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ANALYSIS

Diet and the distribution of environmental impact

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Abstract

This paper examines the relationship between scale and distribution issues. It is argued that since achieving a sustainable scale requires economic activity to stay within biophysical limits, considerations of equity should not be limited to the distribution of monetary measures such as income, but should include the distribution of scarce environmental services as well. In order to make this point this paper examines how differences in diet across populations lead to inequality in the distribution of environmental impact. First, the distribution of food consumption across the world's population is examined using national data. Next, ecological footprints are estimated in order to ascertain how differences in diet affect the distribution of environmental impact. The results show that the meat-intensive diet enjoyed by many in the industrialized world leads to a greater degree of inequality in the use of environmental services than is apparent from examination of the distribution of food consumption across countries.

Keywords: Scale; Distribution; Equity; Ecological footprint

1. Introduction

Daly (1991, 1996) has argued that scale, distribution, and efficiency are the three issues that ecological economics must address. While neoclassical economists have long studied the problems of distribution and efficiency, it is scale that distinguishes the ecological economics paradigm from that of neoclassical economics. Ecological economists argue that achieving a sustainable scale should be the primary policy goal instead of the pursuit of growth that is favored by neoclassical economists (Daly, 1996). However, since achieving a sustainable scale necessarily requires the human economy to stay within biophysical limits, scale has important implications for distribution issues (Luks and Stewen, 1999). Unlike income, which can theoretically grow without bound, an economy facing biophysical limits must address how scarce environmental services are distributed in use. While the degree of equity in the distribution of income will continue to be an important issue, the distribution of bio-

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physical measures such as the ecological footprint will become increasingly important in the future.

The significance of scale for distribution issues depends on the decision criterion being employed. Utilitarian and Rawlsian social welfare functions have often been used as decision criteria for distribution questions (Atkinson and Stiglitz, 1980). Regardless of whether an economy is pursuing growth or sustainability, under a utilitarian decision rule goods should be distributed to those who receive the greatest satisfaction from consumption of those goods. Distribution according to revealed willingness to pay is therefore consistent with a utilitarian perspective. On the other hand, a Rawlsian decision criteria which focuses on the position of the individual with the lowest utility leads to different results under the different policy goals. A growth policy is consistent with a Rawlsian viewpoint only if the growth leads to an increase in the utility of the least well-off individual. This is the rising-tide-lifts-all-boats scenario. In contrast, a policy aimed at maintaining a sustainable scale could meet a Rawlsian criterion of improving the position of the least well-off individual only through redistribution efforts. This paper employs a Rawlsian perspective to examine how food consumption patterns affect the distribution of the use of scarce environmental services in agriculture.

Over the last 30 years there has been an increase in food production worldwide. This resulted from an increase in the amount of land under cultivation and from improved yields on existing agricultural lands (FAO, 1996a). Unfortunately, evidence is mounting that food production may be approaching limits. Brown and Kane (1994) report that growth in per capita grain production has leveled off since the mid-1980s as efforts to increase yields begin to exhibit decreasing returns. Harris and Kennedy (1999) examined yield growth patterns and argue that the world is already near carrying capacity in agriculture. Overfishing of the world's oceans has created a situation where fish catch is likely to decline over the next several decades (McGinn, 1998). Overgrazing of rangelands has left them degraded and unable to maintain current livestock levels (Durning and Brough, 1991). There also appears to be limited potential for increasing the amount of land under cultivation (Goodland, 1997). In a world where population is growing by more than 90 million annually (WRI, 1994) and as much as 20% of the population is still classified as undernourished (FAO, 1996b), the ability of agriculture to provide an increasing amount of food appears to be diminishing.

