Mr. Lockyer meets the Index Number Problem: the standard of living in Canton and London in 1704

By

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Little is known of the life of Charles Lockyer beyond what he tells us in his remarkable Account of the Trade in India published in 1711. In 1703, Lockyer sailed from England on the East India Company's ship Streetham. He was not the chief supercargo, who was a Mr. Brewster, but he was probably a subordinate.[1] In this capacity, he became fully acquainted with the trading possibilities in Asia, which he described in his book.

The voyage lasted three years.[2] The Steetham, a 350 ton ship, left England in February 1703 and reached Batavia on 9 October. In view of the monsoon, she could not continue directly to China and so traded between Malacca and India. Indeed, Lockyer begins his chronicle in Fort George with a lengthy account of the East India Company's administration. The Streetham left Madras on 17 May, 1704, and headed for Acheen where Lockyer described the foreign exchange market in June, 1704. The cargo included opium which was sold in Acheen for 220 Taels per bahar. The voyage continued to Malacca and then to Pulo Condore, which was reached on 27 July, and finally to China. The Streetham reached Macao on 7 August and Whampoa on 18 August before docking in Canton. The latter was not trivial, for it required securing permission and paying various fees, which had to be negotiated.

Business finally began in early September. On 8 September, the Streetham's cargo of broadcloth, lead, and perpetuanoes was sold for cash, and the return cargo was purchased shortly afterwards. The main item was wrought silk, which was bought on 15 September. We do not know the full cargo on the Streetham's return voyage, but another East India Company ship in Canton at the same time was the Kent, and it brought the following back to London:

Wrought silk……	80,000	Taels
Copper, Yunnan, 600 chests……	6,180	
Quicksilver and vermilion, 400 piculs……	17,200	
Green ginger, 500 piculs…….	2,000	
Tea, 470 piculs…….…...	14,000	
Chinaware……...	3,500	
Pepper (taken at Batavia), 525 piculs……..	3,600	
Rhubarb, 15 piculs……..	460	
Cowries, 22 piculs……...	60	
Total value of cargo	**127,000**	**Taels**

The Streetham remained in Canton for three months. The cargo it sold was not actually delivered until November, and Lockyer's price currant is dated December 1704. The Stretham left Canton on 14 December and cleared Whampoa the next day. The ship did not return to England immediately but continued to trade around the Indian Ocean. The Streetham headed for Cocheen, which it reached on 10 March, 1705, and where it took on rice and other provisions that were sold at the next stop in Mocho. Then the Streetham headed to Muskat and Goombroon (modern day Band~r Abb~s) at the mouth of the Persian Gulf. Afterwards, it was a sail down the west coast of India stopping at Goa, Carwar, Telichery, Calicut, and, once again, at Cocheen. Finally, the Streetham headed back to England, stopping on the way at the Cape of Good Hope and at St. Helena in 1706 before the

[1]Morse (1926, Vol. I, p. 135). Dermigny (1964, p.51, 146n6) refers to Lockyer was the 'subrécargue'.
[2] My account of the voyage is based on Lockyer (1711) and Morse (1926, Vol. I, pp. 128-44, 309).

final run up the Atlantic.

While the East India Company had a monopoly on trade between the East Indies and England, it allowed its employees to trade on their own account, and many took advantage of this opportunity. How to trade your way to riches was the passion behind Lockyer's book For each port he visited, he listed the English goods that could be sold profitably and the local produce that could be exported to England or sold elsewhere in Asia. In Malacca, for instance, he observed that "The Dutch, who trade in Sloops and small Vessels to Jahore, Quedah, Pegu, and among the Sindy Islands , make very profitable Returns in Tin, Tutanague, Wax, Ivory, Sugar, Pepper &c. all which are much cheaper here than any where, to the Westward of the Nicobar Islands, and therefore most of these Commodities are Brought up by Ships bound that way." (Lockyer 1711, p. 72) He always summarized the local weights and measures and their conversions among each other and into English units. Money and coinage received equal attention, both to establish the sterling equivalents of Asian prices and because gold and silver could be shipped around Asia to arbitrage the money markets.

Despite the usual tone of excitement at the prospect of getting rich, there are melancholy passages that suggest that Lockyer, like others in his position, were less successful than they hoped. In Goombroon at the mouth of the Persian Gulf, he wrote, "poor Factors and Writers at 15l. and 5l. per Annum, have a hard Bargain with the Company." Lockyer, however, concocted a scheme to make the most of the bad situation. "Here's an Opportunity of growing rich sooner than at more healthful Places." The trick was to make an agreement "with another of equal Fortune, that at the Decease of either, the Estate he was possess'd of shall fall to the Survivor." Since mortality was so high, "one has a fair Chance in four or five Years time to be in better Circumstances than the best Management in Bunder could otherwise procure. I recommend this to the Consideration of all, whose Fortunes may lead them in that way." To those who found the plan morbid or were concerned that a man's estate should be left to relatives in England, Lockyer responded: "A Man is not nearer the Grave for such Provision, or would his Relations at home fare the worse, for the Loss of his Estate by Assignment: For, if by former Events we may judge of what will be, they have reason to conclude, not a third part of what is left with Trustees will be accounted for; often none at all; and to make the Company Executors in Trust is a very tedious way, unless one of the Directors be a Party concern'd." (Lockyer 1711, pp. 217-8)

