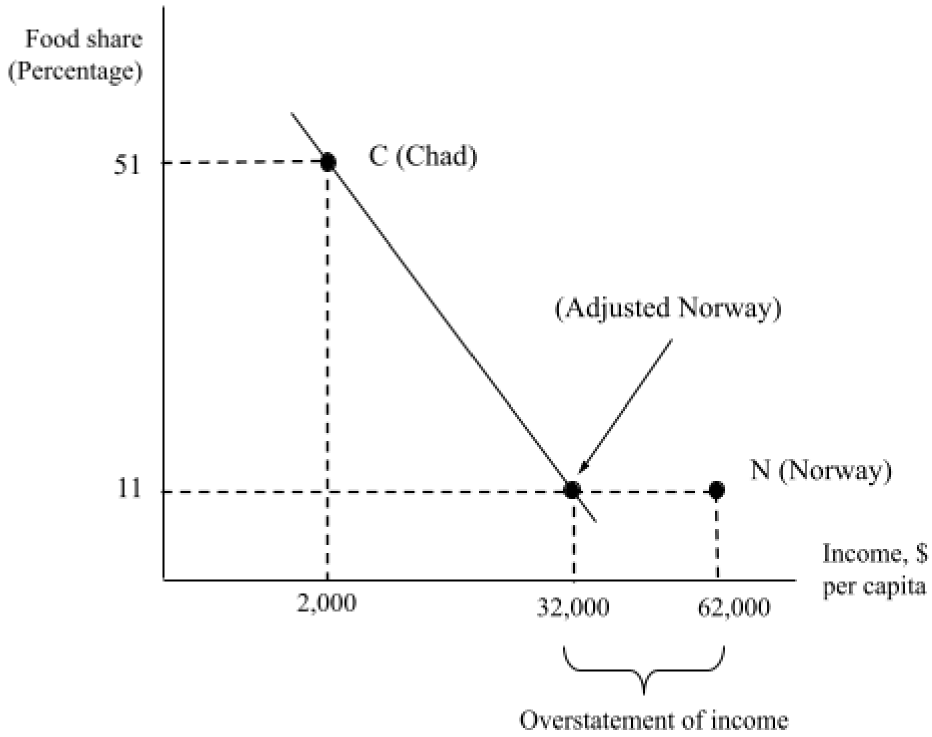


Figure III.1
Demand Shocks, Price and Quantity Dispersion

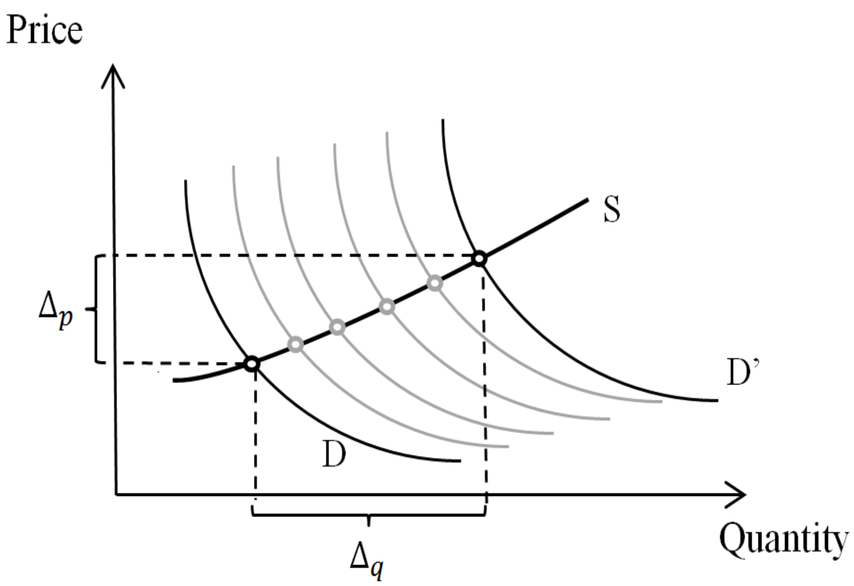
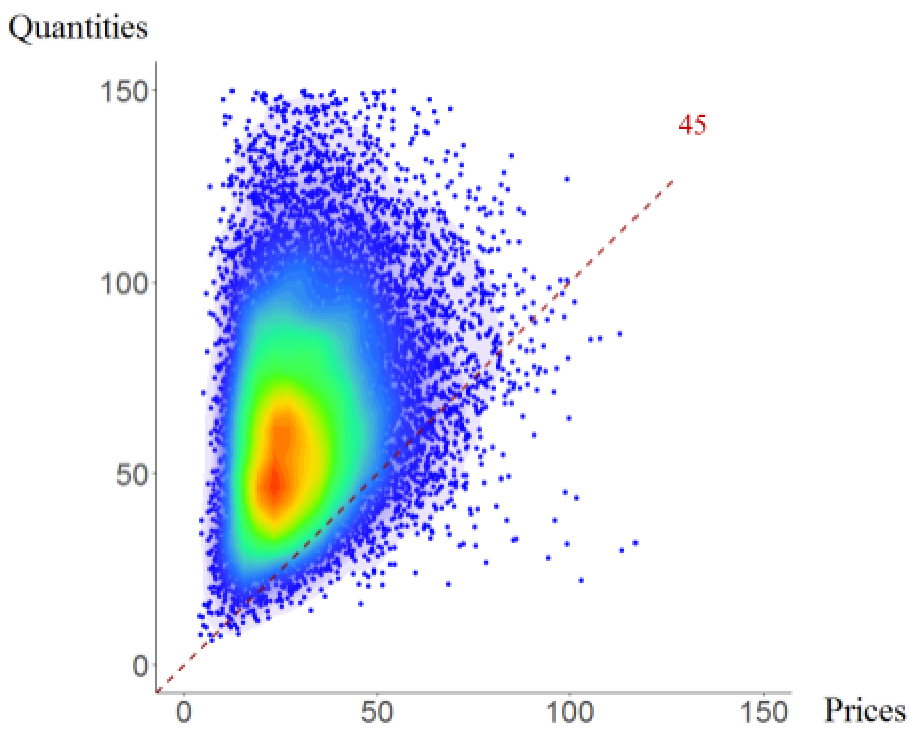


Figure III.2

Dispersion of Quantities and Prices,

Pairs of 176 Countries, 2011



Notes:

1. Points here represent the standard deviations (SD) of quantities and prices (both $\times 100$) for each pair of countries *c* and *d*, where $c, d = 1, \cdots, 176,\ d > c$. The SD of quantities of the 9 goods is the square root of the Divisia variance of quantity differences between countries *c* and *d*, $\sigma^2_{q,cd} = \sum_{i=1}^{9} w_{i,cd}\left(Dq_{i,cd} - DQ_{cd}\right)^2$, where $w_{i,cd} = \frac{1}{2}\left(w_{ic} + w_{id}\right)$ is the average of the budget shares in *c* and *d;* $Dq_{i,cd} = \log log\, q_{ic} - \log log\, q_{id}$ is the log-difference between per capita consumption of good *i* in *c* and *d*; and $DQ_{cd} = \sum_{i=1}^{9} w_{i,cd} Dq_{i,cd}$ is the Divisia volume index for *c* relative to *d*. The SD of prices is the square root of the Divisia variance of price differences, $\sigma^2_{p,cd} = \sum_{i=1}^{9} w_{i,cd}\left(Dp_{i,cd} - DP_{cd}\right)^2$, where $Dp_{i,cd} = \log log\, p_{ic} - \log log\, p_{id}$ is the log-difference between the price of *i* in *c* and *d*; and $DP_{cd} = \sum_{i=1}^{9} w_{i,cd} Dp_{i,cd}$ is the Divisia index of prices in *c* relative to *d*. See text for details of the data.
2. This is a heat map in which "redder" colours represent denser groups of observations.
3. Both variables are truncated to [0,150].
4. More than 90 percent of observations lie above the 45-degree line.

