Towards a more appropriate method for determining the optimal scale of production units

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1 August 2002
Second revision: 26 August 2002

Abstract

In this paper the overall diseconomies experienced beyond certain production unit scale thresholds are investigated. These are due to several costs, including those relating to the consumption of non-renewable resources, which firms have generally not internalised, to the extent that they can operate far beyond the socially optimal scale. Economic instruments such as environmental taxes may induce a shift towards marginally more sustainable production levels for a plant of a given size, but they are not designed to affect the plant size itself. This paper suggests a method for determining a socially optimal scale, by focussing on the factors which determine optimality. The results of applying this method show that establishing the scale of production units at a social optimum rather than a private one implies a significant decrease in scale for most economic activities. Downscaling has significant economic welfare and environmental advantages. Incentives linked to the factors which determine the social optimum are put forward as measures for inducing a shift towards an optimal size for production units.

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1. Introduction

Even before Erich Schumacher's *Small is beautiful* was published in 1973, there has been a certain amount of unease about the relentless trend towards an ever-increasing scale of production units in order to take advantage of the economies of scale. The economies of scale had become a major part of economic understanding since the Industrial Revolution. But some have argued that there are several factors leading to diseconomies of scale which begin to outweigh these economies even at an intermediate scale.

This paper reviews mainly the environmental externalities that accompany plant size expansion, but also reviews the production unit's *internal* returns to scale. A more appropriate methodology for determining an optimal scale for production units is investigated. This is done by focussing on factors which determine optimality.

Incentives and disincentives linked to these factors are put forward as measures to be introduced by governments for inducing a shift towards a socially, rather than privately, optimal scale for production units.

2. Environmental constraints

There are several environmental or natural resource constraints which not only limit the overall scale of human activities, but also the scale at which individual activities can operate, because of a more than proportional use of resources as the activity expands.

Taking energy consumption as an example of one of the more serious environmental constraints currently being faced, the per capita US requirement for energy serves to illustrate the situation. The per capita requirement is just less than 300 kWh/day. The sectoral consumption is set out in Table 1.

Table 1: United States energy requirements (1997)

Sector	GWh/day	% of total	MtC	% of total	kWh/day/ capita	Solar aperture/ capita (m^2)
Residential	15 256	20%	287	19%	58	45
Commercial	12 205	16%	237	16%	46	36
Industrial	27 942	37%	483	33%	106	83
Transport	20 073	27%	473	32%	76	59
TOTAL	75 476		1480		287	224

MtC = metric tons of carbon

Sources: Calculations based on: Kribus, A. et al. 1995. Feasibility of a solar-driven combined cycle. Unpublished.
U.S. Department of Energy. 2000. Scenarios for a clean energy future. U.S.A: DoE.

Assuming an overall conversion efficiency of 20%, which is highly optimistic, the practicalities of converting this amount of energy from solar to any other form of energy (e.g. chemical (H_2), heat, electric current) will be problematic for the foreseeable future. Although the cost of producing electricity can be brought within reach of developed world incomes with the aid of subsidies, the cost of converting this energy to other forms is not yet affordable.

But more important than the financial constraints are the physical constraints. The surface area required to produce this amount of energy is vast. To serve the U.S. population, an area the size of the state of North Dakota would need to be covered entirely with solar thermal collectors. If the world's population were consuming at U.S levels, land equivalent to 40% of the United States would need to be covered entirely. Even if it could be afforded, the availability of the required materials, and the energy to produce them, comes into question. At almost 3% of the world's land surface area, it would even become a significant contributor to the displacement of natural habitats.

We should also note that transportation alone currently contributes a third of carbon emissions, and requires more than a quarter of the energy being used. This is significant, because the scale of production units has a direct impact on transportation requirements.

Rather than attempting to substitute fossil fuels with other sources of energy at current consumption levels, or attempting to save on consumption by marginally increasing the energy efficiency of various devices, appliances or vehicles, it may be better to look at the energy efficiency of the economy in general, that is, how to reduce the input of energy required to produce a given output towards meeting human needs. The key to this is to look at the scale of production units, and the impact of scale on energy costs, as well as material and ecological costs.

3. Economies and diseconomies of the scale of production units compared

Some factors of production become less costly per unit as the scale of the production unit increases, but others become more costly. In Table 2, we see an overview of the economies and diseconomies experienced in large scale production units, as compared to the economies and diseconomies experienced in small scale production units.

Table 2: Comparison of economies and diseconomies w.r.t. scale of production units

	Small scale	**Large scale**
Economies	• Short transport distances • Retention of quality of materials and energy • Reduced treatment and packaging requirements • Greater quality of management over full product life-cycle • Small external capital costs	• Lower internal fixed costs per unit of output • Lower average variable costs as a result of specialisation and division of labour and automation • Greater quality control over specific stages in product life-cycle
Diseconomies	• Higher internal fixed costs per unit • Higher average variable costs due to lack of specialisation and division of labour • Lack of quality control over specific stages in product life-cycle	• Long transport distances (labour, inputs, outputs) • Greater consumption of non-renewable energy • Loss of quality of materials and energy during transfer • Increased treatment and packaging requirements for the purpose of transfer • Lack of management over full product life cycle • Larger external capital costs per unit of output

4. Factors contributing to scale diseconomies

Each of the factors that contribute to the diseconomies of scale with respect to plant size will now be investigated in more detail.