In a recent article Goodland (1997) argues that diet is an important factor in achieving sustainability in agriculture. Goodland points out that the predominantly meat-based diet consumed by the more affluent citizens of the world requires a significantly greater amount of environmental resources per calorie than a more grain-based diet. An increased demand for meat has encouraged farmers to raise livestock instead of grain (UNEP, 1999), and currently almost 40% of the world's grain currently goes to feeding livestock and is therefore unavailable for human consumption (Brown and Kane, 1994). Policies designed to discourage meat consumption through taxation or other incentives could improve health and food availability (Goodland, 1997). In addition, reducing the amount of meat consumed by the affluent could lead to more equity in the distributions of both food consumption and environmental impact.

This paper will explore how differences in diet affect the distribution of environmental impact. In the next section, the implications which sustainability has toward the issue of equity will be developed using a simple conceptual model. Recent trends in food availability will then be examined with particular attention paid to how the consumption of food calories is distributed across the world's population. Following this, ecological footprint analysis will be used to estimate how the distribution of environmental impact across the world is affected by differences in diet. The analysis reveals that there is potential for reducing inequality in the distribution of environmental impact through alteration of diet.

2. Model

The relationship between food consumption, diet, and environmental impact can be explained with the following model:

$$I_i = P_i \cdot \left(\frac{C_i}{P_i}\right) \cdot \left(\frac{I_i}{C_i}\right) \tag{1}$$

where I_i is the degree of environmental impact of nation i, P_i represents population of nation i and C_i is the caloric intake of nation i. Eq. (1) simply states that total environmental impact from food consumption depends on population, calories per capita, and the ratio of environmental impact per calorie consumed. Since different foods generate different levels of environmental impact the ratio (I/C) will be referred to as the diet impact ratio.[1]

Achieving worldwide sustainability in agriculture will require the total amount of environmental impact ($I = \Sigma I_i$) be stabilized at or below some maximum sustainable scale, S^*. Setting $P = \Sigma P_i$ and $C = \Sigma C_i$, the following relationship must therefore be true for sustainability:

$$I = P \cdot \left(\frac{C}{P}\right) \cdot \left(\frac{I}{C}\right) \leq S^* \tag{2}$$

Ascertaining whether current agriculture has reached the maximum sustainable scale S^* is beyond the scope of this paper, although previously cited evidence suggests that this may in fact be the case. However, assuming that limits to agricultural production are eventually faced, Eq. (2) becomes an equality and several important equity issues arise. First, for any given population, a Rawlsian goal of increasing the calories available to the least well-off groups could be achieved through a redistribution of calories from high-calorie to low-calorie consumers. Alternatively, a reduction in the diet impact ratio could allow for additional calorie consumption on the part of the least well-off groups without a reduction in calories consumed by the rest of the population as the shift to a more grain-intensive diet would free up agricultural capacity.

In addition to equity in the distribution of available calories, achieving a sustainable scale may require a second equity issue to be addressed: equity in the distribution of environmental impact. The existence of a maximum sustainable scale highlights the scarcity of environmental services, and therefore the degree to which those scarce services are shared is important from an equity standpoint. Of course, in the case of food consumption, the distribution of calories will influence the distribution of environmental impact, reinforcing the importance of equity in calorie distribution. In addition, differences in the diet impact ratios will lead to disparity in environmental impact per person, which suggests that the choice of diet is itself an equity issue.

3. Equity and food availability

Recent evidence indicates that world food security has improved over the past several decades. Since the 1960s world food production has grown more rapidly than population (FAO, 1996c). Regional data presented in Table 1 show that total calories consumed per capita has in general increased during the period from 1985 to 1995, FAO (1997).[2] The regions with the lowest levels, Africa and Asia, experienced 5 and 6% increases in per capita consumption, respectively, while North America, already with high food availability, increased by over 8%. Only Europe experienced a significant drop in food availability. This is a result of the decrease in food production of the former centrally planned economies of Central and Eastern Europe (FAO, 1996b). While the overall trend in food availability has been encouraging, there are still an estimated 840 million people who are considered undernourished (FAO, 1996b), and although most reside in low-income countries there are also significant numbers of undernourished in more developed and industrialized countries.

