CHAPTER 6

Core and periphery in the early modern world system

A time-space appropriation assessment

Rikard Warlenius

In this chapter, methods usually associated with ecological economics are applied to world history studies, in an example of what Martínez-Alier and Schandl (2002) have called "ecological-economic history". It is understood as going beyond a general ecological concern in environmental history to the application of measures and methods originating from ecological economics. Ecological economics is a heterodox school of economic thought which acknowledges the planetary limits of (a sustainable) society and in which biophysical measures such as ecological footprints and material flow analysis are frequently applied to economic analysis.

This chapter uses a biophysical method grounded in world system analysis and ecological economics – Alf Hornborg's (2007) *time-space appropriation* – to investigate one of the main questions posed on the "battlefields" of global history: was the early modern world economy centered on Europe or China? As a case study, it focuses on the exchange of Swedish bar iron and Chinese Bohea tea in the eighteenth century via the Swedish East India Company. In time-space appropriation, the amount of productive land and human labor embodied in the commodities exchanged is assessed, as well as the quantities exchanged at the prevailing price relation, in order to establish a net flow of biophysical quantities – time and space – between the parties of exchange. The underlying assumption is that monetary prices are masking uneven relations of power, and that an equal exchange of money often hides an unequal exchange of biophysical resources. In this particular case, the method is used to discuss the structural position of Western Europe and China respectively within the early modern world system, assuming that the net-receiver of resources in the exchange is the more central area. The empirical findings and assessments are collected in a separate section (p. 206).

The "ReOrientation" of world history

With its strong focus on methodology, the rich theoretical and historical debate about Eurocentrism in (world) historiography is largely left aside in this chapter. I only wish to note that a strong movement for dismantling Eurocentric historiography has existed for some decades, which is most closely associated with the "California school", a fairly heterogeneous historical school that borrows ideas and methods from neoclassical economics and institutionalism, as well as structuralism. Its most prominent work is arguably Kenneth Pomeranz' *The Great Divergence* (2000). It was, however, to an even greater extent structuralist scholars, including Janet Abu-Lughod (1989), Samir Amin (1989), James Blaut (1993, 2000), and Andre Gunder Frank (1993, 1998), who pioneered this "ReOrientation" of world history.

Frank offered the most radical revision and the importance of his *ReOrient* (1998) is equal to the work of Pomeranz (2000). Although the theoretical perspectives differ, their conclusions on Eurocentric historiography are quite similar. Frank's main aim, stated in the first sentence of his book, is to "turn received Eurocentric and social theory upside down" (Frank 1998: xv). He asserts that more recent historical research, mainly from the peripheries, synthesized holistically into a new world history, shows that other parts of Afro-Eurasia were at the same economic level as Europe, or were even more advanced, up until circa 1800. In a posthumous book (Frank 2014) he argues that for China, this was the case even up to the last three decades of the nineteenth century.

According to Frank (1998: 111), in the early modern world system, China was the core for two main reasons: its "preeminence in production and export" and its "function as the final 'sink' for the world's production of silver". The two factors were connected, since

China's exports of silk, porcelain and tea were unrivaled, based on its superior productivity, and led to a trade surplus "with everybody else" – other parts of Asia, Europe, Africa, and America (Frank 1998: 116) – which was balanced through silver payments. The silver enabled the Chinese market economy to expand on a silver basis. In fact, the whole world economy was on a silver standard, and China was the center of this silver-based world economy.[1] However, silver also played the role of a "Trojan horse" that would eventually create a shift in global dominance. The extremely rich silver discoveries in Mexico and Bolivia not only fueled China's further economic expansion, but became Europe's ticket to the much greater Asian economic train (Frank 1998: 277). Still, it was not until after the Western Industrial Revolution that Westerners were able to "displace the Asians from the locomotive" of the world economy (Frank 1998: 37).

Flynn and Giráldez, the most prominent historians on the early modern silver trade, also share Frank's Sinocentric view and the importance of China's silver imports. They disagree with Frank's contention that China was enriched by its silver imports and emphasize the high social costs of substituting a practically free paper money system with silver paid for with exports. However, China's capacity to do so for centuries only "underscores the centrality of the Chinese economy as global juggernaut" (Flynn & Giráldez 2002, cf. Flynn & Giráldez 2000).

Ecological-economic history

Environmental history has now become an established subdivision of history, and while for a long time it was mainly national in scope, environmental explanations for world historical events are now both advanced and acknowledged. However, Jason W. Moore (2003) notes that environmental history is surprisingly void of social theory, and mentions James O'Connor's "second contradiction", John Bellamy Foster's theory of the metabolic rift, Wallerstein's world system analysis, actor-network theory, and political ecology, as potential inspirations for a more theoretically-concerned environmental history. From a methodological perspective I would like to add ecological economics as another potential inspiration.

Ecological economics is a growing academic field that started as a "break-away" from neoclassical economics, merging economics with natural science to investigate the biophysical foundation of economic activities.[2] Several such biophysical measures have been developed in ecological economics. These include Odum's emergy concept (see Brolin 2006; Foster & Holleman 2014); Material Flow Analysis elaborated by the Vienna Social Metabolism school (e.g. Fischer-Kowalski & Hüttler 1999); Borgström's (1965) concept of ghost acreages; and the more elaborated concept of ecological footprints (Wackernagel & Rees 1996; WWF 2010).

Ecological economics shares with world system analysis a critique of neoclassical theories of trade and prices. At the base lies a conviction that prices on the world market do not neutrally reflect value solely as a response to supply and demand, but in some way reflect power, social relations and cultural constructions. As the human ecologist Alf Hornborg puts it:

> [T]he cultural bubble of neo-liberal economics excludes all those other possible measures of exchange [besides money] – such as energy, materials, hectares, labor time – with which it is fairly easy to show that world trade is indeed highly unequal (Hornborg 2009: 262; cf. Hornborg 2001: 39).

Hornborg is critical of any value theories, including those of Marx, Odum (1983) and Bunker (1985), since he argues that any "objective" valuation of a commodity denies that valuation is highly cultural. Prices are not a neutral reflection of supply and demand, as economists would have it, but related to power relations, social relations and cultural valuations. Even if prices mask power relations, and there is no "objective" value theory with which prices can be compared and unmasked, they can be measured against real, physical inputs such as labor time – what the structuralist economist Arghiri Emmanuel (1972) called *unequal exchange*.

The theory of unequal exchange is rooted in Ricardo's (1953, orig. in 1817) classical trade theory of comparative advantages, according to which a country gains by specializing in the production of commodities in which it has a relative advantage, and by trading with other countries for the commodities in which they have a relative advantage. Given immobility of labor and capital, both countries will gain from the exchange – although Ricardo fully understood that this would lead to an unequal exchange of labor time. Marx picked up on Ricardo's theory and observed in *Capital* that "the privileged country receives more labor in exchange for less" (Marx 1981: 345). However, this agreement, in substance, leads to very different conclusions. Ricardo's theory laid the foundation for the Heckscher-Ohlin model of factor endowments and all current mainstream trade theory in which low wages are regarded as a comparative advantage or the result of an abundant factor of production to be used in international trade. In Marxist and structuralist theory the concept of unequal exchange – in essence "more labor in exchange for less" (Marx 1981: 345) – has been regarded as a core explanation of uneven development and the maintenence of core-periphery relations in an unjust world system.

Later on, this concept was situated at the centre of attempts to 'green' world system analysis by analyzing uneven or unequal exchange, not only of labor but also flows of material and/or energy. An ecological version of unequal exchange was first developed by the sociologist Stephen Bunker (1985). To be able to actually test the hypothesis that the world system is characterized by uneven flows of energy and matter, the biophysical measures developed within ecological economics have proven useful. For instance, ecological footprints have been used to measure uneven flows of trade in several studies (for recent overviews, see Hornborg 2009: 249; Foster & Holleman 2014: 11).

Ecological economists have also occasionally applied their methods to historical cases[3] – what Martinez-Alier and Schandl (2002) call "an *ecological-economic history* concerned with the physical assessment of the impacts of the human economy … a history of 'social metabolism'"[4] – but historians are still mostly uninterested in quantifying the entropic flows, ecological footprints, energetics regimes and so on of past societies and economies. One exception is Andre Gunder Frank, who late in life began to see entropic flows as an important analytical tool for global history (Frank 2006, 2014; Bergesen 2011; Denemark 2011). The English ascendance of the nineteenth century, he argued, was characterized by the displacement of ecological and social entropy from the center to the periphery, permitting greater order and democracy in core regions while simultaneously imposing disorder, ecological devastation and conflict/violence onto the periphery forced to absorb the entropy. This displacement of entropy, as well as the converse transfer of exergy to the core, is distributed through the world market where price differences favoring the core serve as the engine (Frank 2006: 304–307). In his posthumous book *ReOrienting the 19th century* (2014), Frank set the task of explaining the "the great divergence" partly through entropic flows, but unfortunately he was not able to finish those sections before he was lost to cancer in 2005 (Denemark 2011).

One obvious problem in measuring asymmetric entropic flows in general, but especially in history, has been the difficulties in putting it into operation in empirical research based on existing data. Hornborg suggests one feasible way:

> [D]etect such structural asymmetries in trade by converting statistics on commodity flows into quantities of "embodied land" and "embodied labor". Both these factors of production can be sources of exergy for the accumulation of capital, but have the advantage of being quantifiable, for example in annual hectare yields and in hours of human labor (Hornborg 2007: 261).