4.1 Transport distances

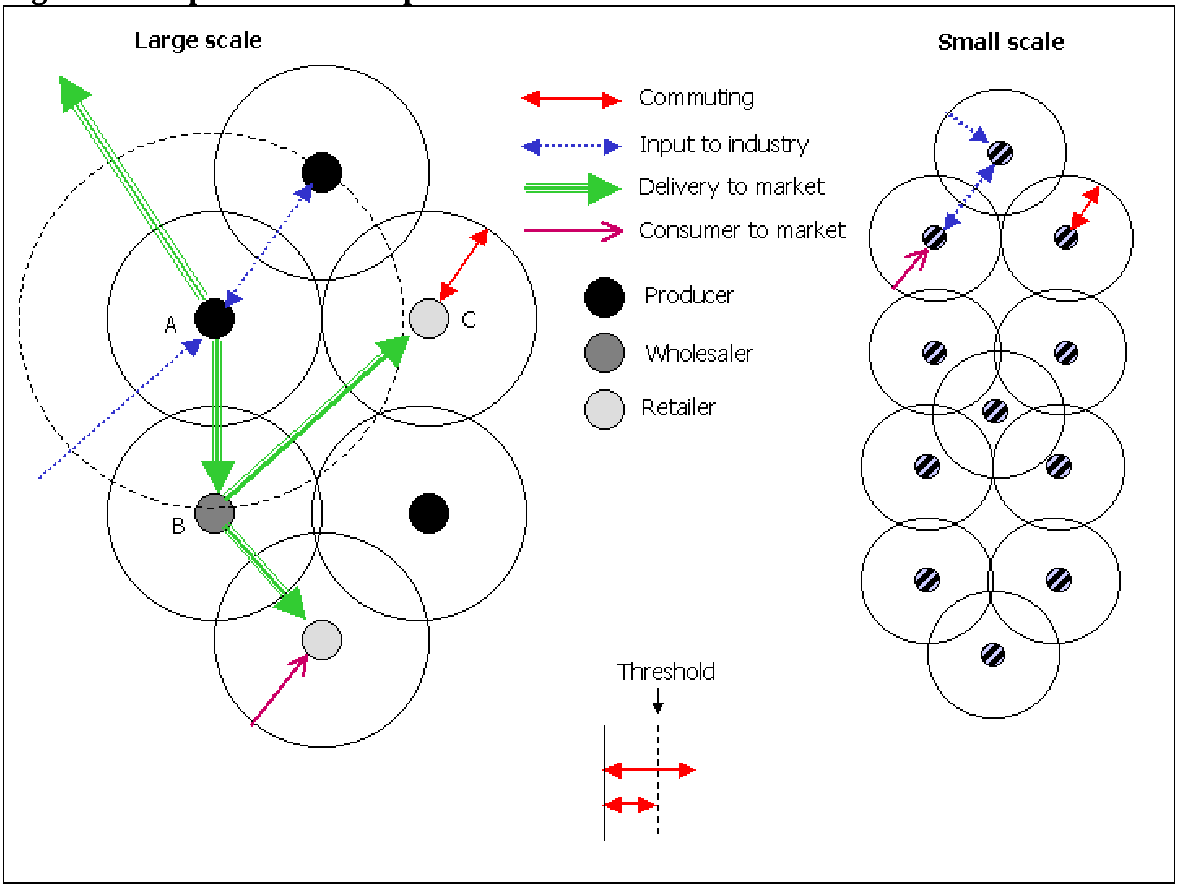
Large production units with large outputs are associated with large market areas and large input and labour catchment areas. Smaller production units will have smaller market areas and the diversity of labour required can be housed in close proximity to the plant. This may not happen automatically, but with small scale operations of 10 to 15 employees such arrangements can be made more easily than if 1000 people were employed.

A generalised schematic illustration comparing the different trips undertaken to and from a production unit are shown in Figure 1. Mainly four types of trips are undertaken, namely:

- employee commuting trips
- input-to-industry trips
- delivery-to-market trips
- consumer-to-market trips

The frequency of the latter two types of trips may increase if the mode of transport were also downscaled, because payloads are likely to be smaller. But below a certain threshold, the mode of transport could be reduced to cycling or walking, in which case a renewable source of energy is used, namely food. It may also result in savings on trips to the local fitness centre!

Figure 1: Trip distances compared



Below a certain threshold, production units are not specialised enough to warrant a distinction between producer and retailer, for example in the case of the local craftsperson selling from his or her workshop. This is indicated by the two-toned hatching in the small-scale circles. Above that threshold, a consumer may live at either point A or B, and need to travel to C to make purchases of individual items manufactured at A or distributed from point B, simply because there are no factory sales to the public, and wholesalers only sell in bulk.

Inter-regional trade is more prevalent amongst large-scale producers. The economies of scale manifested internally as lower unit costs of production as well as externally as less costly bulk transport, make transport over long distances more affordable. A larger market area is penetrated, represented as the dotted circle in Figure 1. Market area quadruples when transport distance doubles. The large resulting sales volumes are required to pay off large capital investments which have been made to take advantage of these economies of scale.

Competition is also more prevalent amongst large-scale producers, because market areas are more likely to overlap. This results in external diseconomies. As in Herman Daly's example (1996: 150), inter-regional trade means that Danish butter cookies are exported to the US, and American butter cookies are exported to Denmark. Overlapping market areas result in lower demand densities for each producer. Market areas therefore need to be expanded further yet, in order to compensate for these lower demand densities. Although qualitatively there is more consumer choice, this does not mean that more consumer needs are satisfied quantitatively. It can be questioned whether this variety warrants the resulting large negative externalities of scale, and whether, as Daly suggests, variety could not be achieved through the simple exchange of recipes. In essence, it can be questioned whether scale and competition drive down prices to a greater extent than the costs to society as a whole are driven up. As we will see later, it can also be questioned whether the lower prices per se are an indicator of increased welfare.

