AN ECONOMIC FRAMEWORK FOR ENERGY TRANSITIONS

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ABSTRACT

There is special interest in the patterns of fuel use among low-income rural communities and their transition from one form of energy use pattern to another. Understanding energy transitions will help in developing energy policies for the poor and promoting new energy markets that will improve their household budgets. Energy suppliers, such as utilities, would be better able to work in low-income communities for their mutual benefit. Households could benefit from more convenient and healthier forms of energy. This paper develops a simple micro-economic framework describing aspects of energy supply and use in low-income settings. We assume that consumer utility is the driver of transitions, subject to fuel-appliance availability and budget constraints. We explore the hypothesis that reductions in "market failure" often help to encourage energy transitions.

1. METHODOLOGY

The purpose of this paper is to describe the cause and effect of energy transitions within rural low-income communities. In particular we investigate the role of market failure. To do this, we adopt a simple model of economic behaviour and show how energy transitions relate to this model. We then specifically discuss the relationship between market failure, energy transitions and the economic model. Finally, we argue that reducing market failures tends to encourage energy transitions to so-called modern forms of energy.

1.1 CONSUMER UTILITY

We assume that consumers tend to maximise utility, subject to constraints of budgets and the availability of consumables, and assume that this is bound by the information that they have at hand. Behaviour is therefore assumed to be rational, but "bounded" [1]. We define a consumer as someone that acquires goods or services for direct use or ownership rather than for resale or use in production and manufacturing. These goods or services are referred to as "consumables", and the consumer's budget is derived from his or her disposable income. Utility is defined as some level of satisfaction received by the consumer from consuming a good or service.

If the acquisition of consumables, $x_1,\ldots,x_n$, with prices, $p_1,\ldots,p_n$, increases the utility of the consumer and expenditure is limited by available budget, m , it is likely that some "best fit" mix of consumables (or Marshallian demand correspondence) will be purchased, where $x_1*p_1+\ldots+x_n*p_n \leq m$. Certain consumables may be more desirable than others and certain consumables may cost more than others. Certain consumables may not always available.

1.1.1 Energy service as a consumable

Services derived from energy use in appliances are a set of consumables that will receive attention. We shall term these "energy services". Clearly there may be differences in the utility associated with certain "luxuries", such as entertainment, compared to "basic needs" such as cooking. There may be differences in the cost of fuel-appliance combinations required to deliver energy services. Fuelwood and an open fireplace may be essentially free while a television and electricity are not. According to this model, energy services are chosen simply to maximise consumer utility, subject to budget constraints.

1.1.2 The energy transition

When there is a change in the fuel or appliance used to supply a service, we shall term it an "energy transition". Where different fuel-appliance combinations can supply the same energy service, there may be different costs and attributes that affect the choice of the combination. If there is little difference in non-cost attributes that affect utility, then, to maximize utility, the cheaper combination will be chosen. According to our simple model, the consumer can now receive the same level of utility but at lower cost. He can now reallocate the money saved changing his demand correspondence. Perhaps he shall consume more of the cheaper service, perhaps other services so as to increase his utility. (Similarly, where the same fuel, but a different appliance, can be used to provide the same energy service at a lower cost, it is likely that the new appliance will be replaced.) Depending on the efficiency with which the appliance provides the service, it may be that less energy is required to supply the orin, and that overall, costs may decrease. Such a change in the system is sometimes termed an energy conservation opportunity [2]. Further, if more of the same energy service is consumed, it may result in energy savings (were service consumption held constant) being offset by some level of increased energy consumption due to an increased demand for the said energy service. (Increased energy-service consumption due to a reduction in price of that service is known as the "rebound" effect [3].)

1.1.3 Market failure

A market is said to fail when the price established in the market does not equal the marginal social benefit of a good and the marginal social cost of producing the good. There are typically two (often related) reasons for this occurring. The first is that market structures are not optimal. The second that costs or benefits are not accounted for in the price of the consumable: they are "external", and referred to as "externalities". We investigate some causes of this failure, which will affect the prices paid for consumables, and energy-services in particular.

Market structures may not be optimal where competition is limited or restricted, such as in the case of monopoly suppliers or producers (although this does not necessarily create price distortions if regulated correctly). Certain types of incomplete information about the consumable will tend to result in externalities. For example, there may be misconceptions about the dangers or health effects of fuel-appliance combinations. Environmental damages, such as deforestation, may not be accounted for, which might affect future land value or the utility of future generations. Finally, distortions may have resulted from the situation of the supplier/ producer. We shall discuss these in the section describing market failures affecting producers.