Lockyer's observations paint a vivid picture of economic life in Asia. He found the Malays and Sumatrans to be lazy (Lockyer 1711, p. 78), but he was impressed by the commercial vigour of the Chinese. In Malacca, "Arek, commonly called Bettle-nut," could be purchased cheaply, and it "would bear all Charges of Freight, Package, and China Dutys, and fetch fifty per Cent. Profit in Canton on a large Quantity, towards the End of Anno 1704." This remarkable return "is more than any other Commodity within my Knowledge." However, such high profits would not last, "for the Chinese, who like Bees search all the Coasts betwixt Arracan and their own Country for Profit, have undoubtedly long since brought down the Price by filling their Markets with it." (Lockyer 1711, p. 72)

Lockyer may have had experience in construction, for he was an accurate and interested observer of house and ship building. In Goombroon, "Abdel la Ford, a Moor, is said to have fifteen or sixteen Sail of Ships of his own, from 100 to 500 Tuns Burthen. They are expert in building, and take the Dimensions of all new English Vessels that arrive: If they like the Model, the next they have on the Stocks shall resemble her in all things. They have not the least regard to the Dutch, whose high Sterns seem to be a hindrance to their Sailing.

They building altogether with Teak, a firm, lasting sort of Timber: Nor are their Seams ever caulk'd, as with us; but, instead of it, the Planks are rabbeted, and let one into another so dexterously, that a little Dammer and Oakham laid between, makes them as tight as a dish. They use Coire, or Coconut Cordage; and Anchors and Guns are brought them from Europe." (Lockyer 1711, p. 257-8)

Lockyer was also interested in labour costs, living standards and diet. Arab ships occasionally "get English Men for Pilots, but are always mann'd with Lascars, who are very good Sailers for the Cloimate. They serve for small Wages, and are Victual'd at a much cheaper Rate than our Ship's Companys: Salt-fish, Rice, Gee, and Doll, with a few Fowls, being all the Provisions they care for. Doll is a small Grain, less than Fetches, contains a Substance like our white Peas, and being boil'd with Rice makes Kutcheree." (257-8) Evidently, kedgeree was not as popular among the British in 1704 as it is today. This is a fact of some consequence, as we will see.

Our immediate interest, however, is not with Lockyer's observations but with the data that he collected. The relative standard of living in pre-industrial Europe and Asia is an issue at the forefront of historical discussion today. The long standing consensus running back to the classical economists was that Europe was more prosperous than Asia far back into the distant past. The revisionist challenge claims that real incomes in Asia were on a par with those in Europe until the nineteenth century when Europe pulled ahead and Asia declined. Quantitative analysis of the question has been hampered by the absence of information on wages and prices in Asia.[3] Such data are available for Europe due to a century and a half of scholarship that has produced price histories for many European cities. Similar data for many parts of Asia exist but have not yet been collected. Lockyer's book is a case in point, for it contains information on hundreds of Asian prices. I begin with some discussion of the prices, and then consider the comparison of real wages. One reason I begin with prices is that the data make it clear that relative prices were quite different in England and in China. The price divergences lead to significant index number problems in the comparison of real incomes. Some theoretical approaches to this problem are considered. The calculations that result show no significant difference in real wages between Canton and London in 1704.

Asian and European prices in 1704

Lockyer presents information on the prices of hundreds of products across Asia. The major markets he described are Canton, Malacca, and Goombroon. For Canton, he recorded the prices of Chinese export goods as well as many prices "of Stores, Provisions, Herbs, Roots, &c. of Use to Stewards of Factorys, and Surgeons of Ships" (150-1). For Malacca, he summarized the prices of many southeast Asian goods, and for Goombroon he tabulated the prices of Chinese, Indian, and Persian products. Prices were also recorded sporadically for ports around the Indian ocean.

I am in the process of matching the Asian prices to European counterparts. Results so far are limited to relatively homogeneous items. Table 1 shows the price in Canton divided by the corresponding price in England. In these comparisons, as in all others in this paper, the

[3] Pomeranz (2000) is a leading revisionist text. Allen, Bengtsson, and Dribe (2005) summarizes the debate and includes many recent contributions.

Chinese price is first converted to English pence using the East India Company's exchange rate of 1 Tael = 80d. This is rate is close to the silver parity exchange rate. That correspondence is not surprising since money was exchanged based on its silver content. Lockyer explained how the coins were weighed, how the Chinese reckoned fineness, and the resulting exchange rates. Silver parities, therefore, are reliable guides to exchange rates in Asia.

Table 1. Ratios of Chinese to English Prices

tea	.04
rice	.05
sugar	.07
pepper	.13
cup	.15
teapot	.20
unskilled labour	.27
cotton cloth	.30
ironwork	.32
copperwork	.35
alum	.38
candles	.45
lamp oil	.58
pork	.60
nails	.69
beef	.70
broad cloth	.75
brass work	.80
paper	.83
flour	.98
milk	1.13
lead	1.20
mutton	1.68
bread	1.76
charcoal	5.28

Note: Chinese prices in Tael have been converted to English prices at the East India Company's exchange rate of 1 Tael = 80 d. This is close to the silver parity of the two currencies.

A glance at the table establishes two important generalizations. First, relative prices varied enormously. Many things were cheaper in Asia than in Europe, but not everything. Second, the relative prices map out the distinctive features of the cultures of the two ends of Eurasia.

The items at the top of the table were particularly cheap in China. They include tea, rice, sugar, pepper, porcelain cups and teapots, and cotton cloth. Tea, pepper, porcelain, and cotton were Asian exports. Rice was the staple of the Asian diet. Unskilled labor was also very low in Asia and features among the cheapest entries.

At the bottom of the table are items characteristic of British life. These include milk (probably representing all dairy products) lead, mutton, bread, and charcoal. The British diet was based on bread, meat, and cheese, and they were comparatively cheap there. Lockyer (Lockyer 1711, p. 147) thought that lead was the most profitable item to export from Britain to China.

