

Sweet Diversity: Colonial Goods and the Welfare Gains from Global Trade after 1492*

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Abstract: When did overseas trade start to matter for living standards? Traditional real-wage indices suggest that living standards in Europe stagnated before 1800. In this paper, we argue that welfare rose substantially, but surreptitiously, because of an influx of new goods as a result of overseas trade. Colonial luxuries such as tea, coffee, and sugar transformed European diets after the discovery of America and the rounding of the Cape of Good Hope. These goods became household items in many countries by the end of the 18th century. We use three different methods to calculate welfare gains based on price data and the rate of adoption of these new colonial goods. Our results suggest that by 1800, the average Englishman would have been willing to forego 10% or more of his income in order to maintain access to sugar and tea alone. These findings are robust to a wide range of alternative assumptions, data series, and valuation methods.

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I. Introduction

There is a broad consensus that living standards stagnated for millennia before the Industrial Revolution. It was only after the transition from “Malthus to Solow” (Hansen and Prescott 2002) that per capita consumption improved. The logic of the Malthusian world ensured that the “iron law of wages” held: Population increases undermined the benign effects of higher productivity (Malthus 1803, Galor 2005). Estimated living standards seem to confirm the theoretical predictions. According to most real wage series, life in 1850 was no better than it had been in the Middle Ages.¹

In this paper, we argue that living standards prior to the Industrial Revolution improved substantially, and that these gains have been largely overlooked because they operated through gains from variety. Trade with overseas regions after 1500 increased European living standards importantly through the introduction of new colonial goods such as sugar, tea, and coffee. Traditional real wage indices use consumption baskets with fixed weights (Phelps-Brown and Hopkins 1981, Allen 2001).² These tend to be dominated by bread, wheat, and beer. Traditional real wage indices will fail to capture the true change in welfare from the introduction of new goods (Boskin et al. 1998). The mismeasurement is important because early modern consumers increasingly voted with their pocketbooks in favour of sugar, tea, and coffee. Starting either from zero (for tea, tobacco, and coffee) or from very low levels of consumption (sugar), English imports per head surged to 23 pounds of sugar, 2 pounds of tea, 1 pound of tobacco, and 0.1 pound of coffee by 1804-06.³ By 1800, ten percent of the budget of English working-class

¹ Clark (2005). Clark (2007) concluded that Englishmen in 1800 were no better off than their ancestors on the African savannahs

² Clark (2005) uses periodic updating of expenditure weights. For reasons that are well-known, this will still understate gains from variety to an important extent (Hausman 2003).

³ Mokyr (1988).

households was spent on sugar, tea, and coffee (Feinstein 1998). The rise of hot, sweetened beverages transformed meals (Braudel 1988, Cowan 2005). Other new goods such as chocolate, spices, and tobacco increased variety even more.

Focusing on England during the period 1600 to 1800, we use detailed historical data on the price and consumption of increasingly affordable colonial goods to estimate welfare gains from their introduction. To put a value on new goods requires data on both prices and quantities consumed (Hausman 1996). We compile a comprehensive data set on the adoption on tea, sugar, and coffee, and use a variety of techniques for analysing welfare gains from new products.⁴ We adapt the methods of Hausman (1999), Feenstra (1994) and Broda and Weinstein (2006), as well as Greenwood and Kopecky (2013) to our historical data. The results suggest that by 1800, English welfare had increased by approximately 10 percent as a result of the availability of these goods alone – and possibly by 20 percent or more. These findings lend further support to the argument that trade boosts living standards through gains from variety (Broda and Weinstein 2006).⁵

The welfare gains we document were not limited to a small elite. Contemporaries in England noted that new colonial luxuries were important for rich and poor alike. In the late 18th century, one commented that ‘[t]hroughout the whole of England the drinking of tea is general. You have it twice a day and, though the expense is considerable, the humblest peasant has his tea twice a day just like the rich man; the total consumption is immense’ (quoted in Macfarlane and Macfarlane, 2003). Even at the very bottom of the social hierarchy, tea and sugar were consumed

⁴ Hausman (1996); Bresnahan and Gordon (1996); Greenwood and Kopecky (2013); Petrin (2002).

⁵ They recently investigated the issue empirically, and concluded that between 1970 and 2000, variety growth alone added 2.2-2.6 percent to US real income. Feenstra (1994) and Romer (1994) had earlier suggested that trade liberalizations may be welfare enhancing because they raise the range of goods available.

regularly.⁶ We estimate welfare gains by social group, and show that both poor and rich profited by the gains from variety.

Incorporating the value of variety in welfare analysis has a long tradition in economics (Hotelling 1929, Lancaster 1975). Papers in the development literature have examined the demand for calories relative to the demand for food.⁷ In models of consumer choice in the Dixit and Stiglitz (1977) and Spence (1976) tradition, variety adds directly to consumer welfare. Models of the Dixit-Stiglitz-Spence type are widely used in international trade, macroeconomics, and economic geography (Krugman 1979, Grossman-Helpman 1991, Helpman and Krugman 1985, Fujita et al. 1999). Important work on estimating the gains from variety include work on the introduction of the minivan (Petrin 2002), online booksellers (Brynjolfsson et al. 2003), the internet (Goolsbee and Klenow 2006), and satellite TV (Goolsbee and Petrin 2004). Many papers use detailed micro data on the characteristics of consumers, as well as take-up rates to implement estimation in the style of Berry et al. (1995). In a historical setting, this data is not available. Instead, we use the three methods that can be implemented with historical data. Hausman's (1996, 1999) short-cut method offers a first approximation based on the price elasticity of demand for a new good. We also use the Greenwood and Kopecky (2013) method because it makes less stringent demands of the data. Their approach is more macroeconomic, and only requires aggregate data on prices and take-up rates of a new consumption item. Finally, we also implement a version of Feenstra's (1994) and Broda and Weinstein's (2006) price index

⁶ By the middle of the 19th century, Friedrich Engels (1844) commented in *The Condition of the Working Class in England* on the importance of tea for all groups: "Tea is regarded in England, and even in Ireland, as quite as indispensable as coffee in Germany, and where no tea is used, the bitterest poverty reigns."

⁷ Behrman and Deolalikar (1987), Strauss and Thomas (1995) and Deaton (1997) examine the demand for food variety versus the demand for calories in the Third World. Jensen and Miller (2008) analyse the consumption of Giffen goods, i.e. tradeoffs between calories and variety when food is scarce.

correction, based on estimating the elasticity of substitution between new and old goods in English consumption baskets.

Other related literature includes papers in unified growth, as well as papers on the historical significance of 1492. Adam Smith called the discovery of America and Vasco da Gama's rounding of the Cape of Good Hope "the two most important events in recorded history." Scholars like Bentley (1999) and Frank (1998) agreed with the proposition, arguing that a worldwide trading system emerged quickly. Wallerstein (1974) concluded that a Europe-centric mode of capitalist production emerged from the 16th century onwards. At the same time, economic historians found little direct effect of Atlantic trade on the European economy. Profits from transatlantic trade were small (O'Brien 1982, Engerman 1972, Thomas and Bean 1974), and the supply of raw materials from the New World was also unimportant (Clark, O'Rourke, and Taylor 2008). The only paper that argues for a major impact of Atlantic trade emphasizes indirect effects on institutions (Acemoglu, Johnson and Robinson 2005). The paper closest in spirit to ours is Nunn and Qian (2011), who also argue for a major impact of the Age of Discovery. In contrast to our study, they focus on the introduction of the potato. They conclude that it increased agricultural productivity and led to higher urbanization rates. Nunn and Qian do not argue that it improved living standards directly.⁸

Research on unified growth such as Kremer (1993), Galor and Weil (2000), Jones (2001), and Hansen and Prescott (2002) often assumes that millennia of stagnation in terms of living standards preceded the transition to rapid growth. That a period of gradual acceleration preceded "take-off" is argued by Galor and Moav (2002), and has been explored in terms of implications for the cross-section of economic growth (Voigtlaender and Voth 2006). However, there is

⁸ Potato consumption may not have improved the quality of life by much – consumers remained sceptical of its appeal for a long time, and only ate it when no other source of calories was available (Schivelbusch 1992).

disagreement about the extent to which living standards remained broadly constant before 1800. Nordhaus (1996) examines the history of lighting to suggest that cost of living indices have vastly underestimated the decline in the cost of many goods over the last 200 years.⁹

We proceed as follows. First, we discuss the historical background and context – how did sugar, tea, and coffee enter European consumption? In section III, we discuss our data sources. Section IV summarizes the three methods we use as well as our findings. In section V, we examine extensions, the robustness of our findings to alternative data source, as well as the limits of our argument. Section VI concludes.

II. Historical Background and Context

In this section, we summarize the existing literature on living standards over the long run. We also describe how sugar, tea, and coffee became items of mass consumption in Europe.

Living standards in England before 1800

Real wages broadly suggest stagnation until 1800.¹⁰ Figure 1 presents two real wage series for the period of this study, one by Phelps-Brown and Hopkins (1981) and a more recent series by Clark (2005). Phelps-Brown and Hopkins used a Laspeyres index for the seven centuries covered by their index, with a weight of 70% for food. Grain prices are the single biggest determinant of how the Phelps-Brown Hopkins index moves over time. It suggests that Englishmen saw their living standards surge by almost 200% after the Black Death in the middle of the fourteenth century. After 1500, a long period of decline set in. By 1600, much of the gain in living standards from the plague had disappeared. The 17th century then saw a recovery, followed by stagnation in the 18th century. By 1800, real wages were no higher than in 1700 – and some

⁹ Hulten (1996) questions the plausibility of Nordhaus's result.

¹⁰ According to Maddison (2001), English GDP per capita rose at a rate of less than 0.3% between 1500 and 1700.

25%-50% lower than they had been in 1450. Loschky (1980) reworked the Phelps-Brown and Hopkins series, using Paasche and chain weighted price indices. His findings are more optimistic, showing a smaller decline during the early modern period. This is mainly due to changes in the relative price of manufactured goods, which became cheaper. For example, his Paasche index recovers its post-Plague peak by the middle of the 18th century, a full 100 years before the date indicated by the Phelps-Brown and Hopkins series.

Clark's real wage series is derived from an expanded dataset containing many more expenditure items than previous indices. He changed both the wage series and price index. His expenditure weights come largely from the end of the period. Since the Clark price index tracks many more items, it is less volatile; his real wage index surges and falls less sharply. Clark confirms the earlier, pessimistic results by Phelps-Brown and Hopkins for the period after 1500—it wasn't until 1850 that the average Englishman had a real wage that was greater than his counterpart's in 1500.¹¹

None of the existing indices of living standards during the early modern period incorporate the value of new goods. Loschky (1980) changed the weight for manufactured goods by using a different definition of the consumption basket. Feinstein used separate weights in his Laspeyres indices for three sub periods between 1770 and 1870.¹² Clark uses a geometric index of the price of consumer goods, using constant expenditure shares as weights. Since he bases his

¹¹ The question if living standards improved after 1750 – the classic period of the industrial revolution – has been hotly debated since the days of Marx and Engels. Initial estimates by Lindert and Williamson (1983, 1985) implied large wage gains. Their cost-of-living indices were comprehensively revised by Feinstein (1998), who expanded the range of commodities covered. By doing so, he found markedly smaller wage gains – a plus of 30% between 1780 and 1850, instead of Lindert and Williamson's gain of close to 90%. Recent analysis suggests a range of improvement between 40% (Allen 2007) and 50% (Clark 2005). Clark's (2005) index, based on additional data and a rebalanced consumption basket, indicates that living standards increased by more than implied by Williamson -- a rise by 50%. Allen's latest reworking of the wage and price information again yields a more pessimistic view -- a plus of 40%.