Motorised transportation, in turn, has its own externalities, amongst which are the following (Maibach, et al., 2000):

- Congestion
- Accidents
- Noise
- Air pollution
- Climate change
- Impact on nature and landscape
- Restriction of movement of pedestrians and cyclists
- Space scarcity in urban areas
- Additional upstream and downstream costs

The size of these externalities relative to the fuel price have been determined for the purpose of this study. The range of values are shown in Table 3.

Table 3: Estimation of transport externalities

Calculations based on:	Ratio to basic fuel price
Environmental Transport Association / Basden, A. (excludes road building)	3,10 : 1
Moving South Africa – SA Department of Transport	2,57 : 1
INFRAS, IWW – Maibach, M. et al.	2,31 : 1

As can be seen, there is some variation in the estimation of this difficult-to-measure variable, but most agree that current fuel taxes in countries worldwide do not cover these externalities. In South Africa the retail price of fuel is only about 1,9 times the basic fuel price. Users of transportation are therefore subsidised by society at large.

4.2 Greater consumption of non-renewable energy

Large-scale operations are usually more capital intensive. In order to run the machinery, a larger amount of energy from non-renewable sources is required per unit of output.

4.3 Loss of quality of materials and energy during transfer

Materials transported over long distances take longer to reach their destination. For example, foodstuffs lose nutritional value, and electricity needs to be converted to high voltage and then back down to low voltage before reaching the consumer. By contrast, food grown in the neighbourhood can be consumed shortly after harvesting, and water heated by a rooftop solar water heater does not need energy transformation at all.

4.4 Increased treatment and packaging requirements

Because perishable products need to be refrigerated, preserved and packaged, and fragile products need additional packaging to retain value, additional materials and energy are required over and above that required for transportation when producing for a mass market.

4.5 Lack of management over full product life cycle

Goods leaving the large-scale factory enter a long supply chain which includes distributors, wholesalers and retailers before finally reaching the consumer. Cradle-to-grave management is therefore difficult to implement, and usually the producer has no incentive to engage therein. Packaging, and even hazardous waste, often simply end up in the municipal landfill. On the other hand, the neighbourhood fresh produce stall manager can supply containers directly to the consumer and request their return for refilling. The proverbial lamp trader can exchange new lamps for old. Re-use or renewal of finished products is possible at the smaller scale, which is more efficient than recycling the materials from which they are made.

4.6 Larger external capital costs per unit of output

Much of the enormous amount of infrastructure required for transportation, often cited as an economy of scale or an agglomeration economy when it is shared, is in fact an additionality resulting from producing at a scale larger than a certain threshold scale.

5. Scale thresholds and dependent variables

In all of the above examples of diseconomies, thresholds are involved, namely:

- the points at which a modal change from non-motorised to motorised transport needs to be made for moving inputs, outputs, labour and consumers respectively
- the points at which products need to be treated or transformed for preservation (additives, pasteurisation, freezing, transformation of electricity to high voltage etc.)
- the point at which it is no longer feasible or practical to return packaging or spent products to the producer
- the point at which materials or energy need to be converted into another form in order to be transferred (drying, pulverising, heat to electricity conversion etc.).

There are also more gradual transitions with increasing scale:

- the transition from labour-intensive to capital-intensive production
- the transition from mostly well-paid managers of processes to mostly poorly-paid and semi-skilled or unskilled machine attendants
- the transition from varied work to specialised work.

6. The importance of determining transport volumes

In general, commodities lie between, on one end of the scale, high value-to-weight ratios (or value-to-volume ratios where bulk is a greater constraint than weight) and durability, and at the other end of the scale, low value-to-weight ratios and perishability. From the firm's point of view, the former commodities can typically be produced at a larger scale, and can have large market areas even if demand densities are low, while the latter types of commodities require high demand densities to have similar market areas. Typical examples of the latter are food and beverages, where high demand densities (units demanded per land area per time unit) make it feasible to transport commodities over long distances.

Transport volumes for the outputs of a production unit can be calculated as the product of the weight of the outputs and the demand density in the market area, i.e. kilograms per hectare per day, or similar. In terms of energy requirements, the constraint to transportation is determined by transport volumes. Firm decisions regarding profit maximisation would be based on the value-to-weight ratio as well, but from the point of view of resource conservation, the value-to-weight ratio is not relevant for the same reason. If the numerator (monetary value) is high enough for the firm, the transportation of any weight becomes feasible at regular intervals, but for society this depletes resources.

From an environmental point of view, high demand densities should be seen as a constraint to transportation over long distances, rather than as a facilitator.

7. Determining optimal scale

7.1 Development of a quantitative model

The unit costs of production are dependent on a relatively complex set of variables and interrelationships between these variables. Factors such as the product characteristics, specialisation of labour, market area overlap, population density and concentration nodes, and labour source areas need to be integrated to understand the effects of scale on unit costs and average income, which in turn determine profits and optimal plant size. A quantitative model has been developed to determine optimal plant size and market areas, namely the Scale and Market Area Optimisation Model (SCAMARO). This model uses all the factors mentioned and more in order to determine the optimal scale and market area of a production unit. Especially important are the characteristics of the commodity to be produced:

- unit mass and volume of inputs and outputs
- durability of inputs and outputs (in time units)
- demand density per time unit (monthly sales per km^2)

The production process of the commodity at different scales determines the following:

- long-run average fixed cost schedules
- long-run average variable cost schedules, specifying:
    - average labour remuneration
    - average material input costs

In addition, the population distribution across the potential market area is required. Other variables such as transport costs per mode, and packaging and treatment costs are also included in the model. Where variables are dependent on the scale of the production unit, this variation is modelled.

7.2 Indices for determining optimal scale

To determine optimal scale, assuming unlimited capital, firm decisions are based on maximising profit, which is achieved through a combination of low unit costs and large volumes, hence the pursuit of economies of scale. However, maximum profit does not necessarily imply maximum economic welfare, even if all profits were distributed in ways which increased economic welfare. To find maximum economic welfare obtained from a given economic activity, the *product earnings index* (PEI) is introduced.