The fact that charcoal was, relatively, the cheapest item in Britain is of considerable interest. Historians from Nef (1932) onwards have claimed that Britain was running out of

wood in the eighteenth century, and that its price had been rising steeply since the sixteenth century. Nevertheless charcoal was vastly cheaper in England than in coastal China. British coal provided even cheaper energy. It is not necessary to look beyond prices to understand why the British were inventing techniques to increase energy use in the eighteenth century (e.g. the steam engine), while the Chinese were inventing energy saving technologies (huge kilns for firing pottery).

Table 1 contains some anomalies that, upon analysis, lend credence to the figures. English broadcloth is one. The East India Company was selling it at a lower price in Canton than Westminster College was paying for it in England. The East India Company was required to export some English manufactures. Lockyer (1711, p. 264) remarked that "The [East India] Company send Course Cloths, and several sorts of Woollen Manufactures; but, I believe, 'tis here, as in other Parts of India, a good Market when it will pay Charges, and bring the prime Cost." More often, broadcloth was a losing proposition, and the comparison of prices bears that out.

Table 1 raises deep questions about the importance of culture as an explanation of material life. Does culture explain why the Chinese ate rice, while the English diet was based on bread and mutton or were these differences simply questions of economics, i.e. of what was cheapest at each end of Eurasia? People certainly have preferences about the food they eat, but Table 1 raises the question of how deep seated, rigid, and hard to change those preferences are. Do people alter their eating habits easily when put in another environment or do they pay huge sums to eat as they did before? And what of people in the eighteenth century? It turns out that these questions have important implications for comparisons of living standards.

real wage comparison

Lockyer's data are sufficiently rich that they permit an advance in our understanding of comparative living standards in England and China at the beginning of the eighteenth century. Specifically, we can use them to compare the real wage of unskilled workers in Canton and London since we have information on the relevant wage rates and consumer goods prices in both cities. In addition, because we know the prices of a range of goods in both cases, we can explore theoretical questions about real wage comparisons. I will begin with the simplest deflator (the price of a calorie from the staple carbohydrate) and compare the result to more broadly based consumer price indices. One of the biggest problems in intercontinental comparisons is how to deal with differences in diet; in particular, the fact the rice was the main source of calories in China, while bread was its counterpart in Europe. I will focus on this issue by comparing and contrasting different ways of incorporating diet differences into the consumer price indices.

Table 2 lays out basic data about wage rates and the 'basket' of goods included in the consumer price index. Shares of spending assumed for both countries are also shown. These are derived from the best survey data on consumer spending patterns available–Horrel and Humphries (1992) for England and Fang (as summarized by Pomeranz 2000, p. 137) for China. As always, there are compromises in the actual calculations since prices are not available for all categories of spending (most obviously rent is excluded) and products for which we have prices are used as proxies for the prices of vaguely defined spending

categories. Nonetheless, Lockyer's data are much richer than any previously available, so this problem is somewhat less intense than in other cases. In addition, the relatively wide range of prices highlights the technical issues involved in the comparisons.

Table 2. Basic data relating to comparison of real wages

	English shares	Chinese shares	English price/ Chinese price
bread	.48	0	.57
rice	0	.60	19.95
meat	.13	.05	1.66
milk	.13	.01	.89
tea	.03	.05	26.60
sugar	.04	.12	15.24
charcoal	.04	.02	.19
lighting	.05	.03	1.96
cotton cloth	.05	.08	3.38
iron work	.02	.02	3.12
nails	.02	.02	1.45
calorie			4.97
wage rate			3.67

Note:
(1) English shares were constructed in two stages. First, shares were assigned to the categories based on Horrell and Humphries (1992). These assigned shares summed to .94 since rent equalled 6% of spending. The assigned shares were divided by .94 to calculated the shares shown above. These values shown here are rounded to two places. The index numbers shown later were computed with the unrounded quotients.
(2) Chinese shares are contrived from the skeletal summary in Pomeranz (2000, p.137).
(3) Chinese prices were converted to English pence at the East India Company exchange rate of 1 tael = 80 d. This is close to the silver parity of the currencies.
(4) The price of a calorie assumes the bread was 2450 calories per kilogram and rice was 3570 calories.
(5) The price of lighting is the average of the prices of lamp oil and candles.

First Approach: deflating with the price of a calorie

The first comparison of living standards is the easiest: divide the relative wage by the relative price of a calorie. The wage at the exchange rate (or the silver wage) was higher in London than in Canton. In 1704, an unskilled worker in London earned 22 d. per day, while a porter in Canton earned .075 Tael or 6 d. (6 = .075* 80 d/Tael). At the exchange rate, the English worker made 3.67 times as much as the Chinese worker. However, rice was so cheap in China that a calorie in London cost 4.97 times as much as in Canton. Hence, using the price of a calorie as the deflator implies that the real wage of an unskilled London worker was 74% (3.67/4.97) of that of his counterpart in Canton. The classical economists are stood on their heads!

There are two limitations to this finding: first, people consumed things besides bread and rice, and, second, these foods contain other nutrients and have culinary properties that make their reduction to calories problematic. I begin with the first of these issues.

Second Approach: consumer price index reducing rice and bread to starch

In the second approach to the comparison of living standards, I aggregate the prices of goods in the two cities into a consumer price index. Bread and rice are dealt with by reducing them to a category 'starch' and using the price of a calorie as the price of starch. Table 3 lays out the data.