¹² He uses expenditure shares similar that are similar to Horrell (1996). However, since his analysis starts in 1770, it cannot capture changes in living standards before then as a result of the arrival of new goods.

index on expenditure shares from the 1790s, his index captures some of the benefit that consumers derived from the declining prices of new commodities. The reasons why the value of new goods is not captured in price indices – even if budget shares are updated – are well-known.¹³ As a result, the welfare implications of the radical transformation of consumption patterns and diets between 1500 and 1800 have been largely overlooked. We turn to these changing patterns next.

The adoption of colonial goods after 1492

Tea and coffee were new to Europe in the early modern period, while sugar had only been available in very limited quantities before 1500. We summarize how each was first brought to Europe, how it was consumed, and the corresponding changes overseas.

Sugar can be derived from a variety of sources—sugarcane, sugar beets, roses, sorghum, honey, and other products. Early forms of sugar were available in small quantities at prohibitive prices. Europe’s first taste of sugar derived from sugarcane came courtesy of Arab conquerors. Sugarcane production had reached Valencia and Sicily by the 10th century (Mintz 1985). The Crusaders are said to have encountered Egyptian sugar when they advanced into Syria. From there, cultivation of sugarcane spread to Cyprus. From the twelfth century onwards, medieval court records show that English kings consumed sugar.¹⁴ It was also grown in the Azores, the Canary Islands and on Madeira before reaching Brazil in the 1520s (Braudel 1988). By 1572, a French observer commented that “people devour it out of gluttony... What used to be a medicine is nowadays eaten as a food.”¹⁵

¹³ Cf. the report of the Boskin Commission to the Senate Finance Committee (1996). The committee recommended that even with a speedy introduction of new goods prices into the CPI it would be necessary to either extend backward their price history or incorporate a welfare adjustment measure similar to Hausman’s.

¹⁴ It is mentioned in the pipe rolls of Henry II (1154-89). Cf. Mintz (1985).

¹⁵ Cit. acc. to Braudel (1988).

The introduction of sugar to the New World facilitated large increases in output. Sugar refining became technically more sophisticated, producing a whiter, more consistent product. As Europe's taste for sugar developed, 'sugar barons' in the Caribbean and elsewhere became rich. Using imported slave labor, sugarcane was eventually cultivated in most European colonies with a suitable climate. Rum was produced as a by-product. While medieval Cyprus produced no more than an estimated 50-100 tons of sugar per year, Santo Domingo in the 18th century alone produced 3,500 tons. England in 1700 imported approximately 10,000 tons; a century later, this figure had risen to 150,000 tons (Braudel 1988).

As the price of sugar declined, consumption spread to the lower classes. It was frequently used as a substitute for a protein source, consumed in the absence of beef or poultry when and where meat was too expensive. In addition, sugar was used to add sweetness and calories to food and drink, especially to tea or coffee, or added in liquid or powdered form to a whole range of foods.¹⁶ It also had decorative value, as an ornament for other foods or in large-scale models of everything from houses and castles to human figures.¹⁷ Jam and marmalade made the taste of fruit available year-round, and largely consist of sugar. While quince-based marmalade was known since Roman times, and made with honey, widespread consumption of jam only took off in the 17th and 18th century, when Caribbean sugar arrived in Europe. Eventually, the production of marmalade was industrialized (after 1797; Mintz 1985). Sugar was also used in medicines.

Combining caffeinated drinks with sugar was a European innovation, as was the adding of milk (Goodman 1995). Sweetened tea became popular amongst all classes in England. Tea and sugar (or coffee and sugar) were therefore complementary goods. For the poor, a cup of

¹⁶ Sugar in semi-liquid form is called treacle, a by-product that remains after the sugarcane is crushed, boiled and processed through a centrifuge. Being dark in color and retaining more impurities than white sugar, it was sold at a lower price and was popular amongst the lower classes.

¹⁷ Mintz (1985).

sugary tea could reduce feelings of hunger, and give energy for a short time. Tea could serve as a substitute for a hot meal, especially where heating fuel was in scarce supply. Tea reached Europe from China in 1606.¹⁸ By the 1630s, it had spread to France; by the 1650s, to England via Holland. The English diarist and naval administrator Samuel Pepys describes trying it for the first time in 1660.¹⁹ Establishing direct trade links with China was crucial for boosting the volume of imported tea. Until the East India Company imported tea from China, it was normally exported to Batavia first, from where it would be shipped in Dutch vessels. However, by the middle of the 18th century, the English had overtaken the Dutch as principal traders. Over the course of the 18th century, English tea consumption increased by a factor of 400 – much of it smuggled from the continent to avoid high customs duties. Outside the British Isles, tea was only consumed in substantial quantities in Holland, Russia, and parts of Northern Germany. Production in English colonies took some time to become quantitatively important. It was only after the 1850s that the East India Company began production on the subcontinent on any scale. No tea produced in India reached Britain before 1850 (Forrest 1973).

Coffee was probably consumed as early as AD 800-1000 in Yemen and Ethiopia. It spread throughout the Middle East, before reaching Europe via Venice by 1615. By the middle of the 17th century, coffeehouses were springing up in many larger European cities (Schivelbusch 1992). By the 18th century, Paris alone had 600-700 cafés (Braudel 1988). Initially, most coffee reached Europe via the Mediterranean, having been grown in Yemen. Consumption surged after European powers took over control of cultivation and distribution. The Dutch plantations in Java and Surinam started production shortly after 1700. In a few years, they had replaced all imports from the Arabian Peninsula. France began production on Martinique and

¹⁸ Goodman (1995).

¹⁹ Entry for 25 September 1660, cit acc. to Pepys (1854).

Santo Domingo, and half a century later, England did the same in Jamaica. Output increased swiftly. By 1789, Santo Domingo produced 40m pounds. Braudel (1988) estimates that half a century earlier, total European consumption had amounted to a mere 4m pounds.

The availability of hot drinks transformed eating habits. Over the course of the early modern period, breakfast changed profoundly. It went from a relatively heavy meal, often consisting of porridge or other grains, with some cold cuts, combined with wine or beer, to the modern-style, often light meal. Tea and coffee, more likely than not sugared, were combined with bread or pastry. As an English observer in 1722 noted: “before the use of tea, breakfasts were more substantial; milk in various shapes, ale and beer, with roast cold meat... sack and wines for the higher orders of mankind”.²⁰ In France, a Parisian observer noted the change in consumption amongst all classes by the eighteenth century:

“Consumption [of coffee] has tripled in France; there is no bourgeois household where you are not offered coffee, no shopkeeper, no cook, no chambermaid who does not breakfast on coffee with milk in the morning. In public markets and in certain streets and alleys in the capital, women have set themselves up selling what they call *café au lait* to the populace.”²¹

The political economist and politician Joseph Massie (1760) estimated sugar consumption by social group circa 1759. To derive his figures, he divided the English population into four categories, according to the frequency with which they consumed coffee, tea, or chocolate. Table 1 summarizes his results. At the top of the distribution are families which consumed the new drinks twice a day – everyone from the Royal Dukes to Esquires, master manufacturers to high clergymen. Households in this category numbered approximately 70,000, and consumed more than a pound of sugar per day. Those who only consumed coffee or tea included tradesmen,

²⁰ Cit. acc. to Goodman (1995).

²¹ Braudel (1988).

inferior clergymen, and officers as well as inn-keepers. Their ranks were considerably more numerous, according to his estimates – 236,000 households fell into this category, consuming 92 pounds of sugar per year. Amongst the ‘middling sort’, spending on tea could exceed that on bread as early as the 1730s (Davis 1966). Families drinking coffee or tea occasionally numbered 400,000, according to Massie. Their consumption of sugar was only half that of those consuming tea or coffee every day.

By the end of the 18th century, even the lowest ranks of society drank tea frequently. What had once been luxury goods, enjoyed by the few, was being consumed *en masse*. In 1800, the European continent as a whole imported 120 m. pounds of coffee, 125 m. pounds of tobacco, 40 m. pounds of tea, and 13 m. pounds of chocolate (Braudel 1988). Table 2 shows colonial goods consumption in a number of countries (DeVries, 2008). In combination, the introduction of coffee, tea, and sugar transformed European consumption habits.

By the late eighteenth century, production sites had been established around the globe, mostly in European colonies. A vast trade of slaves provided the labor force necessary to satisfy European appetites, producing the kegs of molasses, sacks of coffee and bales of tobacco that sailed to the old continent in thousands of ships. The reliability of the supply system was remarkable. One historian argued that, by the late 18th century, European “consumers could often rely on the availability of sugar, tea, or tobacco more certainly than on the supply of dairy products and some cereals” (Shammas 1990).

Smuggling

Data on consumption of new goods in Britain comes from official import statistics. These will underestimate true consumption if goods arrived via illegal channels. At various times, smuggling was rife in Britain during the early modern period. Tariffs and excise taxes were high,

especially for tea and tobacco. A standard way to smuggle goods into the country was to officially ‘re-export’ colonial goods, and then land them illegally.²² Tea and tobacco, were easy to smuggle. Sugar and coffee were affected much less because the weight/value ratio was less favorable.²³ Mokyr (1988) estimated that between half to over 90 percent of all tobacco consumed in Great Britain had been smuggled.

Standard statistics on retained imports deduct re-exports fully from the import figures, some of which may have returned as smuggled goods to Great Britain. This is particularly problematic since the incentive to smuggle varied over time. For example, duty on tea fell from a high of 125 percent of net cost in 1736-40 to a mere 12.5 percent in 1787-91 (Cole 1958). The incentive to smuggle therefore declined markedly over time (though by the 1820s, tea duty had returned to 100 percent of net cost); the share of smuggled goods in final consumption probably fell.²⁴ Since the Greenwood and Kopecky welfare estimates depend on how quickly the consumption of new goods rises, the legal import figures may paint too optimistic a figure – real consumption may have risen much less during the periods of tariff reductions. The extent to which one can correct for smuggling in British import statistics is controversial (Cole 1958, Hoh-Cheung and Mui 1975, Cole 1975). In the main data section, we will use the ‘official’ statistics on retained imports. We will examine the issue of smuggling, and its impact on our results, in the robustness section.

III. Data

²² This required forging the landing documents from a foreign port, or bribing an official to provide them (Hoh-Cheung and Mui 1975).

²³ Mokyr (1988).

²⁴ In figure A5 in the appendix, we plot legal imports and the tariff rate side-by-side.

In calculating welfare gains for colonial luxuries, we use three types of data: quantities consumed, prices, and income. For price data we rely mainly on the recent work by Clark (2004) who has computed detailed series for the period. Since the goods we are interested in do not grow in the British Isles, we can use retained imports (imports less re-exports) per capita as a measure of consumption (Schumpeter 1960, Sheridan 2000). Finally we use daily workers' wages from Clark (2005) for income.

Figure 2 presents the Clark series for the real price of sugar (deflated by the CPI) in the left panel, with sugar consumption in pounds per year on the right, from 1600 to 1800. The real price of sugar declined dramatically over a relatively short period. It fell from a high of over 32 pence per pound in 1600 to less than 15 by the 1650s, before declining to 8.3 pence per pound in 1800. We obtained per capita consumption by dividing total retained imports by population.²⁵ Our sugar consumption quantity data combines two series: Sheridan for the 17th century and Schumpeter for the 18th century. Sheridan estimates 2.13 lbs. of sugar were consumed per capita per year in 1663-1669. This grows to 4.01 lbs per capita in 1690-1699. Sugar consumption takes off in the 18th century, ending at 23 lbs. per capita in 1790-9 as measured by Schumpeter. We set an initial point of zero consumption of sugar at 1600, and interpolate between 1600 and 1700.²⁶

Figure 3 shows the real price of tea (left panel) and consumption per capita (right panel). Tea shows an even more dramatic price decline than sugar. The Clark series falls from a high of over 830 pence per pound in 1690 to 72 pence in 1800, a price decline of 91%. Beginning at very low levels of consumption in the late 17th century, tea consumption grew to 2 lbs. per capita by the late 18th century. We assume that tea consumption was zero in 1690. Qualitative evidence

²⁵ Population figures are from appendix tables A5.2, A5.3 and A6.1 in Wrigley et al. (1997).