Figure IV.1

The Demand Curve

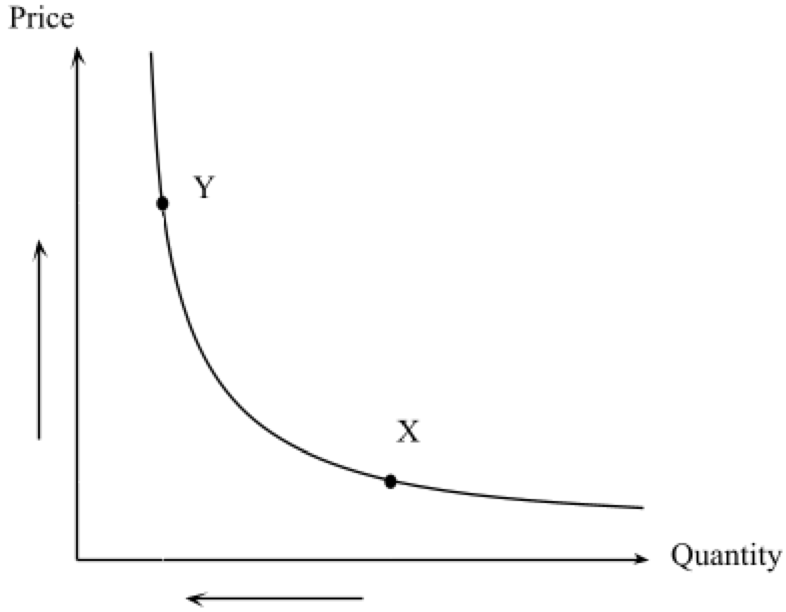
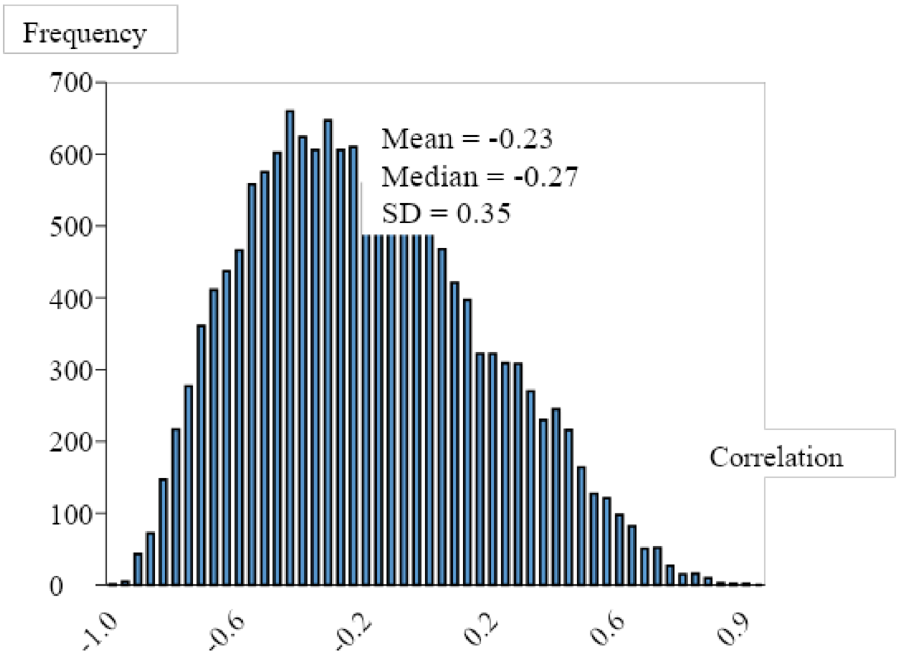


Figure IV.2

Price-Quantity Correlations,

Pairs of 176 Countries, 2011



Note: For the pair of countries $\{c, d\}$, $c, d = 1, \cdots, 176$, and the 9 goods, the Divisia price-quantity correlation is $\frac{\sigma_{pq,cd}}{\left(\sigma^2_{p,cd} \cdot \sigma^2_{q,cd}\right)^{\frac{1}{2}}}$, where

$\sigma_{pq,cd} = \sum_{i=1}^{9} w_{i,cd}\left(Dp_{i,cd} - \log log\, P_{cd}\right)\left(Dq_{i,cd} - \log log\, Q_{cd}\right)$ is the covariance;

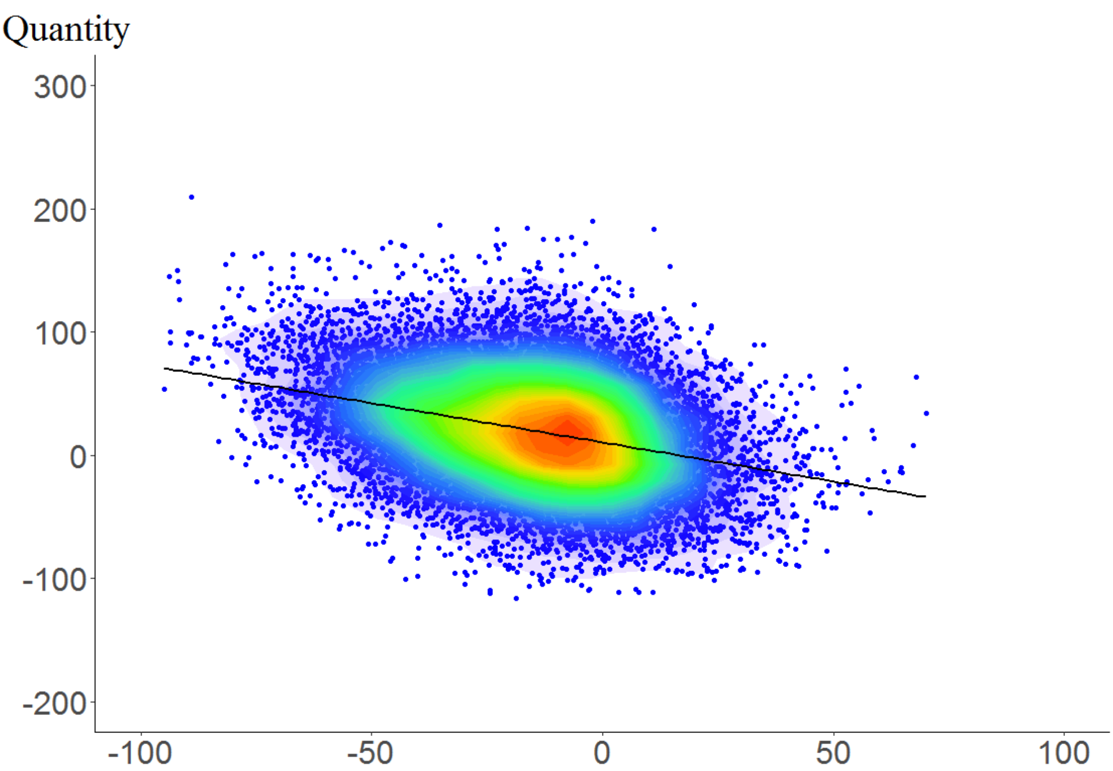
$\sigma^2_{q,cd} = \sum_{i=1}^{9} w_{i,cd}\left(Dq_{i,cd} - DQ_{cd}\right)^2$ is the quantity variance; and