PEI is defined here as the number of units of the firm's product that can be afforded with the average earnings of one hour's work, if the price of the product is set equal to the social cost. The social cost is considered here to be the factor cost plus externalities. The remuneration of entrepreneurship, or profit, is considered part of the earnings. It must be noted that firms can profit at the expense of society when social costs are not internalised. The concept of *social profits* is therefore introduced, and is defined as the difference between total revenue and social cost. The general ratio being determined for product earnings index can be stated as follows:

$$PEI = \frac{\text{Average remuneration per hour}}{\text{Average social cost}} = \frac{R/E}{SC/Q}$$

where:

- R = hourly remuneration of employees and entrepreneurs (social profits)
- E = number of employees and entrepreneurs
- SC = social cost of production
- Q = number of units of output

The PEI is related to labour productivity which is generally defined as the ratio C/E. But the PEI takes both hourly earnings and physical units into consideration to reflect the spending power derived from the production of a good in terms of the affordability of the good itself. The inverse of this value reflects the effort required to derive a certain amount of utility from the production process, or more precisely, the number of person hours required to be able to afford one unit of output. The PEI is of little interest to firm managers because all they need to know is that lower unit costs mean larger profits per unit, and when multiplied by large volumes, it will afford them all the spending power they need.

Using social cost in the PEI provides a truer reflection of the sustainable economic welfare derived from an individual economic activity than when market prices are used, because market prices are based only on current supply and demand, and not on future supply, which diminishes in the case of non-renewable resources. The social cost reflects the actual situation experienced in the marketplace after all desirable environmental taxes, which take account of future scarcity, pollution and other externalities, have been fully phased in.

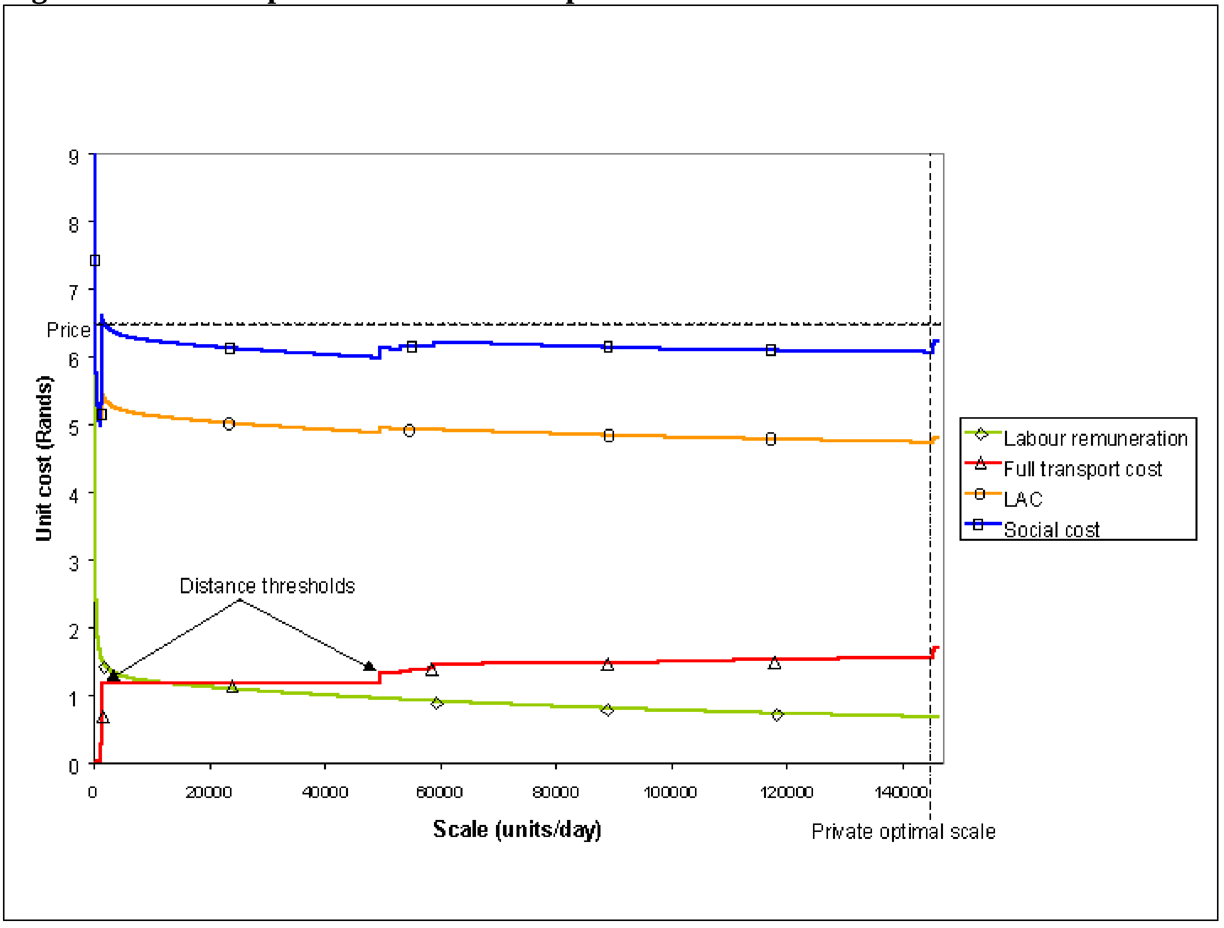
We shall therefore consider the scale at which maximum PEI is achieved as the optimal scale for the production unit. Although the PEI is not comparable amongst different products, it can be used to determine where maximum sustainable economic welfare can be obtained from the production of a given commodity.