²⁶ We experimented with different assumptions about the year to which we attribute zero consumption, and with leaving out interpolated values in our welfare calculations. Results are broadly unchanged (available upon request).

such as the existence of London tea houses from as early as the 1660s (Forrest 1973) and Samuel Pepys's diary suggest there was some consumption before that period. However, the earliest data on retained imports (from 1700) show that per capita consumption was still very low. This makes 1690 a conservative starting point.²⁷

Finally, changes in the price of coffee (left panel) as well as quantities consumed (right panel) are shown in figure 4. The price of coffee declined from a high of nearly 140 pence per pound in 1710 to a low of 55 pence per pound in 1800. Per capita consumption comes grew from very low levels in 1700 to 0.279 lbs. per capita in 1790-9. As a percentage of household budget, coffee never reached the importance of tea. By 1800, the English consumed almost ten times more tea than coffee by weight. This is partly because the price of coffee was much higher. Coffee was briefly fashionable in the mid-17th century. However, its consumption never took off until the 19th century (Cowan 2005). We assume zero consumption of coffee in 1690.

Income data comes from three series in Clark (2007). Clark provides daily wages for 'farm', 'craft', and 'building laborer' in pence per day²⁸. We calculate income as follows: We know the prices and per capita consumption of sugar and tea. From these, we can calculate total expenditure on these goods. Contemporary budget surveys give an idea of the share of spending devoted to these goods. This in turn gives us an implied annual income. We translate Clark's daily wages into annual per capita incomes by adjusting the days of work per year such that the implied expenditure shares for sugar and tea match the budget surveys. This method suggests an average of 180 days of work per year.²⁹ Feinstein (1998) shows sugar accounting for 4.8% of a

²⁷ For the Greenwood and Kopecky method it is necessary to set an initial point of zero consumption. This initial point has no implication for other methods of welfare estimation used.

²⁸ We use as a raw wage series the arithmetic mean of the three series. Weighting is not an issue, as the income level is set by the number of days worked per year.

²⁹ The number for adult males was probably much higher (Clark and van der Werf 1998, Voth 1998, 2001). Note that we are estimating the number of working days per Englishman, from infant to the elderly, in adult male wage equivalents.

household's budget in 1788-92. Using consumption per capita of sugar from retained imports, our estimated incomes show sugar to be 4.38% of income in 1790. With regard to tea, in 1800 using our income estimates we estimate the expenditure share of tea at 3.1%, close to Horrell's estimate of 3.2% for 1801³⁰.

Consumption of colonial luxuries rose with incomes (Horrell 1996). Mokyr (1988) found that colonial goods had positive income elasticities that decreased with income. Consumption per capita eventually reached a saturation level, which Mokyr estimates to be between 2 to 3 times the average level of consumption in 1855. Because of this high value, we can be fairly certain that welfare gains did not just accrue to a few upper-class families consuming the new goods – most families were still hungry for more colonial luxuries, even at the end of our period. The qualitative historical literature emphasizes how the consumption of tea and sugar spread throughout most social classes. The only exception to this is the earliest part of the period, when consumption was limited to the wealthy.³¹

IV. Methods and Results

How should we value the spread of new, hot, caffeinated drinks and sugar from overseas? In this section, we briefly summarize the methods developed by economists to deal with the problem of estimating the consumer gains from new goods. Three can be implemented with historical data. While no adaptation of the different methods is perfect, they agree to a considerable extent. We present the results, and examine the robustness of our findings.

We express welfare gains in terms of two measures – compensating variation and equivalent variation. Suppose there are two states of the world: In state 2, consumers have access

³⁰ See Appendix II.

³¹ A quantitative impression can be gleaned from Table 8, where we construct spending by social class.

to the good; in state 1, they do not. State 1 can be considered as a special case of state 2 where the price of the new good is infinitely high. The equivalent variation (EV) is the increase in income needed (λ) to give the consumer in state 1 (without access to the new good) the same level of utility as a consumer in state 2 (with access). This can be written as

$$W((1 + \lambda_{EV})y_2, \infty) = W(y_2, p_2) \quad (1)$$

where $W(y_t, p_t)$ is the indirect utility function which has as inputs current prices p_t and income y_t . EV is expressed in percent of income in state 2. Similarly, compensating variation (CV) is defined as the amount of income a consumer would be willing to lose, provided he retained access to the new good. Formally, this implies

$$W((1 - \lambda_{CV})y_2, p_2) = W(y_2, \infty) \quad (2)$$

CV is similarly expressed as a percentage of income in state 2. With quasi-linear preferences, the results for both will be identical.

Hausman Method

Hausman (1999) suggested a simple method for estimating welfare gains from the introduction of new goods. This method can be applied to any standard utility function:

$$CV \approx \frac{1}{2} S \eta^{-1} \quad (3)$$

Where CV is compensating variation, S is the share of the new good in expenditure, and η is the price elasticity of demand. Effectively, the Hausman method estimates the welfare gain as the area of a triangle in a demand diagram with price and quantity on the y- and x-axis. The triangle is formed by the area between the price-quantity combination, the y-axis, and the tangent to the (compensated) demand curve. The lower the price elasticity of demand, the greater the windfall for consumers from the introduction of a new good.

We think of the great fall in colonial goods prices after their introduction as exogenous. As the historical background section argued, tea, sugar, and coffee appeared on English retail markets at some point in the 17th century. At their time of introduction, prices were very high. As Europeans began to combine slave labor with near-ideal growing conditions for sugar and coffee in their tropical colonies, and established large tea plantations in the Far East, prices fell quickly. In our analysis, we assume that price declines reflect a sharp supply shock in the form of the slave system, and the introduction of coffee plants, sugarcane, and tea into overseas possessions.

The Hausman method requires values for the price elasticity of demand η and for S , the budget share of new goods. Budget shares can be obtained from estimates of import values and expenditure. Massie (1760) presented figures for annual sugar consumption for 51 different groups in English society – from the highest ranks of the nobility to the lowest rungs of the social ladder. He estimates that in aggregate, spending on sugar amounted to 3.4% of all expenditure. For 1800, we have estimates from Horrell (1996) for both working-class spending and England as a whole. She finds expenditure shares for workers of 2.6% for tea and coffee and of 3.6% for sugar and treacle. At the national level, this rises to 3.2% and 6%.

One attempt to estimate η for sugar and tea from historical data was by Moky (1988). Using time-series data from the period 1855 to 1900 and an inverse-log specification, he obtains own-price elasticities of -0.54 to -0.64 for tea, and of -0.068 to -0.099 for sugar. The data used in this estimation comes from the period after 1800, and may not be well-suited to our purposes. One alternative way of obtaining estimates of η is to use micro-data.³² Horrell (1996) does so, analysing working-class expenditure patterns to estimate an almost ideal demand system (AIDS). She finds an own-price elasticity of -0.25 for tea and coffee, and of 0.4 for sugar. While the first

³² For the restrictions that are necessary to identify η see Bresnahan (1997).

estimate is similar to the ones obtained by Mokyr, the latter, positive one is difficult to rationalize – there is little reason to think that sugar was a Giffen good.

We go beyond earlier work by using historical time-series data combined with a new instrument for prices. The downside is that the number of observations is lower than in studies based on micro-data. The advantage is that we can make use of historical cost-shifters that were exogenous to British consumption patterns. Since imported sugar, tea, and coffee, naval wars had a negative effect on imports.³³ The eighteenth-century saw Britain fighting numerous wars. Most of them involved naval warfare in the North Atlantic. Privateers attacked Britain's merchant ships, increasing shipping costs and seizing cargo (Mokyr and Savin 1976). As a result, imported commodities were, on average, more expensive in years of war. For example, tea was, on average, 18% dearer during war-years between 1700 and 1850; sugar rose in price by 15%.³⁴

Table 3 shows the OLS and 2SLS estimates of the price elasticity for sugar, tea, and coffee. We detrend the dependent variables.³⁵ We then regress the log of consumption on the log of the real price. Under OLS, we obtain elasticity estimates of -0.398 for sugar, -0.17 for tea, -0.186 for coffee, and -0.134 for sugar and tea estimated as a joint composite good. Sugar and the sugar-tea composite good are significant at the 0.05 level, and tea is significant at the 0.1 level. Using 2SLS, we instrument the real price of the commodities with a war dummy and the size of the British navy.³⁶ For tea, coffee and sugar-tea we obtain negative coefficients that are statistically significant. For sugar, we find a positive, insignificant coefficient. Most of the

³³ The exercise is similar in spirit to Angrist, Graddy and Imbens (2000).

³⁴ The overall price trend is downwards for both commodities. If we detrend the data by deriving the residuals from a linear regression of price on a year trend, we still find large and statistically significant differences.

³⁵ We do so by regressing the log of consumption on a linear trend, and using the residuals in the specification. The time trend is estimated over the whole time series. Results are available from the authors on request.

³⁶ For the latter, we use establishment figures, not actual men in the navy provided by Floud, Gregory, Wachter (1990). This should capture the size of the threat faced on the seas by Britain at least as well as actual manpower, which was constrained by difficulties of impressment, etc. We use as an additional instrument for tea the log of the tea duty rate.

coefficients under instrumental variable estimation are larger in absolute value than the ones obtained under OLS. This could indicate measurement error of prices. We remain agnostic about the need for instrumentation. While demand shifts may have played some role in setting prices of colonial goods in the UK, it is clear that the overwhelming identifying variation comes from the short-term impact of hurricanes, shipping disasters, and war as well as the long-term effects of massively growing supply.

Table 4 presents the Hausman CV gains using the elasticity estimates from Table 3. The OLS results suggest welfare gains of 9% overall in 1759 – 5% for tea and coffee, plus 4% for sugar. This rose to 17% by 1801, with both sugar and caffeinated drinks contributing in roughly equal measure. When we estimate for sugar and tea jointly – which may be desirable, since they are complementary goods – we find bigger effects: 19% in 1759, rising to 34% by 1801. The IV- results suggest somewhat smaller gains. The result for sugar is non-sensical. We emphasize the estimate for sugar and tea estimated jointly, which reduces the influence of noise. For the middle of the 18th century, we calculate welfare increases of 11%, rising to 20% by 1801.

When we use the Horrell (1996) price elasticities, we obtain CV values for tea and coffee of 3.4% in 1759, and of 5.2-6.4% in 1801. Her estimated own-price elasticity for sugar is positive, which leaves the welfare gain undefined. If we use the value for tea and coffee instead, the CV for sugar is 6.8% in 1759, rising to 7.2-12% in 1801. Mokyr's elasticity estimates imply a smaller effect for tea and coffee, and a bigger one for sugar. According to his tea elasticity, the welfare gain in 1759 equalled 1%, rising to 2-3% forty years later. For sugar, his figures imply gains of 20% in 1759, rising to 22-36%. While each historical estimate produces different welfare gains, the results for 1800 strongly suggest that new goods added at least 10% to the welfare of Britons – and possibly much more.

Modern-day estimates of the demand elasticities reinforce this conclusion. Gemmill (1980), in a comprehensive survey of data from 73 countries, estimates the price elasticity of demand for sugar to be between -0.25 and -0.38 in the short run. Kanayama et al. (1999) estimate the demand elasticity for sugar to be between -0.13 and -0.16. Taking the highest absolute value elasticity estimate by Gemmill of -0.38, we obtain a welfare gain of 4 percent in 1759, and of 5-8% in 1801. Using Kanayama's lowest estimate (in absolute value) we estimate a welfare gain of 13% in 1759 and 23% in 1801. Overall, we conclude that the orders of magnitude for welfare gains calculated from the Hausman short-cut method are robust to a wide range of alternative elasticity estimates and data sources. For colonial goods in combination, even the most pessimistic results suggest correction factors of 10%. Our preferred estimate, using elasticities derived from OLS using historical data, implies a 9% welfare gain in 1759, and a 17% gain in 1801.