$\sigma^2_{p,cd} = \sum_{i=1}^{9} w_{i,cd}\left(Dp_{i,cd} - DP_{cd}\right)^2$ is the price variance. For more information on these measures, see notes to Figure III.2. See text for details of the data. The above is a frequency distribution of the correlations for $c, d = 1, \cdots, 176,\ d > c$.

Figure IV.3

A Food Demand Curve,

Pairs of 176 Countries, 2011

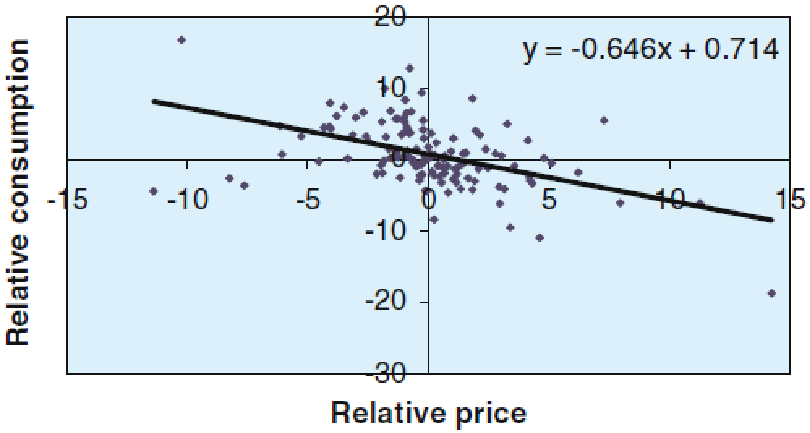


Note: The points underlying this heat map are the log-differences in the quantities of food consumed and the corresponding relative price differences between countries *c* and *d*, for $c, d = 1, \cdots, 176,\ d > c$. Quantities are adjusted for income differences (with an income elasticity of ½), that is, $100\left(Dq_{i,cd} - \tfrac{1}{2}\log log\ Q_{cd}\right) = 100\left(\log log \frac{q_{ic}}{Q_c^{1/2}} - \log log \frac{q_{id}}{Q_d^{1/2}}\right)$ for $i = food$. The relative price difference is $100\left(Dp_{i,cd} - \log log\ P_{cd}\right) = 100\left(\log log \frac{p_{ic}}{P_c} - \log log \frac{p_{id}}{P_d}\right)$. For more information on these measures, see notes to Figure III.2. See text for details of the data.