Thus, the method Hornborg labels time-space appropriation is an attempt to measure ecologically unequal exchange. He uses the trade between England and its former American colonies in the mid-nineteenth century as a case study. To actually assess the land and labor embodied in the traded commodities turned out to be much harder than anticipated, however.[5] However, by studying a broad spectrum of literature and estimated figures often used for other purposes, an assessment was possible. Accordingly, in 1850, 1,000 sterling pounds worth of raw cotton from the former colonies embodied circa 21,000 hours of mostly slave labor and 59 hectares of land, whereas 1,000 sterling pounds worth of cotton textiles from England embodied circa 14,000 hours of labor and less than one hectare of land (Hornborg 2013: 91). This unequal exchange was made possible through technological superiority emanating from capital accumulation that, over time, became self-enforcing when the profits derived from the unequal exchange were invested in further technology (Hornborg 2007: 267). In conclusion, Hornborg's calculations are used to reinforce an analysis of British industrialization, not so much as the rise of growth and productivity, as of successful appropriation of other people's land and labor in what is essentially a zero-sum game: "to save time and space by the application of increasingly 'efficient' technologies may often tend to imply that someone else in the world system is losing time or space in the process" (Hornborg 2007: 270).[6]

By including both land and labor, Hornborg bridges the Marxist-oriented world system analysis, within which the concept of unequal exchange focusing on labor emerged, and ecological economics and global history, which focus on flows of embodied land.

A time-space appropriation assessment of an early modern Swedish–Chinese trade exchange

Time-space appropriation

To summarize the introductory part of this chapter, a non-reductionist, structuralist, non-Eurocentric, ecologically concerned global history is favored, and special attention is paid to biophysical methodologies associated with ecological economics. One such method, time-space appropriation (TSA), is used to build a case that aims to test, or at least shedding some light on, a world history controversy, namely Andre Gunder Frank's hypothesis that the early modern world system was essentially Sinocentric and not Europe-dominated. This approach is novel in at least one sense. It seems self-evident which parts of today's world system are cores and which parts are peripheries, but going back in history, this is not as obvious – hence the controversy. While the methodologies related to (ecologically) unequal exchange have been developed to explain how existing cores exploit peripheries, and how an unjust world system is thereby maintained, here the aim is to determine which part of a historical world system was core, and which periphery. Presupposing that the same tendencies that apply now were also in function some hundred years ago – basically, that the peripheries exchange more labor and more nature for less – measuring energetic net flows in world trade might indicate which parts of the world system were more central, and which parts were more peripheral.

TSA has been chosen for a number of reasons. It has a solid and straightforward theoretical underpinning that is not based on controversial and, arguably, metaphysical value theories. While most biophysical measures, such as ghost acreages, or ecological footprints, only take ecological resources such as land into account, and while Emmanuel's unequal exchange only focuses on labor and wages, TSA defines energetic flows more broadly by including both land and labor. Like unequal exchange, it is reciprocal, i.e. it compares both import and export to assess net flows, which gives a fuller picture than a one-way assessment. Finally, its variables rely on data that should be assessable for many historical cases. There are, of course, also some disadvantages and complications with the method that will be dealt with as they arise and summarized towards the end.

First though, it is not self-evident that TSA should be used as a general measurement of unequal exchange – of core/periphery status – within any world system. Even though Wallerstein is not ignorant about ecological factors (cf. Moore 2003), he nonetheless defines economic status in the world in exclusively economic and political terms; in *The Modern World System I* (Wallerstein 1974), variables such as "the complexity of economic activities, strength of the state machinery, cultural integrity, etc" (Wallerstein 1974: 349) are described as the differences between cores and peripheries. The world economy is distinguished by its axial or geographical division of labor, and the core countries dominate through tasks "requiring higher levels of skill and greater capitalization" (Wallerstein 1974: 350). These are factors that are not easily operationalized. In 1974, Wallerstein made no reference to Arghiri Emmanuel or unequal exchange. Over time however, Emmanuel's analysis was incorporated into world system analysis (see Wallerstein 1980: 50; 2004: 28, 98), and was even proposed as a measure of core/periphery status.[7] In his theoretical introduction, *World System Analysis* (2004), Wallerstein states that cores and peripheries are defined by their production processes, and that their status can be decided by examining the degree to which they are monopolized, or submitted to the rules of the free market (core production processes are more monopolized and peripheral ones are more exposed to competition, Wallerstein 2004: 28). Core/periphery status is here defined by the rate of profit of the production processes, but profitability is seen as directly related to the degree of monopolization. In an exchange, the competitive commodities are in a weaker position than the (quasi-) monopolized ones, which results in a permanent flow of surplus value from the peripheral producers to the core producers. "This has been called unequal exchange" (Wallerstein 2004: 28).[8]

Following Wallerstein, either unequal exchange or factors relating to the level of profitability or market dominance should be operationalized in order to measure core/periphery status within a world system. But if we agree with Bunker, Hornborg and other proponents of a "green" structuralism – that the world system is not only characterized by an unequal exchange of labor time, but also of natural resources, which is also in line with the above excursion on the relevance of ecology in historical explanations – then it becomes logical, and true to the original world system analysis, to use e*cologically* unequal exchange as an indicator of core/periphery status. As has already been shown, time-space appropriation is one usable method for measuring ecologically unequal exchange.[9]

Constructing a case of time-space appropriation

To use measurement of time-space appropriation to shed light on"divergence" before the Industrial Revolution, we need, first and foremost, to single out one, or a few, representative cases. Hornborg's example, the exchange of American raw cotton and finished British textiles in the mid-nineteenth century, is key to understanding the Industrial Revolution. Does such an emblematic case of exchange between Europe and Asia in the early modern period exist? Having identified such a case, we shall need to create a theoretical model, and find dependent variables and relate them to each other, before getting into the empirical details and calculating the results.

Europe's main export commodity to Asia in early modern times was silver, and the main import product was tea (silk in the earlier period), so it would be natural to use silver and tea (or silk) in our case study. There are, however, four problems with using silver, of which one seems insurmountable. First, silver is mysterious because of its use partly as money, partly as a commodity. The non-economic use value of silver is limited and it is hardly an important part of any economy's direct social metabolism. If we were to treat silver merely as money – as a means of payment and a residual store of exchange value – then it might be unsuitable for a time-space assessment, since its value might be largely symbolic and backed by states and might therefore say very little about its biophysical content. The relation between its embodied exergy and its price would then be distorted and hard to compare with other commodities. There are, however, good reasons to treat silver as a commodity in the early modern world market (cf. Flynn & Giráldez 1995 and 2002; Pomeranz 2000: 160). Even if it was mainly used to mint coin, its advantage as money, compared with, e.g., paper money (which in China had failed bitterly during the Ming era), was that it also had a market value as a metal commodity, which made it less risky to accept as money. Thus, even when used as money it seems that its value was market-based rather than state-backed. Therefore, silver may be compared to other commodities and could be suitable for a time-space assessment.

Second, we might still suspect that silver's market value was a result not only of the land and labor it embodied, but also of its scarcity. This could also distort the correlation between exergy and price. The counterargument would be that scarce metals are also related to exergy input, since much labor time is usually spent on finding the ore and refining the metal. Third, that silver is an *abiotic* – nonliving – resource is not ideal for a time-space assessment. No attention is given to the fact that it is harvested only once, from a natural process that is extended in geological time rather than in space (as opposed to biotic, i.e. living resources), which might distort the land factor used in TSA. On the other hand, this concern is probably of little economic importance since what nature "gives" – either photosynthetically or geologically – is usually considered in economics as *gratis*. In any case, as we will see below, the extraction of minerals often had a large land component anyway because of the wood or charcoal needed for refining, or at least this was the case in the "old" organic regime when energy was mostly dependent on land.

There is, however, a fourth problem with using silver, which has nothing to do with its particular material characteristics, but is rooted in the unique role this money-commodity played in the early modern world economy. One important assumption in how time-space appropriation is used here is that the net receiver of land and labor in a particular exchange – such as England in Hornborg's example – is more central in the world system, higher up in the hierarchy, with the power to influence pricing. In this case, a confirmation of a Frankian, Sinocentric hypothesis would mean that the land and labor embodied in the silver exported to China is higher than in the commodities for which it was exchanged (e.g. tea), making China more central. But even if this were the general pattern, there might be exceptions to the rule. Not every single commodity exported by China would have to be less land- and labor-intensive than silver for the general pattern to be true. Perhaps, not even some very important commodities have to follow the general pattern for the pattern to be true. The problem here is that several informed observers claim that Europe's silver export to Asia *was* this exception to the rule. According to Pomeranz (2000: 160), silver was one of very few commodities with which Europe could beat its global competitors, and for Frank it was precisely the profits from silver that in the long run made Europe strong enough to overthrow the Asian economic hegemony, even though it took several centuries (Frank 1998: 37, 277).

Because of silver's supposed deviation from the general rule, a result pointing to a net transfer of land and labor to Europe would not be easily translatable into a more general claim of European world dominance. At the same time, it would not be reasonable to make the opposite claim: to regard a net flow of land and labor towards Europe as a vindication of Frank's and Pomeranz' claims, because what would a result supporting a Eurocentric world economy then look like? Since both results could be interpreted in favor of the hypothesis, constructing a falsifiable theory on silver's role in the time-space appropriation of the early modern world system seems impossible. Another possibility is to look for other European export commodities to compare with those imported from China.

A major problem is that there were hardly any: silver was essentially the only thing the Chinese wanted from the Europeans, until the British success in balancing its China trade with Indian opium, but by then we are already on the verge of the industrial era.

If silver was almost the only thing the Chinese wanted in exchange for their tea and other commodities, and this exchange is likely to have been characterized by a net time-space flow to Europe, do we have to give up on using TSA as a measure of structural position within the world system? I think it is a better idea to circumvent the particularities of silver by constructing another case study where silver is included but treated as money instead of as a commodity, and see if such a case study implies a net transfer to China or to Europe. Several such case studies can be constructed. For the trade carried out by the Swedish East India Company that I have studied, the most relevant case, for reasons explained below, is the exchange of Swedish iron for silver, which in turn was exchanged for Chinese tea. A focus on other commodities traded by the British, Dutch or French East India Companies might have been as relevant, or even more relevant, for understanding whether Europe or China was more central in the early modern era, but they have not been investigated so far. Hopefully, this particular example can still provide some methodological insights for anyone tempted to construct further case studies.