Price Index Correction

Ideally, we should be able to correct price indices so as to take account of changes in the range of available goods. Feenstra (1994) proposes a method to do this, and applies it to the value of foreign products. Broda and Weinstein (2006) refine the method and obtain estimates of the welfare gains from additional varieties resulting from foreign trade. As argued by Diewert (1976), an exact price index has to show the same change over time as the change in the minimum cost necessary to attain the same level of utility. For an unchanging set of goods, Sato (1976) and Vartia (1976) demonstrate that the exact price index takes the following form for a CES unit-cost function:

$$P_g(\mathbf{p}_{gt}, \mathbf{p}_{gt-1}, \mathbf{x}_{gt}, \mathbf{x}_{gt-1}, I_g) = \prod_{c \in I_g} \left(\frac{P_{gct}}{P_{gct-1}} \right)^{w_{gct}} \quad (4)$$

where P_g is the exact price index for the composite good, \mathbf{p}_{gt} is the vector of prices of the constituent goods at time t , \mathbf{x}_{gt} is the vector of quantities consumed. $I_g = I_{gt} \cap I_{gt-1}$ denotes the set of consumed goods common to both period t and $t-1$. The parameter g denotes individual goods, and c denotes the country of origin for the good. The weights w are derived from the cost shares.³⁷ Since the range of goods consumed changes, we need to add a correction term to (4)

$$P_g(\mathbf{p}_{gt}, \mathbf{p}_{gt-1}, \mathbf{x}_{gt}, \mathbf{x}_{gt-1}, I_g) = \prod_{c \in I_g} \left(\frac{p_{gct}}{p_{gct-1}} \right)^{w_{gct}} \left(\frac{\lambda_{gt}}{\lambda_{gt-1}} \right)^{1/(\sigma_g - 1)} \quad (5)$$

where $\lambda_{gt} = \frac{\sum_{c \in I_g} p_{gct} x_{gct}}{\sum_{c \in I_{gt}} p_{gct} x_{gct}}$ and $\lambda_{gt-1} = \frac{\sum_{c \in I_g} p_{gct} x_{gct}}{\sum_{c \in I_{gt-1}} p_{gct-1} x_{gct-1}}$. The λ terms thus measure the expenditure on

goods common to both periods relative to the expenditure on goods available at time t or $t-1$. The ratio between λ_t and λ_{t-1} is then used to correct the standard price index. The correction will be greater the closer σ_g , the elasticity of substitution for good g , is to unity. Intuitively, if σ is large, consumers find it easy to replace one good with another. Reducing the range of available goods between two time periods would not result in a major welfare loss. Since there are no goods that disappeared (as potential consumption items) between the beginning of our period and 1800, λ_{gt-1} is equal to unity in our case. With the budget shares for the country as a whole from Horrell (1996), $\lambda_{gt} = 0.908$ – sugar, tea, coffee, and treacle accounted for 9.2% of aggregate expenditure.

³⁷ For details, cf. Feenstra (1994).

Estimating σ is key for implementing the Feenstra/Broda-Weinstein method. We cannot use the authors' method directly – a similarly rich dataset on foreign trade does not exist for our period. Instead, we estimate the elasticity of substitution similarly to Behrman and Deolalikar (1987), who regress consumption ratios of different goods on price ratios. We estimate with and without a measure of real income, which we linearize in the manner of Deaton and Muellbauer (1980) by using a geometric price index:

$$w_{ijt} = \alpha_i + \sum_{j=1}^n \gamma_{ij} \ln p_{ijt} + \beta_i \ln(X_t / P_t) + u_{it} \quad (6)$$

where w_{ijt} is the expenditure ratio of good i to good j at time t , p_{ijt} is the price of good i relative to good j , X is total expenditure, and P is a price index (from Clark 2005). We thus regress the ratio of expenditure on good i relative to good j on the relative price of good i relative to j , and a real wage index. Since we do not have a rich dataset on expenditure patterns over time, we simplify the setup by using the price of good i relative to the overall the price index, and using expenditure on good i relative to residual spending on the left-hand side.

Results are reported in Table 5. We use both OLS and 3SLS (to account for the potential correlation of errors). This yields σ for sugar in the range of 1.55 and 1.66; for tea, between 1.53 to 1.645; and for coffee, 2.42 to 2.5. Broda and Weinstein (2006) report a median estimate of σ for goods at the 3-digit SITC level of 2.2, a little higher than our estimate for tea and sugar, but similar to the coefficient estimate for coffee. Intuitively, the elasticity of substitution should fall as the level of aggregation rises. Given the high level of aggregation at which we are estimating, the results of our regression exercise seem reasonable.

Table 6 calculates the implied welfare gains, under both OLS and 3SLS. Since budget shares are normally given for coffee and tea jointly, we use the elasticities for each good, and apply them to the combined budget share. Sum 1 gives the sum of welfare gains for sugar and tea

plus coffee, evaluated with the elasticity for tea; sum 2 reports the same, but with the elasticity for coffee. Results under 3SLS are slightly larger than under OLS because the estimated values for σ are smaller. Welfare gains are large, especially for sugar. Its addition to the diet alone is equivalent to lowering conventional price indices by 9-11%; tea and coffee may have added another 2-6% to this. Overall, the results from the Feenstra-Broda/Weinstein method are largely very similar to the findings from the Hausman method.

Greenwood-Kopecky method

An alternative approach for valuing new goods has recently been proposed by Greenwood and Kopecky (2013). They use a standard CRRA function, but shift the marginal utility from the initial consumption of a new good so that it is bounded. From this, they derive estimates of welfare gains CV and EV. In the Greenwood and Kopecky model, utility is fully separable between new and old goods. Consumers derive utility $V(n)$ from consuming quantity n of new goods, and utility $U(c)$ and from quantity c of old goods. Both the consumption of new and old goods follow standard CRRA preferences, with one important qualification in the case of new goods:

$$U(c) = \frac{c^{1-\rho}}{1-\rho}, \text{ with } \rho \geq 0 \quad (7)$$

and

$$V(n) = \frac{(n+v)^{1-\rho}}{1-\rho}, \text{ with } V(0) = \frac{v^{1-\rho}}{1-\rho} > -\infty \text{ and } V_1(0) = v^{-\rho} \quad (8)$$

Where ρ is the degree of risk aversion, and $1/\rho$ is intertemporal elasticity of substitution. Adding v to the CRRA preferences shifts the standard utility function so that the marginal utility of the first item of a new good is finite. At zero consumption of the new good, marginal utility of the

first unit is v^ρ . This leads to a threshold price, \hat{p} for the new good where $\hat{p} \geq \hat{P}(y)$ and

$\hat{P}(y) = \frac{1-\theta}{\theta} v^{-\rho} y^\rho$. If the price of the new good is higher than this threshold price, consumption

of the new good will be zero. Welfare gains are calculated from the indirect utility functions with and without access to the new good.

Consumer maximize overall utility

$$W(y, p) = \max_{c, n} [\theta U(c) + (1-\theta)V(n)] \quad (9)$$

with $0 < \theta < 1$; $c, n \geq 0$; and subject to the budget constraint $c + pn = y$

Utility maximization generates a demand function for new goods of the form

$$\hat{n} = \frac{y + p}{p + [(1-\theta)/\theta]^{-1/\rho} p^{1/\rho}} - v \quad (10)$$

which is greater than zero as long as price is below the threshold price, \hat{p} , otherwise $\hat{n} = 0$. Here, θ is the utility weight on the old good, and $(1-\theta)$ the utility weight of the new good, c serves as a numeraire, p is the relative price of new goods, and y is income.

Observed data on income (y), prices (p) and new good consumption (n) are used to calibrate the preference parameters: the intertemporal elasticity of substitution ($1/\rho$), the weight on utility of non-new good consumption (θ), and the utility shift parameter (v). Equation (10) is used to calculate Marshallian demand functions for \hat{n} (new good consumption). We calibrate v , θ , and ρ to minimize the sum of squares of differences between observed new goods, n , and the predicted new goods, \hat{n} .³⁸

³⁸ As in Greenwood and Kopecky, we constrain consumption in the beginning of the period to zero. Due to the nonconvex nature of the equation (10), a simplex nonlinear optimization algorithm is used for the sum of squares minimization.

We use a composite index of sugar, tea, and coffee to estimate the common parameter value ρ . The composite good is constructed using time-varying expenditure weights. Using it should help us cope with noise in our data: While each observation for a commodity at any one point in time may be observed with error, it is much less likely that the data for all three is simultaneously affected. Also, the value for ρ that best predicts new good consumption should be derived for all new commodities, since it should govern the adoption of all comparable goods: For composite good take-up, we obtain an estimate of ρ of 0.44, and a v of 0.0075. Figure A1 in Appendix I compares the predicted and actual rise in consumption of the sugar, tea, and coffee composite. Overall, the fit is excellent ($R^2=0.974$). Since the marginal utility of the first unit of the new good is v^ρ , this implies a value of 8.6. This is much less than the marginal value of computers estimated by Greenwood and Kopecky (2013) for the first computers. Total welfare gains according to our results in panel A of Table 7 are 11% for the equivalent variation, and 10% for the compensating variation. This is similar to the order of magnitude obtained under the Hausman and the price index methods. It reinforces our conclusion that the introduction of these three ‘small luxuries’ had big consequences for the well-being of the English population.

This conclusion is not affected when we estimate welfare gains for each good separately (panel B of table 7). For sugar and coffee, we find relatively low values for v and ρ , suggesting marginal utilities of initial consumption between 1.7 and 3.7. For tea, we find a value of 7.7. Figures A2-A4 in Appendix I show predicted and actual changes in the consumption of sugar, tea, and coffee, derived from estimation with varying ρ . The fit of our calibrations is not as high as in the case of the composite good. At the same time, we match the overall rise in consumption and an important part of the decade-to-decade fluctuations as well. Despite these differences with

the results in panel A, we find broadly similar welfare results: CV and EV are almost identical for each good, and the sum of gains is 8.3-8.5%.

In panel C, we adopt an intermediate strategy, and estimate v and θ separately for each good, while imposing ρ from the joint estimation in panel A. This yields similar marginal utilities, and welfare results that are higher than in panel B and below those in panel A. We find a sum of EV values of 9% and CV of 10.28%. Compared to panel B, the fit of data series is not as good.

V. Extensions and Qualifications

We first examine the robustness of our findings, examining the impact of smuggling on our estimates. We then analyse welfare gains by class, before turning to value to consumers of tobacco. Finally, we turn to potential upward biases in our measures of welfare, such as a potential decline in dental health and the importance of leisure lost due to longer working hours.

Correction for smuggling

English consumers drank more tea and coffee, and used more sugar, as the price of these goods fell. The price decline was driven by three factors – lower tariffs, greater competition amongst producers, and improvements in production technology. As tariffs were cut, smuggling probably declined. Some of the measured increases in consumption may thus not be the result of consumers responding enthusiastically to small declines in the price of tea and the like. Instead, legal sales as a share of the whole may have increased. It could be argued that, by using data on legal imports, we are effectively stacking the odds in favor of finding a large welfare gain.

To correct for this problem, we estimate the legal quantity of tea sold as a function of the price of tea, and the duty levied (details are presented in Appendix II). The corrected series gives

higher predicted values than the official series for those periods with very high duties. The opposite is true of periods under moderate tariffs. For our calibration of welfare gains, we effectively abstract from the increases in ‘legal’ consumption that coincide with lower tariff rates. Based on the corrected series, we obtain estimates of EV (CV) of 6.2% (6.3%).³⁹ This is between one and two percentage points higher than under our baseline calculation. This is probably because much of the initial take-up of tea occurred in a context of high import duties.

Welfare gains by class

As the section on historical background argued, consumption of new goods was wide-spread. Even ordinary workers benefited from sugar and jam, and many members of the lower classes enjoyed coffee and tea regularly. For 1800, we have estimates of consumption of the new commodities for the population as a whole, and for the working class. This allows us to examine how great the benefits were for those outside the social and economic elite.