[1] Eq. (1) is a modified version of the well-known ‘impact’ or ‘I = PAT’ equation of Ehrlich and Holdren (1971). However, in the current case ‘A’ (affluence) represents calories consumed per person rather than the more typical income per capita, and ‘T’ (technology) represents the chosen diet of the population as summarized by I/C.

[2] Calorie consumption data was obtained from the Food and Agriculture Organization of the United Nations, FAOSTAT Statistics Database, (http://www.fao.org). Figures are net of trade and therefore represent an estimate of average calorie consumption. Reported per capita figures are actually 3-year averages with 1985 and 1995 representing the averages of 1984–86 and 1994–96, respectively.

Table 1
Calorie intake per day (kcal/cap per day)[a]

Region	Total calories per capita		Veg. calories per capita		Animal calories per capita		Ratio of animal to total	
	1985	1995	1985	1995	1985	1995	1985	1995
Africa	2253	2379	2066	2210	186	170	0.08	0.07
Asia	2457	2615	2241	2295	217	321	0.09	0.12
South and Central America	2703	2782	2243	2277	461	504	0.17	0.18
Oceania	2924	2906	1975	1987	950	919	0.32	0.32
Europe	3343	3154	2360	2231	992	924	0.30	0.29
North America	3284	3572	2319	2576	965	994	0.29	0.28
World	2645	2720	2243	2288	401	432	0.15	0.16
Coefficient of variation	0.180	0.159	0.115	0.120	0.855	0.699		
Gini coefficient	0.101	0.088	0.063	0.063	0.436	0.377		
Hoover index	0.073	0.062	0.046	0.041	0.352	0.271		

[a] Source for calorie data: United Nations Food and Agriculture Organization, FAOSTAT Statistics Database (http://www.fao.org).

Table 1 also shows the breakdown of available calories into the two food categories of vegetable products and animal products which allows for differences in diet to be considered. For example, by 1995 the available calories per capita from vegetable sources was spread fairly evenly across regions, with only Oceania falling much below the world average. On the other hand, calories derived from animal products was much more unevenly distributed, with Europe, North America, and Oceania consuming over five times the calories of Africa on a per capita basis, about three times that of Asia, and about twice that of South and Central America. Comparison with 1985 shows Asia, South and Central America and North America experienced substantial increases in the consumption of calories from animal sources, while the other regions all experienced reductions. On a worldwide basis, about two-thirds of the increase in total calories per capita that occurred between 1985 and 1995 is explained by the increase in calories from animal products, indicating diets in general have been becoming more meat-intensive. The final two columns in Table 1 show the fraction of total calories per capita derived from animal products. This is a simple measure of the degree to which a diet is dependent upon meat and other animal products. On average, Oceania, Europe and North America have the most meat-intensive diets while Africa and Asia are the least meat-intensive although Asia has seen a fairly significant increase during the 1985–95 period.

Three statistical measures were estimated in order to quantify the degree of inequality that exists in the distribution of food calories and are also reported in Table 1.[3] The first measure reported is the coefficient of variation, which is the S.D. divided by the mean. The second measure, the gini coefficient is a measure that is commonly used in studies of income distribution. It represents twice the area between a ‘Lorenz curve’ and an equality line, where the Lorenz curve is a plot of the cumulative proportion of population against cumulative proportion of income when the population is sorted in ascending order of incomes. When income is equally distributed across a population then the gini coefficient will be equal to zero, and when income is highly concentrated amongst a few the gini coefficient

[3] Calculation of the inequality measures were based upon national calorie availability and population data of 178 nations in 1995 and 158 nations in 1985 obtained from the United Nations Food and Agriculture Organization, FAOSTAT Database (http://www.fao.org)

approaches one. While the current analysis uses calories rather than income, the calculation and interpretation of the gini coefficient are unchanged.[4] The final measure used to estimate the degree of inequality in the distribution of food is the Hoover concentration index. The Hoover index measures the proportion of some variable that would need to be redistributed in order to achieve a completely equal distribution of that variable. It has been applied to the distribution of income across a population, the distribution of a population across land area, and other cases.[5] Like the gini coefficient, the Hoover index is bounded by zero (complete equality) and one (total inequality).

