Stakeholders And Market Transformation: An Integrated Analysis Of Costs And Benefits

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Synopsis

The paper takes a radical and integrated view of market transformation strategy. It concludes market based instruments cost more to consumers than efficiency standards.

Abstract

Market transformation is often an ill defined and misapplied phrase, but should include any or all actions which produce an irreversible and substantial increase in the energy efficiency of products sold. Policy options which may help to transform markets include research and development, technology procurement, labels, rebates and mandatory efficiency standards.

Based on innovation theory, this paper proposes that all market transformation actions may be used for any given technology, but at different stages in the development of the technology and the market (i.e., exploration, consolidation, minor innovation, or decline). An approach is proposed for selecting instruments at any one moment in time for a given end-use.

The paper then challenges the traditional notion that an engineering analysis can easily identify the additional costs associated with future efficiency improvements and the resulting consumer price, and examines two other approaches: analysis of the current market, and time series analysis of price and efficiency. An example is given where actual prices for energy efficient products appear lower than engineering estimates.

Many factors affect any theoretical additional cost. Innovative products carry higher development, tooling and marketing costs. On the other hand, economies of scale from increased production volume would reduce the cost of efficiency improvements. Thus the actual cost of future efficiency is not fixed, but is policy dependent. Improvements in efficiency made through market based instruments (energy labelling and rebates) allow greater profit margins for manufacturers at greater cost to consumers, compared to savings made through efficiency standards which may cost more to manufacturers but with lower costs to consumers. The net cost and benefits to different stakeholders of improving energy efficiency thus depends on the mix of policy, and this should be explicit in any market transformation strategy.

Market transformation should be a much more integrated process, based on a wider and deeper analysis of costs and benefits, and not a collection of uncoordinated instruments implemented by different actors with different motivations.

1. Introduction

Purchasing decisions can be influenced through several approaches:

- informational instruments, which presume that, if consumers had more information, including the operating expense or the environmental impacts of the products they buy, some consumers would purchase more energy-efficient products. Energy labels have recently been introduced in Europe for a variety of products, and addi-

tional consumer advice programmes are under development in several countries to allow labels to be used as a tool of comparison between similar products,
- regulatory instruments, which ban the manufacture and sale of less energy-efficient designs in the whole market, and
- economic instruments, which broadly attempt either to raise the cost of polluting, or *reduce* the cost of *preventing* pollution and thus influence buying and behaviour patterns. Examples include rebate programmes which reduce the consumer purchase price of the most efficient appliances (Vine 1996), and procurement programmes which guarantee a market for preferred technology and hence reduce the risk associated with new product development (NUTEK 1993, 1994).

Market transformation has been described elsewhere as aiming to produce significant and lasting change in efficiency of appliances sold, and may use any or all of the above instruments. Geller and Nadel (1994) describe a number of specific initiatives applied to a number of end uses (refrigeration appliances, lighting, motors and others). The most useful theoretical conclusion was that the direct effects of technology procurement could be to increase market penetration of a new technology to 2% while the indirect effect may be much greater. As rival manufacturers introduce similar products to market in order to compete, the technology may increase to say 10% penetration. Rebates or tax differentials could increase penetration to say 20-40%. Minimum standards may underpin the transformation and increase penetration of an efficient technology to 100%.

The programmes that Geller and Nadel examined were implemented by different actors at different times for different reasons. A utility may do Demand Side Management only because in certain (and increasingly restricted) circumstances it is cheaper to promote efficiency than to build new generating capacity. That logic is entirely different and unconnected to why government might consider mandatory standards cost effective from a societal perspective.

