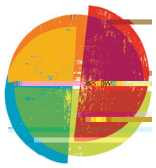
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Content

1. Introduction

> *“All crises begin with the blurring of a paradigm and the consequent loosening of the rules for normal research… Or […] a crisis may end with the emergence of a new candidate for paradigm and with the ensuing battle over its acceptance.”*
> Thomas S. Kuhn – 1963

Accepting a new concept is a lengthy process. As Kuhn

2. Virtual water for water scarcity: A critical approach

2.1. Understanding virtual water

As with any relatively new term, it is constructive to begin the analysis with its conception and early development, thus appreciating the concept's different components as well as the agendas of its creators and advocates. Tony Allan[1] has largely been credited for coining the concept (see for example Hoekstra, 2005; Moench, 2002; Wichelns, 2001; Chapagain and Orr, 2008) and it is true that he is responsible for its growing acceptance. However, Allan (2003) himself acknowledges the work of Israeli economists for stimulating his interest in the role of water in trade. Working in the 1980's, these economists recognised that the marginal economic cost of exporting water-intensive crops such as avocado caused additional water stress for Israel (Fishelson, 1994). Building on this analysis, Allan elaborated his paradigm of hidden—or embodied—water. The concept however did not gain prominence until 1993, when Allan renamed it *virtual water* for the purpose of a conference (Allan, 1998; 1999; 2001; 2003; 2011; Lant, 2003; Chapagain and Orr, 2008).

The epicentre of this concept is the idea that every crop[2] has a higher input of water than is contained in the final product. A famous equivalence often used by Allan is that a thousand tons of water are necessary to produce a ton of wheat (Allan, 2003; 2011). This water is used in every stage of agriculture, from the amount used at the site of production like irrigation—both from groundwater and other sources—to the water used in processing, refrigerating, transferring, etc. the harvested crop. It therefore binds water, food and trade in an innovative way. This is particularly significant since achieving food security[3] is high on the political agenda of countries across the world (Skoet and Stamoulis, 1996).

The logic behind virtual water trade is derived from Ricardo's (1973) theory of comparative advantage. In his prominent book *On the Principles of Political Economy and Taxation*, Ricardo suggests that trade can be favourable to both partners, provided that they each export the goods they have a comparative advantage in producing. It relies on notions of marginal costs and trade-offs be-

mostly economic—costs, and necessitates an organised effort to divert water from other activities into agriculture (Allan, 1999).

Given that the alternatives to deal with water scarcity are far from perfect and that virtual water trade is depicted as beneficial for all involved, the optimism could be justified. However, when looking closely at both the explicit and implicit assumptions made in the litera-

To build the analytical framework, I begin by contextualising the origin of the concepts of core and periphery. Then follows a qualifcation of the relation between the two, both from a historical perspective and using the concept of imperialism as employed by Caldwell (1977). A model using systems theory and the notion of entropy to explore the interactions between the socio-economic and natural spheres of these two regions is fnally built, using virtual water as the hidden content of food trade.

3.1. The origins of the core-periphery relation: A historical approach

Any investigation on the relations between the North and the South must originate from a historical understanding of how this theme has been approached. The end of the colonial era marked a turning point in international relations. Rising from the fallen empires, the newly decolonised countries emerged as a seemingly homogenous group, clearly at a different developmental stage than the North, thus raising questions on how progress occurs (Steans and Pettiford, 2004). In the 1950's and 1960's, modernisation theory was the discourse addressing issues of growth; it rid developed countries of any potential blame for the South's underdevelopment, while maintaining an advantaged position for the North as a success story, an example to be followed. The central idea of modernisation theory is that the South needs to pursue development—and hence prosperity—following the path established by the North. Development, as characterised by economic growth, is seen as a linear process leading from a 'backward' traditional society to a modern and wealthy one[1] (Biel, 2000). Modernisation theory predicts that 'things will get worse before getting better', thus explaining poverty and inequality as a necessary evil on the road to development[2].