Table 3. Real Wage Comparison

	p_i	English point of view		Chinese point of view	
	English price/ Chinese price	s_i English shares	p_i^{si}	s_i Chinese shares	p_i^{si}
starch	4.97	.48	2.15	.60	2.62
meat	1.66	.13	1.07	.05	1.03
milk	.89	.13	.98	.01	1.00
tea	26.60	.03	1.11	.05	1.18
sugar	15.24	.04	1.12	.12	1.39
charcoal	.19	.04	.93	.02	.97
lighting	1.96	.05	1.04	.03	1.02
cotton cloth	3.38	.05	1.07	.08	1.10
iron work	3.12	.02	1.02	.02	1.02
nails	1.45	.02	1.01	.02	1.01
cpi			3.00		4.91
wage rate			3.67		3.67
real wage			1.22		.75

I use geometric indices to compute the consumer price indices:

$$P = \prod p_i^{s_i}$$

where P is the consumer price index, p_i is the price of the ith good, s_i is the share of spending on that good, and the multiplication (represented by Π) is across all of the goods. Since spending patterns were different in England and China, two consumer price indices can be constructed by using the weights of each country. With English weights, the English price level is three times higher than the Chinese. This is less than the wage differential, so this calculation puts English real wages 22% above Chinese. On the other hand, with Chinese weights, the English price level is 4.91 times the Chinese. In this calculation those expensive English calories are given more weight, so the implied difference in average prices is greater. With the measured price difference exceeding the wage difference, the use of Chinese weights implies that English real wage was only 75% of the Chinese wage.

The discrepancy is an example of a classic index number problem. What are we to make of the discordant answers? The first response is that they reflect two ways of looking at the world–two cultures–the English and the Chinese. These are represented in the

calculations by the different weights placed on the various items. These weights, in turn, reflect differences in the underlying preferences of the two populations. In terms of index number theory, the geometric index is 'exact for' (that is, faithfully tracks) a Cobb-Douglas expenditure function[4], which, in turn, is dual to a Cobb-Douglas utility function[5]. The differences in spending shares tell us that the underlying preferences are different. Culture matters in comparing living standards, and the index number problem shows us by how much. When the question of living standards is put to a Chinese worker with Chinese tastes, he concludes that he would be better off in China, while an English worker comes to the opposite conclusion. In this analysis, one cannot say which workers are the best off–it all depends on the point of view. From either point of view, however, wages would have had to rise by about one quarter to offset the unfavourable prices.

Is that all we can say? In fact, we can reach stronger conclusions. To illustrate how, it will be convenient to represent the problem with an indifference curve diagram. Figure 1 shows the indifference curve of a Chinese consumer (U_c), his budget line (ab), and his consumption choice. The two commodities distinguished are starch (S_c) and 'all others' (O_c). These are distinguished since bread and rice loomed large in spending everywhere. Moreover, shares in spending differed between London and Canton, as did the relative prices of starch.

[4] The expenditure function shows the cost of reaching a reference indifference curve. The prices of consumer goods are arguments in the expenditure function. A price index is a function of two sets prices. A price index is exact for an expenditure function if they always agree; in particular, if the price index shows an average price difference between the two situations that equals the relative cost of reaching the reference indifference curve as implied by the expenditure function when it is evaluated for the two situations.

[5] A utility function and an expenditure function are dual to each other if the expenditure function can be derived from the utility function using the first order conditions for utility maximization. When they are dual, the utility and expenditure functions give equivalent representations of preferences.

Figure 1. [Title]

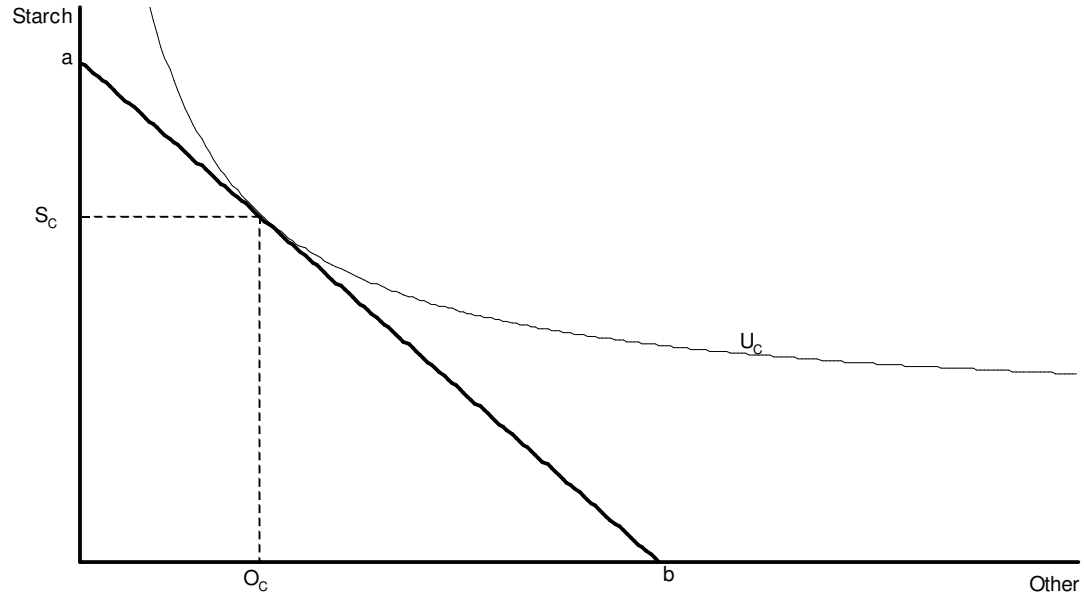
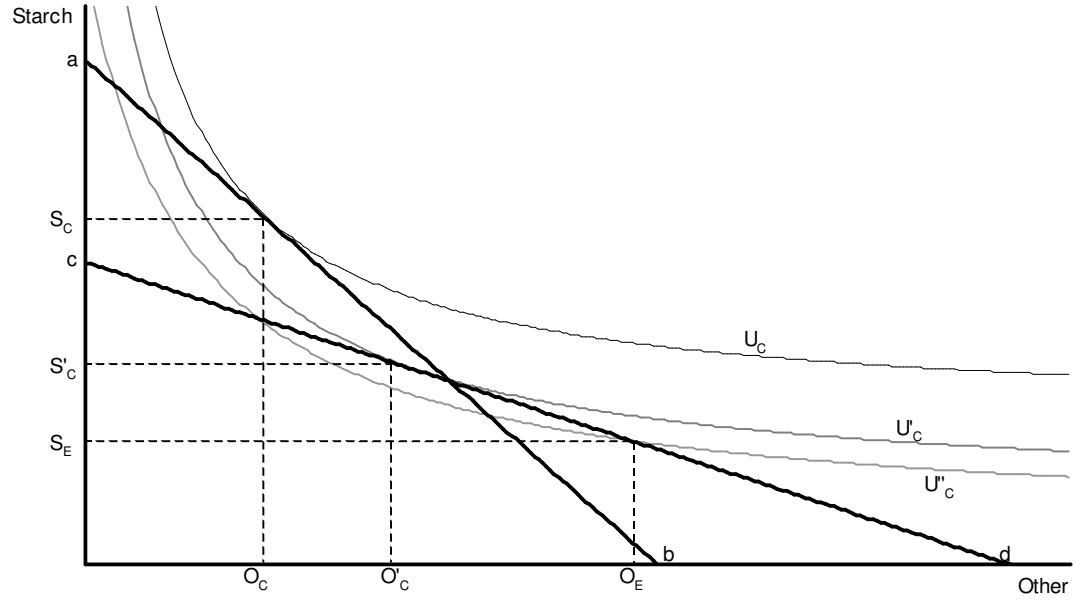