1.2 PRODUCER PROFIT

We follow a similar argument to describe producer behaviour. We assume that producers wish to maximise their profits, subject to the availability of a market for their goods, as well as availability and cost of factors of production. Again their choices and rational behaviour are bounded by the information that they have on hand. We define a producer as a person or an organiaation that consumes or uses factors of production for resale or production purposes (including, therefore, subsistence producers and harvesters of fuelwood.). This takes into account the effect of increasing the output per unit, decreasing the cost per unit or substituting a cheaper factor of production for the existing one.

1.2.1 Factors of production

Classical economics distinguishes between three factors of production which are used in the production of goods:

- Land or natural resources – naturally occurring goods such as soil and minerals. The payment for land is rent.
- Labour – human effort used in production. The productivity of labour is dependent on aspects such as education, working conditions and health.
- Capital goods – human-made goods (or means of production), which are used in the production of other goods. These include machinery, tools and buildings. Machinery requires energy to function.

1.2.2 Energy services as factors of production

As machinery requires energy to function and a service is derived, we shall again use the term "energy-service", and "energy transition" for any change in the combination of machinery and fuel. The choice of machinery is limited by the energy carriers available to the producer. For example, if oil is available you can run vehicles, and if electricity is available you can provide services such as refrigeration with relatively low-cost machinery. If oil and electricity are not available, it is not possible to produce many energy-services required for scores of productive purposes, limiting the potential for development. Assuming that profit maximization is the goal, energy transitions, when they occur will tend to increase productivity and reduce costs.

1.2.3 The energy transition

We would expect several types of energy transitions to occur. Energy conservation opportunities are expected where the cost of supplying the required energy service is reduced. Rebound effects may result in less conservation than expected were there a change in service required. The producer might be able to substitute capital for labour. The option of new machinery holds the potential for significant improvements in efficiency and productivity. It also offers other productive opportunites such as increased beneficiation and new enterprise. This assumes, of course, that the local market would allow increases in productivity and new means of production to be translated into profit.

1.2.4 Market failure

At this point we describe certain market failures as they affect producers. We include both the suppliers of energy services and producers of other goods, which may be exported beyond the low income rural setting. Information on the market potential of consumables may be limited when producers seek to supply energy, appliances, machinery or other goods to new markets. Local labour may be less productive than expected because of poor health associated with local conditions. Access to markets (especially in the case of subsistence farmers) may be severely restricted, preventing any increases in productivity from being translated into profit. Furthermore, if producers are not in the cash economy it may prove difficult to for them exchange the goods they produce for the goods they want. Inefficient allocation of resources may also occur where a firm has a monopoly and can increases prices to increase profit. This is especially the case when consumers' demand for service will not change drastically with price, and regulation is inefficient. In the case of communal land access, rent may not be charged and there may be unclear, or unenforced, property rights. This might cause the land to be poorly managed – the "tragedy of the commons". High transaction costs for services may require several potential customers to pay the cost of the required investment before anyone can accrue benefit. If certain customers do not pay this cost they would receive a good for free (becoming "free riders"). In such cases it may be

difficult to regulate against free riders. This will distort prices.

1.3 CONSUMERS, PRODUCERS AND FACTORS OF PRODUCTION IN RURAL SETTINGS

For our discussion we shall now consider consumers and producers, and discuss certain factors of production in low-income rural areas in South Africa. We describe conditions that are similar to many other rural communities in developing countries.

We define consumers and producers in terms of activity rather than as separate agents. Thus a consumer could also be the producer: a subsistence farmer, for example, both produces and consumes crops – there are two activities taking place but only one agent, who takes on different roles at different times.

1.3.1 Low-income rural consumers

Consumers will often have limited and sporadic income. Typical energy services include the provision of heat for cooking, water- and space-heating, and lighting, refrigeration, entertainment and communication.

In South Africa, low-income rural communities, especially those not connected to the grid, rely heavily on biomass for cooking, space- and water-heating. Lighting and some thermal requirements are met by kerosene. Wood is often available at no financial cost and is therefore a fuel of choice. Candles are also used for lighting. Liquefied petroleum gas (LPG) is occasionally used for refrigeration, and batteries for entertainment and communications services. Modern fuel distribution systems are limited [4]. Communities may not be aware of the full health costs associated with indoor fuel burning [5], and can spend several hours collecting wood daily [6]. Health treatment is often subsidised by government through rural clinics [7]. Emissions may also damage the local environment. Where biomass is consumed faster than it is re-grown there is a loss of carbon dioxide to the atmosphere, resulting in global pollution [8].

1.3.2 Low-income rural producers

For this discussion we differentiate between three types of producer. The first is the fuel-appliance and machinery supplier. Though they may supply only one of these items, we shall term this the "energy-service supplier", and the category may include residents collecting fuel wood, shops selling fuels and appliances as well as the electrical utility. Secondly there is "local industry". Typically this operates on a small scale and may be informal; it includes subsistence farming. Goods may be traded, but this may be limited by access to markets, and transactions need not necessarily be cash based (as goods and services may be directly traded or swapped). Local industry is dependent on locally available fuels. Finally we define "other industry", which is industry that has access to fuels not available to local consumers. Other industry may rely in part on local labour.