Perhaps unsurprisingly, the Northern bias[3] and hardly concealed political agenda[4] of this school of thought came under scrutiny and increasing criticism. Dependency theory emerged as a Southern alternative to modernisation. It gave development a much-needed political component, centred on the power differentials of two main groups: the core and the periphery. Authors like Gunder Frank (1966), Baran (1957) and Rodney (1973) contested the idea that underdeveloped countries were simply at an earlier stage of development, claiming that such a belief disregarded the historical experience of these regions. They argued that underdevelopment and development were inversely linked: as the North developed and the capitalist system engulfed the rest of the world, it caused the South to serve the interest of the North, thus impeding its own development. "Historical research demonstrates that contemporary underdevelopment is in large part the historical product of past and continuing economic and other relations between the satellite underdeveloped and the now developed metropolitan countries" (Gunder Frank, 1966). The most important contribution of the dependency theory school of thought was the thorough rethinking of the North-South divide. By looking at historical patterns, the blame of underdevelopment fell on the North's imperialist pursuits, hence creating the notions of core and periphery. The idea of a core-periphery dichotomy remains relevant and has later been used in numerous Marxist theories[5].

Yet, dependency can still not adequately explain the relations between the core and the periphery as it ignores the importance of the environment

The ecosystem and the economic system need to be examined in relation to one another—through trade, particularly since the environment is central in supporting the socio-economic system. If the analysis is limited to economic and social factors, as is done in dependency theory, then a central component of the core-periphery relationship is neglected. To further examine this idea, a working understanding of systems theory and the Second Law of Thermodynamics is necessary.

3.2. Systems theory and Thermodynamics in social science

Defning systems theory can be daunting. Indeed, there exists no defnition all scholars agree on[8], even though there are certain properties shared by all systems (Maturana, 1975). Maturana (1992), for example, stresses the importance of feedback loops—a process where parts of the output return into the system as inputs—in sustaining a regulatory process within a system. In this working paper, however, it is not necessary to dive into the intricacies of complexity science. Systems theory will therefore only be examined through the interactions between the economic and environmental spheres.

A good starting point to delve into the use of systems theory in social science is the work of Nicholas Georgescu-Roegen, a pioneer in refecting upon the repercussions of the capitalist mode of production on the ecosystem. In his 1971 magnum opus *The Entropy Law and the Economic Process* (1971), he applied Thermodynamics to economics,

port of food at this scale is possible, these countries have "extend[ed] imperialist control over the rest of the world and convert[ed] their economies to meet the needs (including the needs for fossil fuels, […] food and foodstuffs) of the metropolitan economies" (Caldwell, 1977, 99).

Hence, there exists a feedback loop fortifying the core's already advantaged position, or a vicious circle of subordination if considered from the standpoint of the periphery. By importing huge quantities of food, the countries of the core manage to focus their economies towards the service sector, which in turn reinforces their financial prosperity and, thus, power. This power permits them to dominate the rest of the world, with no need for costly military control. The periphery's ecosystem is put to the service of the core's socio-economic system, while the detrimental repercussions remain away from the powerful North's territory. In systems theory terms, exergy therefore comes from the periphery's ecosystem to the core's socio-economic system. Entropy, from agricultural production and environmental degradation for example, is exported to the periphery, while the benefits from the energy release are enjoyed at the core. The superstructure—in Marxist terms—that governs this relationship is imperialism, both a product and a driver of the system (Figure 3.2). This imperialist structure is in fact now self-sustaining: having experienced centuries of subjugation, the periphery is now readily exploiting itself to the benefit of the core, in the hope of taking advantage of the window of economic advantage it is being offered. "Anticipating an indefinite prolongation and intensification of dependence, […] the leaders of the rich industrial countries have no option but to seek to maximise the geographical extent of the sphere in which they have a relatively free hand to prospect for and extract […] fossil fuels, and to skim off valuable proteins" (Caldwell, 1977, 102).