Figure 2 adds the English budget line (cd) to Figure 1.

Figure 2. [Title]



Notice that it has a lower intercept than the Chinese line and is flatter. The equation of the

budget line is

$$I = p_s S + p_o O$$

where I is income (the money wage in this case), p_s is the price of starch (price of a calorie), p_o is the price of other goods, S is the quantity of starch consumed, and O is the quantity of other goods. To graph the line, it is solved for S:

$$S = \frac{I}{p_s} - \frac{p_o}{p_s} O$$

The intercept, I / p_s is the real wage measured in terms of calories, and, as we have seen, it was less in England than in China. The relative price of other goods, p_o / p_s was also lower in England. Table 4 shows the prices of the other consumer prices were are dealing with relative to a calorie. The cheapness of rice meant that all other goods (with the exceptions of sugar and tea, the goods imported into Europe) were more expensive than calories in Canton. The indices of the relative price of 'other goods' shown in Table 4 show that tea and sugar did not loom large enough in spending to dominate the comparison: other goods were more expensive than calories in Canton than in London even allowing for the cheapness of tea and sugar in China. Our indifference diagrams are constructed accordingly.

Table 4. The Prices of 'Other Goods' Relative to Calories

	Canton	London
Bread		1.00
Rice	1.00	
Meat	21.42	7.17
Milk	10.71	1.91
Tea	107.10	573.66
Sugar	8.57	26.29
Charcoal	10.71	.41
Lighting	26.78	10.68
cotton cloth	75.97	51.63
iron work	22.84	14.34
Nails	30.72	8.96
share-weighted average	25.27	7.89

Note: The prices for the items in the rows for meat through nails equal the their actual prices divided by the price of a calorie implied by the prices of rice and bread for Canton and London, respectively. Share-weighted average computed as a weighted geometric average of the figures here for meat through nails. The weight for each item is its spending share in Table 3 divided by 1-share of starch in its table.

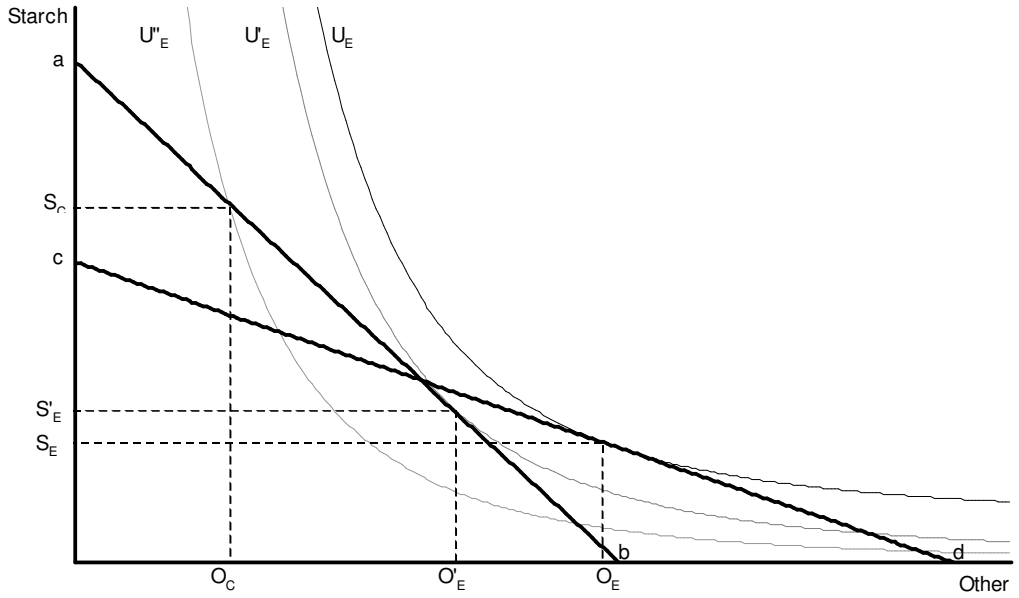
Figure 2 also shows two other indifference curves of the Chinese consumer ($U_c^{'}$ and

$U_c^{"}$). If the Chinese consumer were confronted with English prices and wages (cd), he would have chosen $S_c^{'}$ of starch and $O_c^{'}$ of other goods. The actual English spending pattern of (S_E) starch and (O_E) of other goods.