We derive ‘elite’ consumption as a residual of the figures in Horrell (1996).⁴⁰ Table 8 gives an overview. Upper-class households approximately devoted a 50% higher share of expenditure to coffee and tea; they also spent (as a proportion of income) more than twice as much on sugar. Nonetheless, because lower-class budget shares were not small, welfare gains even for those on the lower rungs of the economic ladder were substantial. We estimate gains of 12.2-13.9% for the lower classes, using the Hausman and Feenstra methods, as shown in panel B.⁴¹ For the upper classes, who spent nearly 12% of their income on new colonial luxuries, the

³⁹ This is the result using ρ unrestricted. Calibrating $\rho=0.4407$ we find gains of 3.5% for both CV and EV.

⁴⁰ We use her aggregate expenditure figures from her Appendix II, and combine them with her estimates of budget shares for working class expenditure (her table 5). We combine this with the estimate of total working class expenditure (her table 7) to derive total spending per item by the working class. The residual we then call ‘elite’ consumption.

⁴¹ We use the OLS coefficients for the price elasticity to derive the Hausman results. We cannot implement the Greenwood-Kopecy method separately by class, since we have no time-series data on their relative consumption. The Feenstra results are calculated using the average σ from Table 6 (for sugar, the average for OLS and 3SLS; for sugar and tea, the average of the four estimates).

results are bigger. The Hausman method suggests a welfare gain of 21.2%; the Feenstra method implies one of 27.9%.⁴² Thus, while sugar, tea, and coffee mattered more for the well-being of those with higher incomes, welfare gains from new goods were not the preserve of a privileged few. Instead, they materialized across the social spectrum, with working class households gaining substantially as a result.

Tobacco

Europeans first encountered tobacco during the voyages of discovery. Columbus noted the smoking of tobacco by Native Americans on Cuba in November 1492. Afterwards, it took almost a century for consumption to grow significantly. The plant was largely treated as a botanical curiosity. It was only in the 1570s that the medical writings of Nicolas Monardes, who produced a compendium on the plants of the New World, gave a push to tobacco use. Europeans consumed it as snuff, as chewing tobacco, and in pipes. The use of cigarettes first became common in Spain, and then spread to other countries. Initially produced by Native Americans, Spanish settlers in the New World eventually learned to make it themselves.

Tobacco was cultivated in Spain from the 1550s, and then spread to Italy, the Balkans, Java, the Philippines, and India. However, production in the North American colony of Virginia overtook all other sources of tobacco. By 1700, almost all European imports came from either Virginia or Brazil. England imported it on a vast scale, only to re-export it to the continent. By the early 18th century, Virginia tobacco exports alone filled 200 boatloads per year (Braudel 1988). As early as 1690s, consumption reached over two pounds per capita according to Shammas (1990).

⁴² The true difference in welfare gains may be greater than estimated in table 8. Behrman and Deolalikar (1987) show that the elasticity of substitution between goods in the consumption basket falls as incomes rise – the rich have a greater taste for variety.

Tobacco is similar to the other new goods – it arrived in Europe from overseas, it has no close substitute amongst native plants, the import price fell rapidly, and consumption became a mass phenomenon. We nonetheless do not treat it on par with the other goods because of its addictive properties. Tobacco in some ways is not a “good”, but a “bad” – the health effects can be strongly negative, even if life expectancy was perhaps too low for the full carcinogenic effects to make themselves felt. Becker and Murphy (1988) define a good as addictive if tolerance increases over time, users find it ever harder to stop consuming it, and suffer from unpleasant feelings ranging from cravings to withdrawal symptoms. By this definition, sugar, tea, and coffee are probably not addictive in the strict sense, while tobacco clearly is.⁴³

Estimating welfare gains for tobacco is complicated by the issue of smuggling. Existing estimates of tobacco imports show a puzzling decline in absolute per capita consumption after 1700. We test the sensitivity of our findings by examining welfare results for take-up between 1630 and 1700 as well as 1630 to 1800.

Table 9 gives the results for tobacco using the Greenwood-Kopecky method.⁴⁴ If we allow ρ for the Greenwood-Kopecky method to be determined by tobacco consumption itself, we obtain a reasonable fit. The marginal value of the first unit of tobacco is reasonable, too. The equivalent and compensating variations in 1700 equal 7-8%. If we take results up to 1800, we find welfare gains of 4.5%. These gains are higher or on par with the welfare gains from sugar and tea. Using the Hausman method, we find similar results. Both IV and OLS results suggest that the price elasticity of demand was close to -0.35. This implies a welfare gain of around

⁴³ This could be a problem for our method because we implicitly assume time separable utility. Because the pleasure of consuming an addictive good today depends on the history of personal consumption, this is not strictly correct. However, we analyse tobacco use over a long period in which several generations of users are born and die. This allows us to abstract from the non-separability of utility for each of them, and apply the basic method for estimating welfare gains.

⁴⁴ Details of the data handling are described in Appendix III.

4.5%, almost identical with the results from the Greenwood and Kopecky method using the estimate from 1630-1800.

Consumer surplus of old goods

A common question that arises in the estimation of welfare gains from new goods concerns the consumer surplus lost from old goods. Note that the demand curve for the new good already captures all consumption possibilities that existed previously – it maps from prices to quantities, given the pre-existing set of choices which includes food consumed earlier. Rising consumption of new goods was not driven by old products disappearing – Britons could have continued to breakfast on meat porridge, and a few did. Presumably, they preferred sugared tea and bread with jam. In this sense, there is no upward bias in any of the measures discussed earlier. A few goods may have fallen so much out of use that knowledge on how to produce them disappeared. For example, if local herbs were brewed up prior to the arrival of tea, it is possible that this concoction was no longer a choice for consumers in 1800. The Feenstra (1994) method allows us to deal with the disappearance of goods. The correction factor for the exact price index is

$\left(\frac{\lambda_{gt}}{\lambda_{gt-1}}\right)^{1/(\sigma_g-1)}$. If the range of choices declines, λ_{gt-1} falls, inflating the price index. Crucially, λ_{gt-1}

will not deviate much from unity since the budget share of spending on items that can possibly have disappeared must have been quite small.

Leisure lost

Some authors have argued that the length of the working day increased after 1750 (Voth 1998, 2001). This has been interpreted as a sign that backward-bending labor supply curves declined (DeVries 2008) – people worked more as more consumer goods became available. It could be argued that the introduction of new goods led to a decline in leisure. This would imply that while

utility from the new goods increased, our calculations might be upward-biased because we fail to account for the negative effects of longer hours.

Correcting for changes in leisure would be mistaken, in our view. First, the evidence that hours increased is controversial (Clark and Van der Werf 1998). Second, many of the gains in consumer welfare from new goods materialized long before work intensification became (potentially) an issue – by 1750, take-up rates were high. Third, as long as households supply labor hours via utility maximization, their revealed preference in the early, low-hours period was for leisure. This implies that the shadow value of time was low. If the availability of new goods by 1800 lead households to supply more labor, this suggests that that working was now worthwhile because the shadow value of time increased.⁴⁵ Deducting the value of leisure lost – when it was clearly of low value initially – would be inappropriate.

Health implications

Many of the new goods that Europeans started to enjoy after 1600 were initially considered to have medicinal qualities. Nicolas Monardes' 1571 tract on medical plants from the New World argued that 36 health problems could be cured by tobacco. Today, we know that most of this advice was misguided. Smoking causes cancer, and excessive sugar consumption leads to diabetes, obesity and dental decay. Both longitudinal studies and cross-country evidence suggest that increases in sucrose levels in the diet directly increased the prevalence of caries (Newbrun 1982). Caffeine in tea and sugar may increase coronary disease. The argument is articulated in extreme form by Thomas and Bean (1974):

“The only group of clear gainers from the British trans-Atlantic slave trade, and even these gains were small, were the European consumers of sugar and tobacco and other plantation crops. They were given the chance to purchase dental decay and lung cancer at somewhat lower prices than would have been the case without the slave trade.”

⁴⁵ This is the approach favored by Usher (1980).

Should we adjust the estimated welfare gains to take changes in health into account? Most of the health issues that could arise are not of major concern for our time period. Life expectancy in England was low – in the range of 30-35 years. Even heavy smoking must have resulted in few additional deaths, as many people would have died too early to be affected by cancer. Also, diabetes and obesity cannot have been major health concerns, given the low overall nutrient intake.

The one issue that is of potential concern is dental decay. Keane (1981) shows caries rates fluctuating in the range 5-10/100 between 3,000 BC and the Middle Ages, before reaching levels of 15-25 in the modern era. Saunders et al. (2002) find a wide range of caries prevalence in 18th and 19th century British samples, with rates between 20-42 percent. Data collection at higher frequencies is currently under way, but results are not yet available (Steckel et al. 2006). The addition of highly refined sugar to European diets, at a time when oral hygiene was poor, must have boosted the prevalence of carious decay. There is no obvious way to incorporate the welfare effects of dental decay into our measures of the standard of living, just as there is no obvious way to adjust income measures for other changes in the ‘biological standard of living’ (Steckel 2008). We conclude that medical effects – with the potentially important exception of tooth decay – are unlikely to qualify our welfare analysis in an important way.

VI. Conclusions

When did globalization begin to matter for living standards? According to the prevailing consensus, the answer is – not before the 19th century. O’Rourke and Williamson (2002) analysed traditional wage indices to show that trade across the Atlantic did not change real incomes before the 1830s. This paper argues that global trade quickly began to matter for living

standards. As Europeans rounded the Cape of Good Hope, they brought back tea; from the New World, they brought tobacco, chocolate, and potatoes. In the Caribbean and other tropical colonies, Europeans set up a production system for sugar, tea, and coffee that transformed the supply of these goods. By the eighteenth century at the latest, consumption habits had undergone a profound transformation. The new goods offered variety where monotony had once reigned. Just as in the US in the last decades of the 20th century, trade had a direct and important impact on living standards due to gains from variety (Broda and Weinstein 2006). As a result, life got significantly better as hot, sweet caffeinated beverages replaced water and ale, and bread with jam provided an alternative to porridge – by revealed preference, consumers favored tea, sugar, and coffee.

We use three different methods, pioneered by Hausman, Feenstra/Broda-Weinstein, and Greenwood and Kopecky, to estimate the value of sugar, tea, and coffee for British consumers in 1800. All of them have the advantage of using information on both changing quantities and prices, instead of price information only. As Hausman (2003) argued, this is essential for capturing welfare gains from new goods. Results are broadly similar across different methods. The best guess estimate is that colonial luxuries made consumers better off by at least one tenth of final-period consumption. Far from a side-show in the history of living standards, the introduction of caffeinated hot beverages and sugar contributed substantially to the welfare of the first industrialized country.

Our quantitative results for tea, sugar, and coffee constitute a lower bound on the discoveries' overall effect. An even wider range of 'new goods' that arrived on European shores as a result of overseas expansion (Nunn and Qian 2010). The addition of tomatoes, potatoes, chocolate, exotic spices, polenta, and tobacco transformed consumption habits in even more

fundamental ways than sugar, tea, and coffee. If data tracking the rise in consumption of all of these colonial goods were available, welfare increases for European consumers after 1492 would be even larger than our findings suggest.

Compared to the gains from new goods today, the welfare increases from introducing sugar, tea, and coffee in the past appear large. In Table 10, we compare the impact of recently invented new goods with our results. Even for the biggest items, such as personal computers and the internet, welfare gains are much smaller compared with historical precedent. To ensure comparability despite the substantial changes in average incomes, we use the standard metric in the literature and look at welfare gains relative to average consumption expenditure at each point in time. Goolsbee and Klenow (2006) calculate a gain of approximately 2% for the internet. For the good with the biggest estimate, personal computers, Greenwood and Kopecky (2013) show gains equivalent to 3.5-4% of income. Our findings suggest welfare gains that are up to an order of magnitude larger (except personal computers).⁴⁶ Other studies of gains from trade through increasing variety also show smaller increases than the ones we derive. Broda and Weinstein (2006) found welfare gains of 2.2-2.6%, approximately 1/4 of our “best-guess” improvement of 10% from sugar, tea, and coffee alone.