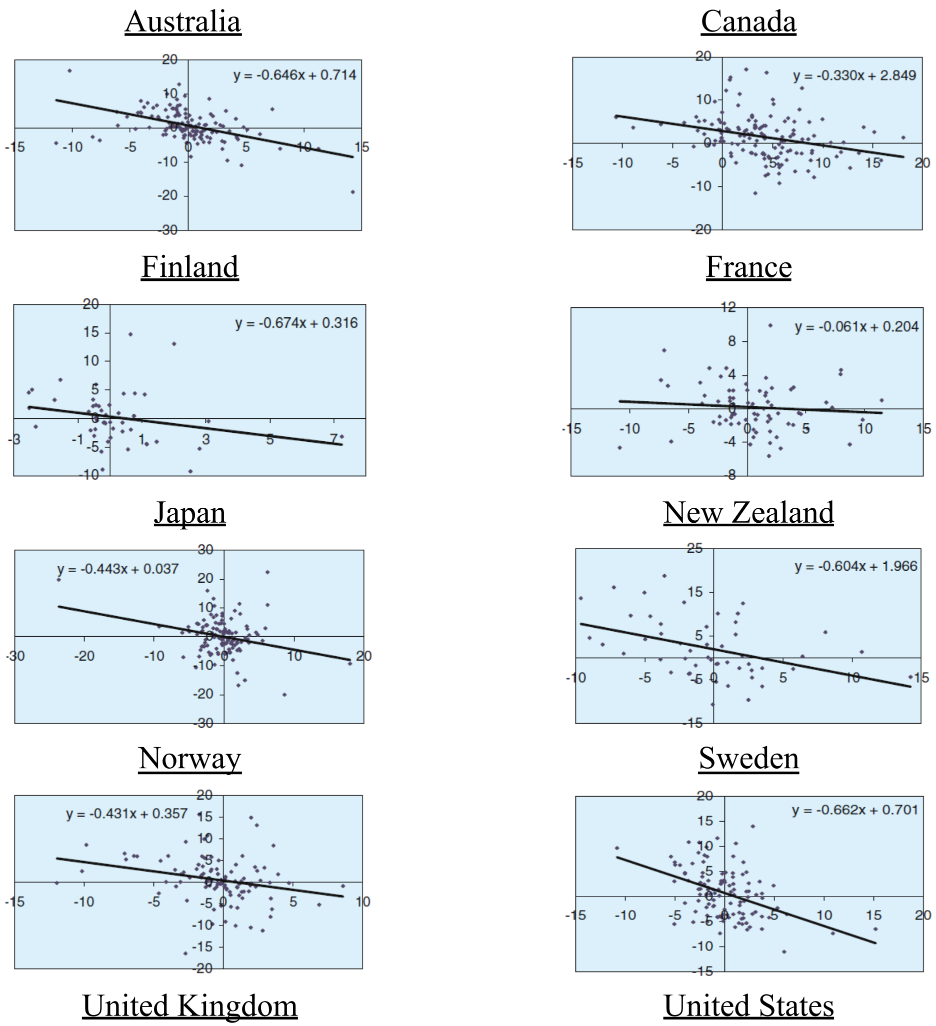
Figure IV.4

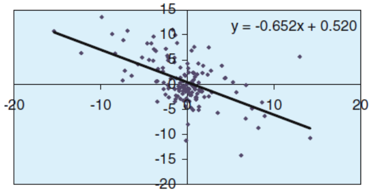
Demand for Alcohol, 10 Countries

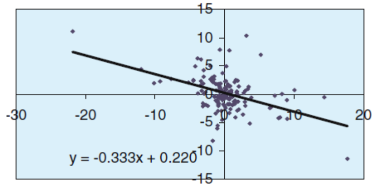
A. Australia



B. 10 countries



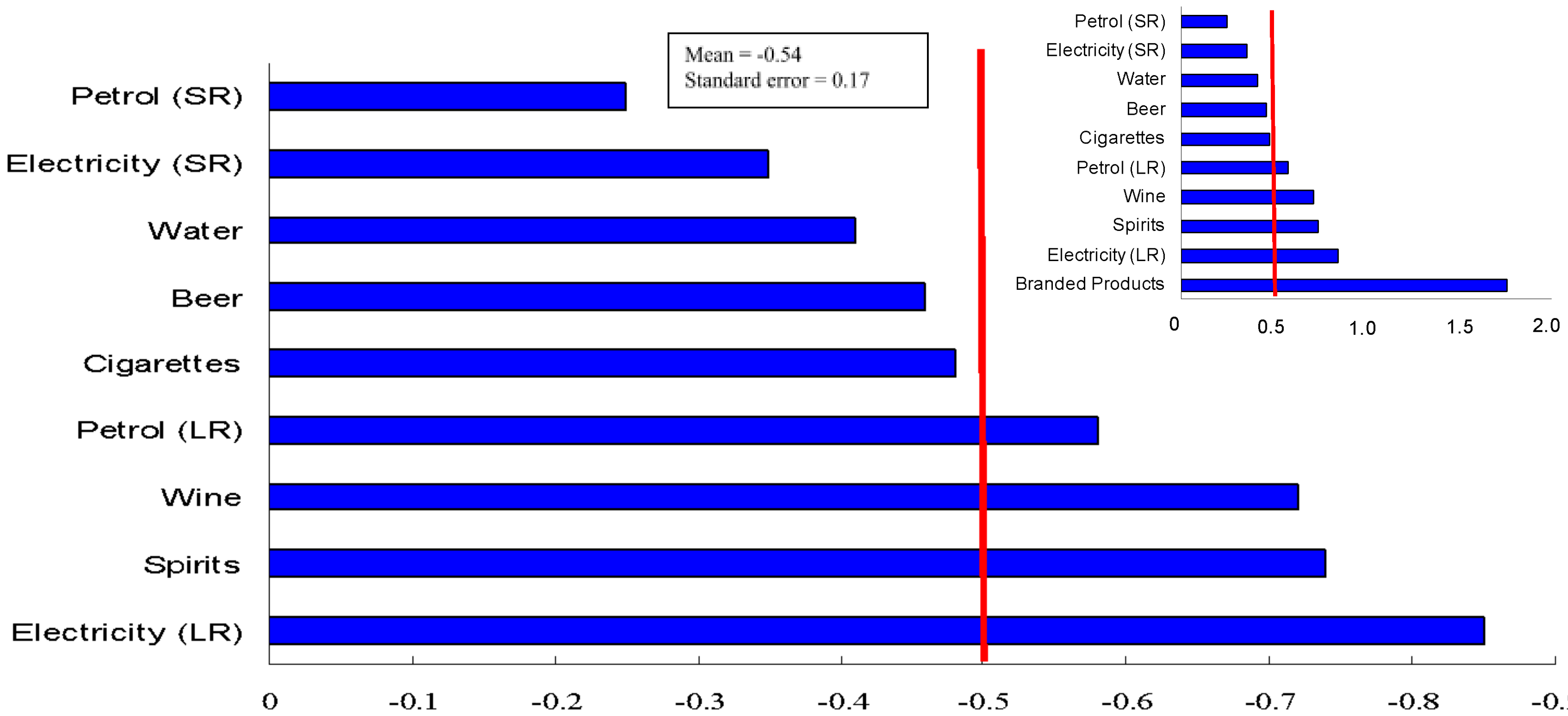




Source: Selvanathan and Selvanathan (2007).

Figure V.1

Price Elasticities of Demand



Note: The elasticity values in this figure are the means from Table V.1. In those cases where these are multiple means for the same product, we use those with the largest number of observations. The elasticity value for petrol (SR) of -0.25 is from the third entry in panel 6 of the table; electricity (SR) of -0.35 is from the first entry of panel 7; water of -0.41 is from first entry of panel 5; beer of -0.46 is from the first entry of panel 1; cigarettes of -0.48 is from first entry of panel 4; petrol (LR) of -0.58 is from the fourth entry of panel 6; wine of -0.72 is from the first entry of panel 2; spirits of -0.74 is from the first entry of panel 3; electricity (LR) of -0.85 is from the second entry of panel 7; and branded goods (included only in the “mini version” of the figure in the top right-hand corner) of -1.76 is from panel 8. SR denotes short run, and LR denotes long run.

APPENDICES

A1. NOTES ON PRICE-QUANTITY REGRESSIONS

Equation (IV.2) contains the relative price of good i in country c as compared to the price in d, $\log \mathit{log} \frac{p_{ic}}{P_c} - \log \mathit{log} \frac{p_{id}}{P_d}$, and the corresponding difference in the quantity, $\log \mathit{log} \frac{q_{ic}}{Q_c} - \log \mathit{log} \frac{q_{id}}{Q_d}$. Denote the Divisia price-quantity correlation of equation (IV.1) by

$$\rho_{cd} = \frac{\sigma_{pq,cd}}{\sqrt{\sigma^2_{p,cd} \bullet \sigma^2_{q,cd}}} \qquad -1 \leq \rho_{cd} \leq 1,$$

where $\sigma_{pq,cd}$ is the Divisia price-quantity covariance of equation (IV.1), and $\sigma^2_{p,cd}\ and\ \sigma^2_{q,cd}$ are the corresponding variance of prices and quantities, defined in equation (III.5). As the law of demand means the covariance is usually negative, so is the correlation ρ_{cd}.

Consider the relative consumption of good i as a function of its price:

(A1.1)
$$\left(\log \mathit{log} \frac{q_{ic}}{Q_c} - \log \mathit{log} \frac{q_{id}}{Q_d} \right) = \beta \bullet \left(\log \mathit{log} \frac{p_{ic}}{P_c} - \log \mathit{log} \frac{p_{id}}{P_d} \right) + \varepsilon_{i,cd},$$

where $\varepsilon_{i,cd}$ is a zero-mean disturbance term. The simple nature of this equation is to be noted: (i) The slope coefficient β is the price elasticity of demand, which is the same for each commodity. (iii) The role of income is controlled for in a rudimentary manner by deflating consumption of the good by income. (iii) Consumption of the good depends only on its own price, not that of the others. Note also the absence of an intercept in the equation. If each of the two countries had the same income and the same prices, then an intercept would represent any systematic residual difference in consumption. In the name of simplicity, this will be abstracted from and the intercept suppressed.