Comparing the estimated measures of inequality reveal several patterns. First, over the 10-year period from 1985 to 1995 total calories have become more evenly distributed amongst the world's population, as indicated by the decrease in each of the three measures. Second, comparison of the inequality measures of total calories with those of vegetable and animal calories shows that in general calories from vegetables are more evenly distributed than total calories, while animal calories exhibit a greater degree of inequality than either total or vegetable calories. The magnitude of the inequality in the consumption of calories from animal products is worth noting as each of the measures for animal calorie inequality is over four times the corresponding measures for total calorie inequality. The discrepancy in the inequality measures indicates that differences in diet affect the ultimate distribution of calories per capita but do not reveal how differences in diet translate into differences in environmental impact. This will be addressed in the next section.

4. Equity and environmental impact

Livestock farming requires a greater amount of resources per unit of food than other types of agriculture. For example, cattle must eat approximately 7 kg of grain in order to generate a single kg of beef, and pigs require about 4 kg grain for 1 kg of pork. Fowl such as chicken and turkey are more efficient, but still require approximately 2 kg of feed per kilogram of poultry meat. In addition, livestock farming can lead to overgrazing which causes soil erosion, desertification, and even tropical deforestation as land is cleared to make way for cattle herds (Brown and Kane, 1994). Therefore, the meat-intensive diet of some of the world's population leads to a disproportionate share of the environmental impact resulting from agriculture.

In order to examine the degree to which differences in diet affect environmental impact ecological footprint analysis was utilized. Wackernagel and Rees (1994, 1996) have developed the ecological footprint concept and applied it to a variety of situations. Briefly defined, an ecological footprint of a population is the amount of ecologically productive land that would be necessary to provide current levels of consumption on a sustainable basis. An ecological footprint is therefore a measure of environmental impact, with a larger estimated footprint implying greater land requirements and therefore a greater impact on the environment by a population.

For the current application national ecological footprints were estimated for food consumption. The methodology used to calculate the footprints followed that of Wackernagel and Rees (1996). A footprint of a population is estimated by dividing the level of consumption of some item by the average annual yield of producing that item. The resulting quotient is the land area necessary to produce the current consumption level. For example, the footprint resulting from the consumption of wheat in the United States in 1995 was calcu-

[4] The gini coefficient (G) was calculated using the following formula: $G = 1 - \Sigma p_i(Q_i + Q_{i-1})$, where p_i represents the proportion of world population which resides in country i, and Q_i is the cumulative proportion of calories or footprint attributed to countries $1 \ldots i$, when countries are ranked in ascending order. See Sundrum (1990) for a description of the characteristics of a gini coefficient.

[5] Calculation of the Hoover concentration index (H) is completed using the equation: $H = 0.5\Sigma|(q_i/q) - (p_i/p)|$, where q_i, represents calorie consumption of country i, p_i is the population of country i, and q and p represent the world totals of calories and population respectively. See Hoover (1941) and Plane and Rogerson (1994) for a more detailed explanation of the Hoover concentration index.

Table 2
Per capita ecological footprint for food consumption (ha/cap)

Region	Total footprint per capita		Veg. footprint capita		Animal footprint per capita		Ratio of animal footprint to total	
	1985	1995	1985	1995	1985	1995	1985	1995
Africa	0.191	0.197	0.149	0.160	0.042	0.037	0.22	0.19
Asia	0.182	0.212	0.146	0.156	0.036	0.056	0.20	0.26
South and Central America	0.297	0.315	0.182	0.191	0.115	0.124	0.39	0.39
Oceania	0.442	0.422	0.166	0.167	0.276	0.255	0.62	0.60
Europe	0.413	0.380	0.190	0.182	0.223	0.198	0.54	0.52
North America	0.524	0.545	0.241	0.268	0.283	0.277	0.54	0.51
World	0.249	0.259	0.162	0.169	0.087	0.090	0.35	0.35
Coefficent of variation	0.473	0.408	0.235	0.260	1.017	0.836		
Gini coefficient	0.246	0.208	0.129	0.142	0.505	0.431		
Hoover index	0.198	0.156	0.092	0.099	0.417	0.322		