7.3 Running the model

The model has been run with products of various characteristics. At first it was suspected that the scale at which maximum PEI is achieved is determined significantly by the fact that the average wage in a small firm is higher than in a large firm as a result of a higher ratio of management to labourers. The model was therefore first run assuming a uniform wage rate within the firm to eliminate this factor. Nevertheless, it was found that the PEI optimum is always at a scale smaller or equal to the profit-maximising optimum, regardless of whether wages are uniform or not, and regardless of their level, as long as both optima are profitable.

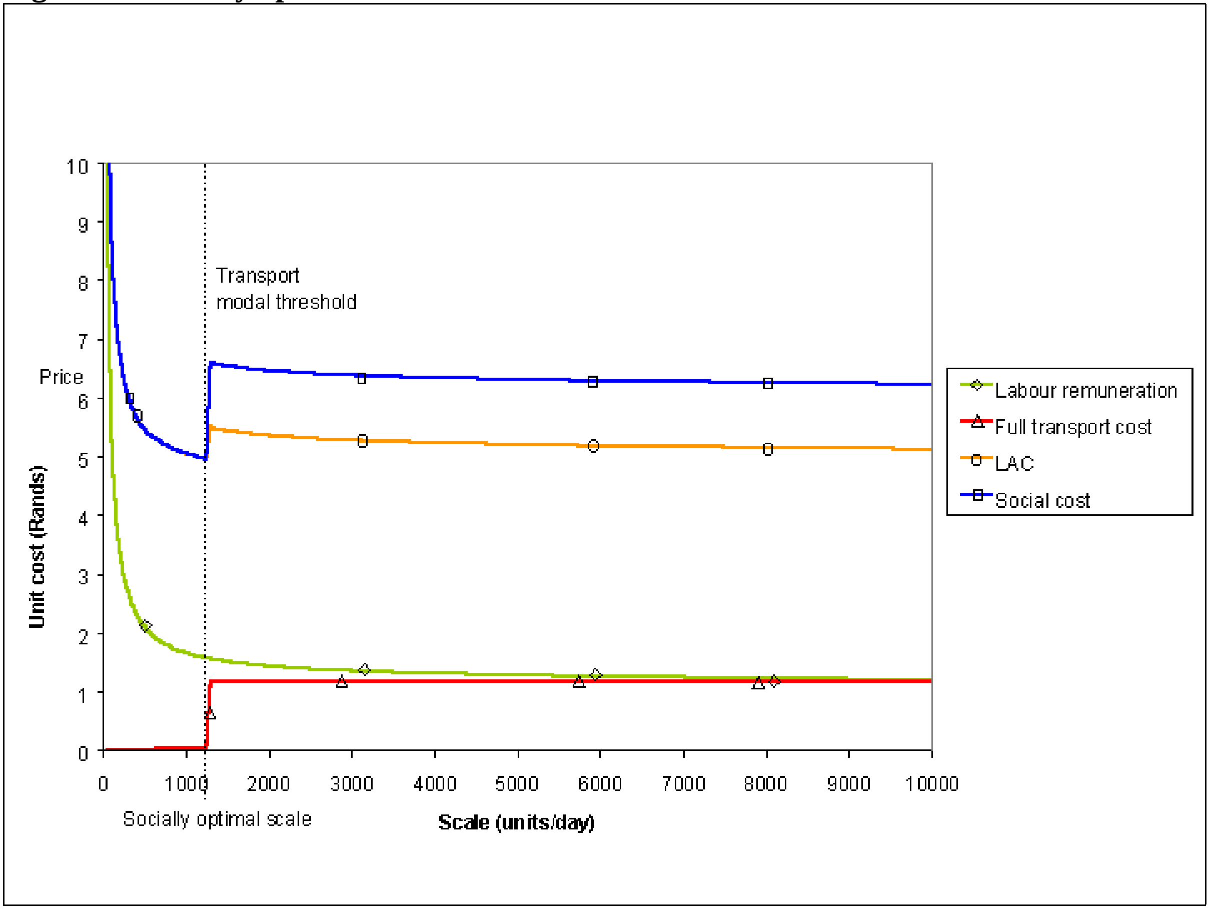
After allowing for wage differentiation and assuming that the firm is a price taker, an approximation of real world data for a fruit juice factory in South Africa's Western Cape province was entered into the model. It was clear, for example, why some of Pretoria's pasteurised orange juice with lower nutritional values in urecyclable packaging originates from the Western Cape (1500 km away) when oranges are grown in and around Pretoria on orange orchards as well as in many suburban backyards. Figure 2 shows the internally optimal scale based on profit maximisation.