Notwithstanding the limitations of this demand model, it is instructive to consider estimating equation (A1.1) for the country pair (c, d) with the data on the $i = 1, \cdots, 9$ commodities. Using the budget shares $w_{i,cd}$ as weights, the weighted least-squares estimator of the price elasticity is

$\hat{\beta} = \frac{\sigma_{pq,cd}}{\sigma^2_{p,cd}}$, or

(A1.2)
$$\hat{\beta} = \rho_{cd} \frac{\sigma_{q,cd}}{\sigma_{p,cd}} .$$

In words, the estimated price elasticity is the price-quantity correlation scaled by the dispersion of quantities relative to prices.

With only 9 observations for a given pair of countries, there is sure to be considerable randomness, and so it is desirable to average over country pairs to evaluate the price elasticity (A1.2). To explore briefly the numerical implications, we use the results from the ICP data given in Table III.1, an extract of which is reproduced below. Comparing countries in the richest income quintile with those in the next richest, from the entry in the top left corner of the bottom panel of the table below, the average correlation is $-\ 0.46$, while the corresponding ratio of the standardard deviations is 1.69 (from the top panel). Plugging these values into (A1.2) yields $\hat{\beta} =-\ 0.46\times1.69 =-\ 0.78$. Using the same procedure for the other adjacent quintiles in this table yields estimates of $-\ 0.58$, $-\ 0.59$, $-\ 0.60$. While these values are not unreasonable, in view of the simplifying underlying assumptions, they should still be taken with a pinch of salt.

		□ Richer			Poorer □
		Group 2	Group 3	Group 4	Group 5
C. Ratios of quantity to price dispersion					
Richer	Group 1	1.69	1.53	1.96	2.56
	Group 2		1.70	2.04	2.90
	Group 3			1.91	2.70
Poorer	Group 4				2.38
D. Price-quantity correlations					
Richer	Group 1	-0.46	-0.35	-0.13	0.11
	Group 2		-0.34	-0.18	0.03
	Group 3			-0.31	-0.16
Poorer	Group 4				-0.25

Source: Table III.1.

What if we take an alternative approach and take prices to be determined by quantities? For this reciprocal approach the equation becomes:

(A1.3) $$\left(\log log \frac{p_{ic}}{P_c} - \log log \frac{p_{id}}{P_d}\right) = \beta' \bullet \left(\log log \frac{q_{ic}}{Q_c} - \log log \frac{q_{id}}{Q_d}\right) + \varepsilon'_{i,cd}.$$

Such an approach is used in agricultural economics to determine the impact of a change in the quantity sold on the price and the slope coefficient here, β', is known as the price flexibility. The WLS estimator of this slope is:

$$\hat{\beta}' = \rho_{cd}\frac{\sigma_{p,cd}}{\sigma_{q,cd}}.$$

Setting the disturbances in equations (A1.1) and (A1.3) at their expected values of zeros, $\frac{1}{\beta'} = \beta$. However, this property is not satisfied by the above estimators since the demand model will not usually fit the data exactly. As $\frac{1}{\hat{\beta}'} = \frac{\hat{\beta}}{\rho^2_{cd}}$, only when the correlation coefficient is unity (that is, when the regression fits perfectly) does the inverse of the estimated slope of equation (A1.3) coincide with the estimated slope of equation (A1.1). In all other cases, if the negative signs are ignored, $\frac{1}{\hat{\beta}'} > \hat{\beta}$ as $\rho^2_{cd} < 1$. Another way of expressing the same result is $\hat{\beta}\hat{\beta}' = \rho^2_{cd}$. For related results, see Berndt (1976, p. 61).

A2. ASSESSING PREFERENCE INDEPENDENCE

The preference-independent utility function is given by equation (V.1), $u\left(q_i, \cdots, q_n\right) = \sum_{i=1}^{n} u_i\left(q_i\right)$. This states that utility from consumption of the *n* goods is the sum of *n* sub-utility functions, one for each good. Frisch (1959, p. 186) argues preference independence is not likely to be appropriate for narrowly define goods, but satisfactory for broad groups of goods:

> If the goods are specified in all concrete detail (say, margarine with one technical specification as distinguished from margarine with another technical specification), it will hardly ever be realistic to assume [preference] independence for any of the goods. But if the goods are aggregated in a reasonable way ... one will in practice get goods about which we can say a priori with considerable confidence that they are [preference] independent.

While preference independence would seem to be not unreasonable for broad aggregates, it is still a strong assumption as, for example, it rules out complementarity and inferior goods. It is, therefore, perhaps not surprising that the hypothesis has been subject to considerable empirical testing, some of which has resulted in the applicability of preference independence being severely questioned. As this assumption lies behind the law of ½, this appendix reviews the evidence regarding the appropriateness of preference independence.

Deaton (1974) tests preference independence indirectly by investigating whether luxuries are more price elastic than necessities, the proportionality relationship between price and income elasticities, equation (V.10). Using UK data, he finds a lack of proportionality and concludes in unequivocal terms: "*[T]he assumption of additive preferences* [preference independence] *is almost certain to be invalid in practice and the use of demand models based on such an assumption will lead to severe distortion of measurement*" (his emphasis). However, such a strong conclusion need to be tempered by the work of Selvanathan (1993), who uses elasticities from 18 OECD countries and finds the evidence not inconsistent with the proportionality relationship.

Direct tests of preference independence involve examining the validity of the implied parametric restrictions on demand equations. For example, the preference-independent version of the Rotterdam model is:

$$\bar{w}_{it} Dq_{it} = \theta_i DQ_t + \phi\theta_i \left(Dp_{it} - \sum_{j=1}^{n} \theta_j Dp_{jt} \right) + \varepsilon_{it}, \quad i = 1, \cdots, n. \qquad \text{(A2.1)}$$

Here, $\bar{w}_{it} = ½\left(w_{it} + w_{i,t-1}\right)$ is the arithmetic average of the i^{th} budget share in periods *t* and *t-1*; $Dq_{it} = \log log\, q_{it} - \log log\, q_{i,t-1}$ is the i^{th} quantity log-change; $\theta_i = \frac{\partial\left(p_i q_i\right)}{\partial M}$ is the i^{th} marginal share; $DQ_t = \sum_{i=1}^{n} \bar{w}_{it} Dq_{it}$ is the Divisia (1926) quantity index, a measure of the change in real income; $\phi < 0$ is the income flexibility; $Dp_{it} = \log log\, p_{it} - \log log\, p_{i,t-1}$ is the log-change in the price of *i*; and ε_{it} is a disturbance term. The parameters of this model are $\theta_1, \cdots, \theta_n$ and ϕ. Equation (A2.1) expresses the share-weighted change in the demand for good *i* in terms of the change in income and the good's relative price, $\left(Dp_{it} - \sum_{j=1}^{n} \theta_j Dp_{jt} \right)$. This is a constrained system as it contains on the right-hand side only the own-relative price; and the coefficients attached to this relative price, $\phi\theta_i,\ i = 1, \cdots, n$, are constrained to be proportional to the marginal shares.[27]

The appropriateness of the preference independence hypothesis can be tested by comparing the fit of (A2.1) with that of its unconstrained counterpart containing all *n* relative prices:

$$\bar{w}_{it} Dq_{it} = \theta_i DQ_t + \sum_{j=1}^{n} \nu_{ij} \left(Dp_{jt} - \sum_{k=1}^{n} \theta_k Dp_{kt} \right) + \varepsilon_{it}, \ i = 1, \cdots, n,$$

where ν_{ij} is a price coefficient. In a review of the earlier econometric evidence, Barten (1977) states that the restrictions of preference independence tend to be rejected. But caution is needed here also as the tests employed in many of the earlier studies are subject to small-sample biases. When this issue is avoided using a resampling approach, preference independence is rejected less frequently (Selvanathan, 1987, 1993, Selvanathan and Selvanathan, 2005).