lated by dividing total US wheat consumption of 23 233 720 metric tons by the estimated yield of 2.5 metric tons/ha.[6] The result of 9 293 488 ha represents the amount of the world's cropland needed to meet the amount of wheat consumed in the US in 1995. By comparison, in 1995 Chile consumed 1 679 155 metric tons of wheat, which translates into a footprint of 671 662 ha of land, much smaller than the US estimate. Estimating per capita footprints allows for comparison of environmental impact per person. The US per capita footprint for wheat consumption was 0.035 ha per person in 1995, while Chile's was 0.047 ha per person. This implies that the average citizen of Chile is utilizing a greater share of the world's cropland than the average citizen of the US in order to meet their consumption of wheat. While this example uses wheat consumption, similar estimates can be made for other agricultural products by using the appropriate yield and food consumption data.

Determining the ecological footprint of animal products such as meat, eggs, or milk required some additional assumptions. As noted earlier approximately 40% of world grain production is currently fed to livestock which means using an estimate of rangeland productivity in the calculation of ecological footprints for animal products would provide a misleading estimate of environmental impact from animal agriculture. Instead several conversion factors were used to translate the quantity of animal products produced into a grain-equivalent amount.[7] For example, Brown and Kane (1994) estimate that it requires approximately 7 kg of grain to produce 1 kg of beef. Therefore, the 1 961 641 metric tons of beef consumed in Argentina in 1995 would require approximately 13 731 487 metric tons of grain. This grain estimate is then divided by the average grain yield of 2.5 metric tons/ha to arrive at a footprint of 5 492 595 ha of land or 0.158 ha per person in Argentina. In contrast, Japan consumed 1 348 338 metric tons of beef in 1995 resulting in

[6] The food data for this and all calculations in this paper were obtained from the FAOSTAT Database of the United Nations Food and Agriculture Organization (http://www.fao.org). The yield is an estimate of the worldwide productivity of land used in producing wheat and is derived from FAO data for world food consumption and land use. The purpose of using the world average yield rather than a yield specific to each country is to focus on the distribution of food and environmental impact across the world's population and not on the distribution of productive capacity. All calculations for 1995 are based on a 3-year average of 1994–1996, and all 1985 calculations are averages of 1984–86 data.

[7] The following conversion efficiencies were used to convert animal products to grain-equivalents: 1 kg beef or mutton = 7 kg grain; 1 kg pork = 4 kg grain; 1 kg poultry = 2 kg grain; 1 kg eggs = 2.6 kg grain (Brown and Kane, 1994).

a footprint of 3 775 346 ha (= 1 348 338*7/2.5) or 0.030 ha per capita thus showing a much lower impact as a result of a less beef-intensive diet.

For this paper, ecological footprints were estimated for 19 categories of food for 1995 and 1985. Since the footprint associated with each food category is measured in hectares of land each may be added together to estimate the total amount of land area needed to support food consumption. This total footprint provides an overall estimate of the degree of environmental impact resulting from food consumption in each nation. Estimates were completed for 178 countries in 1995, and 158 countries in 1985. Table 2 shows the results of the footprint calculations expressed on a per capita basis and broken down by region. Comparison of the relative magnitudes is revealing. For instance, while the average North American consumed about 50% more calories than the average African in 1995, the North American's diet generated approximately 175% more environmental impact than the African's diet. Notice also that while calories per capita was greater in Europe than in Oceania in 1995, Oceania had a greater environmental impact per capita as a result of the heavy reliance on animal products in the diet. The trend since 1985 is mixed, with North America, South and Central America, and Asia all exhibiting increases in environmental impact per person while the other regions show decreases. However, the world average reveals that overall agriculture has increased in environmental impact per capita since 1985.