Iron for tea

Founded in 1731, the Swedish East India Company ("Swenska Ostindiska Compagniet", SOIC) conducted 132 expeditions to Asia. These expeditions were almost exclusively to Guangzhou (Canton) in China, although a few voyages were also made to India before the SOIC was dissolved in 1813. Tea was the most important Chinese import to Europe in the eighteenth century, for the SOIC as well as for the other East India Companies, and black Bohea tea was the most preferred sort. According to Robert Constant, a French merchant in Guangzhou in the mid-eighteenth century, "it is tea which draws European vessels to China; the other articles that comprise their cargoes are only taken for the sake of variety" (quoted in Gardella 1994: 33). Between 1739 and 1767, a total of 16,533 tons were imported by the SOIC (Koninckx 1980: 211). Bohea tea constituted 13,851 tons or 84 per cent of the total known imports of tea (Koninckx 1980: 207). According to the statistical compilation of the value of imported goods by the SOIC in Nyström (1883), tea comprised 71.4 per cent of total value of imports between 1769 and 1777.[10]

If we assume some stability over time, it seems that Bohea tea alone made up more than half of the cargo arriving at Gothenburg on the Swedish East Indiamen. This makes Bohea tea the most relevant Chinese commodity for further research in this study. I have not investigated whether the ratio between land and labor in tea is representative for the other important commodities imported to Sweden, such as raw silk, cotton clothing or porcelain. Obviously, the data for Bohea tea cannot automatically be applied to Chinese export commodities in general since it might theoretically be another exception, just as with silver, discussed above. However, it has been chosen because it was by far the most important commodity.

What then did the SOIC export? Mainly metals and timber. According to Koninckx (1980: 184), whose study on the SOIC covers the years between 1731 and 1766, "[m]etals in the form of semi-finished or finished products constituted the bulk of the Swedish Company's exports. The most interesting items relate to iron"; "[i]n general, bar iron always dominated Swedish exports, at least at the beginning of the eighteenth century" (Koninckx 1980: 185). Thus, bar iron seems to be the most important export commodity and is chosen for the same reasons as Bohea tea. However, the problem of the dominance of silver in the Sino-European trade returns. It turns out that most, if not all, of the bar iron and the other Swedish export commodities were not carried to China, but only to Cádiz in Spain, where they were sold to pay for chests of silver (Koninckx 1980: 193). Up to 1766, there is data on silver cargoes from a dozen of the SOIC's expeditions and Koninckx confirms that silver was practically the only thing the Swedes could sell in China: "the cargo of Spanish piasters was the *sine qua non* of the Company's trade" (Koninckx 1980: 190). By treating the silver as money, as a residual store of the value of the bar iron for which it was exchanged, a comparison between the iron and the tea bought with the silver coins is still possible.

Relations of the variables, and hypothesis

TSA is the difference in land and labor input into commodities from two areas exchanged at a certain price rate. If commodities from the areas are called I and II, TSA exists if there is an exchange of I and II and if I ≠ II. TSA is the difference II–I. It is assumed that the part with the highest value is peripheral to the part with the lowest value. If I > II, Area A is periphery and Area B is core. It is crucial to establish the price relation of the exchange: otherwise it will be impossible to assess how much of I was exchanged for II.

The ratio II/I expresses the magnitude of the inequality in the exchange. In order to assess the magnitude of the TSA, we also need data on what quantities of the commodities were exchanged. By multiplying the sum with the quantities of the exchange, the total TSA is assessed. In this case, however, the total quantities of the exchange are not the focal point. Both Pomeranz' use of ghost acreages and Hornborg's use of TSA aim to measure European ecological relief by former colonies, and therefore emphasize the total sums of the land and labor saved, but I am interested in using TSA here as a measure of the relative exchange of land and labor in the trade between Sweden and China, in order to settle their positions in the hierarchy of the world system.[11]

Each factor (I and II) has two dependent variables: annual hectare yields (i) and the human labor (ii) embodied in production (cf. Hornborg 2007: 261). That there are two variables measured in different units is a complicating factor since no clear independent variable can be established in the equation. If the measure is formalized as

TSA = (I ≠ II)

and the dependent variables of I and II are I.i, I.ii, II.i and II.ii but no common unit exists for the categories i and ii, the equation is unsolvable unless divided into two equations:

space appropriation (SA) = (I.i ≠ II.i)
time appropriation (TA) = (I.ii ≠ II.ii)

where, of course,

$$TSA = TA + SA$$

If there is a net transfer of land and labor in the same direction, such as

$$(I.i < II.i) \land (I.ii < II.ii)$$

it is possible to qualitatively conclude that there is time-space appropriation to either Area A or Area B, and it is also possible to calculate quantitatively the SA and the TA of the commodities separately, but it is not possible to quantify the extent of total TSA. If there is a mixed result, such as

$$(I.i < II.i) \land (I.ii > II.ii)$$

it is not possible to conclude whether there is any time-space appropriation at all; even if, for instance, the net TA appears to be much larger in one direction than the net SA in the other direction, trying to forge them together without a common unit is like comparing apples with pears.

For this case we have four dependent variables:

I. i: Annual hectare yields embodied in the cultivation and production of Chinese Bohea tea per price unit.
   ii: Days of human labor embodied in the cultivation, production and transportation of Chinese Bohea tea per price unit.

II. i: Annual hectare yields embodied in the extraction and production of Swedish bar iron per price unit.
   ii: Days of human labor embodied in the extraction, production and transportation of Swedish bar iron per price unit.

A clear-cut Sinocentric relation of these variables must state that China was the net receiver of both embodied land and labor. The quantitative part of this essay's hypothesis can thus be stated as:

$$(I.i < II.i) \land (I.ii < II.ii)$$

Frank and Pomeranz had divergent views on the importance of land and labor in determining "the Great Divergence", and the basis for this was their differing views on the relative wages and land pressure in China and Europe. Pomeranz asserts that both wages and pressure on land were roughly equal, while Frank claims that wages were lower in China, mainly as a consequence of higher land pressure. Straining these assertions somewhat, it could be claimed that Pomeranz would expect that the labor and land input per price unit in the Sino-European exchange would be roughly the same, while Frank would expect that the Chinese input of labor per price unit would exceed the European input, but the opposite would be true for inputs of land, which would be higher in Europe than in China. The logic behind these assertions would be that the relative costs for land use[12] and labor would decide how much of these factors could be put in commodities that are equally exchanged price-wise.

If the logic is accepted, three scenarios could be set up, corresponding to the hypothesis of this essay (RW) and to my interpretations of the implications of Pomeranz' (KP) and Frank's (AGF) hypotheses:

RW: $(\text{I.i} < \text{II.i}) \wedge (\text{I.ii} < \text{II.ii})$	Embodied land and labor of Swedish export commodities exceed those of the Chinese
KP: $(\text{I.i} \approx \text{II.i}) \wedge (\text{I.ii} \approx \text{II.ii})$	Embodied land and labor of Swedish export commodities roughly equal those of the Chinese
AGF: $(\text{I.i} < \text{II.i}) \wedge (\text{I.ii} > \text{II.ii})$	Embodied land of Swedish export commodities exceeds those of the Chinese, while the opposite is true for embodied labor

Approximate values

To give approximate values to the dependent variables and relate them quantitatively through prices and currency exchange rates, all data collected would ideally be from a limited time period. To obtain that requires hard empirical work, in my experience, since the labor time and land requirements for commodity production are usually not readily available in the standard works of economic history. Through reading of a lot of sources, and with some puzzling, estimating and adding, I think it has been possible to get reasonable estimates for the data needed. Of course, the values could have been based on even more detailed and comprehensive studies, but one has to draw the line somewhere. I decided to include the direct labor used in the production of the commodities as well as in the most important inputs – raw material and fuel, and the labor used to transport the commodity to the domestic staple port. For land, it is also essentially the land required for raw materials and fuels that is included in the assessment. Thus, the land and labor needed to feed workers and animals are not included, neither is an assessment of the land and labor invested in capital (industrial or landesque), or the labor put into, for example, the trans-oceanic voyages and their ships.[13]

One interesting methodological question concerns how to account for the additional labor and increased price due to long-distance transport. What I call the staple port method may be able to give an accurate answer. In this method, the prices of bar iron and Bohea tea are compared in the staple ports of Gothenburg and Guangzhou with respect to the currency rate between Swedish *silver daler* and Chinese *taels*. The method implies that the role of the SOIC was limited to transporting the items involved, adding transport labor costs and profits to the selling prices, but not really altering the price relation between the commodities. Instead of dividing the extra labor of the journey and the resulting price increase equally between the two commodities, transport and higher prices are cut out of the operation. Hence, the currency rate is very important in determining the price relation between the commodities. Besides data on the embodied land and labor of the commodities involved, the staple port method requires data on the prices of the commodities in the staple ports – bar iron in Gothenburg and Bohea tea in Guangzhou – as well as the currency rate between Swedish silver dalers and Chinese taels.

Results: exchange of time and space

A compilation of all the data is reported in the last section (p. 206), and the results of the quantitative estimations are summarized in Table 1.

Table 1. Embodied land and labor in eighteenth century Chinese Bohea tea and Swedish bar iron.

I.i: Embodied land in tea: 3.1 (2.9–3.3) hectares/ton.
I.ii: Embodied labor in the production and transportation to Guangzhou of tea: 1,432 (1,377–1,487) working days per ton.
II.i: Embodied land in bar iron: 41 (37.4–46.9) hectares (mid-century), 38 (34.3–42.7) hectares (late century) per ton.
II.ii: Embodied labor in the production and transportation to Gothenburg of bar iron: 163 (141–184) working days per ton.