Figure 2: Private optimal scale based on profit maximisation



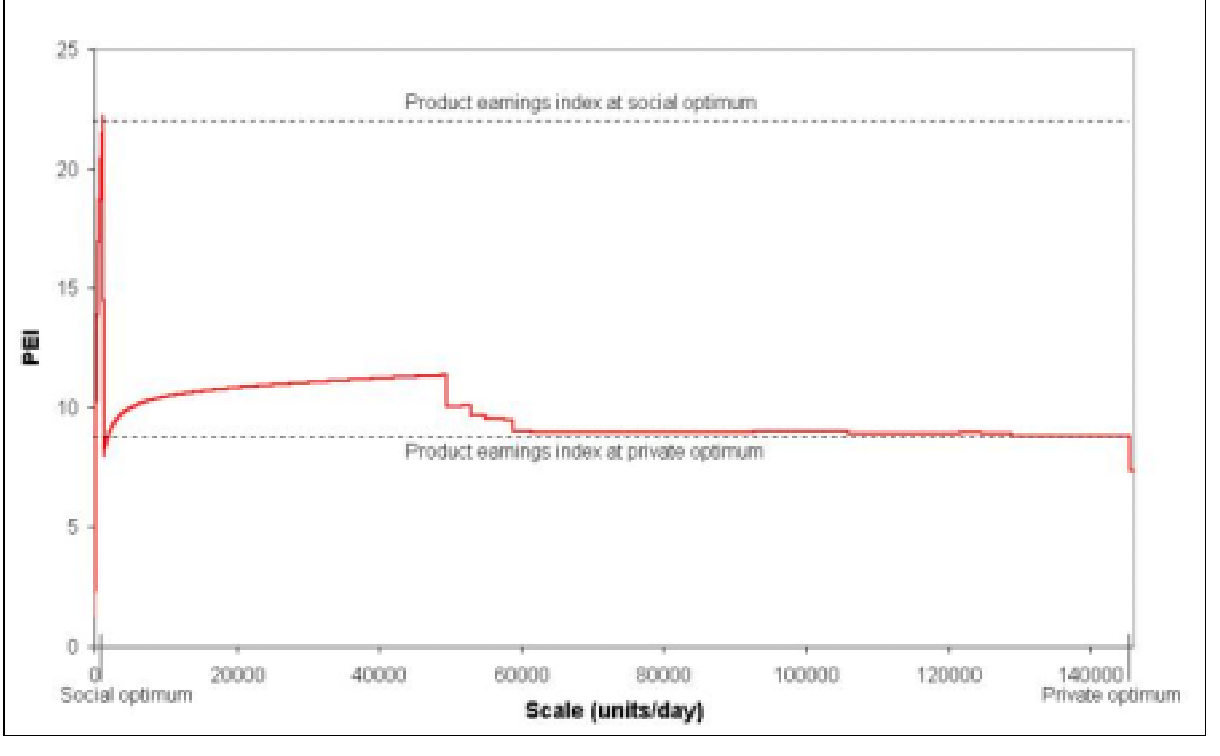
At the profit-maximising scale, the price per litre lies just above the social cost of production (which includes externalities as determined in *Moving South Africa*, 1998). The distance between the long-run average cost curve (LAC) and the price at the private optimal scale multiplied by the quantity are private profits. Entrepreneurs are therefore reaping profits mostly at society's expense. The scale of the horizontal axis of Figure 2 is too large to see what happens at the small end of the scale. Figure 3 zooms in to the small end.

Figure 3: Socially optimal scale based on maximum PEI



The transport modal threshold shown in Figure 3 is based on a market area radius of 2km which is considered to be maximum walking or cycling distance for moving outputs to the consumer. Figure 4 shows the PEI curve.

Figure 4: Product earnings compared



The stepping down curve is characteristic of the market area expanding from one urban centre to the next, and as transport cost increase at each distance threshold.

The profit-maximising optimum is at a scale almost 120 times as large as the PEI optimum in this example. But the PEI at the small scale (social) optimum is more than two-and-a-half times that of the large scale (private) optimum for the data used in the model. This is a significant outcome, so we need to understand why this is so.

The reason for this is that the average social cost varies with scale because different levels of energy and materials are used per unit of output with respect to scale. Coupled to this is the fact that although greater transportation to larger market areas facilitates greater consumer choice, it does not by itself add to the quantity of consumer products. For the most part, it is a non-productive factor of production, as are disposable packaging and certain types product treatments. Greater spending on these factors increase cost, while the product quantity remains the same. The result is a final product with a higher cost in relation to average earnings.

It should be noted that even if the concept of social cost was not included in the analysis, the PEI would still be greater at a scale smaller or equal to the profit-maximising optimum. For most products there are significant advantages to be obtained with respect to product earnings by operating at a much smaller scale.

7.4 The effect of transport volumes on optimal scale

The results of the analysis are sensitive to weight (or bulk) of inputs and outputs of the production unit respectively, and to the demand density in its market area. In terms of energy requirements, the constraint to transportation is determined by transport volumes. The private and social optima for various transport volumes for a product weighing 1kg is shown in Figure 6.