In the case of the energy-service supplier, wood is often gathered at no financial cost. Access to the land where wood is grown generally does not require the payment of rent [4]. New entrants to the market, such as electrical utilities or LPG suppliers, have little knowledge of local conditions [9]. For the same reason, appliances and machinery marketed to consumers may be difficult to maintain [10] and may not produce the anticipated increase in utility or consumption levels [11]. In the case where suppliers are limited and incomes high, fuels such as LPG are charged at high rates [9].

For local industry, available fuels are limited. Typically, when they are electrified, households in remote areas receive only enough electricity to power a television and some lighting [12]. Local industry has limited access to markets and not all transactions are for cash. Therefore there may be a disproportionately low profit – or none – associated with increasing productivity. Consequently, if new energy-services are made available, there is no motivation for these to be taken up.

1.3.3 Land in low income rural settings

Land is often communally *available* though only six per cent of South African woodland is in fact communally *owned*, as there is often communal access [13]. In many areas it supports livestock, informal agricultural activities and wood-fuel growth. It is often subject to deforestation due to excessive fuelwood collection, especially in arid and semi-arid areas [14]. Due to dwelling-land patterns, ownership and management structures, communally available land is often not used for organised agricultural activity, nor is rent charged for its use. This consequently limits the potential for increased local production and employment. Generally, where energy investments in low-income areas require collective cost sharing, administration and organisation; this is often hampered by lack of knowledge and potential free rider problems [15].

1.3.4 Labour

The population, and therefore labour, in and from low-income rural areas, because of dependence on solid fuel burning, is often less healthy than in areas where commercial fuels such as LPG and electricity are the thermal fuels of choice [4].

2. CONSEQUENCES OF MARKET FAILURE REDUCTION

We now reflect on the effects of removing or regulating aspects of market-failure in the micro-economic setting we have described.

When land is better managed, rent should be charged in some form for the growing of fuel wood. (This should equal the marginal cost associated with fuel-wood growing including environmental costs. If it is not, the community is likely to pay the external costs or opportunity cost lost). Should this land be managed either by the community or local government, it may be used for other agricultural purposes and income may be derived from this [16]. The effects of removing these market failures will result in an increase in the price of wood, improved environmental management of the common, and, if other productive activity takes place, increased

income for producers. If these are local residents, consumers' income will increase, relaxing budget constraints. The effect of increasing the cost of wood, and the affordability of more convenient fuels, will tend to encourage a transition from wood.

Improved access to markets will allow subsistence farmers who produce an excess to derive profit from this. Increasing the proportion of cash to barter transactions will facilitate purchases of new fuels, appliances and machinery. Both of these effects will in turn increase the demand for new energy-services, which will encourage increased or new production. This will encourage a transition to non-fuelwood based energy-service.

Improving information relating to the health effects of fuel burning may change the consumption levels of different fuels. If people realise how damaging wood and kerosene are, they will consider purchasing more healthy energy services. If it is cheaper for the government to subsidise a clean energy service than to subsidise healthcare related to disease caused by unclean energy services, then this a more efficient subsidy. In these cases, again there will be a tendency to move away from fuelwood-based energy services. As there is a movement to cleaner fuels, health levels will improve and so will the productivity of the local labour force.

Should collective transactions be carried out efficiently, suppliers will be more likely to make a profit and pay less for the delivery of energy services. This will encourage the supply of non-fuelwood energy to consumers and producers. (Fuelwood can currently be collected by individuals, with little potential for benefits to free riders. It is also has a relatively low energy content for the volume that needs to be transported.) In the case of building or improving roads, if this is efficient, it will allow improved access to markets and increased productivity.

With improved information on consumption patterns and production needs, energy-service suppliers will reduce the costs of delivery and increase the potential for service payment. This will tend to reduce the costs of new fuels to consumers and producers, and to increase the profits of energy-service suppliers.

3. CONCLUSION: FUEL TRANSITIONS AND DEVELOPMENT

In all cases of reduced market failure, we see direct pressure to move from traditional fuels such as fuelwood to more modern forms of energy, such as electricity. As an indirect consequence, it is likely that more desirable energy-services will be used as incomes rise. In the case of rural South Africa, these will be services such as entertainment and convenient methods of supplying heat.

It seems that there is a link between reducing market failure and increasing incomes. While the link between income and fuel transition has been described [17], it is not clear what the relative roles of reducing market failure and increased incomes have played. It is, however, clear that with the availability or provision of energy-services the potential for increased producer profit and consumer utility can be significantly improved, which will tend to increase the demand for new energy-services. However, where certain market failures exist, changes in the availability of energy-services may have little effect [11].

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