Time-space appropriation, as defined previously, requires a comparison of land and labor content per price unit. The annual hectare yield and days of labor embodied in 1,000 silver dalers' worth of Swedish bar iron are calculated in Table 2, and for Chinese Bohea tea in Table 3. They indicate that there was an extraordinary net transfer of land from Sweden to China, while the net transfer of labor went in the same direction, but not at all to the same extent. According to Table 4, the ratio for land exchange is between 130:1 and 161:1, i.e. the land transfer per price unit was more than 100 times greater from Sweden to China than in the opposite direction. The ratio for labor exchange is between 1.23:1 and 1.40:1. Thus, the transfer of labor per price unit is measured to be circa 23–40 per cent greater eastwards than westwards.

Table 2. Embodied land and labor of Swedish bar iron.

Year	Price per ton (silver daler:öre)	Amount for 1,000 silver daler (ton)	Embodied land of 1,000 silver daler (hectares)	Embodied labor of 1,000 silver daler (working days)
1743	100:13	9.96	408 (373–467)	1,623 (1,404–1,833)
1748	113:25	8.79	360 (329–412)	1,433 (1,239–1,617)
1770	158:9	6.31	240 (216–269)	1,030 (890–1,161)
1772	185:–	5.41	206 (186–231)	881 (763–995)

Table 3. Embodied land and labor of Chinese Bohea tea.

Year	Price per ton (taels)	Amount for 1,000 taels (ton)	Amount for 1,000 silver daler (ton)	Embodied land of 1,000 silver daler (hectares)	Embodied labor of 1,000 silver daler (working days)
1743	234.6	4.26	0.8875	2.75 (2.57–2.93)	1,271 (1,222–1,320)
1748	247.2	4.05	0.723	2.24 (2.10–2.39)	1,036 (996–1,075)
1770	234.6	4.26	0.513	1.59 (1.49–1.69)	735 (707–763)
1772	226.2	4.42	0.502	1.58 (1.46–1.66)	719 (692–747)

Table 4. Exchange ratio of land and labor per price unit for Swedish bar iron and Chinese tea.

Year	Embodied land bar iron:tea	Embodied labor bar iron:tea
1743	148:1	1.28:1
1748	161:1	1.38:1
1770	151:1	1.40:1
1772	130:1	1.23:1

According to Table 4, the amount of both time and space appropriation is greatest in 1748 and 1770. In the first case, this is because of high Chinese prices and a currency exchange rate that favored China. In the 1770s, it is the combined effect of inflation in Sweden and deflation in China that causes the considerable differences between 1770 and 1772. In 1772, tea prices were among the lowest in Glamann's (1960) table covering 1732 to 1772.

These results clearly suggest that the eighteenth-century trade between Sweden and China was characterized by ecologically unequal exchange, as measured by TSA. The quantitative part of the hypothesis, defined as

$$RW = (I.i < I.ii) \wedge (I.ii < II.ii)$$

with a price unit equal to 1,000 silver dalers, can be expressed as

$$RW = (2.75 < 408) \wedge (1{,}271 < 1{,}623)$$

for the year 1743 and is thus verified with an immense margin for land and a slight margin for labor. The results for 1748, 1770 and

1772 reveal a congruent pattern. The measures for labor in Sweden and China could be defined as roughly the same, thus confirming the Pomeranz-inspired KP scenario for labor but not for land, where the difference is vast and robust. The RW hypothesis can be regarded as further strengthened by the reasonable assumption that Swedish bar iron embodied more "dead" labor in the form of greater capital stocks than Chinese tea. Had the resulting higher labor productivity been included in the calculation, the calculated net transfer of labor from Sweden to China would have been greater.

These results do not fit the Frankian AGF hypothesis for labor, since it predicted higher input per price unit for the Chinese export commodities than for the Swedish. For land, it predicted higher input in European export commodities, similar to the RW-thesis. This was also very much the case. If the assumed higher Chinese land productivity had been quantified and included in the study, the difference in land input would, however, have been less striking.

Even though no far-reaching inferences can be drawn from this study on the divergent opinions of Pomeranz and Frank regarding wages and land pressure in Europe and China, I can at least conclude that the results do not support Frank's claim that wages were lower in China, and they do fit into Pomeranz' view of roughly similar wages. On the other hand, the results do not support Pomeranz' assertion that land pressure was roughly equal in Europe and China. They indicate greater land pressure in China since vastly more land could be invested in the export commodities from Europe.

Regarding the qualitative part of the hypothesis of this essay – "In the early modern world system, China was in a more central structural position than western Europe" – the results point to a confirmation since the quantitative part – "and thus net receiver of embodied land and labor in the SOIC's eighteenth century trade between Sweden and China" – is verified. However, whether or not the net transfer of land and labor is indeed an expression of structural position within the world system cannot be settled by quantitative methods: it remains a point of analytical persuasion. The arguments for such an understanding were thoroughly discussed above.

Taking into account the (semi-)peripherality of both Sweden and tea-producing Fujian to the interregional cores, plus Sweden's access to subsidized Spanish-American silver *and* the clear results in this case study; taken all together it at least suggests that the early modern Western European nations were peripheral to the world system core of China. The results thus support Frank's view of a Sinocentric world system rather than Pomeranz' view of a polycentric one.

Developing time-space appropriation

Time-space appropriation is quite a novel and undeveloped method, but with the potential to be a sophisticated indicator of ecologically unequal exchange in the past. I have briefly discussed some methodological concerns, such as how to account for the past ("dead") labor put into the capital used in the production of the selected commodities; where to draw the line for which land- and labor-requiring activities to include in the production of the selected commodities, including the reproduction of the labor force; how to value abiotic resources harvested only once; and the lack of a common unit for land and labor which is potentially obstructive to unequivocal results.[14] The discussions of TSA as a relevant measure of core/periphery status in the world system and the methodological choice of the staple port method were more detailed. Without any doubt, all these concerns or problems could be developed further, as could the theoretical foundations discussed in the first part of the chapter. My conclusion is that it would be worthwhile to do so, since the advantages of the method, on balance, seem greater than the drawbacks.

Empirical accounting in detail: Approximate values and their relation

Points in time

The initial ambition was to be able to calculate the time-space appropriation for this case of Swedish–Chinese exchange as early as possible after the foundation of the SOIC in 1732. The reason is that the early modern period is the focus of this chapter; it ended about 1800 but many Asian economies started to show signs of decline as early as in the mid-eighteenth century (Frank 1998: 264). However the determining factor, it turned out, was access to the necessary data. To calculate the time-space appropriation in this case, we need data about the embodied land and labor of Swedish bar iron and Bohea tea, their prices in Gothenburg and Guangzhou, and the exchange rate between the Swedish silver daler and the Chinese tael. Access to this data is patchy and insecure, as will be shown below. The final approximations are rough, but I still deem them solid enough to provide an interesting result.

The point in time when the most data are simultaneously available is the early 1770s. We have access to market price scales in Sweden for all of the 1770s, and Guangzhou tea prices for 1770 and 1772. I was also able to conduct calculations for two years in the 1740s. There was a fast depreciation of the Swedish currency during this decade. In 1743, the silver daler was at a peak in relation to the tael, with a ratio of 4.8:1. Five years later the tael was almost one silver daler more expensive. We have access to Guangzhou tea prices for the 1740s as well as market price scales for bar iron in Värmland. However, there are no observations permitting an adjusted estimation of the transportation costs of bar iron from Värmland to Gothenburg. I will therefore also use an estimation of transportation cost from the 1770s for the 1740s. It biases the study only marginally since the transportation cost is only a small part of the total cost.

Swedish bar iron: embodied land

The land embodied in iron is not derived from the area used for the mine, which would be minimal, but from the forest area needed to grow the timber used for the charcoal and the "mine timber" necessary for production. The only estimate obtained of mine timber consumption – 15 cubic meters per ton of iron – concerns the mid-seventeenth century (Sundberg et al. 1995), but I assume it also to be valid also for the eighteenth century. Estimates of the charcoal needed in the foundry and at the trip hammer for the production of one ton of bar iron vary between 50 and 52.5 cubic meters early in the eighteenth century, and 40 to 44.5 at the end of the century (Arpi 1951: 92–93; Hildebrand 1987: 77).[15] According to Arpi (1951: 110), to produce one volume unit of charcoal required 1.2 units of fresh wood, while Nordström (1952: 33), uses a ratio of 1.57 cubic meters of wood per cubic meter of charcoal, to "maximize the safety margin", and Sundberg et al. use a 1:1 volume ratio. I will stick to Arpi's better-founded ratio, which is close to the mean value of the other two estimates and implies that the amount of fresh wood needed to produce the required amount of charcoal is between 60 and 63 cubic meters early in the century, and 48 to 53.4 at the end of the century.

The sustainable yield of Swedish forests in the eighteenth century varied with climate and forestry practices, and approximations in the literature are few. After comparing sources, Arpi (1951: 214) arrives at the estimation that the average forest growth in the iron-producing area of Sweden in 1830 was between 1.5 and 2.0 cubic meters per hectare of forest land. He uses the median figure, 1.75, for his calculations. Since productivity was probably somewhat lower in the eighteenth century, a marginal 5 per cent reduction of Arpi's figures leads to a productivity between 1.42 and 1.9 cubic meters. This is also close to Nordström's (1952: 33) assumption of a growth rate of 1.5 cubic meters per hectare in the eighteenth century.[16] This uncertainty, however, widens the span of probabilities.

Table 5. Estimates of fresh wood and land requirements for production of Swedish bar iron.