Figure 6: The effect of transport volumes on optimal scale

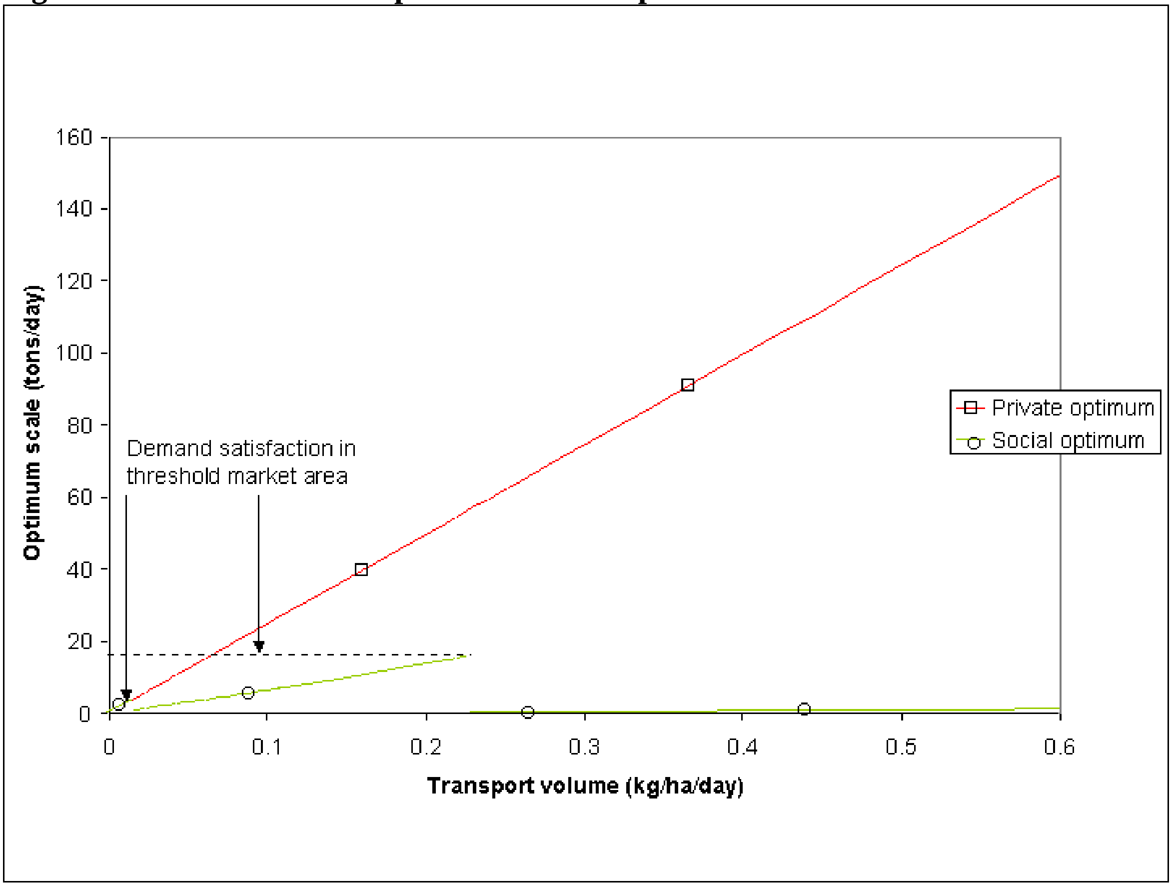


Figure 6 shows that the social optimum is lower than the private optimum even at low transport volumes. For example, a transport volume of 0,2kg/ha/day is equivalent to each person consuming 1kg every 6,5 months if the population density is 50 persons per hectare. At very low transport volumes, the social optimum is the same as the private optimum scale. The greater the quantities and/or the shorter the intervals between purchases, the greater is the difference between the social and private optimum scales. The transportation of goods in smaller quantities less frequently can be sustainable over long distances.

With assumptions such as 50 persons per hectare in urban areas, and urban areas with populations up to 4 million, the model shows that a product weighing 1kg can be produced for a national market of 13 million (the first distance threshold shown in the figure) from a single plant if a household consumed it once every 2 to 3 years. The same good can be produced for a city-wide market area with a radius of 14 km (second threshold) if each person consumed it once every 6 months. If transport volumes are higher, it should be produced for a market area which has a walking or cycling distance radius.

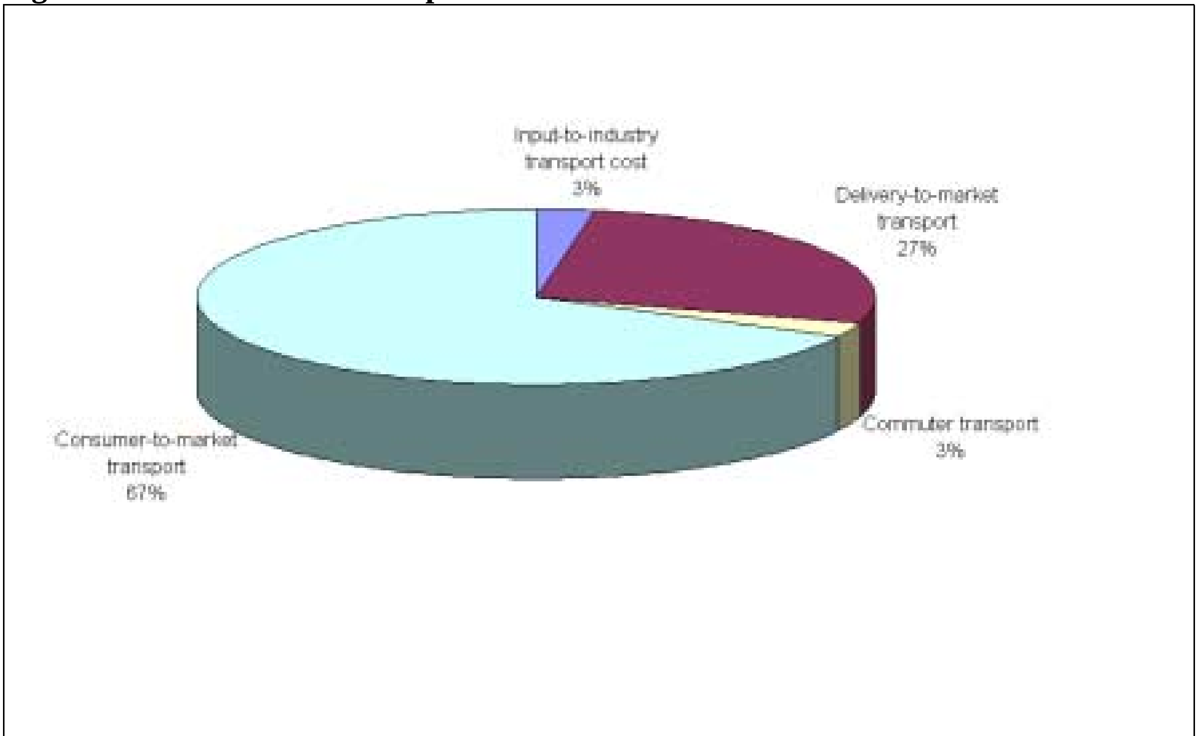
7.5 Transport volumes and potential increases in product earnings

The greater the transport volumes, the greater the potential savings from reducing scale to eliminate motorised transport, and therefore the greater the potential increase in product earnings. The potential increase in product earnings in the national economy resulting from a general move towards the socially optimal scale is currently being determined using data from amongst others the manufacturing census, but results were not available at the time of writing.