To conclude, the assumption of preference independence is attractive in its simplicity. It has its critics and advocates. While it is in the nature of these matters that one can never the absolutely

[27] The more general version of the Rotterdam model, one without preference independence, is discussed in the next paragraph. The Rotterdam model is due to Barten (1964) and Theil (1965). For a recent review of this model, see Clements and Gao (2015).

certain, a reasonable position to adopt is that it seems safe to apply preference independence to broad aggregates of goods.

A3. THE INCOME FLEXIBILITY

The income flexibility ϕ is an unknown parameter for which we used the value -½ on the basis that estimates tend to be clustered around this value. This appendix summarises the evidence regarding the value of this parameter. The first part of this summary is based largely on Clements and Si (2017, 2018).

A3.1 <u>A Demand Model</u>

The estimates of ϕ to be presented are derived from the preference independent version of the Rotterdam model, equation (A2.1). The marginal share θ_i appears three times on the right-hand side of that equation. Treating this as a constant parameter can lead to unattractive implications of the behavior of the income elasticities; an alternative approach is to set $\theta_i = \overline{w}_{it} + \beta_i$, with β_i a constant satisfying $\sum_{i=1}^{n} \beta_i = 0$ (Working, 1943).[28] Equation (A2.1) then becomes

$$\overline{w}_{it}\left(Dq_{it} - DQ_t\right) = \beta_i DQ_t + \phi\left(\overline{w}_{it} + \beta_i\right)\left(Dp_{it} - DP'_t\right) + \varepsilon_{it}, \qquad i = 1, \cdots, n, \tag{A3.1}$$

where $DP'_t = \sum_{i=1}^{n}\left(\overline{w}_{it} + \beta_i\right)Dp_{it}$ is a marginal-share weighted price index. To simplify estimation, the time-varying budget shares on the right of this equation are replaced with their means over time.

Clements and Si (2017) estimate equation (A3.1) for $n = 9$ with annual data for each of the 37 OECD countries listed column 1 of Table A3.1; this table also contains the relative incomes of countries. Thus, there is a set of estimates of the coefficients of (A3.1) for each country, from which the income and price elasticities can be derived. The income elasticities differ across countries, but they can summarised by averaging over countries, as in Table A3.2. As can be seen, food is a clear necessity, in agreement with Engel's law, while education and miscellaneous goods and services are both strong luxuries. Table A3.3 contains the 37 ϕ-estimates, which seem to be more or less

[28] Let i be the income elasticity of good i. When prices are held constant equation (A2.1) becomes witDqit=iDQt, where the disturbance has been set at its expected value of zero. Dividing both sides by wit shows that the income elasticity is i=iwit. When i=constant, the elasticity is inversely proportional to the budget share, that is, dηii=-dwitwit. Thus, when income growth causes the budget share of food to fall (Engel's law), the corresponding income elasticity rises, so greater affluence makes food less of a necessity, or more of a luxury. This violates economic intuition. Alternatively, when i=wit+i, i=1+iwit with dηii=1-iidwitwit. For necessities 0<i<1, the income elasticity now moves in the same direction as the share, while the reverse is true for luxuries i>1, This approach thus solves the problem.

scattered randomly around the mean of -0.54. Using several tests, Clements and Si (2017) find that these income flexibility estimates are unrelated to income.

As ϕ appears as a common coefficient in each equation of (A3.1), if β_i is known (or set at its previously estimated value), ϕ can be estimated for each year with a cross-commodity regression by regressing $\overline{w}_{it}\left(Dq_{it} - DQ_t\right) - \beta_i DQ_t$ on $\left(\overline{w}_{it} + \beta_i\right)\left(Dp_{it} - DP'_t\right)$ for $i = 1, \cdots, 9$. Clements and Si (2018) use this approach with the OECD data and the results are given in Figure A3.1 in the form of a frequency distribution of the estimates of ϕ. There is a fairly well defined centre-of-gravity to this distribution and the mean is -0.41, which is not too far away from $-$ ½.

Clements and Si (2018) also apply the approach described in the previous paragraph to the 2011 round of the International Comparison Program (World Bank, 2015). Rather than comparing changes from one year with the next, this cross-country application involves a comparison of each of the 176 countries with each of the others, a total of $176C_2 = 15,400$ pairwise comparisons. Figure A3.2 and Table A3.4 give the results. The average over all countries of the estimates of ϕ is -0.52, but the qualification is that here there is some heterogeneity at the top of the income distribution, where for the countries in the top quartile the mean is lower (in absolute value) at -0.22.

A3.2 Summary and Other Approaches

To summarise: The three sets of estimates of the income flexibility discussed would seem to be not inconsistent with the idea of using for ϕ the value $-$ ½. This value is also in broad agreement with earlier estimates, as reviewed by Clements and Zhao (2009, pp. 228-29). Employing similar approaches to those described above, this previous literature includes Theil (1987, Sec. 2.8), who uses earlier ICP data pertaining to 30 countries; Selvanathan (1993, p. 189, Sec. 6.4), for OECD countries; Chen (1999, p. 171), using the average changes over a decade or two in 42 countries; and Selvanathan and Selvanathan (2003, p. 107 and 157), for 23 OECD countries and 23 developing countries. The evidence is also consistent with a survey of older studies by Brown and Deaton (1972, p. 1206), who state "there would seem to be fair agreement on the use of a value for ϕ around minus one half".[29]

[29] Also relevant is Frisch's (1959) conjecture that the absolute value of the income flexibility increases with income. As mentioned above, Clements and Si (2017) find that the income flexibility to be unrelated to income. The conjecture has been also been tested in several other studies as summarised by Clements and Zhao (2009, p. 228). The majority of the evidence is not strongly supportive. However, there are some studies supportive of Frisch, including DeJanvry et al. (1972), Lluch et al. (1977) and Gao (2012, p. 106). Accordingly, the empirical status of the Frisch conjecture has not been completely resolved. It is to be noted, however, that Frisch might not be too uncomfortable with setting equal to -½, a value he felt would pertain to the "middle income bracket, 'the median part' of the population" (Frisch, 1959, p. 189).