Relatively large(r) gains in the past make sense intuitively. Introducing a new good matters more when the pre-existing range of goods is small. Put another way – adding Apple Cheerios to the range of choices for breakfast cereals has (some) value. However, being able to replace beer soup, porridge and cold cuts with milky, sugary coffee and bread with jam was much nicer. Exotic new goods from the Americas and the Far East – pepper and nutmeg, tea and sugar, coffee and tobacco, chocolate and cloves – improved living standards by far more than

⁴⁶ In a similar vein, the findings in Nordhaus (1996) and Leunig (2006) also suggest large welfare gains from new goods introduced in the past.

modern consumers, satiated by an ever-expanding range of new goods, can readily appreciate. The reason why seemingly mundane goods like sugar, coffee and tea made a big difference to living standards is that life was not just ‘nasty, brutish, and short’ in Hobbes’ phrase at their time of introduction – it was also (in culinary terms) boring and bland.

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FIGURES AND TABLES

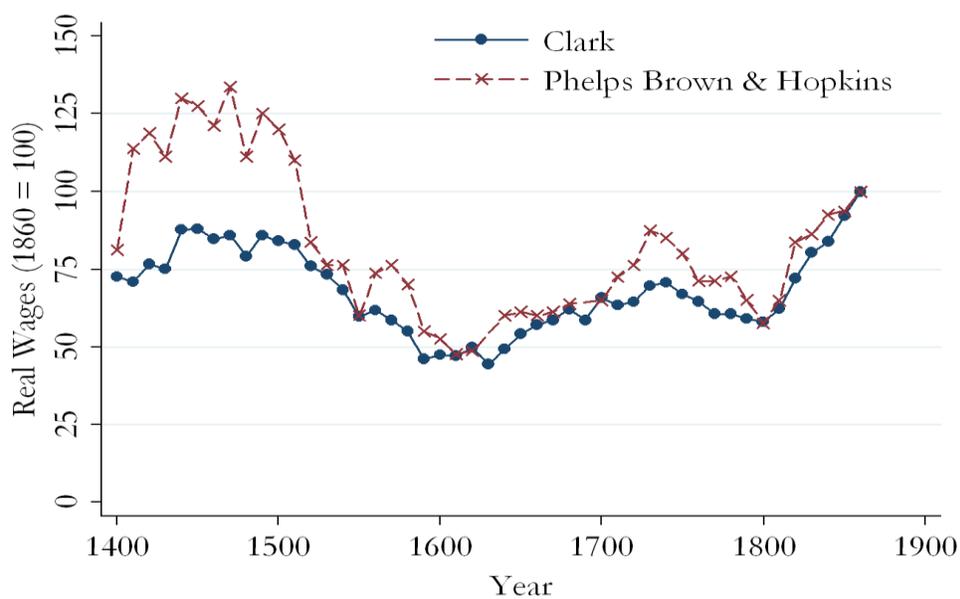


Figure 1: Real wages in England, 1400-1860

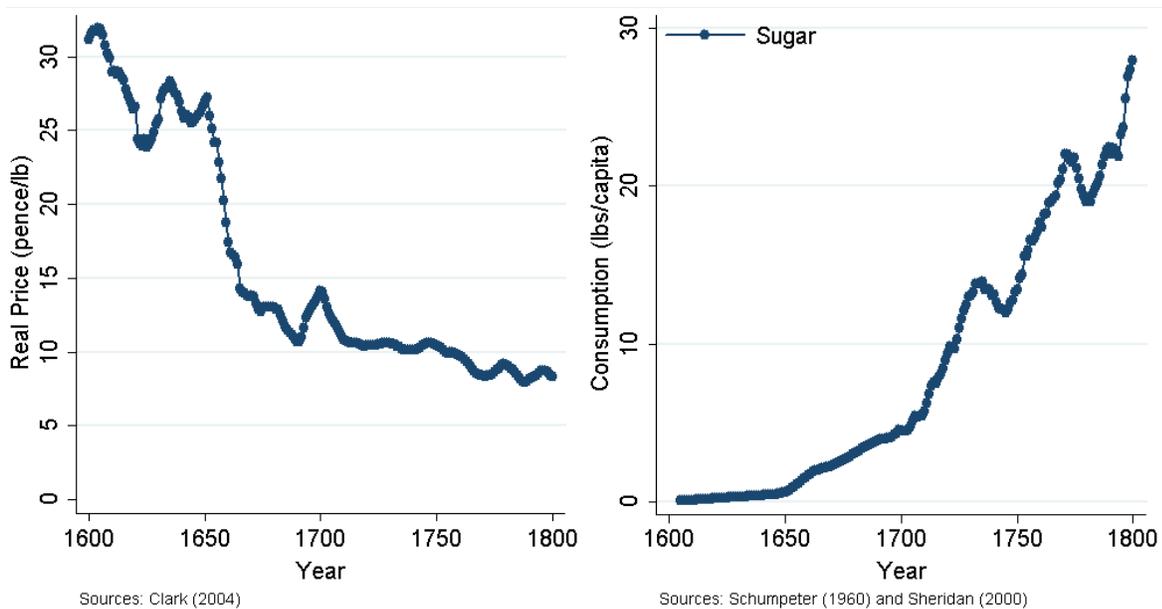


Figure 2: Real Sugar Prices and Sugar Consumption Per Capita in England, 1600-1800

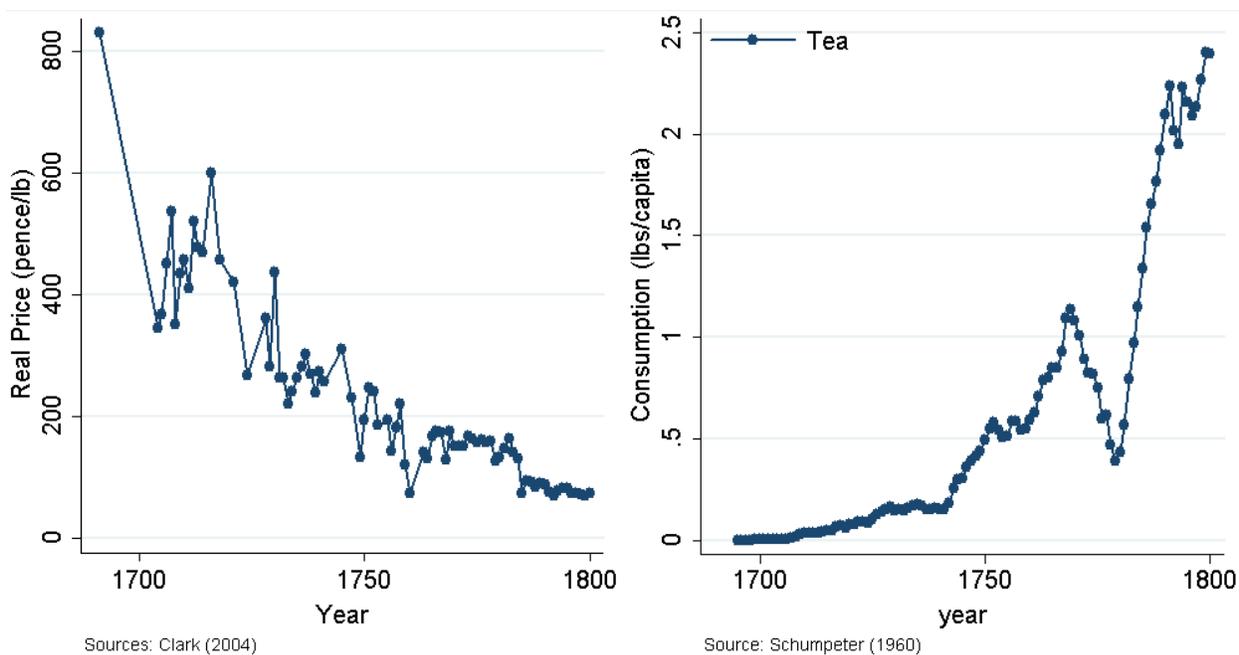


Figure 3: Real Tea Prices and Consumption Per Capita in England, 1600-1800

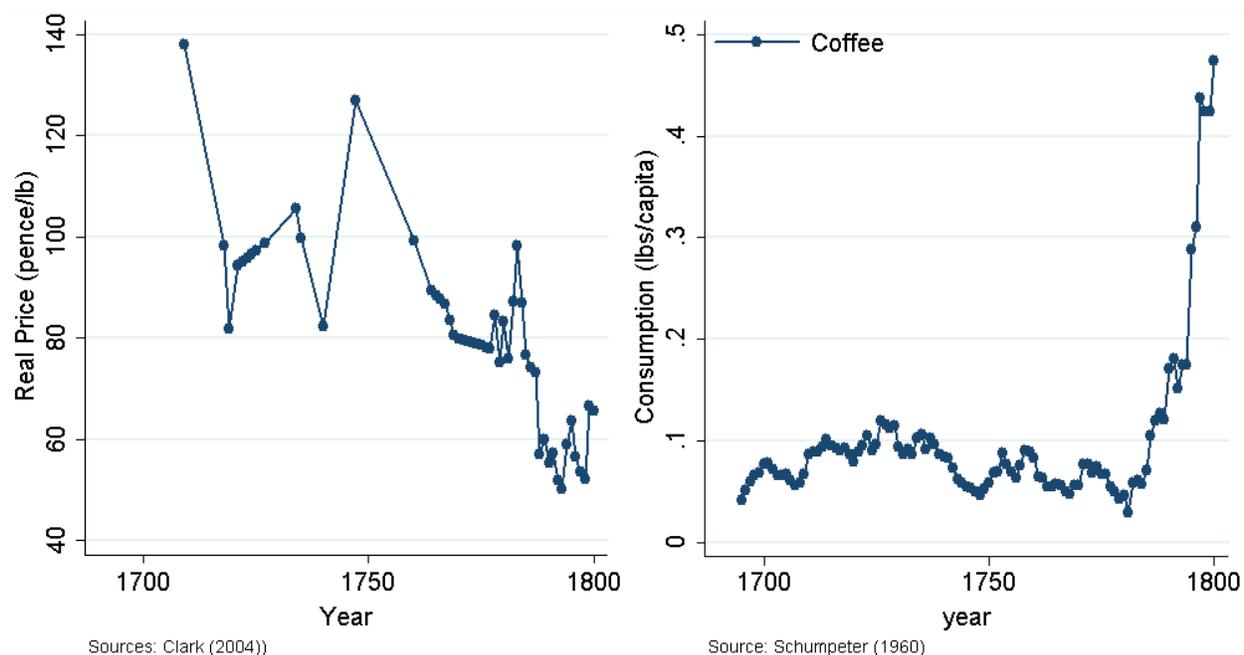


Figure 4: Real Coffee Price and Consumption Per Capita in England, 1600-1800

Table 1: Wages and spending on new goods by class

families which drink...	Number of households	Avg. expenditure In £	Avg. sugar consumption In pounds p.a.	Avg. spending on sugar In £
tea, coffee, or chocolate, morning and afternoon	70,000	250	369	12
tea, or coffee in the morning	236,000	49	92	3
tea, or coffee occasionally	400,000	44	45	1
labouring families, etc.	750,000	18	14	0

Source: Massie (1760)

Table 2: Consumption of colonial luxuries in Europe, early modern period (lbs per head and year)