7.6 Distribution of transport costs

The SCAMARO model provides a breakdown of transportation costs for the modelled firm, operating at the large scale optimum, by each stage in the supply chain. This is shown in Figure 7.

Figure 7: Distribution of transport costs



Consumer-to-market transport costs, which are borne by individual consumers as opposed to organisations using bulk transport, constitute almost three-quarters of the transport costs along the supply chain for the example product. Producers do not carry this cost, nor are they primarily responsible for them. The scale at which retailers operate determines this cost. If retailers operated at a smaller scale and higher density, and their market areas were be reduced to a walking or cycling distance radius, producers would have more delivery points and a finer route network. To distribute the product to retailers downscaled in this way would imply on the one hand reducing the overall transport costs, and on the other hand, shifting the remainder of these costs to producers.

7.7 Benefits versus trade-offs

The question is, will an increase in product earnings resulting from operating at a smaller scale compensate for the decrease in the consumer choice which is available when forms operate at a large scale and engage in inter-regional trade? Choosing the socially optimal scale means that a greater degree of local self-reliance will be required. A greater diversity of products will need to be produced within the confines of a local community, and there will be less regional specialisation. Inland dwellers, for example, will not be able to partake in seafood as often, and coastal dwellers may need to make their own sacrifices. Retailers operating at a smaller scale may need to make pre-ordering possible to a greater extent rather than stocking more or less indiscriminately. But certain initiatives towards local self-reliance, such as urban agriculture and ecovillages have already been established successfully for several years now, based on the need for a more sustainable lifestyle and a healthier social arrangement than that which an industrial society offers.

For at least some consumers greater real earnings may be worth the reduction in consumer choice. A general move to the socially optimal scale across all industries would result in greater earnings for less work. It may be argued that greater earnings would result in higher prices as demand increases, but generally, the products with high demand densities are those for which the marginal propensity to consume is small, like food, beverages, energy and water. Demand will therefore not increase significantly if earnings increase. Greater savings will be available for the purchase of durable goods.

What is important is that this will lead to a more sustainable situation, because if production of all commodities could be downscaled to the social optimum, the direct savings on overall energy consumption could be in the region of 20%, and carbon emissions could be cut back by about 25%. This does not include indirect savings attributable to the upstream and downstream activities linked to transportation.

8. Policies and measures to induce movement towards an optimal scale

Environmental taxes are usually designed to induce a movement towards a level of production where the costs to society as a whole are minimised. This means that an optimum overall scale of production should be reached where the internal cost curve of externality mitigation with respect to scale intersects the externality cost curve. When referring to scale in this sense, it generally means the aggregate level of production, and not plant size as we have discussed so far. In order to achieve this level of production (or generate the revenue for mitigation), the environmental tax should be equal to the marginal external cost. However, this approach does not take into consideration the scale thresholds discussed in this paper.

To induce a movement towards the socially optimal scale would be quite a radical policy direction for governments to take, because it implies that most activities with even moderately high transport volumes per time unit would begin to operate at a much smaller scale, which would not only have repercussions for resource consumption, but for society in general, including some undoubtedly negative ones. It would be tantamount to putting the Industrial Revolution in reverse, but without a loss of technology. But if this policy direction were chosen, the following specific measures could apply to the various economic sectors:

For agriculture:

- a charge for large-scale mechanised and chemical processes which cause land degradation and loss of product quality.

For manufacturers:

- non-tax-deductible payment of full transport costs of employees, including compensation for time spent travelling
- a charge for the recycling costs of packaging not retrieved
- a greater charge for packaging which is not recyclable
- a charge for loss of value of products due to processing for the purpose of transfer.

For distributors and retailers:

- all of those applying to manufacturers where applicable, and
- a charge to compensate for transport costs of customers in market area with radius greater than a threshold, calculated from transport volumes and scale.

For service industries:

- all those applying to the above, where applicable, and
- incentives to allow people to work from home.

This list of measures is not exhaustive, and the details and impacts are still to be determined.

9. Conclusion

There are great environmental and economic welfare advantages to be obtained from downscaling production units with even moderately high transport volumes. The economic welfare advantages are especially evident when factoring in externalities, but it is important to realise that these advantages are evident even if externalities are not factored in, albeit to a lesser extent.

In order to shift the burden of externalities of especially transportation to producers, retailers and distributors also need to be targeted through environmental taxes. If retail and distribution activities are downscaled and replicated spatially in response to such taxation, this would require producers to carry a greater share of the distribution costs, which will result in a re-optimisation of the plant size. Inter-regional trade will be reduced substantially, and there will be a greater need for local self-reliance.

The analysis presented is bad news for the proponents of free trade and globalisation, but good news for several movements which have been in need of an economic justification rather than just a hunch about a sustainable future, such as the proponents of various forms of local self-reliance, namely ecovillages, bio-regionalism, permaculture and urban agriculture.

References

Basden, A. & Environmental Transport Association. 1998. *External costs of road use*. Unpublished.

Daly, H. E. 1996. *Beyond growth*. Boston: Beacon Press.

Hoover, E.M. & Giarratani, F. 1985. *An introduction to regional economics*. New York: Alfred A. Knopf.

Kribus, A. et al. 1995. *Feasibility of a solar-driven combined cycle*. Unpublished.

Maibach, M. et al. 2000. *External costs of transport*. Zürich/Karlsruhe: INFRAS, IWW.

Schumacher, E.F. 1973. *Small is beautiful*. London: Blond & Briggs Ltd.

South Africa. 1998. *Moving South Africa*. South Africa: Department of Transport.

U.S.A. 2000. *Scenarios for a clean energy future*. U.S.A: Department of Energy.