Three features of Figure 2 need highlighting. First, the real income (highest attainable indifference curve) of the Chinese consumer is lower under English conditions under Chinese ($U_c^{'}$ is closer to the origin than U_c). Our calculations show that the short fall was 25%. Second, when he is confronted with English wages and prices, the Chinese consumer shifts his spending in the direction of the English pattern, but the response is incomplete–he reduces his consumption of starch but still consumes more than the Englishman and conversely for other goods. Third, the English spending pattern is on a still lower indifference curve ($U_c^{"}$), and the English consumption pattern is nonoptimal, i.e. the English budget line cd is not tangent to $U_c^{"}$ when S_E and O_E are chosen. It should also be noted that all of these features of Figure 2 are indicative of the rigidity of the Chinese preferences as manifest in the curvature of the indifference curve.

How does the situation look from the English point of view? Figure 3 illustrates the answer. The budget lines and consumption choices are the same in this diagram as in Figure 2, but the indifference curves have changed–they now embody English preferences (U_E), so they illustrate how the world is seen from the English point of view. The key change is that the indifference curve that rationalizes the English consumption pattern rises more steeply to the left of that point than in Figure 2 and now goes to the right of the pont representing the Chinese consumption pattern. As a result, all of the highlighted features of Figure 2 occur mutatis mutandis in Figure 3: First, when confronted with Chinese wages and prices, the Englishman reaches a lower indifference curve than he did before ($U_E^{'}$ is closer to the origin than U_E). Second, the Englishman shifts his consumption in the direction of the Chinese pattern, but incompletely. Third, the Chinese spending pattern is on a still lower indifference curve ($U_E^{"}$), and is suboptimal. In essence, the Englishman faced with Chinese wages and prices did not have enough income to reach the indifference curve that he could have attained in London. Our calculations show that the shortfall was 22%.

Figure 3. [Title]



Figures 2 and 3 show that the index number problem arises since the price indices correspond to indifference curves that are fairly rigid. That is the sense in which differences in culture lead to different assessments of relative well being.

Third Approach: Törnqvist consumer price index

Is there no way around this? Fortunately, there is a response that can be justified by common sense and by a technical argument that, as it turns out, makes a cultural point.

The common sense response to the discrepant results is to average them. I will use a geometric average for reasons that will be clear shortly. The geometric average of the price indices is 3.84, which is very close to the wage ratio (3.67). Dividing the relative wage by the average cpi indicates that the English real wage was 96% of the Chinese. Near equality is the claim of Pomeranz and Co. and contradicts the certainties of the classical economists.

Can we give a rationale for this procedure other than the common sense of averaging? Indeed, we can. Taking a geometric average of the two cpi's is equivalent to calculating a consumer price index using the average shares in the two cases. If we call the price indices P and use superscripts C for China, E for England, and G for geometric average to distinguish variables, we can write:

$$P^G = \left(P^C P^E\right)^{\frac{1}{2}} = \prod p_i^{\frac{s_{Ci}+s_{Ei}}{2}}$$

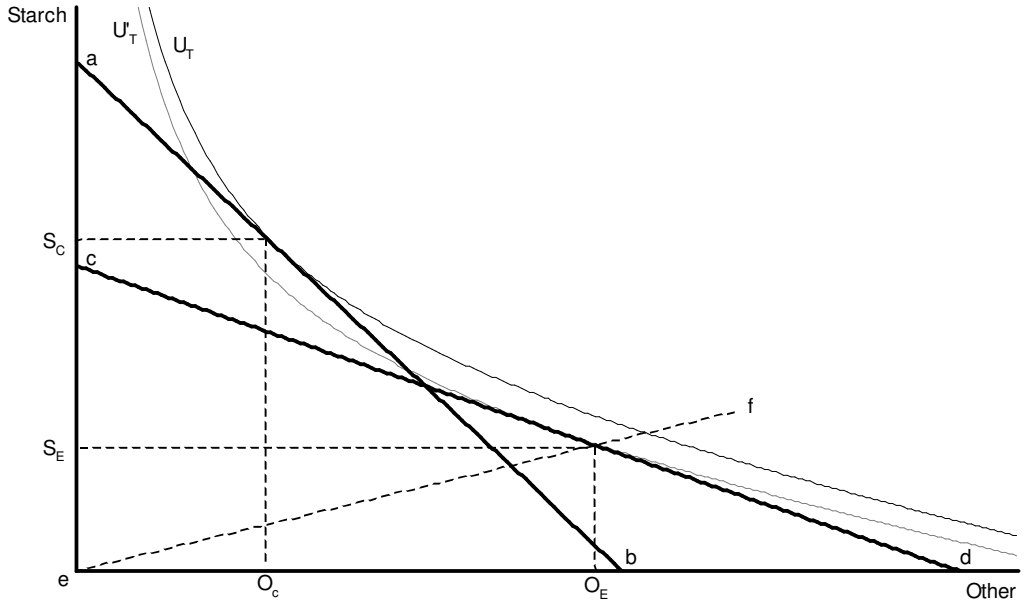
where s_{Ci} and s_{Ei} are the Chinese and English spending shares, respectively.