Sadly, individual programmes which may be part of a market transformation strategy continue to focus on what should be considered tactical issues (a particular level of standard, or whether the IEA should develop a specific technology procurement programme). There is a failure to recognise that a market transformation strategy requires more than, and achieves more than, the sum of its parts. This paper aims to develop a framework or strategy for market transformation, within which those tactical issues could be considered. In particular:

- it revisits innovation theory to discuss the different impacts of instruments,
- it then discusses how government might select one instrument at a particular moment in the development of a technology,
- and it discusses how different instruments have different costs and benefits to different groups. The net cost and benefits to different stakeholders of increasing energy efficiency thus depends on the mix of policy. It would seem rational to minimise the costs to both groups, and therefore to use some mix of incentive and regulation to minimise the risk that one group in particular would benefit from, or bear the cost of, improved efficiency.

2. Innovation theory and market transformation

Innovation theory and market transformation is briefly discussed by Nilsson in 1992, but is worth revisiting and extending. Roy (1994), describes several stages in the evolution of a product:
1. the exploration stage, in which inventions and experimental designs are conceived and developed,
2. consolidation, when a limited range of dominant designs is established,
3. maturity, in which a range of standardised products is produced efficiently and diffused widely into society, the emphasis shifting from product to process innovation,
4. minor innovation and development of product families, to capture new markets,
5. decline and replacement by products based on a new concept or technology, thus beginning the evolutionary process once again.

Innovation theory recognises that the market is inherently dynamic, where technologies compete for survival.

Table 2.1 shows a number of technologies evolving, becoming dominant and potentially dying out, in relation to one particular process, that of cleaning clothes. While society may always want clean clothes, the technologies available to achieve clean clothes is constantly progressing. Figure 2.1 shows that in terms of ownership the refrigerator has, since 1975, been in decline, and freezers have almost saturated in terms of penetration, though the upright freezer is growing in comparison to the chest freezer. The dominant design is the combined fridge freezer, which is demonstrating an almost classic S curve, or epidemics model. Crudely this proposes that the pattern of adoption of an innovation is similar to the pattern of spread of disease; beginning from a low base, increasing as the innovation becomes more efficient, then slowing as potential 'adopters' become scarce.

Table 2.1 Innovation and washing technologies

exploration	dolly tub with a motor and integrated heaters, addition of motor powered mangles, development of twin tubs, better controls lead to single tub, vertical axis, horizontal axis automatic
consolidation	dominance of horizontal axis machines,
maturity	innovation on production rather than design reduces costs, electronic controls replace electro-mechanical, penetration to 95% ownership,
minor innovation (development of sub-technologies)	falling wash temperatures, reduced water consumption (e.g. shower wash), fuzzy logic replaces fixed response, higher spin speeds,
decline and replacement	development of a new technology e.g. tubless drum, or ultrasound or bubblewash