	Mine timber (m^3/ton)	For charcoal (m^3/ton)	Total (m^3/ton)	Forest land (hectares/ton)
Early 18th (≈1700–1732)	15	60–63	75–78	47.2 (39.5–54.9)
Mid 18th (≈1733–1765)				43.9 (36.3–51.5)[a]
Late 18th (≈1766–1799)	15	48–53.4	63–68.4	40.6 (33.1–48.2)

a Mean values of Early and Late eighteenth century estimates.

Sources: Arpi 1951; Hildebrand 1987; Sundberg et al. 1995.

Thus, all in all, some 44 hectares of forest land were needed to produce one ton of bar iron in the mid-eighteenth century, decreasing to 41 hectares at the end of the century.

Swedish bar iron: embodied labor

To produce iron, labor was put into logging, charcoal-making, and the transport of wood and coal to the trip hammer; into the often long transport of iron from the trip hammer to the staple port; into manual work at the production sites (smiths, melters, fire-watchers etc.), as well as into administration (scribes, clerks etc.). None of the three studies referred to below reports all of these kinds of labor input, and therefore I will have to use different sections from different studies to complete the puzzle.

In 1762, 332 persons were on the payroll for the iron works *Horndals bruk* in Dalarna, but this figure corresponded to only about 100 full-time employees (Hildebrand 1987: 89). The consensual opinion (Boëthius 1951: 414; Essemyr 1989: 73, Montelius 1962: 245) is that a year in Sweden at the time consisted of 300 working days, which for Horndal gives us 30,000 working days to produce between 200 and 250 tons of bar iron per year in the second half of the eighteenth century (Hildebrand 1987: 89). Using the mean figure, 225 tons, every ton of bar iron from Horndal in 1762 would thus have embodied 133 working days. However, parts of the production process are missing, such as administration and management, as well as the mining of the ore. In a similar study on the Säfsnäs agglomerate of iron works in Dalarna, mining is included and assessed at 5–6 per cent of the total labor input in bar iron (Montelius 1962:

288). If we suppose that the same relation was true in Horndals bruk in 1762, the total number of working days embodied in one ton of bar iron rises to 140 (126–159) days.[17]

Mats Essemyr (1989) lists the people working at the iron works at Forsmark in northern Uppland in the year 1765. His thorough presentation also includes administration and management – even the priest and the parish clerk. If we exclude them,[18] 114 persons were employed in the industry (Essemyr 1989: 46), which, if they worked 300 days a year, corresponds to 34,200 working days. The production of this industry in 1765 was 3,042 ship pounds "mine weight", or 455 tons (Essemyr 1989: 73, 195). This would mean that the embodied labor of each ton of bar iron at Forsmark amounted to 75.2 working days. This excludes the labor required for the mining of the ore and only includes a minor part of the production of the charcoal needed. It probably also excludes a large part of the transport work needed. Adding the estimated 6–9 working days needed for mining the ore used produce one ton of bar iron in Säfsnäs, the number rises to 82.5 (81.2–84.2) working days per ton. Most of the charcoal needed was produced by the surrounding farmers (Essemyr 1989: 45). By estimating the total input of labor needed to produce the charcoal and fresh wood, and subtracting the working days put in by Forsmark employees, the labor input of farmers, including transportation to the mine and iron works, adds over 30,000 working days a year or 67.3 working days per ton of bar iron.

Commonly, peasants from the surrounding area also carried out most of the transportation work. According to Essemyr's list, nine drivers and three boatswains were employed by the industry, capable of 3,600 working days or about 5.3 per cent of the labor time calculated so far. In the other studies, transport (excluding transport of charcoal) amounted to 19 per cent in Horndal 1762, and 32 per cent in the more remotely situated Säfsnäs in 1768 (Montelius 1962: 288). Even though the location of Forsmark, about 30 kilometers from the Dannemora mine and close to the Baltic sea, certainly lowered the need of transport work compared to the inland iron works, it seems very doubtful that only 5.3 per cent of the total labor input would have been used for transport. A conservative guess is to at least triple the amount of total transport work to 10,800 working days. This adds another 15.8 working days per ton of bar iron bought from farmers and puts transport at about 14 per cent of the total labor input at Forsmark. All in all, one ton of its bar iron thus embodied 166 working days.

From Forsmark we can now derive the factors missing for Horndal; i.e. administration and mine timber. In Forsmark, the administration consisted of 6 employees, equalling 4.0 working days per ton of bar iron, and labor input in mine timber was 6.8 working days per ton. When added to the earlier calculation based on Horndal's iron works in 1762, the total number of working days embodied in one ton of its bar iron rises to 151 days. We now have at least two fairly detailed estimations of embodied labor in Swedish eighteenth century iron: 151 (137–170) working days per ton of bar iron in Horndal in 1762, and 166 in Forsmark in 1765. As a conservative estimate, in further calculations I will use the mean of the two earlier estimates, which is 158.5 (137–180[19]).

For this study, it is, however, justifiable to further increase the input of transport labor. The reason is that the Swedish East India Company sailed from Gothenburg, which is further away from the iron-producing sites than, for example, Stockholm. The iron traded in Gothenburg regularly came from industries in Värmland, and was first transported to Karlstad or Kristinehamn on Lake Vänern, and thereafter shipped to Vänersborg on the southern shore of the lake. Until the Trollhättan Canal was opened in 1800, further land transport was necessary from Korseberg near Vänersborg to Åkerström south of Trollhättan, from whence the river Göta älv was navigable to Gothenburg. The cost of getting the bar iron from Kristinehamn to Gothenburg "was widely greater than a simple trip on Mälaren" to Stockholm, according to Hildebrand. One calculation from the 1770s reports that it cost almost 3 copper dalers to freight one ship pound of iron from Korseberg to Åkerström, but only 21 öre (about one fifth of the cost) to send it by boat from Åkerström to Gothenburg (Hildebrand 1957: 334–337). Additionally, the iron works in Värmland had a longer than average journey to the staple ports. The bar iron from the large-scale industry in Uddeholm, for example, had to be trans-shipped from rowing boats to horsedrawn carts and back to rowing boats eight times before even reaching Karlstad (Hildebrand 1957: 339).

When adding an estimate of the transport labor input for bar iron in Gothenburg, it therefore seems most reasonable to use the estimation of transport used for the remote Säfsnäs (which also de facto delivered iron bars to Gothenburg). At Säfsnäs, the transport of bar iron constituted 9 per cent of the labor input of the iron ore in 1768, according to Montelius (1962: 288), while mining constituted 6 per cent. Above, we estimated mining to contribute 7.3 working days per ton of bar iron, which would mean that transport of bar iron amounted to 11.0 working days per ton. From Horndal's iron works in the middle of the iron-producing region of Sweden, still inland but not as remote as Säfsnäs, the transport of bar iron in 1762 required 6.8 working days per ton of bar iron[20] (Montelius, Utterström & Söderlund 1959: 218), i.e. 4.2 working days fewer than for Säfsnäs. An additional 4.2 working days per ton of bar iron therefore seems reasonable, if conservative, in this particular case. To sum up, one ton of eighteenth-century Swedish bar iron transported to Gothenburg would have embodied about 41 hectares of land and 163 (141–184) working days. This labor assessment is based on studies of the 1760s, and I will assume that the figure is valid both for the middle and the late eighteenth century.

Chinese Bohea tea: embodied land

The most preferred tea from the Swedish East India Company – as well as from the other European Companies – was Bohea black tea, originating from the Bohea, or Wuyi, mountains in the north-west of the province of Fujian. This tea undergoes several stages of production. After being picked, the leaves are spread in thin layers that allow a current of warm air to circulate around them for roughly twenty-four hours. The withered leaves are rolled in order to break down the cell walls and release their oils, and are then sorted according to size and condition into various classes of tea. Next comes fermentation, in which the leaves are spread out and exposed to very humid and temperate air for one to three hours. The leaves are finally dried in hot air (Stella 1992: 39–40). The assessment of the embodied land of eighteenth-century Bohea tea will be divided into three parts; first, the actual land needed for cultivation of the tea bushes; second, the land needed to provide the firewood used for processing the leaves into dried tea; and third, the land needed to provide the manure or other types of fertilizers used in cultivation.

I have not been able to find any literature referring to original sources on the hectare yield of Bohea tea in the eighteenth century. There are, however, sources on and estimates of the yield in the late nineteenth and early twentieth centuries.[21] Robert Gardella, in *Harvesting Mountains*, refers to conservative estimates, based on both English and Chinese sources, of an average tea yield per acre in Fujian in 1887 and 1941 of around 400 pounds in both cases (Gardella 1994: 118). Even though not explicitly stated by Gardella, the land productivity of Fujian tea-farming does not seem to differ substantially between the eighteenth and the late nineteenth or early twentieth centuries. I will therefore assume that an average yield of 400 pounds, or 181.4 kilograms, of dried tea per acre is also valid for the eighteenth century. One ton of tea thus required 5.5 acres – 2.24 hectares – of tea plantation.

The production of tea also required fuel for heating, for which mainly firewood was used. I have come across no historical data or assessment on the amount of fuel needed to produce any specific amount of tea. The closest I came is an article reviewing the energy consumption of Chinese tea production in the 1980s, which also gives a figure for 1949 (Ni & Zhou 1992). Accordingly, the 1949 Chinese output of 46,000 tons of tea required 93,700 tons of CE (Coal Equivalent: 2.93 GJ/ton), or 2.04 tons of CE per ton of tea. According to Ni and Zhou, the processing of black tea of the Bohea type requires less energy then green teas. While the processing of one kilogram of green tea consumes on average 2.04 kg of CE, black tea only requires, on average, 1.27 kg. If we assume that energy efficiency improvements between 1949 and 1980 were the same for black tea as for the total tea production, then the energy consumption for one ton of black tea in 1949 was 1.40 tons of CE. That corresponds to circa 2.45 tons of firewood. This can be compared to the claim that "in some mountain areas in Zhejian Province, the villagers still cut 4 tons of firewood for making one ton of tea" (Ni & Zhou 1992). In the same paragraph, it is stated that "in Yingshan County, Hubei Province, 9,000 tons of firewood are needed every year for tea baking, equalling an annual productivity of 36,000 mu (5,929 acres) of forest", which implies that one acre of Hubei forest annually produces 1.52 tons of firewood. That would imply that the 2.45 to 4 tons of firewood estimated for the production of one ton of black tea required the annual firewood yield from 1.61 to 2.63 acres of forest.