Aficionados of index numbers will recognize P^G as a Törnqvist (or Divisia) index

number. Its significance in this context is that it is exact for a translog expenditure function. A translog function–the equation is in Table 5–is a mathematical generalization of the Cobb-Douglas function that allows spending shares to varying. It is a more flexible functional form. Indeed, it is so flexible that in a binary comparison like this, both the Chinese and the English spending patterns are generated when a representative consumer using the same utility function in both England and China maximizes utility with the prices of either country. All the differences in spending are imputed to differences in prices with this model–rather than to differences in preferences.

Figure 4 shows how the budget data of Figures 2 and 3 are analyzed with the utility function dual to the translog expenditure function. The budget lines are the same as before. Two indifference curves (T and T') are drawn. T is tangent to Chinese budget lines at the point that rationalizes the Chinese spending pattern, and T' is tangent to the English budget line at the English spending pattern.

Figure 4. [Title]



This diagram differs from the others in its key features. First, when the Chinese consumer is confronted with English wages and prices, he responds complete choosing the English consumption pattern. All intercontinental differences in consumption are attributed to price differences with this model. Second, the English consumption pattern is optimal for the Chinese consumer. Third, there is still a decline in utility, but it is less than previously. Our calculations show it to have been only 4%. Moreover, it should be emphasized, that identical conclusions would be obtained if the analysis were reversed and begun from the English point of view.

Table 5. Exactness Relationships

Price index		Corresponding expenditure function		Corresponding Utility function	
Name	**Formula**	**Name**	**Formula**	**Name**	**Formula**
Part I – Nonsuperlative indices					
Laspeyres Paasche	$\frac{f(p^1)}{f(p^0)} = \frac{\sum_{i=1}^{n} w_i^0 p_i^1}{\sum_{i=1}^{n} w_i^0 p_i^0}$ $\frac{f(p^1)}{f(p^0)} = \frac{\sum_{i=1}^{n} w_i^1 p_i^1}{\sum_{i=1}^{n} w_i^1 p_i^0}$	Leontief	$f(p) = \sum_{i=1}^{n} w_i p_i$	Leontief	$f(X) = \min\left\{\frac{X_1}{b_1}, \ldots, \frac{X_n}{b_n}\right\}$
Geometric	$\frac{f(p^1)}{f(p^0)} = \prod_{i=1}^{n}\left[\frac{p_i^1}{p_i^0}\right]^{s_i}$	Cobb-Douglas	$\ln f(p) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i$ Where $\sum_{i=1}^{n} \alpha_i = 1$	Cobb-Douglas	$f(X) = \beta_0 + \sum_{i=1}^{n} \beta_i \ln X_i$ Where $\sum_{i=1}^{n} \beta_i = 1$
Part II – Superlative indices					
Fisher ideal	$\frac{f(p^1)}{f(p^0)} = \left[\frac{\sum_{i=1}^{n} w_i^0 p_i^1}{\sum_{i=1}^{n} w_i^0 p_i^0}\right]^{\frac{1}{2}}\left[\frac{\sum_{i=1}^{n} w_i^1 p_i^1}{\sum_{i=1}^{n} w_i^1 p_i^0}\right]^{\frac{1}{2}}$	Generalised Leontief	$f(p) = \left[\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ji} p_i p_j\right]^{\frac{1}{2}}$ Where $a_{ji} = a_{ij} \forall i, j$	*[utility function not explicitly defined]*	
Törnqvist	$\frac{f(p^1)}{f(p^0)} = \prod_{i=1}^{n}\left[\frac{p_i^1}{p_i^0}\right]^{\frac{s_i^0 + s_i^1}{2}}$	Trans-log	$\ln f(p) = \sum_{i=1}^{n} \alpha_i \ln p_i + \sum_{i=1}^{n}\sum_{j=1}^{n} a_{ji} \ln p_i \ln p_j$ Where $\sum_{i=1}^{n} \alpha_i = 1$, $a_{ji} = a_{ij} \forall i, j$ and $\sum_{i=1}^{n} \alpha_{ij} = 0$ for $i = 1, \ldots, N$	*[utility function not explicitly defined]*	

From a technical point of view, there are two reasons why Figure 4 gives a different analysis than the earlier figures. First, the presence of both the Chinese and the English shares in the Törnqvist index implies that the underlying indifference curves are sufficiently flexible that they can be forced to be tangent to two budget lines at the same time. The Cobb-Douglas indifference curves underlying the previous figures were less "bendy" and could only be made tangent to a single budget line at a time. Second, the indifference curves corresponding to the Törnqvist index are less tightly curved than Cobb-Douglas indifference curves and so accommodate larger changes in consumption patterns for a given change in prices.

What are these more flexible preferences? If we think of the geometric indices as embodying Chinese and English preferences, then the translog expenditure function embodies 'international' preferences. They are an evolving feature of the modern 'global village'. Since food is such an important part of the present exercise, a culinary example makes the point. Vancouver is a modern multicultural city, and Kitsilano is a neighbourhood in the vanguard with restaurants featuring German, Italian, Greek, Chinese, Indian, Mexican, and African cuisine. In addition, however, it has restaurants that combine elements of all of these traditions. A typical example of Kitsilano cuisine is a meal starting with a Caesar salad and Kirin beer, followed by an entrée of huevos rancheros, fresh asparagus, and Bombay potatoes served with a South African chardonnay, concluding with Chinese toffee apples and Kenyan coffee. The cultures might be shuffled differently at the next table.