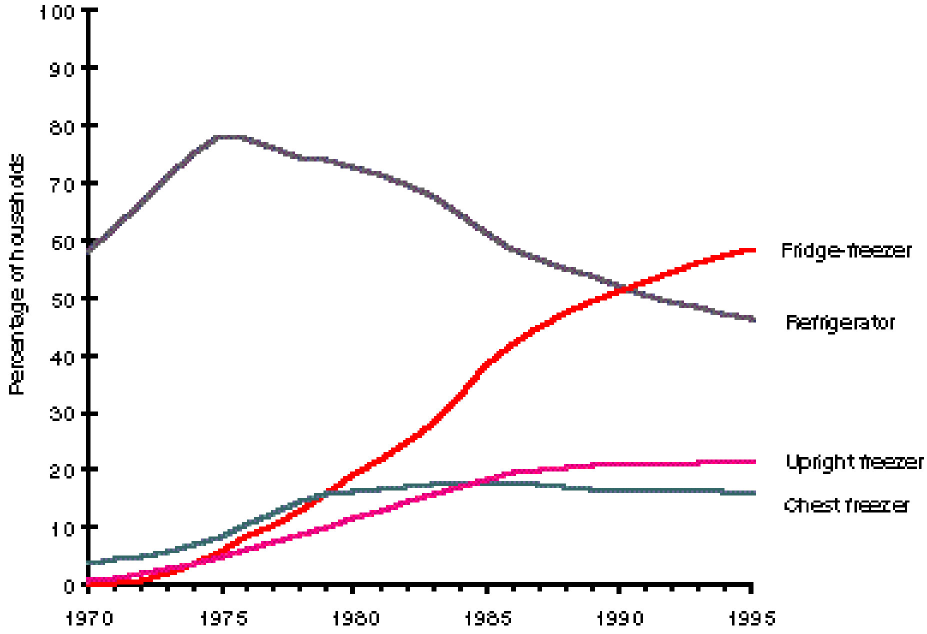

Figure 2.1 UK Ownership of cold appliances

The biological analogy for competition between technologies can be extended. Using a Darwinian evolutionary model for the spread of innovation, Langrish identifies five essential and common characteristics of biological and technical evolution:

1. competition,
2. variety,
3. some mechanism for ensuring the transmission of the attributes of fitness to a new generation,
4. some mechanism for the production of novel entities (i.e. some analogue to mutation of the genes), and
5. changes in the rules of fitness.

(Langrish 1987 p.1)

In the animal world, the 'rules of fitness' are the laws of nature. If the climate changes, animals have to adapt. In the human world, the rules of fitness are controlled through market acceptance and, to some extent, through legislation, so for example:

> safer automobiles are not obtained by asking designers to design safety into cars. In survival terms, it is first necessary to ask politicians to pass legislation that ensures the non-survival of non-safe cars. (Langrish 1987 p.3)

In the market for domestic appliances the 'rules of fitness' are changing to incorporate energy efficiency. Langrish suggests that according to Technological Darwinism:

> if inventions occur randomly in large numbers and only a small number survive, the timing of important innovations should depend on the survival conditions and not on the invention producing mechanism... [In a period of sudden change] technical ideas which already existed in many cases, acquired some advantage over other technical ideas and were hence made use of. (Langrish 1977 p.37)

Thus, while ideas about energy efficiency have been around for some time, these ideas may be more important now than they have been, because of a change in the 'rules of fitness'. These conditions can be changed through policy intervention at any or every of the above stages for any particular end use. It was shown above that to achieve the aim of clean clothes there are several competing technologies (or sub-technologies) which could in the short term be optimised, and in the long term replaced. The ideas of Langrish and Roy can be combined with policy instruments (Table 2.2).

There are thus several essential and inevitable conclusions from this: there is a natural change in the market as individual consumer preferences, spending power and technology evolve, and manufacturers eagerly respond. Individual choice can legitimately be collective, or societal choice and affect the products offered or chosen, through Langrish's 'rules of fitness'. Manufacturers deciding their product offerings, as well as consumers making purchase decisions are in a position to influence the rules of fitness. The replacement of refrigerators with combined fridge freezers is a transformation in the market triggered by consumer choice and spending power. There is no reason why the 'rules of fitness' could not be changed to affect the market as dramatically. However, in achieving such a transformation, policy should recognise the long timescales, and the various stages that an innovation may go through, before achieving transformation.

At any one moment in time, one of these approaches is likely to be applicable to any particular technology. To take an example, Compact Fluorescent Lamps have moved beyond the exploration phase, but only relatively recently. There has been a lot of work on electronic ballasts replacing magnetic ballasts, on size, flicker, speed of reaction, and increasing light output. Consolidation could be encouraged through rebates (which in the UK the Energy Saving Trust continues to develop), or tax differentials (such as reducing Value Added Tax on energy efficient products) which would provide a more substantial mechanism for consolidation. At some stage in the future, depending on a variety of factors, it may be appropriate to consider encouraging decline of old technologies (e.g. magnetic ballasts) through minimum efficiency standards.