Three further contributions that deal with alternative ways of estimating the income flexibility should also be noted:

1. Evans (2005), in discussing the use of the income flexibility for calculating the social discount rate, emphasises the estimation of ϕ from the country's income tax schedule with the equal sacrifice model. The average of estimates of $-\frac{1}{\phi}$ from 20 OECD countries is about 1.4, so ϕ is about -0.71.
2. Layard et al. (2008) use survey data on subjective happiness to estimate $-\frac{1}{\phi}$ ranging from 1.34 to 1.19, with a combined estimate of 1.26. The implied range for ϕ is from $\frac{1}{-1.34} = -0.75$ to $\frac{1}{-1.19} = -0.84$, while the combined estimate is $\frac{1}{-1.26} = -0.79$. That these values are somewhat away from $-$ ½ might be regarded as a qualification to our approach, although it seems an open question whether reported subjective happiness coincides with our concept of utility.
3. Related to Evans (2005) and also in the context of the value of the social discount rate, Groom and Maddison (2018) present five ways of estimating ϕ: (i) The equal sacrifice model; (ii) the Euler-equation approach associated with the life-cycle model (Hansen and Singleton, 1982) of regressing the growth in consumption on the real interest rate to estimate as its coefficient $-\frac{1}{\phi}$; (iii) the Rotterdam model for food and nonfood under preference independence, which is equation (A2.1) for $n = 2$; (iv) the coefficient of relative risk aversion with insurance data; and (v) the subjective happiness approach of Layard et al. (2008) mentioned above. Combining these five approaches yields a combined estimate of $\frac{1}{\phi}$ of about -1.5, or $\phi \approx -0.67$, which is unlikely to be significantly different from -0.5.

A4. AGGREGATING GOODS INTO BROAD GROUPS

The previous discussion dealt with the situation in which all n goods are preference independent. This appendix considers a more general setting that permits utility interactions among some goods. These goods are then formed into groups that are preference independent. Let the n goods be divided into $G < n$ groups, denoted by $S_1, \cdots, S_G$, such that each good belongs to only one group. To give an economic interpretation to them, we suppose each group contains goods that are reasonably close substitutes, while there is limited substitution between goods belonging to different groups. Within each group, goods can interact fully, while, in a marginal utility sense, there are no between-group effects. We shall show that under certain conditions, the rule of ½ continues to hold for the price elasticities of the groups of goods. This material is mostly based on Clements (1987) and Theil (1975/76, 1980).

Suppose each group S_g provides a certain "basic function" in generating utility. An example might be the meats group, comprising beef, pork, chicken and lamb, a group that provides tasty nutrition in the form of protein. There is likely to be some utility interactions among the four meats – most commonly substitutability -- but possibly less with respect to other goods outside the group. Thus, if the marginal utility of each basic-function group of goods is independent of the others, the utility function can be represented as the preference independent form with respect to groups:

(A4.1)
$$u\left(q_1, \cdots, q_n\right) = \sum_{g=1}^{G} u_g\left(q_g\right),$$

where $u_g(\bullet)$ is the sub-utility function of group g and q_g is the vector of $q_i's$ belonging to group g. Here there are full utility interactions within groups, but none between them. As equation (A4.1) implies that the Hessian matrix is block-diagonal, with the g^{th} block containing $\frac{\partial^2 u}{\partial q_i \partial q_j}, i, j \in S_g$, it is known as <u>block-independence</u>. Block-independence is a generalisation of preference independence as represented by equation (V.1); only when $G = n$ does utility function (A4.1) coincide with (V.1)

It can be shown that under (A4.1), the proportionality relationship (V.10) becomes

(A4.2)
$$\sum_{j \in S_g} \eta'_{ij} \approx \phi \eta_i, \quad i \in S_g, g = 1, \cdots, G.$$

In words, for a given good, the sum of the within-group own- and cross-price elasticities are approximately proportional to the income elasticity of the group, with the income flexibility the proportionality factor.[30] The budget share of group S_g is $W_g = \sum_{i \in S_g} w_i$ and the within-group budget share of $i \in S_g$ is $\frac{w_i}{W_g}$, so that $\sum_{i \in S_g} \frac{w_i}{W_g} = 1$. Averaging both sides of equation (A4.2) over $i \in S_g$, using as weights the within-group budget shares, gives $\sum_{i \in S_g} \frac{w_i}{W_g} \sum_{j \in S_g} \eta'_{ij} \approx \phi \sum_{i \in S_g} \frac{w_i}{W_g} \eta_i$, or

(A4.3)
$$N'_{gg} \approx \phi N_g, \quad g = 1, \cdots, G.$$

[30] Result (A4.2) is exact, not approximate, for Frisch price elasticities. The same applies to (A4.3).

Here, $N'_{gg} = \sum_{i \in S_g} \frac{w_i}{W_g} \sum_{j \in S_g} \eta'_{ij}$ is the own-price elasticity of group g and $N_g = \sum_{i \in S_g} \frac{w_i}{W_g} \eta_i$ is the income elasticity of this group. It follows from restriction (V.3) that

$\sum_{g=1}^{G} W_g N_g = \sum_{g=1}^{G} W_g \sum_{i \in S_g} \frac{w_i}{W_g} \eta_i = \sum_{i=1}^{n} w_i \eta_i = 1$, that is, the weighted-average of the group income elasticities is also unity. So, if we put the group income elasticity at its average value of unity, and set ϕ equal to $-$ ½, (A4.3) means that price elasticities of groups of goods are now approximately minus one-half.

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Table A3.1

OECD Data

Country	Period	Per capita GDP, 2010	
		International dollars	US = 100
(1)	(2)	(3)	(4)
1. Luxembourg	1995 - 2015	85,621	177.3
2. Norway	1970 - 2014	58,054	120.2
3. Switzerland	1995 - 2013	53,132	110.0
4. United States	1970 - 2015	48,291	100.0
5. Netherlands	1995 - 2014	44,542	92.2
6. Denmark	1995 - 2015	43,057	89.2
7. Ireland	1996 - 2014	42,803	88.6
8. Australia	1985 - 2014	42,350	87.7
9. Austria	1995 - 2015	41,944	86.9
10. Sweden	1993 - 2015	41,649	86.2
11. Belgium	1995 - 2014	40,003	82.8
12. Germany	1995 - 2014	39,918	82.7
13. Canada	1981 - 2015	39,885	82.6
14. Finland	1975 - 2015	38,781	80.3
15. Iceland	1995 - 2014	38,411	79.5
16. France	1959 - 2015	37,209	77.1
17. UK	1995 - 2015	35,769	74.1
18. Japan	1994 - 2013	35,203	72.9
19. Italy	1995 - 2014	34,893	72.3
20. Spain	1995 - 2014	31,968	66.2
21. New Zealand	1987 - 2014	31,133	64.5
22. Korea	1970 - 2015	30,664	63.5
23. Israel	1995 - 2014	29,646	61.4
24. Greece	1995 - 2015	28,061	58.1
25. Slovenia	1995 - 2015	27,740	57.4
26. Czech Rep.	1995 - 2015	27,636	57.2
27. Portugal	1995 - 2015	27,331	56.6
28. Slovak Rep.	1995 - 2015	24,939	51.6
29. Estonia	1995 - 2015	21,613	44.8
30. Hungary	1995 - 2015	21,435	44.4
31. Poland	1995 - 2015	20,798	43.1
32. Lithuania	1995 - 2014	19,965	41.3
33. Latvia	1995 - 2014	17,652	36.6
34. Turkey	1998 - 2014	17,464	36.2
35. Mexico	2003 - 2014	14,586	30.2
36. South Africa	1975 - 2014	11,652	24.1
37. Colombia	2000 - 2014	10,680	22.1