The translog model represents this eclectic culture in contrast to the Cobb-Douglas models that are more rigid and lead to discrepant results. Does it make sense to assess living standards in terms of a world culture today? Perhaps--because there are people with these cosmopolitan tastes today. However, 'world culture' sounds ahistorial in 1704. While today Oxford colleges serve kedgeree at lunch, only the lascars ate it three hundred years ago–the English had not yet 'acquired the taste,' as they say. The advantage of a world culture (for index numbers!) is that it rationalizes the use of 'superlative' index numbers like the translog which resolve the 'index number problems' that otherwise arise.[6] But do we want to assume a world culture before chicken tikka masala became a British national dish?

Treating rice and bread as separate commodities

The discussion thus far has assumed that rice and bread could be represented as a single commodity 'starch' by reducing each commodity to its calorie content. Rice and bread differ in other respects, however. Perhaps the consumption model should recognize this by treating them as separate items? The arithmetic is not difficult since we have bread and rice prices in both London and Canton. In the London cpi, starch becomes bread, and in the Canton cpi starch becomes rice. Table 6 shows the data for the two cpi's, their values, and the real wages.

[6] The usual rationale for superlative index numbers emphasizes that they track the true utility function better than other indices since the superlatives are second order approximations to any arbitrary neoclassical function. This argument assumes a 'world culture' (the true utility function), which is at issue here.

Table 6. Distinguishing Rice and Bread: Translog model

	Average Share	English price/ Chinese price
bread	.2394	.5680
rice	.3000	19.9500
meat	.0888	1.6625
milk	.0688	.8867
tea	.0410	26.6000
sugar	.0813	15.2396
charcoal	.0313	.1892
lighting	.0416	1.9633
cotton cloth	.0666	3.3750
iron work	.0206	3.1172
nails	.0206	1.4499
cpi		3.4672
wage rate		3.67
real wage		1.0575

Note: Average shares computed from data underlying Table 2 and carrying the calculation to four decimal places. Likewise for the relative prices.

This new model magnifies the index number problem: The Chinese and the English price indices (hence real wages) are even more discrepant than before. However, as before, we can reconcile the divergent results by taking a geometric average of the two indices. The result shows the English real wage to have been only 6% greater than the Chinese–another victory for the revisionists over the classical economists.

As before, the geometric average can be rationalized with a translog expenditure function. Taking the geometric average of the English and the Chinese cpi's implies a formula in which all commodities–including both rice and bread–enter the index number with average shares. The Törnqvist index is again the result.

There is one difficulty with this conclusion–the translog framework cannot generate spending shares of zero, so–striclty speaking–it cannot rationalize the data presented here when bread and rice are treated as separate commodities. This limitation can be circumvented by using a Fisher Ideal Index and a generalized Leontief expenditure function.

Further notes on index numbers

The data are not available to applying the generalized Leontief framework, but they could be collected, so I will outline it. This discussion also highlights the relationship between the procedures used here and other common index number formulae.

Most discussions of index numbers begin with the Laspeyres and Paasche instead of the geometric. The weights in the Laspeyres and Paasche indices are quantities consumed rather than spending shares as in the geometric. If we had information on quantities for England and China, these indices could be computed.

There is an important similarity between the Paasche and Laspeyres indices, on the one hand, and the Cobb-Douglas, on the other. All of these indices correspond to preferences with rigid features. The geometric index number corresponds to the Cobb-Douglas function in which spending shares are constants irrespective of income and prices; the Paasche and Laspeyres correspond to Leontief fixed proportion preferences in which the quantities of the goods consumed are constants irrespective of income and prices. The rigidity means that neither is a 'flexible functional form'. Mathematically, both the Leontief and Cobb-Douglas are first order approximations to arbitrary neoclassical functions.

Both the Leontief and the Cobb-Douglas expenditure functions can be augmented by adding interaction terms to form the generalized Leontief and the translog functions, respectively. (The equations for these functions are shown in Table 5.) The addition of these terms means that the generalized functions provide second order approximations to neoclassical utility functions, whatever they are. Higher order approximations are superior since they track the data better.

Both of the higher order functions have corresponding index numbers: The Törnqvist index is exact for the translog, while the Fisher Ideal (the geometric average of the Paasche and the Laspeyres) is exact for the generalized Leontief. Both of these index numbers involve the quantities or shares from both instances being compared. Both, consequently, represent global preferences as in Figure 4.

Both Törnqvist and Fisher Ideal indices are considered by economists to be preferable to Paasche, Laspeyres, and geometric indices–that is why Diewert (1976) dubbed such indices 'superlative'. Economic theory does not offer guidance in choosing between them. The generalized Leontief cost function can generate zero consumption of a good, which is one reason why the Fisher Ideal index might be preferred in early modern intercontinental research. However, the superlativeness of both the Fisher Ideal and Törnqvist indices depends on an international culture as a reference indicator, and that may be too ahistorical to contemplate.

Conclusion

In this paper the data of Charles Lockyer have been analyzed with modern index number theory. No systematic difference in living standards was discovered. The analysis has highlighted, moreover, the way cultural differences (preferences) impinge on the comparison of living standards. Many of the moves in modern index number arguments turn out to involve claims about culture, although this is not usually recognized. Keeping all of the dilemmas in mind, it is, nonetheless, possible to model the great differences in diet that exist across the world and still reach defensible conclusions about relative living standards.

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