3.4. Closing the cycle of entropy

Still, a piece of the puzzle is missing. What Caldwell (1977) did not fully explore[10] , was the return of entropy to the core. The entropy exported to the natural system of the periphery is in no way contained within this subsystem. As explained above, the socio-economic system is highly dependent on the double regulatory process of the ecosystem. If this system is in any way impaired—for example robed of its exergy through saturation by the core's entropy—it will be unable to support the social system. Considering a pre-capitalist society relying on the land, the repercussion of environmental degradation becomes readily apparent: if degradation reaches a point of no return, a point where one of the necessary inputs to agriculture runs out, then production will halt and the population will need to relocate. In my opinion, this is a crucial point. When looking at the trade of food, water is definitely an irreplaceable input: there can be no agricultural activity in the absence of water. If export-oriented agriculture depletes the available water resources and there is no alternative, then this region will be forced to stop producing the exported crop—in a best case scenario—or relocate, with substantial repercussions on the local population's livelihoods—in a worse case scenario.

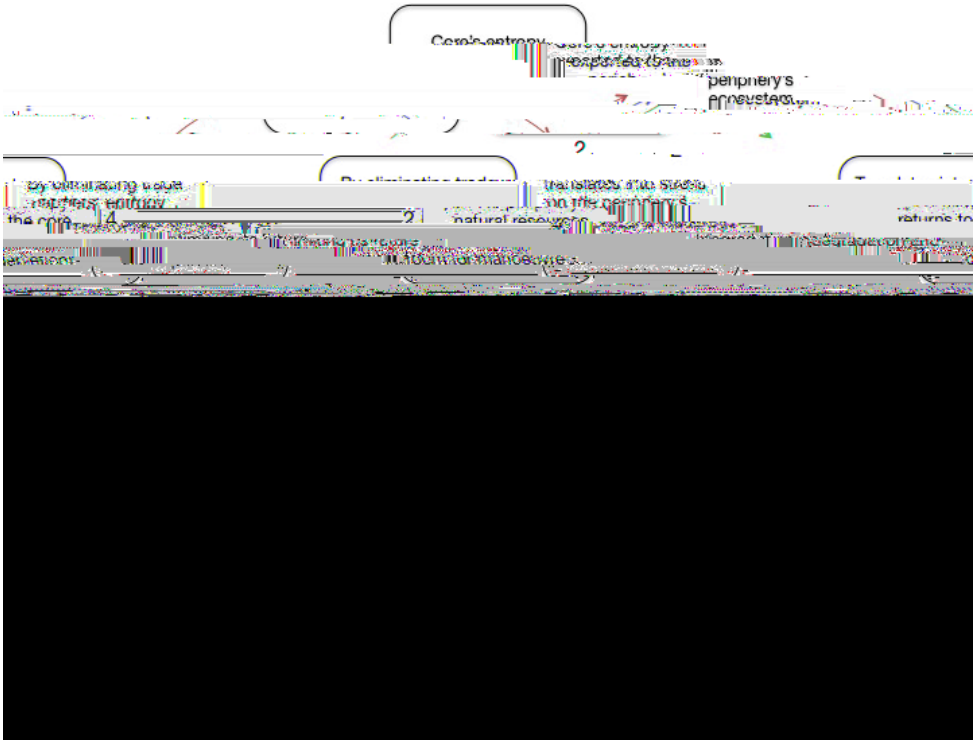
However detrimental to the periphery, such a development is also damaging to the core's economy. By destroying its partner's nature and thus economy, the core is limiting its set of potential trading partners, ultimately limiting its future room for manoeuvre, a manifestation of entropy within the economic sphere that has already been explored[11] (Biel, 2006; 2012). Nevertheless, I maintain that the mechanisms in play, which result in the depletion of the socio-economic potential of the periphery, are diverse. While Biel (2006; 2012) describes a double dissipative action from the core's capitalist mode of production, this paper supports that the depletion of the South's natural resources is in fact driving the social and economic entropy (Figure 3.3), through a series of feedback loops (Figure 3.4).