Turning to fertilizers, Rawski (1972) covers, among other things, the peasant economy during late Ming and early Qing China in the Chien-ning prefecture in northwest Fujian, of which the Wuyi mountains form a part. In the early seventeenth century, gazetteers in Chien-ning recommended the use of ash from firewood and other plants to enrich the soil (Rawski 1972: 82). There were no significant changes in the use of fertilizers for a very long time; even in the twentieth century, one third of the fields in northwest Fujian were not fertilized at all. Rawski's conclusion is that Chien-ning's agriculture remained backward (Rawski 1972: 96). In the light of this general description, it seems that the manure from humans and animals at the farm and the ash from the quite large amounts of firewood used in tea baking would have been the bulk of the fertilizers used in eighteenth-century Wuyi tea production. If so, no further embodied land needs to be added to the production of Bohea tea.

To summarize, I have estimated that in order to produce one ton of black tea in eighteenth-century Fujian, 5.5 acres of tea plantation were needed. In order to process the tea leaves into dried tea, the firewood yielded by 1.61–2.63 acres of forest land was needed. Using the mean figure, the embodied land of one ton of tea was 7.62 (7.11–8.13) acres, equal to 3.08 (2.88–3.29) hectares.

Chinese Bohea tea: embodied labor

The most precise and solid figure that I have come across for labor in Chinese tea production is mentioned in the classic work of J.E. Buck, *Land Utilization in China,* and refers to a massive study of thousands of Chinese farms between 1929 and 1932. In his Table 14. "Man labor requirements (number of days per crop acre) for growing various crops" the figure mentioned for tea is 126 (Buck 1964: 302). I consider this data to be applicable also to eighteenth century conditions, since no major changes in productivity are reported to have occurred in tea farming between the eighteenth and the early twentieth centuries. However, it is not clear exactly what "tea" means in Buck's table. My assumption is that he is referring to crude tea output including all manual work at the farm – planting, fertilizing, picking, baking etc. – while it seems reasonable to exclude the logging of the firewood needed. Since this is quite a marginal part of the embodied labor of tea, I have allowed myself to use a figure from Sweden. Previously, it was concluded that the logging and transportation of wood in seventeenth-century Sweden required circa 0.5 working days per cubic meter of wood, and I will apply the same figure for China.[22] Above, I have claimed that 4 tons of firewood were consumed per ton of tea, which adds 2 working days per ton of tea. For the 400 pounds of tea produced on each acre, the addition of embodied labor for the logging and transportation of firewood amounts to only 0.36 working days.

Additional labor was of course required to produce dried tea from crude tea. I have seen no data, but some valuable clues about labor requirements for the processing of tea do exist. In Gardella (1994: 154), the total employment in China's tea industry in 1935 is estimated. Tea farmers and tea pickers/crude processors outnumbered fine processors, tea manufactories' employees and merchants by 9 to 1. This implies that the bulk of the labor embodied in tea is put in on the farms. However, these figures can hardly be seen as an exact proportion of labor input, since many of the farmers and farm workers were not occupied full-time with tea, while processors and merchants probably were to a higher degree. Another indication is found in Table 21 in Gardella (1994), which deconstructs production costs of Qinmen black tea in 1935. Here, crude tea represents almost two-thirds of the production cost of tea, while processing and packing represent a little more than 20 per cent of the cost. Transportation is 5 per cent and tax, profit and interest on capital constitutes 9 per cent (Gardella 1994: 159). The distribution of costs between crude tea and packed, dried tea is thus 75 to 25 per cent. If we assume that the figures for Qinmen black tea in 1935 are valid for eighteenth-century Fujian tea, and if we assume that the salaries of farm workers and processing workers were the same, we have to add 44.4 working days to the 126 working days, to reach a total of 168.4 working days for the yield of one acre, i.e. 400 pounds of tea. Measured per ton of tea, processing and packing took 245 working days.

The British botanist and East India Company advisor on tea Robert Fortune travelled through the tea districts of China in the 1840s, and tried to estimate the cost of transporting the tea from the Wuyi mountains to Guangzhou and Shanghai.[23] According to his report, crude tea was bought by merchants at the mountain farms and most of it was brought to the city of Tsong-gan-hien for final processing. There, finished tea was bought from the merchants of Guangzhou and Shanghai connected to the interregional and international trade. The tea route from Tsong-gan-hien started with coolies carrying two chests of tea on their shoulders for five to six days northwards to a riverside at Hokow. There, the tea chests were loaded into boats. If intended for the Guangzhou market, they proceeded down the river westwards to the lake Poyang. When describing the rest of the route, Fortune refers to another nineteenth-century representative of the British East India Company, Samuel Ball. According to Ball, the tea chests were

> conducted to the towns of Nan-chang-foo and Kanchew-foo, and they suffer many transshipments on their way to the pass of Ta-moey-ling. … At this pass the teas are again carried by porters; the journey occupies one day, when they are re-shipped in large vessels, which convey them to Canton. The time occupied in the entire transport from the Bohea country to Canton is about six weeks or two months (quoted in Fortune 1853: 224).

Ball stated that the overland route "accounted for more than one third of the total transport cost, which was itself equal to one third of the initial cost of the tea at the point of origin" (quoted in Rawski 1972: 60). Ball's figure of six weeks to two months is a vague estimate but the only one I have come across. I will proceed by assuming that seven weeks was the normal time for the journey.

The labor input in the distance travelled on land – six to seven days according to Fortune and Ball – is the easiest part to calculate.

According to Gardella (1994: 158), one chest of tea contained 0.54–0.62 piculs.[24] One picul equals circa 133 pounds (Gardella 1994, 6) which means that the contents of one chest are 72–82 pounds of tea. Two chests carried by one coolie implies that it would have taken about five (4.9–5.6) coolies to carry the annual crop of one acre (400 pounds). If this was done in six to seven days, the labor input amounts to 29–39 working days per 400 pounds.

After being carried for 6–7 days, and assuming a total transport time of seven weeks, 42–43 days of water transport remained until the tea reached Guangzhou. How much work did this add? In Fortune's study of the cost of taking the tea from Tsong-gan-hien to Shanghai, a journey he estimates at 28 days (of which 4 are spent waiting without any cost attributed), he reported that the cost per chest for one day of land transport is 133 cash, while transport on water cost 33–38 cash ("cash" here is a monetary unit, and the cost varied slightly on the different parts of the route). This cost difference hardly mirrors the difference of labor input exactly, since shipping is more capital intensive and perhaps was also better paid than carrying and therefore might have cost more per hour of labor. However, I will use the cost difference as a rough estimate of the difference in the labor input of land and water transport. I assume that the labor input on water is one fourth of the labor input on land (133/4=33.25), and that the transportation of 400 pounds of tea on water requires 1.2–1.4 working days per day (4.9–5.6/4). For the normal 42–43 days on water, the sum would be 50–60 working days. Adding the land transport, the total labor input for the transport of 400 pounds of tea from Tsong-gan-hien to Guangzhou would be between 79 and 99 working days.

To conclude this section, the production of 400 pounds of crude tea – the average yield of one acre of tea plantation – required 126 days of labor. The processing and packing required an extra 44.4 working days. The embodied labor of the firewood needed was marginal, assessed at 0.36 working days. The transport of the tea from Tsong-gan-hien to Guangzhou adds up to between 79–99 working days. Converted, the estimated labor input per ton of Bohea black tea transported to Guangzhou is shown in Table 6.

Table 6. Embodied labor in Bohea tea in Guangzhou.

Activity	**Working days/ton**
Crude tea	695
Firewood	2
Processing and packing	245
Transport to Guangzhou	435–545
Total	**1,377–1,487 (mean: 1,432)**

Prices of bar iron in Gothenburg

There are several sources for the prices of Swedish bar iron during the eighteenth century, but no continuous source on prices specifically in Gothenburg (cf. Boëthius & Kromnow 1947: 37). Therefore, I use the market scale prices collected for bar iron from Värmland, the major iron-producing region closest to Gothenburg, and add a reasonable transport cost. According to Jörberg (1972: 572), the bar iron prices per ship pound (149.6 kg) in Värmland were 13 silver dalers in 1743 and 15 silver dalers in 1748. In 1770, the price had risen to 21:21 in 1770, in 1772 to 25:21,[25] a more inflationary trend than expected.[26]

A calculation from the Björneborg iron works in the 1780s stated the freight cost of one ship pound over lake Vänern from Kristinehamn in Värmland to Vänersborg at $3\frac{1}{3}$ or $6\frac{2}{3}$ shillings depending on season.[27] In the early 1770s, another calculation stated that the total cost of freighting one ship pound from Vänersborg to Gothenburg was 4 copper dalers and 26 öre (Hildebrand 1957: 336). Since the prices were quite stable in the 1770s and 1780s, without major inflationary tendencies, I will add both these costs in order to get a rough total for the transportation costs from Värmland to Gothenburg.

The $3\frac{1}{3}$ shillings for the trip over Lake Vänern amounts to 13 öre according to the pre-1777 monetary system. Adding the cost from Vänersborg to Gothenburg means that the total freight from Värmland to Gothenburg adds up to 2 silver dalers $\frac{2}{3}$ öre per ship pound. This figure should be reasonably valid at least for the time between the instabilities of the 1760s and the inflation in the late 1790s. Adding the transport cost gives us the estimated Gothenburg prices of bar iron as stated in Table 7 below:

Table 7. Estimated prices of bar iron in Gothenburg (silver daler:öre).