	Date	Sugar lbs. pc	Date	Coffee lbs. pc	Date	Tea lbs. pc
England	1670s	2.2	1699-1701	0.1	1722	0.6
	1700-9	5.7	1749-51	0.1	1750-9	1.1
	1750-9	11.0	1801	0.1	1804-6	1.7-2.2(*)
	1770-9	23.1	1841	0.5	1844-6	1.8
Belgium	1800	3.6	1790	0.1	1720-9	0.1
	1850-4	6.6	1850-4	8.8	1850-4	0.02
France	1730-4	1.0	1781-9	0.5		
	1788-90	2.1	1815-24	0.5	1825-34	0.1
	1830	4.4	1825-35	0.6	1835-44	0.1
Austria	1780	0.3	1780	0.1		
	1800	0.9	1800	0.1		
	1830	2.2				

Notes: Adapted from DeVries (2008) * Sheridan(2000)

Table 3: Price elasticity estimates of sugar, tea, and coffee using OLS and 2SLS

Dep Variable:	1 OLS Sugar	2 OLS Tea	3 OLS Coffee	4 OLS Sugar & Tea	5 2SLS Sugar	6 2SLS Tea	7 2SLS Coffee	8 2SLS Sugar & Tea
Ln sugar real price	-0.398** (0.115)				0.285 (0.295)			
Ln tea real price		-0.170+ (0.091)				-0.381+ (0.205)		
Ln coffee real price			-0.186 (0.126)				-0.595* (0.263)	
Ln sugar & tea real price				-0.134** (0.042)				-0.227* (0.110)
Constant	0.884** (0.255)	0.845+ (0.459)	0.79 (0.539)	1.329** (0.24)	-0.58 (0.644)	2.141* (1.01)	2.416* (1.097)	1.026* (0.435)
Observations	151	151	151	114	129	96	129	96
R-squared	0.075	0.023	0.014	0.193	.	.	.	.
Sargan Test (p value)	.	.	.	.	0.00119	0.00011	6.44E-05	0.00179
Cragg-Donald Wald F-stat	.	.	.	.	14.54	22.32	20.42	34.59
Anderson LM stat	.	.	.	.	24.18	40.43	31.58	40.95
R2 Second Stage	.	.	.	.	-0.0161	0.123	0.034	0.117

Standard errors in parentheses

** p<0.01, * p<0.05, +p<0.1

Notes: Dependent variable is the residuals from regressing a given new good against a time trend. We instrument for price using the number of men in the British Navy and a dummy for years during which there is a major war. For tea, we also include as an instrument, in addition to the ones above, the log of the tea duty rate.

Table 4: Welfare gain of sugar, tea, and coffee using Hausman method

Study	Good	η	CV, 1759	CV, 1801	Method
<i>Using historical elasticities</i>					
Our Estimates	tea and coffee	-0.17	5%	9%	OLS
	sugar	-0.398	4%	8%	OLS
	total		9%	17%	OLS
	sugar+tea	-0.134	19%	34%	OLS
	tea and coffee	-0.381	2%	4%	2SLS
	sugar	0.285	na	na	2SLS
	total	na	na	2SLS	
	sugar+tea	-0.227	11%	20%	2SLS
Horrell 1996	tea and coffee	-0.25	3.4%	6.4%	
	sugar	-0.25	6.8%	12%	
	total		10.2%	18.4%	
Mokyr 1988	tea and coffee	-0.59	1%	3%	
	sugar	-0.0835	20%	36%	
	total		22%	39%	
<i>Using contemporary elasticities</i>					
Kanayama 1999	sugar	-0.13	13%	23%	
Gemmill 1980	sugar	-0.38	4%	8%	

Notes: η is price elasticity, estimated by the authors, and by Horrell and Mokyr. Modern-day data uses contemporary estimates of η and historical budget shares. CV is compensation variation, a measure of welfare increase from the new good, measured as a % of income.

Table 5: Estimates of elasticity of substitution, new vs. old goods

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	3SLS	3SLS	3SLS
sugar price ratio	-1.662*** (-7.22)			-1.55*** (8.7)		
real income	1.121** (2.1)	0.738 (0.60)	0.197 (0.14)	1.1*** (2.43)	0.89 (0.74)	0.202*** (0.14)
tea price ratio		-1.645*** (-13.48)			-1.53*** (-16.5)	
coffee price ratio			-2.504*** (7.15)			-2.42*** (-10.7)
constant	-9.84*** (6.4)	-5.562 (-1.62)	-5.81** (-1.48)	-9.5*** (-7.02)	-6.05* (1.78)	-5.81 (-1.41)
N	120	120	120	120	120	120
R^2	0.409	0.66	0.482	0.41	0.66	0.48

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Dependent variable: expenditure ratio. Dependent and exogenous variables are in logs.

Table 6: Welfare effects, Feenstra/Broda-Weinstein method

estimation	good	budget share	λ ratio	σ	price index	adjustment
<i>OLS</i>						
	sugar	0.060	0.940	1.662	0.91	0.09
	tea	0.032	0.968	1.645	0.950	0.05
	coffee	0.032	0.968	2.504	0.979	0.021
	Sum 1					0.14
	Sum 2					0.111
<i>3SLS</i>						
	sugar	0.060	0.940	1.55	0.89	0.11
	tea	0.032	0.968	1.53	0.94	0.06
	coffee	0.032	0.968	2.42	0.977	0.023
	Sum 1					0.17
	Sum 2					0.133

Notes: Sum 1 is the sum of welfare gains for sugar and tea plus coffee, evaluated with the elasticity for tea. Sum 2 reports the same, but using the elasticity for coffee. The parameter σ is the elasticity of substitution between old goods and a given new good, as estimated in table 5.

Table 7: Welfare estimates of sugar, tea, and coffee using Greenwood and Kopecky method.

New Good	Start	End	N	Sumerr	EV	CV	ν	ρ	θ	R^2
<i>Panel A: Results for joint estimation</i>										
All New Goods	1600	1800	21	0.0351	11.00%	9.96%	0.0075	0.4407	0.8827	0.9748
<i>Panel B: Results with varying rho</i>										
Sugar	1600	1800	21	0.1322	2.82%	2.81%	0.0006	0.1785	0.8077	0.9346
Tea	1690	1800	12	0.0694	5.54%	5.34%	0.0228	0.5399	0.9208	0.9465
Coffee	1690	1800	12	0.2175	0.11%	0.12%	0.0111	0.1183	0.7384	0.6989
Sum					8.47%	8.27%				
<i>Panel C: Results with rho = 0.4407</i>										
Sugar	1600	1800	21	0.5024	4.25%	5.28%	0.034	0.4407	0.8505	0.7514
Tea	1690	1800	12	0.0874	4.65 %	4.49 %	0.0097	0.4407	0.9153	0.9327
Coffee	1690	1800	12	0.2874	0.17%	0.51%	0.3885	0.4407	0.9083	0.6021
Sum					9.07%	10.28%				

Notes: Parameters estimated are ν is the new good utility shift, ρ is the new good utility shift, and θ is the utility weight on old goods. EV is the equivalent variation and CV compensating variation, measures of welfare gain from the introduction of the new good.

Table 8: Welfare gains by class, using Feenstra/Broda-Weinstein and Hausman method.

<i>Panel A: New good budget shares</i>						
	Good	Working Class	Elite	All Classes		
	Tea and Coffee	2.60%	3.74%	3.21%		
	Sugar	3.60%	8.13%	6.02%		
<i>Panel B: Welfare results by class</i>						
Method	Good	η	σ	Working Class	Elite	All Classes
Hausman	Tea and Coffee	0.17	-	7.7%	11.0%	9.4%
Hausman	Sugar	0.40	-	4.5%	11.2%	7.6%
	Sum			12.2%	21.2%	17.0%
Feenstra	Tea and Coffee		1.96	2.7%	3.9%	3.4%
Feenstra	Sugar		1.31	11.2%	24.0%	18.3%
				13.9%	27.9%	21.7%

Notes: η is own price elasticity, σ is the elasticity of substitution. For description of classes see text.

Table 9: Greenwood and Kopeccky estimated welfare gains for Tobacco.

New Good	Start	End	N	Sumerr	EV	CV	ν	ρ	θ	R^2
Tobacco	1630	1700	7	0.0591	8.01%	7.16%	0.5482	2.4964	0.995	0.9312
Tobacco	1630	1800	14	0.3633	4.65%	4.73%	0.9834	4.4605	0.9996	0.8282

Notes: Parameters estimated are ν is the new good utility shift, ρ is the new good utility shift, and θ is the utility weight on old goods. EV is the equivalent variation and CV compensating variation, measures of welfare gain from the introduction of the new good.

Table 10: Impact of new goods on welfare

Good	Welfare Gain (CV)	Year	Source
<i>Modern Goods</i>			
Apple Cinnamon Cheerios	0.002%	1992	Hausman (1996)
Personal computers	3.5–4%	2004	Kopeccky & Greenwood (2009)
Minivans	0.03%	1988	Petrin (2002)
Satellite TV	0.04–0.06%	2001	Goolsbee & Petrin (2004)
Internet	2–3%	2005	Goolsbee & Klenow (2006)
Mobile phones	0.46–0.9%	1996	Hausman (1999)
Foreign varieties	2.2–2.6%	2001	Broda & Weinstein (2006)
<i>Colonial Luxuries, 1800</i>			
Sugar	2.8*-36**%	1600–1800	this study
Tea and Coffee	2.3***-9.0+%	1690–1800	this study
Tobacco	4.5-4.7++%	1690–1800	this study

Notes: * Table 7, varying ρ ** Table 4, Mokyr elasticity *** Table 6, OLS, σ for coffee
+ Table 4, OLS ++ Table 9

NOT FOR PUBLICATION

Appendix I

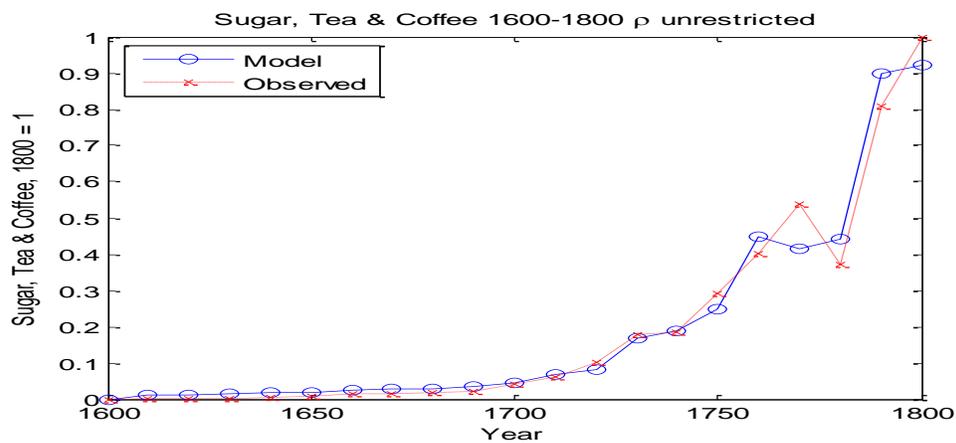


Figure A1: Predicted vs actual values for sugar, tea, and coffee consumption in England, 1600-1800

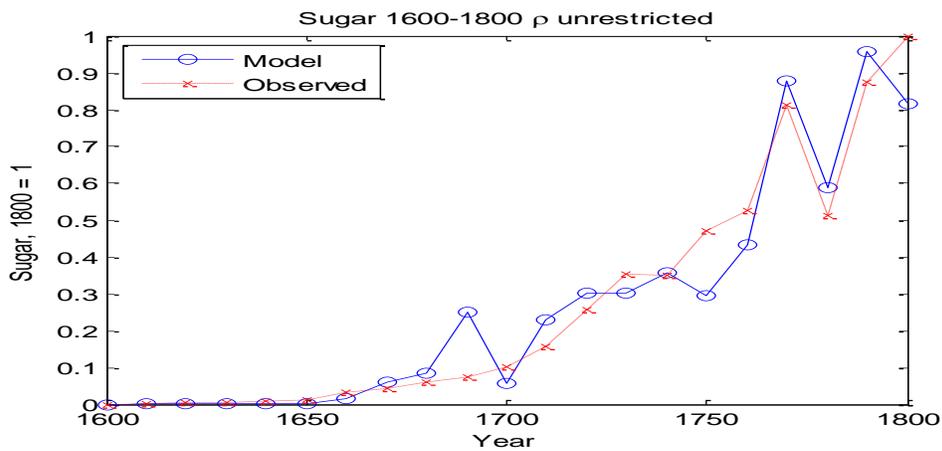


Figure A2: Predicted vs actual values for sugar consumption in England, 1600-1800