With regard to refrigeration appliances, different parts of the market are at different points on this scale, and effi-

Table 2.2 Roy, Langrish, and market transformation

Roy (innovation)	Langrish (Technological	Appropriate policy instruments Darwinism)	Market share of 'efficient' products
exploration	encourage innovation	research and development, procurement	0-2%
consolidation	give the 'fitter' products an advantage they did not previously have	labels and tax differentials or rebates,	2-20%
maturity		labels and tax differentials	20-30%
minor innovation	discriminate between products	labels, short term efficiency standards	30%-40%
decline of inefficient and replacement with efficient	threaten the survival of the least 'fit' products	long term efficiency standards	40%-100%

ciency standards can remove the most energy-consuming appliances, labels can differentiate among remaining products, and technology procurement can encourage development of technologies for additional energy savings (e.g., vacuum panels) simultaneously.

3. Market transformation as an integrated process

3.1 Applying market transformation initiatives to product groups

The above description emphasises time as an important variable, and efficient products sold as a percentage of all sales to be a legitimate public concern. At any one moment in time, policymakers have to make decisions about what programmes are most appropriate for any given product group. How?

The first requirement is a reproducible measure of consumption and efficiency (and increasingly field performance). At the tactical level, test protocols already exist for many appliances (e.g. the cold - refrigerator and freezer - and wet - washing machine, dishwasher, and tumble dryer - appliances). A test method for ovens is in the process of updating. However, for some appliances where this is not the case, there may be no reason why a protocol could not be developed. Test methods are a priority for hobs and other cooking appliances.

Once efficiency can be measured, it can be influenced. Figure 3.1 shows a distribution of efficiency on the current market in the UK, and how parts of that distribution may in future be affected. The three curves show:

- Before intervention: the baseline is the distribution of efficiency for all cold appliances offered by Scottish Hydro Electric prior to the introduction of labelling, where the average model available was an F.
- After labelling: the first stage of market transformation is product differentiation with labels, together with retailer education. The distribution of efficiency of models offered by Scottish Hydro after the introduction of labelling is illustrated. The average model offered moved up to a D (the average of the EU market), with a over-

all improvement of 19% in a single year.

- Market transformation: a theoretical distribution is illustrated, combining a 15% efficiency standard, plus rebates or tax differentials to increase sales of more efficient products and procurement programme. The average appliance might become a B on the label, equal to a 20% improvement on the current EU average, but still accessing only about half of the ETP described by GEA using current energy and equipment prices and excluding vacuum panels.

This process is not static, and the threshold levels for labels, standards, and rebate levels could be revised as research shows it to be economically justified, or until technical limits have been reached.

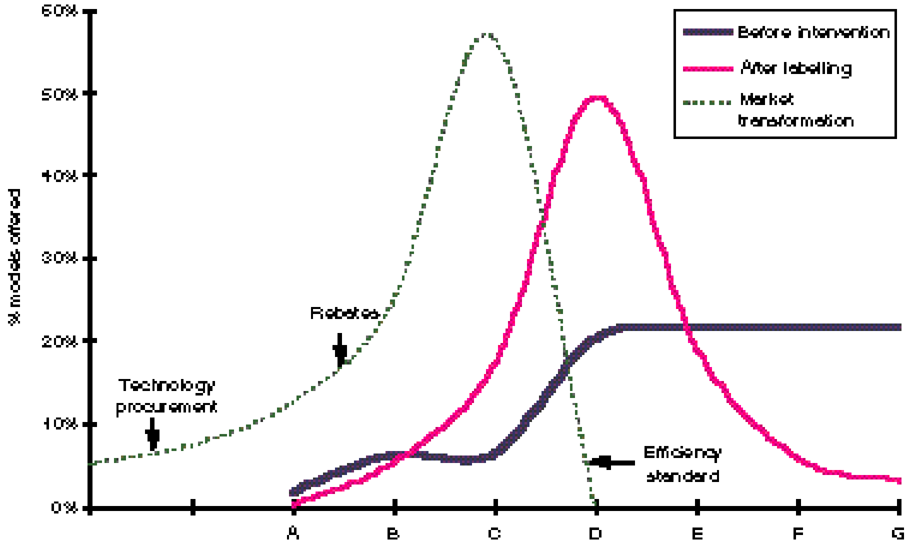

Figure 3.1 Three stages in market transformation (DECADE 1995)