Year	Per ship pound[a]	Per ton
1743	15:2/3	100:13
1748	17:2/3	113:25
1770	23:21 2/3	158:9
1772	27:21 2/3	185:–

a of 149.6 kg.

Sources: Jörberg 1972: 571–572; calculations by Warlenius.

Prices of Bohea tea in Guangzhou

No exact information has been found on how much the Swedish East India Company paid for Bohea tea in Guangzhou. There is, however, some sparse data. Colin Campbell, the supercargo of the first Swedish vessel sailing to China, writes in his diary that he bought Bohea tea for 13 taels per picul and green tea for 10 taels (Johansson 1992: 59). Kjellberg (1974: 217) has found one contract drawn up between the supercargo Jean Abraham Grill and Cantonese merchants in 1767. The price was set at 15.5 taels per picul. There are, however, better sources for the prices paid by the contemporary Danish Asiatic Company, and there is no reason to assume that the Swedes would not have paid about the same. Glamann (1960: 131–133) has compiled a table of median prices of Chinese Bohea tea in Guangzhou for the years 1734–72. It reveals that after fluctuating prices during the first years of trade, there was a continuous increase in tea prices until 1754, when a sharp fall occurred and low prices prevailed until an increase in 1759, followed by high prices in the first part of the 1760s. The last years of the period show a fall in prices. Glamann's table has one column for median prices (taels per picul) for each ship loaded, which could be more than one per year, and another for the range of prices (taels per picul) paid for the loadings – one shipload could consist of tea delivered under slightly different business conditions. I use only the median price in Glamann's Table 6.2, and only data for the years where iron prices in Gothenburg could be assessed. For 1743 there is no data, but the median price in 1742 was 15 taels per picul, and in 1744, 13 taels per picul, so I use the mean value of 14 taels per picul. For

1748, there are figures for two shiploads at 14.7 and 14.8 taels per picul. Again, I use the mean value.

Table 8. Median prices of Chinese Bohea tea in Guangzhou (taels).

Year	Per picul[a]	Per ton
1743	14.0	234.6
1748	14.75	247.2
1770	14.0	234.6
1772	13.5	226.2

a of 59.68 kg.

Source: Glamann 1960: 132–133.

Currency exchange rates

The eighteenth-century exchange rates between Swedish silver dalers and Chinese taels was assessed by Edvinsson (2010) through the silver content of the respective coins. The exchange rate is listed in Table 9 for the years we are concerned with here:

Table 9. Silver dalers per tael.

Year	Silver dalers
1743	4.8
1748	5.6
1770	8.3
1772	8.8

Source: Edvinsson 2010.

Edvinsson's calculations are congruent with other historians' observations, although these are patchy. According to Kjellberg, the value of the tael was 4.5 silver dalers in 1743. Four years later it had risen to 5.4 silver dalers, and in 1777 to 8.8 silver dalers (Kjellberg 1974: 296). According to Nyström (1883: 151), one tael was worth 1½ riksdalers specie equal to 9 silver dalers, which is close to Kjellberg's data from 1777. In Koninckx (1980: 442), the exchange rate is set at "1 tael = minimum 4½ daler smt. [silver dalers]". No date is mentioned, but the period analyzed in the book is 1732–1766.

Notes

1 Pomeranz (2000: 4, 107) and Parthasarathi (2011: 22) reject both the received Eurocentric and Frank's Sinocentric views of the early modern period, regarding it as a polycentric world with several cores that besides China and Western Europe also included Japan, India, Persia, Russia, and the Ottoman Empire.
2 For introductions to ecological economics, see Martinez-Alier 1987 or Daly & Farley 2004.
3 See the special section in *Ecological Economics* 41(2) (Martínez-Alier & Schandl 2002) as well as later, occasional articles (see Barca 2011 for a fairly recent overview), and the chapters in the second part of Hornborg, McNeill and Martínez-Alier 2007.
4 My emphasis.
5 Hornborg's comment that "my impression is that the conventional economic discourse on industrialization conspires to keep such questions – and their answers – out of view" (Hornborg 2007: 362) is something that I can also endorse regarding early modern history.
6 Similar conclusions have been made earlier, by e.g. Borgström (1965) and Pomeranz (2000).
7 Another reason for redefining core/periphery status after incorporating Emmanuel might be his pertinent critique of the common view of peripheral production as "primary" and core production as more complex, requiring more skill or technology: "[S]ugar is about as much 'manufactured' as soap or margarine and certainly more 'manufactured' than Scotch whisky or the great wines of France" … "Are there really certain products that are under a curse, so to speak; or is there, for certain reasons that the dogma of immobility of factors prevents us from seeing, a certain category of countries that, whatever they undertake and whatever they produce, always exchange a larger amount of their national labor for a smaller amount of foreign labor?" (Emmanuel 1972: xxx–xxxi).
8 He continues by stating that unequal exchange is not the only way to transfer accumulated capital from peripheries to cores; plundering, in the form of underpriced "privatizations" of state properties etc., was and still is another important method (Wallerstein 2004: 28), but accumulation by plunder is not considered in what follows.
9 Though we should keep in mind that when we include an ecological variable in the measurement of core/periphery status, it is not under the assumption that peripheral production is necessarily more "primary", but that the resources of the peripheries, like their labor, is underpriced for structural reasons and therefore constitutes an important loss that should be included in the equation.
10 Nyström does not state more closely what "value" refers to. It could, for instance, be the purchase price in Guangzhou or the sales price in Gothenburg, but it could also be the customs value set by Swedish customs for the purpose of taxation.
11 To a certain extent, this research design is a consequence of patchy access to data, making total figures of the exchange impossible to obtain. But the most important reason is that China's early modern exchange with Europe was not about ecological relief. It bought almost exclusively silver from the Europeans, and even though

silver production actually did require vast amounts of land (Moore 2007: 125–128, 133), land pressure was not the reason for China to import silver. There simply did not exist enough silver ore in China to satisfy the market, so imports were the only alternative. Another indication that the import of silver was not about ecological relief is that another precious metal could have been used as a monetary base for the re-monetization, if deemed necessary. China's silver imports were not a necessity, but a possibility.

12 It is presupposed that higher land pressure increases the cost of land use.

13 Arguments for these methodological choices are given in Warlenius 2011.

14 The possibility of converting land and labor into a common unit to get a clearer result in TSA analyses is discussed in Warlenius 2011. See also Hornborg 2009: 250–251.

15 Sundberg et al. 1995 arrive at 60 m^3 of charcoal per ton of iron for the mid-eighteenth century, which, assuming the same efficiency rate as Arpi and Hildebrand for the nineteenth century, would be within the limits mentioned.

16 Sundberg et al assume a yearly "growth potential" of 4 cubic meters per hectare for the seventeenth century, but this figure does not seem to be reached through research in historical sources and is left unconsidered.

17 There is no presentation of total labor time at Säfsnäs in Montelius 1962.

18 Since no personnel conducting religious services are included in the assessment of Chinese tea in the next section.

19 The upward end of the span is assumed to be as far from the mean value used as the lower end, although I have not found any indications of such a high figure.

20 Transport of bar iron is said to be 9 per cent of the working days of the production of bar iron, and the total number of working days is 133.

21 It is of course a problem that this and also other data from China is from the nineteenth or twentieth century, and it is only partly comforting that several authors claim that no major changes in tea production occurred until the second half of the twentieth century. I am aware that referring this data back to the eighteenth century is congruent with the Eurocentric view of a "stagnant Asia", but when earlier data is lacking, I do not see any alternative.

22 Transportation must be much longer in the more sparsely populated Sweden than in China, where trees were generally cultivated near the farms. According to Pomeranz (2000: 231) "transport costs [for fuel-wood] were minimal". However, transport in Sweden was also fuel efficient since it was mainly carried out in wintertime when snow reduced friction.

23 His reason for this was to calculate the profit made by the Chinese merchants who arranged this transport, and to figure out whether cost cuts could be made if this trade was overtaken by the EIC. His conclusion, however, was that "it would appear that the profit upon common teas is very small, so small indeed as to make it a matter of doubt whether they will ever be produced at a reduced rate" (Fortune 1853: 228).

24 He equates 130,000 chests to 70,000–80,000 piculs.

25 Even though not clearly stated by Jörberg, the pre-1776 prices seem to be expressed in the tables as silver dalers and öre with the ratio 1:32.

26 The trend continued the following years, rising to 30 silver dalers per ship pound in 1775.

27 It is not stated which season cost more, but I assume it to be the winter season.

References

Abu-Lughod, Janet L. 1989. *Before European hegemony: The world system A.D. 1250–1350.* New York: Oxford University Press.

Amin, Samir. 1989. *Eurocentrism*. London: Zed.

Arpi, Gunnar. 1951. *Den svenska järnhanteringens träkolsförsörjning 1830-1950.* Uppsala: Uppsala University.

Barca, Stefania. 2011. ”Energy, property, and the industrial revolution narrative”, *Ecological Economics*, 70(7), 1309–1315.

Bergesen, A.J. 2011. “Frankian triangles”, in Manning, P. & Gills, B.K. (eds.), *Andre Gunder Frank and global development: Visions, remembrances and explorations.* London: Routledge.

Blaut, James M. 1993. *The colonizer's model of the world: Geographical diffusionism and Eurocentric history.* New York: Guilford Press.

—— 2000. *The colonizer's model of the world: Vol. 2, Eight Eurocentric historians.* New York: Guilford Press.

Boëthius, Bertil. 1951. *Gruvornas, hyttornas och hamrarnas folk: Bergshanteringens arbetare från medeltiden till gustavianska tiden.* Stockholm: Tiden.

—— & Kromnow, Åke. 1947. *Jernkontorets historia: Minnesskrift. D. 1, Grundläggningstiden.* Stockholm: Jernkontoret.