Table 3
Diet impact ratio expressed as footprint per 1000 kcal (ha/1000 kcal)

Region	Diet impact ratio (ha/1000 kcal)	
	1985	1995
Africa	0.085	0.083
Asia	0.074	0.081
South and Central America	0.110	0.113
Oceania	0.151	0.145
Europe	0.124	0.120
North America	0.160	0.153
World	0.094	0.095

Breaking down the footprint into vegetable and animal products shows that the North American diet has the greatest environmental impact for both categories. In addition, while the footprint associated with vegetable products is relatively consistent across regions there is a wider disparity in the footprint for animal products. The final two columns in Table 2 express the fraction of total footprint that is derived from animal products. Comparison of these values to the fraction of total calories derived from animal products in Table 1 reveals the discrepancy in impact between vegetable products and animal products. For the world, animal products made up only about 16% of total calories while generating approximately 35% of total environmental impact from agriculture.

The statistical measures used to examine the distribution of calories were also employed for the distribution of environmental impact as measured by the ecological footprint. These estimates are shown at the bottom of Table 2 and when compared to the corresponding measures in Table 1 indicate that there is substantially greater inequality in the distribution of environmental impact than there is in the distribution of food calories. Each of the statistical measures of inequality for total environmental impact are over twice the same measures of inequality in food calories. While all the measures tell a similar story the Hoover index provides an intuitive explanation of the issue. Recalling that the Hoover index measures the amount of some variable that would need to be redistributed to obtain a completely equal distribution the estimated Hoover index in 1995 indicates that approximately 6.2% of calories would need to be redistributed for complete equality in food calories. However, the Hoover index implies that 15.6% of environmental impact would need to be redistributed for equality. Therefore, the degree of inequality in environmental impact is roughly 2.5 times the inequality in the distribution of food.

Eq. (1) shows that the source of inequality in the distribution of environmental impact is from two sources: differences in calories per capita (Table 1), or differences in the diet impact ratio. Table 3 shows the average diet impact ratios for regions of the world and reveals that the regions with the highest diet impact ratios are North America and Oceania, whose diets generate almost twice as much impact per calorie as Asia and Africa. Not surprisingly, the average diets of North America and Oceania are also two of the most meat-intensive as indicated in the last two columns of Table 2. The diet impact ratios of South and Central America and Europe are relatively close to one another indicating diets that are similar in environmental impact. This result is masked in Table 2 as impact per capita is influence by both calories per capita and the diet impact ratio, therefore differences in environmental impact between Europe and South and Central America are more a result of differences in per capita calorie consumption than differences in diet. Africa and Asia have the least environmentally damaging diets but Asia exhibited the greatest increase in diet impact ratio of any region over the 1985–95 time period.

Reducing the diet impact ratio through the implementation of a tax as Goodland (1997) suggests or through another means would lead to a greater degree of equality in the distribution of environmental impact. In addition, the ability of the world to feed its population could improve as lower diet impact ratios would allow regions such as North America, Oceania, or Europe to maintain their calorie intake while using a smaller proportion of scarce agricultural resources. Therefore other regions could experience an increase in food availability which in turn would reduce the amount of inequality in the distribution of food calories.

5. Summary and conclusions

This paper has examined how calorie consumption and environmental impact are distributed across the world. A simple model was employed to show how achieving a sustainable scale affects distribution issues. Rawlsian efforts to improve the status of the least well-off individuals could come about from a redistribution of calories or a reduction in diet impact ratios. Analysis of food consumption data reveals there is significantly greater inequality in the distribution of environmental impact than the distribution of caloric consumption, suggesting an alteration of diet could potentially improve equity.

Two important issues have not been addressed. First, while efforts to increase the degree of equity in the distribution of environmental impact are important, achieving a sustainable scale requires the recognition of and adherence to biophysical limits to scale. Sustainability will require policies that prevent agriculture from exceeding sustainable scale while still providing adequate food for the population. Second, while reducing the diet impact ratio can potentially lead to increased food availability for those groups currently consuming the fewest calories, how such improvements in equity could be ensured must be addressed in future research.

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