Once again, virtual water provides a helpful illustration of this relation. The water used in export-oriented agriculture is diverted in large amounts from other potential activities. This water is then "exported" to the core through crops. If water resources are depleted, then trading activities will stop and, if water poverty reaches the point where the surrounding areas loose access to water, the population might need to relocate[13]. For the core, this translates into the loss of a partner. Naturally, this might not be a serious setback in itself since there might be other regions willing to embark in a trading relationship with the core. It does mean however that the number of possible trading regions is now reduced from *n* to *n-1*. The core is thereby limiting its own activity. This limit becomes increasingly restricting as the water resources of different trading regions in the periphery are exhausted.

In the following chapter, this framework is applied to the case study of the trade of asparagus between the United Kingdom and the Peruvian Ica Valley to examine this model in practice. In line with the traditional application of virtual water, the analysis will begin with an examination of water scarcity in each of these trading poles.

Figure 3.3. Entropy in the imperialistic world economy[12] (Author's interpretation of existing literature)

Figure 3.4. The cycle of entropy: Feedback loops explained through different steps (Author's interpretation of existing literature)



1. The expected linearity of the developmental process is perhaps best represented by Rostow's (1953) stages theory, which assumes that economic development can be reached by any society following a pre-determined trajectory through five stages. In particular, Rostow argues that there is a specific 'take-off' stage, eventually leading to the age of mass consumption where all prosper.

2. The best visual representation of this conviction is the Kuznets curve. Simon Kuznets (1955) elaborated a hypothesis that there is an "inverted U" relation between economic growth and the level of inequality in a country: the initial growth engenders an increase in inequality, which is later reduced by increasing distribution of the rising levels of wealth.

3.

As explained in *Chapter 2*, the traditional study of virtual water makes certain assumptions on some characteristics of the two trading poles as well as the motivations be-

rying capacity[3] . Looking at the total water needs for agriculture alone, a mere 38% comes from within the country, the rest being imported in the form of virtual water. In fact, the UK is plagued by regular droughts despite the frequent rainfall, which might explain why it imports 63.6 billion cubic metres yearly (Hepworth, et al., 2010). However, the concept of relative water poverty needs to be introduced at this point. Even accepting Allan's thesis, one must consider the regions the UK is importing its food and foodstuff from. A 2008 Government report on food security noted that sixty-eight per cent of all food imports come from other EU countries, making special reference to Spain as one of the largest exporters for the UK (Cabinet Office, 2008). Yet in the same book, Allan (2011) categorises Spain as a semi-arid country, having clearly less available water than the UK. Considering that the Ica Valley is hyper-arid, Britain certainly does not qualify as a water poor country for the scope of this paper.

4.3. The trade of asparagus between the United Kingdom and the Peruvian Ica Valley

In the past twenty years, the Ica region has experienced a boom in asparagus production, fuelled by an increasing international demand. On the whole, Peru has been allocating an increasing amount of farmland to the production of asparagus, passing from eighteen thousand hectares in 2005 to twenty-eight thousand hectares in 2009 (Benson, 2009). The Ica Valley is at the heart of the Peruvian asparagus production, accounting for nearly ninety-five per cent of total production. In fact, the land allocated to asparagus grew form none in 1990 to over ten thousand hectares in 2008 (Hepworth, et al., 2010). While production is thriving, consumption of asparagus in Peru lingers at an extremely low level: less than one per cent remains within the country; the rest is exported (Benson, 2009). It is thus clear that the asparagus production in Peru—including the asparagus production in Callejón de los Espinos—is entirely export-oriented. The local population has no demand for this good. Internationally however, the demand for asparagus has been rocketing since the early 1990's, and this trend is very clear in the UK as well. The UK is now the third largest net importer of asparagus from this region (Hepworth, et al., 2010).