Borgström, Georg. 1965. *The hungry planet: The modern world at the edge of famine.* New York: Macmillan.

Brolin, John. 2006. *The bias of the world: Theories of unequal exchange in history.* Lund: Lund University.

Buck, John Lossing. 1964. *Land utilization in China: A study of 16,786 farms in 168 localities, and 38,256 farm families in twenty-two provinces in China, 1929–1933*. New York: Paragon Book Repr. Corp.

Bunker, Stephen G. 1985. *Underdeveloping the Amazon: Extraction, unequal exchange, and the failure of the modern state, 2nd edn* 1988. Chicago: University of Chicago Press.

Daly, Herman E. & Farley, Joshua C. 2004. *Ecological economics: Principles and applications.* Washington, DC: Island Press.

Denemark, Robert. 2011. “ReOrient in the Nineteenth Century. Andre Gunder Frank's unfinished manuscript”, in Manning, Patrick & Gills, Barry K. (eds.), *Andre Gunder Frank and global development: Visions, remembrances and explorations.* London: Routledge.

Edvinsson, Rodney. 2010. “The multiple currencies of Sweden-Finland 1534–1803”, in Edvinsson, Rodney, Jacobson, Tor & Waldenström, Daniel (eds.), *Historical Monetary and Financial Statistics for Sweden: Exchange rates, prices and wages 1277–2008.* Stockholm: Ekerlids förlag/Sveriges Riksbank.

Emmanuel, Arghiri. 1972. *Unequal exchange: A study of the imperialism of trade*. New York: Monthly Review Press.

Essemyr, Mats. 1989. *Bruksarbetarnas livsmedelskonsumtion. Forsmarks bruk 1730–1880*. Uppsala: Uppsala University.

Fischer-Kowalski, M. & Hüttler, W. 1999. "Society's Metabolism: The State of the Art. The Intellectual History of Material Flow Analysis, Part II: 1970–1998", *Journal of Industrial Ecology* 2(4), 107–137.

Flynn, Dennis O. & Giráldez Arturo. 1995. "Born with a 'silver spoon': The origin of world trade in 1571", *Journal of World History*, 6(2), 201–221.

—— —— 2000. "Money and growth without development: The case of Ming China", in Latham, A.J.H & Kawakatsu, H. (eds.), *Asia Pacific Dynamism, 1550–2000*. London: Routledge.

—— —— 2002. "Conceptualizing global economic history: The role of silver", in Gömmel, R. & M. Denzel (eds.), *Weltwirtschaft und Wirtschaftsordnung: Festschrift für Jürgen Schneider zum 65. Geburtstag.* Stuttgart: Steiner.

Fortune, Robert. 1853. *Tea countries of China and the British tea plantations in the Himalaya; with a narrative of adventures, and a full description of the culture of the tea plant, the agriculture, horticulture, and botany of China,* Vol. II. Third Edition, London: John Murray.

Foster, John Bellamy & Holleman, Hannah. 2014. "The theory of unequal ecological exchange a Marx-Odum dialectic", *The Journal of Peasant Studies* (41)2, 199–233.

Frank, André Gunder. 1993. "Transitional Ideological Modes: Feudalism, Capitalism, Socialism", in Frank, A.G. & Gills, B.K. (eds.), *The World System: Five hundred years or five thousand?.* London: Routledge.

—— 1998. *ReOrient: Global economy in the Asian Age*. Berkeley: University of California Press.

—— 2006. "Entropy Generation and Displacement: The Nineteenth-Century Multilateral Network of World Trade", in Hornborg, A. & Crumley, C. (eds.), *The World System and the Earth System.* Walnut Creek: Left Coast Press.

—— 2014. *ReOrienting the 19th Century: Global economy in the Continuing Asian Age.* Boulder: Paradigm Publishers.

Gardella, Robert. 1994. *Harvesting mountains: Fujian and the China tea trade, 1757–1937*. Berkeley: University of California Press.

Glamann, Kristof. 1960. "The Danish Asiatic Company 1732–1772", *Scandinavian Economic History Review*, VIII(2), 109–149.

Hildebrand, Karl-Gustaf. 1957. *Fagerstabrukens historia: Sexton- och sjuttonhundratalen.* Uppsala: Almqvist & Wiksell.

—— 1987. *Svenskt järn: Sexton- och sjuttonhundratal. Export före industrialismen*. Stockholm: Jernkontoret.

Hornborg, Alf. 2001. *The power of the machine: Global inequalities of economy, technology, and environment.* Walnut Creek: Altamira.

—— 2007. "Footprints in the Cotton Field: The Industrial Revolution as Time-Space Appropriation and Environmental Load Displacement", in Hornborg, A., McNeill, J.R. & Martinez-Alier, J. (eds.), *Rethinking environmental history: World-system history and global environmental change.* Lanham: Altamira.

—— 2009. "Zero-Sum World: Challenges in Conceptualizing Environmental Load Displacement and Ecologically Unequal Exchange in the World-System", *International Journal of Comparative Sociology* 50, 237–262.

—— 2013. *Global Ecology and Unequal Exchange: Fetishism in a Zero-Sum World* [Revised Paperback edition]. London: Routledge.
——, McNeill, J.R. & Martínez-Alier, J. (eds.). 2007. *Rethinking environmental history: World-system history and global environmental change.* Lanham: Altamira.
Johansson, Bengt. 1992. "The Diary of Colin Campbell: The World's First China Trade Handbook", in Johansson, Bengt. (ed.), *The Golden Age of China Trade: Essays on the East India Companies' trade with China in the 18th Century and the Swedish East Indiaman Götheborg.* Hong Kong: Viking Hong Kong.
Jörberg, Lennart. 1972. *A History of Prices in Sweden 1732–1914: Volume I. Sources, Methods, Tables.* Lund: Gleerups.
Kjellberg, Sven T. 1974. *Svenska Ostindiska Compagnierna 1731–1813: Kryddor, Te, Porslin, Siden.* Malmö: Allhem.
Koninckx, Christian. 1980. *The First and Second Charters of the Swedish East India Company (1731–1766): A contribution to the Maritime, Economic and Social History of North-Western Europe in its Relationship with the Far East.* Kortrijk: Van Ghemmert.
Martínez-Alier, Joan. 1987. *Ecological economics: Energy, environment and society.* Oxford: Basil Blackwell.
—— & Schandl, H. 2002. "Special section: European environmental history and ecological economics", *Ecological Economics* 41, 175–176.
Marx, Karl. 1981. *Capital: A critique of political economy*. Vol. 3. Harmondsworth: Penguin.
Montelius, Sigvard. 1962. *Säfsnäsbrukens arbetskraft och försörjning 1600–1865: Studier i en mellansvensk bygd.* Uppsala: Uppsala University.
—— Utterström, Gustaf & Söderlund, Ernst (eds.). 1959. *Fagerstabrukens historia: 5, Arbetare och arbetarförhållanden.* Uppsala: Almqvist & Wiksell.
Moore, Jason W. 2003. "The Modern World-System as Environmental History? Ecology and the Rise of Capitalism", *Theory & Society* 32(3), 307–377.
—— 2007. "Silver, Ecology, and The Origins of the Modern World, 1450–1640", in Hornborg, A., McNeill, J.R. & Martinez-Alier, J. (eds.), *Rethinking environmental history: World-system history and global environmental change.* Lanham: Altamira.
Ni, Ji Qin & Hang, Zhou. 1992. "Energy Consumption and Conservation in Tea Processing in China", *Renewable Energy* 2(1), 1–5.
Nordström, Olof. 1952. *Relationer mellan bruk och omland i östra Småland 1750–1900.* Lund: Lund University.
Nyström, Johan Frans. 1883. *De svenska ostindiska kompanierna: Historisk-statistisk framställning.* Göteborg: D.F. Bonniers boktryckeri.
Odum, Howard T. 1983. *Systems Ecology: An introduction.* New York: Wiley.
Parthasarathi, Prasannan. 2011. *Why Europe grew rich and Asia did not: Global economic divergence, 1600–1850.* Cambridge: Cambridge University Press.
Pomeranz, Kenneth. 2000. *The great divergence: China, Europa, and the making of the modern world economy.* Princeton: Princeton University Press.
Rawski, Evelyn S. 1972. *Agricultural Change and the Peasant Economy of South China.* Cambridge, MA: Harvard University Press.
Ricardo, David. 1953 [1817]. *On the principles of political economy and taxation*. Cambridge: Cambridge University Press.

Stella, Alain. 1992. "Tea gardens", in Stella, Alain (ed.), *The book of tea.* Paris: Flammarion.

Sundberg, Ulf, Lindegren, J., Odum, Howard T., Doherty, Steven S. & Steinlin, Hans 1995. *Skogens användning och roll under det svenska stormaktsväldet: Perspektiv på energi och makt.* Stockholm: Skogs- och lantbruksakademin.

Wackernagel, Mathis & Rees, William E. 1996. *Our Ecological Footprint: Reducing Human Impact on the Earth.* Philadelphia: New Society Publishers.

Wallerstein, Immanuel. 1974. *The modern world-system I: Capitalist agriculture and the origins of the European world-economy in the sixteenth century*. New York: Academic Press.

—— 1980. *The modern world-system II: Mercantilism and the consolidation of the European world-economy, 1600–1750*. New York: Academic Press.

—— 2004. *World-systems analysis: An introduction*. Durham: Duke University Press.

Warlenius, Rikard. 2011. *Iron for tea: The Trade of the Swedish East India Company as a Cross-Continental Case Study of Ecologically Unequal Exchange in the Eighteenth Century.* Department of Economic History, Stockholm: Stockholm University.

WWF. 2010. *The Living Planet Report 2010: Biodiversity, Biocapacity and Development*. Gland, London & Oakland: WWF.