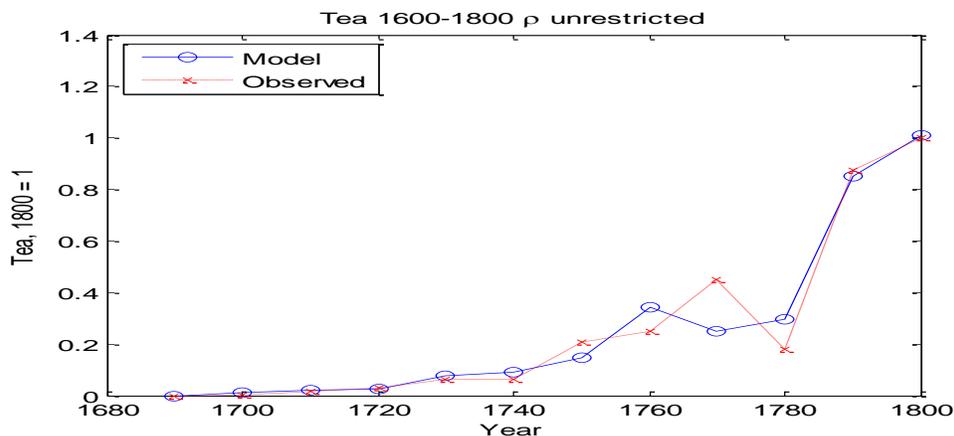


Figure A3: Predicted vs actual values for tea consumption in England, 1690-1800

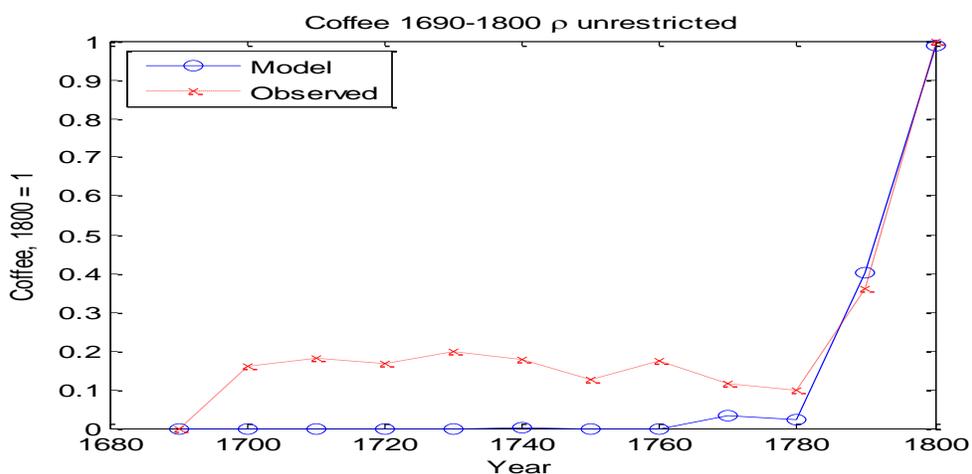


Figure A4: Predicted vs actual values for coffee consumption in England, 1690-1800

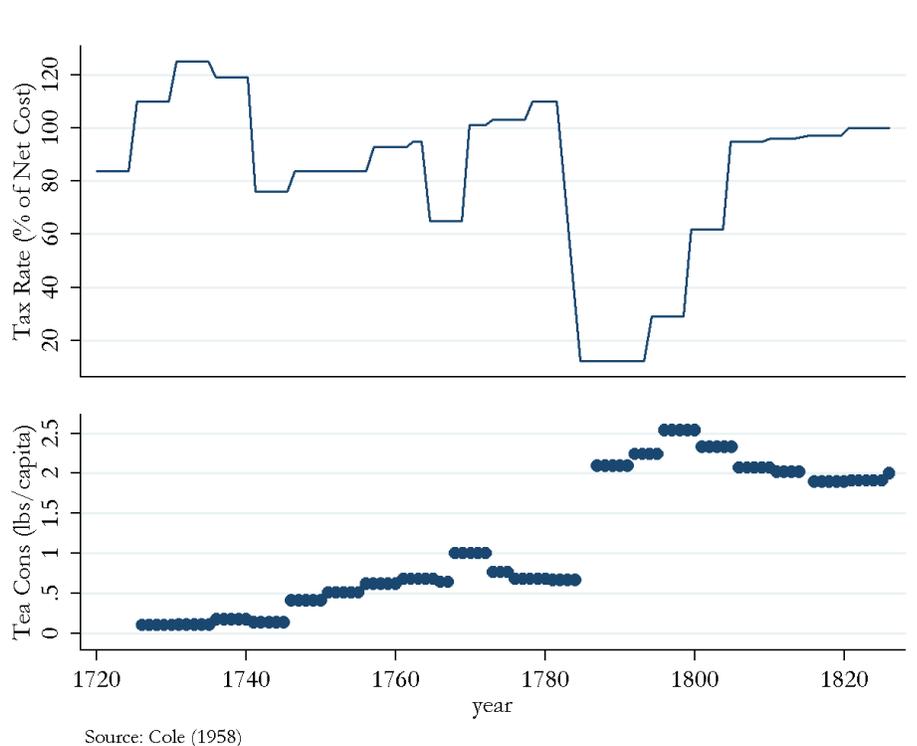
Appendix II

We briefly set out our methodology for correcting the quantity of tea consumed in Britain for the effect of smuggling. Figure A5 demonstrates the problem – legal imports jump around the date of the big duty reduction. To eliminate the effects of tariff changes, we estimate

$$Q_t = C + \beta p_t + \gamma D_t + \varepsilon_t \quad (\text{A1})$$

where Q is the (legal) quantity of tea imported, p is the retail price, D is the duty charged on tea imports, and ε is the error term. Since naval wars and weather events were responsible for most

of the short-term variation in prices, we think of this basic relationship as tracing out the (short-term) demand curve. By adding a control for the tariff, we incorporate information about incentives to smuggle. Estimating eq. A1 yields coefficient (t-statistic) estimates for C , β , and γ of 3.05 [25.9], -0.008 [13.7], and -0.008 [5.8]. This suggests that years with high imports were on average associated with low retail prices. Over and above the effect from low retail prices, lower duty charged also coincides with greater imports.⁴⁷



Source: Cole (1958)

Figure A5: Tea consumption and tax rate

To adjust for the effect of smuggling, we want to know how large total imports would have been had it not been for a (time-varying) incentive to smuggle. To calculate a constant-smuggling series for tea, we hold the tariff rate constant at the period average. We then use the estimated

⁴⁷ To the extent that the regression picks up a common trend, we will be *overcorrecting* for smuggling, thus biasing results against our claim that new goods added substantially to welfare.

relationship from A1 to predict tea demand in the absence of tariff changes. To fully correct for the effects of smuggling, we also want to correct for the effect of tariffs on prices. Years with high tariff rates also saw high prices. If we want to estimate quantities of tea imported in a constant tariff setting, we need to adjust actual prices for the effect of the tariff. We estimate corrected demand for tea from equation A1, using the predicted price in a constant-tariff scenario. Overall, these corrections reduce growth in the British demand for tea. Adjusted tea imports in the (early) years of our sample are now markedly higher. Figure A6 illustrates the change. During the period of the highest tariffs, the middle of the 18th century, there is substantial divergence between the corrected and uncorrected series. Then, as tariffs are cut drastically after 1784, the predicted series falls below the ‘legal’ import series. Overall, the variability of the new, predicted series is lower than that of the official imports. It could be argued that it is not plausible that actual imports were below official ones, since the incentive to smuggle was either positive or zero. In our smuggling robustness check, insofar as the true import series showed greater growth than our corrected series, we will underestimate the welfare gain. Since we argue that gains were large, this only biases results against our hypothesis.

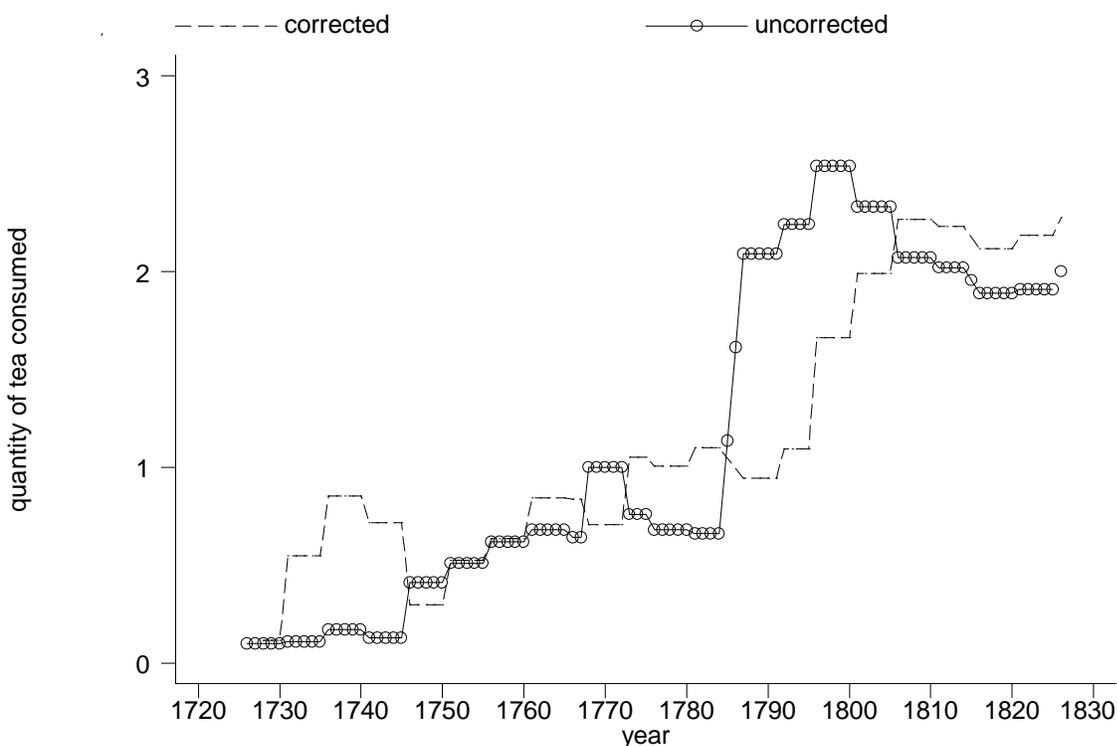


Figure A6

Appendix III

We use a variety of sources to track the price of tobacco and the volume consumed. For the early years, 1630-1693, we rely on Rogers (1887).⁴⁸ At the beginning of our period, there is confusion in the price series about the quality for which prices are being quoted. Spanish tobacco was several times dearer than colonial tobacco. Price fluctuations may be driven by overall changes in the price of tobacco, or by its origin. To sidestep the issue, we adjust the prices of Spanish tobacco by the average price difference between both types.

Smuggling was a major issue in the case of tobacco. We use series that attempt to adjust for it. Shammass (1990) gives consumption figures for 1618-1694. Tariffs only started to impinge

⁴⁸ For the interval 1700-1740, there is data in Clemens (1980). It is for colonial America, and the price trend is different from the one in the UK. We decided not to use it in our estimation procedure since there is no direct way of matching Clemens' data with the Rogers and Clark series.

significantly from the late 17th century onwards (Dowell 1888). We take advantage of the corrected series in Shamma (1990), which is based on Nash (1958) where available.