Table A3.2

Income Elasticities:
Means over 37 OECD countries

Commodity (1)	Income elasticity (2)
1. Food and alcohol	0.57
2. Clothing and footwear	1.01
3. Housing and utilities	0.60
4. Furnishings, equipment	1.30
5. Health	0.98
6. Recreation and culture	1.38
7. Education	1.41
8. Restaurants and hotels	1.06
9. Misc goods and services	1.48

Table A3.3

First Set of Income Flexibilities:
Time-series estimates for each OECD country

(Standard errors in parentheses)

1. Australia	-0.414 (0.054)	21. Lithuania	-0.394 (0.089)
2. Austria	-0.463 (0.062)	22. Luxembourg	-0.848 (0.143)
3. Belgium	-0.050 (0.047)	23. Mexico	-0.830 (0.000)
4. Canada	-0.350 (0.048)	24. Netherlands	-0.282 (0.066)
5. Colombia	-0.082 (0.045)	25. New Zealand	-0.624 (0.067)
6. Czech Rep.	-0.438 (0.067)	26. Norway	-0.906 (0.082)
7. Denmark	-0.530 (0.087)	27. Poland	-0.606 (0.071)
8. Estonia	-0.321 (0.055)	28. Portugal	-0.612 (0.083)
9. Finland	-0.486 (0.059)	29. Slovak Rep.	-0.477 (0.058)
10. France	-0.444 (0.046)	30. Slovenia	-0.336 (0.084)
11. Germany	-0.300 (0.051)	31. South Africa	-0.376 (0.046)
12. Greece	-0.148 (0.134)	32. Spain	-0.219 (0.062)
13. Hungary	-0.524 (0.052)	33. Sweden	-0.515 (0.068)
14. Iceland	-0.806 (0.095)	34. Switzerland	-1.706 (0.031)
15. Ireland	-2.459 (0.053)	35. Turkey	-0.183 (0.039)
16. Israel	-0.017 (0.059)	36. UK	-0.812 (0.078)
17. Italy	-0.526 (0.048)	37. United States	-0.601 (0.047)
18. Japan	-0.605 (0.160)		
19. Korea	-0.209 (0.046)	Mean	-0.538 (0.067)
20. Latvia	-0.423 (0.106)		

Table A3.4

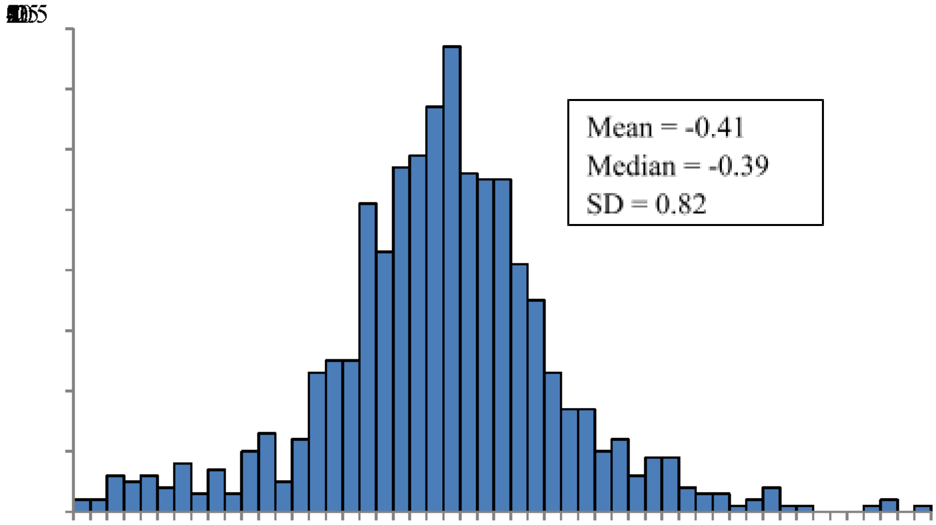
Summary of Third Set of Income Flexibilities:
Estimates for 176 ICP Countries, 2011

Income group of countries	Income (US = 100)		Income flexibility	
	Mean	SD	Mean	SD
Top quartile	68.5	13.9	-0.217	0.375
Quartile 3	35.3	7.5	-0.709	0.512
Quartile 2	16.2	4.6	-0.685	0.389
Quartile 3	4.1	1.9	-0.463	0.830
All countries	31.0	25.7	-0.518	0.592

Note: Denote the estimated income flexibility for country c relative to d by $\hat{\phi}_{cd}$, $c, d = 1, \cdots, 176$. The estimate for c is then $\hat{\phi}_c = \frac{1}{176}\sum_{d=1}^{176}\hat{\phi}_{cd}$. Income is real consumption per capita.

Figure A3.1

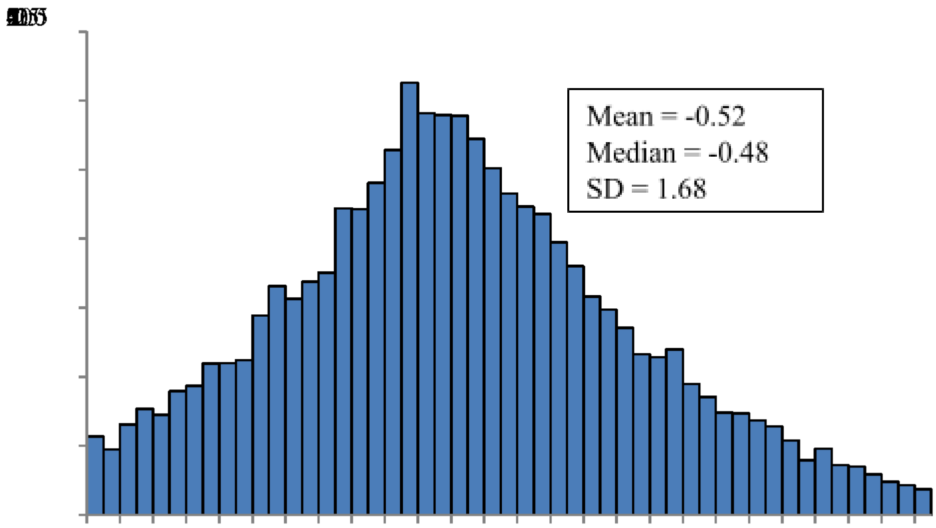
Second set of Income Flexibilities:
Estimates for each year and each OECD country



Note: Values are truncated to [-2.5, 2.5].

Figure A3.2

Third Set of Income Flexibilities,
Estimates for each pair of 176 ICP Countries, 2011



Note: Values are truncated to [-2.5, 2.5].