Applying this theoretical perspective to an end-use requires analysis such as:

- What is the scope for efficiency in a particular end-use, both in absolute terms, and relative to other end-uses?
- Can efficiency be measured easily and reproduceably (i.e. is there an agreed test protocol)?
- At what point on Roy's evolutionary scale is a particular technology: exploration, consolidation, minor innovation or decline?
- How quickly could a technology be expected to move through these stages?
- Is there a range of efficiencies on the present market, and is it useful to differentiate by labels?
- Is there significant potential from optimising an existing technology?
- Is there a relatively new technology on the market but which has a high purchase price, high marketing costs, limited market penetration, and which does not yet benefit sufficiently from economies of scale? (e.g. CFLs and induction hobs).
- Is there a large technical potential for improvement beyond the current market from new technology (e.g. vacuum panels)?
- Is implementation politically feasible given rates of technical change, consumer acceptance, and manufacturer acceptance?

Theoretically any of the policy interventions described above could be targeted at any appliance group (Table 3.1). The number in the box is a subjective ranking from 0-5 (from least to most potential for change) using the best judgement of the authors (and intended to initiate further discussion) based on an assessment combining both the potential improvement in efficiency from that action and total consumption in that appliance relative to other appliances, and informed by total savings from each group identified for the UK by DECADE (Figure

3.2). The effect of policy instruments can be difficult to separate, for example, labels and standards have been under development simultaneously for cold appliances. Are improvements due to standards or labels or a synergistic effect? Similarly, long term efficiency standards depend on introduction of new technologies like vacuum panels through procurement.

Other factors may influence the choice of alternatives (such as speed of savings, certainty of savings, cost to different stakeholders, equity to different social groups), but have not been considered in Table 3.1. The table assumes:

- vacuum insulated panel for refrigeration might be encouraged by technology procurement,
- Compact Fluorescent lamps might benefit from rebates to increase market penetration, and standards for luminaires to accommodate CFLs,
- for electric storage water heaters, procurement might encourage better water heater controls to reduce the time for which water is hot, encourage more solar water heaters, and heat pump water heaters, whilst efficiency standards could effect better insulation reducing the rate of heat loss,
- low emissivity and low thermal mass ovens might benefit from technology procurement,
- heat pump tumble dryers might benefit from technology procurement,
- induction hobs might benefit from technology procurement,
- insulated kettles might benefit from procurement programme

The relative importance in policy terms is a notional figure, and adds together the importance of each individual policy action. Appliances are ranked in terms of relative importance, as too are policies.

Table 3.1 Indicators for policy selection for new appliances

	new technology	recent technology but high cost	Range of efficiency on the market	optimising existing technology	
Stage of innovation	exploration	consolidation/ maturity	minor innovation	decline of inefficient	
Policy	R&D or procurement	rebates or tax incentives	labels	standards	relative importance
Lighting	2	5	4	3	14
Freezer	4	2	3	5	14
Fridge-freezer	4	2	3	5	14
Refrigerator	3	2	3	5	13
Water heating	3	2	2	4	11
Oven	3	1	3	4	11
Washing machine	1	2	3	3	9
Tumble dryer	2	1	3	3	9
Dishwasher	2	1	3	3	9
Hob	2	2	1	2	7
Kettle	2	1	1	2	6
Televisions	1	0	1	2	4
Videos	0	0	1	1	2
Microwave	0	0	1	1	2
	29	21	31	42	