As mentioned above, the production of asparagus is negatively affecting the water resources of this water-poor region. Hepworth, et al. (2010) present testimonies of farmers, some of who are already in the process of relocating as a direct consequence of their farms having lost access to water. As water for irrigation is becoming scarce, small and medium-scale farmers are either selling their land, relocating or going into debt because of the increasing costs connected to sustaining their access to water—which would include expanding the current wells, digging new ones or getting water from areas further away. Clearly, this favours big agribusinesses—like the asparagus producers—rather than traditional farmers. In fact, small and medium-scale farmers are already selling their land and wells to big agribusinesses in order to survive in an increasingly competitive environment (Hepworth, et al., 2010).

Another important distinction between traditional small and medium-scale farmers and export-oriented agribusinesses is the source of water they use. While traditional farmers mostly use surface water diverted from the Ica river, as it is much cheaper, and only complement it with groundwater in the dry season, big agribusinesses only use groundwater for agriculture as they can easily offset the cost. Water use for irrigation is supposedly regulated by a central agency. The reality, however, is that groundwater is available to those able to incur the cost of the extraction (Hepworth, et al., 2010). Perhaps unsurprisingly then, the export-oriented farming of asparagus is therefore using one hundred per cent of groundwater. In the dry season, the water demand for asparagus is more than double that of traditional crops like cotton—thirty thousand cubic metres per year for the former versus fourteen thousand cubic metres per year for the latter (Hepworth, et al., 2010).

Moreover, water for domestic use has already been affected: the access to water of Callejón de los Espinos has been reduced from "two hours of water at least four times a week [to] about one hour of water three times a week" (Hepworth, et al., 2010: 48).

While the water resources in Callejón de los Espinos can still support exporting asparagus, it is safe to assume that this will not be the case indefinitely. The water necessary to meet the UK's imports of asparagus from this region alone corresponds to nine million cubic metres per year, even thought the Ica Valley is one of the driest regions on the planet. Looking at rainfall alone, the UK receives two thousands times more water than the Ica Valley (Hepworth, et al., 2010). Given the on-going trend of groundwater overdraft, the region will run out of water sooner rather than later. When this happens, the repercussions will be severe, both economically and socially. There are countless recorded cases of exhaustion of water resources in the global South. Moench (2002) presents the cases of Saudi Arabia, India and Yemen as cautionary tales of the dangers of extreme water poverty. He discusses the consequences of such relocation on the poor's livelihoods: they do not only loose their land, but, more importantly, their networks. They are thus unable to cope with hardship, and are often forced to move into the cities to work in the informal economy. There are no indications that the case of the Ica Valley will be any different. What is more, these farmers will loose a part of their identity and culture, which is bound to the Valley, an area that has been populated for thousands of years (Hepworth, et al., 2010).

In systems theory terms, the entropic feedback loops in play in this case study are clear. The United Kingdom—the core—exploits the water resources of the Ica Valley—the periphery—leading to a genuine threat of exhaustion. This, in turn, affects the rural population, which stands to loose both their homes and livelihoods. If this trend continues unchanged, the entropy will be imported back into the UK when the region will stop producing asparagus. This could also momentarily disturb the UK's asparagus imports since Callejón de los Espinos represents a significant exporter for the country.

4.4. Why asparagus?: Applying the theory of comparative advantage within a core-periphery framework

A question arising from this case study is *why would a water poor region in Peru grow asparagus*? Surprisingly, this question is, in all likelihood, answered more satisfactorily using the theory of comparative advantage, rather than its successor virtual water. Asparagus can grow on different types of soil "but deep loam or sandy soils with good surface water and air drainage are best" (Motes, et al., n/a). The implication is that asparagus can grow in the UK since it grows on all soils. However, the proximity to the desert

irrigate". Green water "infiltrates into [the] soil and is taken up by natural vegetation and crops. Much is transpired by natural vegetation back into the air" (Allan, 2011: 42). While rivers and streams are the visible water resources, Malin Falkenmark (2008) showed that green water was in fact much more important in

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