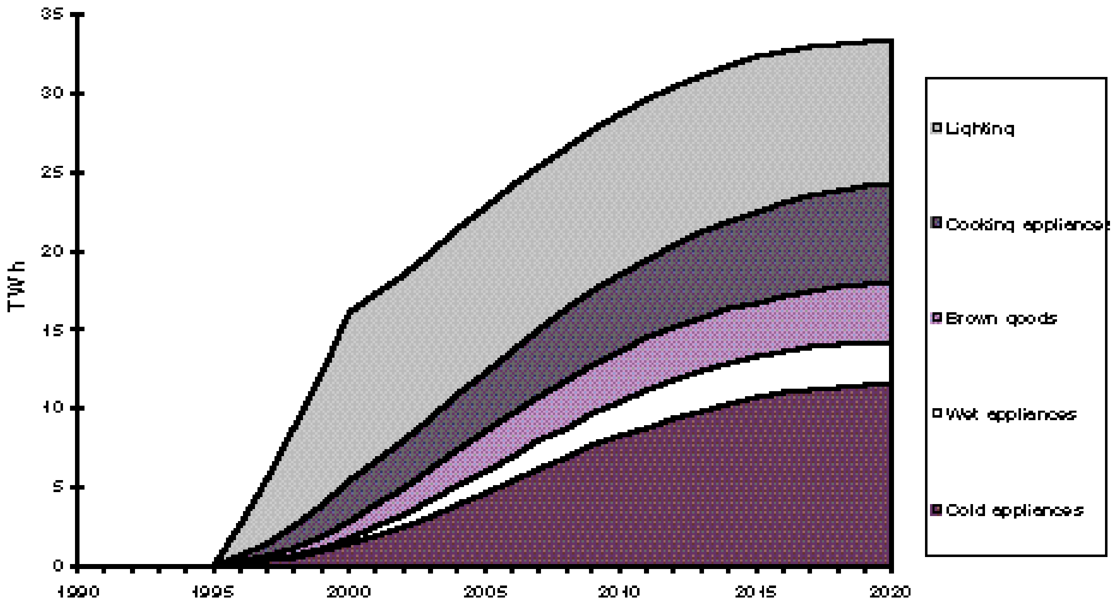

Figure 3.2 Economic and technical savings potential by appliance group, UK 1995-2020 (DECADE 1995), note this study does not include potential savings from water heaters.

3.2 From tactics to strategy: assembling a market transformation strategy

Assembling these tactical components into a strategy requires recognition of several important principles.

First, as discussed above, the ability to measure efficiency is crucial. From a strategic perspective, the process by which test protocols are developed needs examining. At present in the EU, manufacturers have almost complete control over test protocols since harmonisation is seen as an industrial issue not a government issue. In addition, given that there is little public money, the process of revising test procedures has sometimes taken as long as seven years. In the US, the legislation directs NIST (National Institute of Standards and Technology) and US DoE to develop test procedures, based, to the extent possible, on test procedures developed by the appliance industry. DOE has issued test procedures for all 13 classes of product, though these have been modified a number of times based on NIST recommendations (Millhone 1992). In the US, NIST is better placed to assess test methods, and set in train revisions, in consultation with industry.

In the EU, a process is needed that can obtain consensus among all stakeholders (not just manufacturers, but consumer organisations and market transformation programme designers) for a test that provides a fair and replicable ranking of products with respect to energy efficiency, maintain stability in the test procedure for reasonable time periods, and yet be timely in adapting to changing field conditions or new technologies. Test procedures for all appliance groups need updating to be more in line with actual consumer behaviour, and to reduce the tolerances that are allowed in testing to make them more reproducible and less open to challenge or interpretation. Such a process would need enshrining in an EU Directive, together with a regulatory committee, and the appropriate budget to commission research.

Following on from the ability to measure efficiency, must be the recognition that policy initiatives do not exist in isolation, should be designed to be complementary, and should be in stages to make a progressive and logical transition, avoiding conflicting policy signals and disruptive changes. The most beneficial combination of initiatives will depend upon a variety of factors. These include the objectives to be achieved as well as the characteristics of the appliance and its market, as identified above.

- labels (or at least some ‘line in the sand’, about what is efficient and what is not) are a necessary base for several policies.

- The impact of labels is strongly influenced by the knowledge of the retail staff. Consumers are influenced by sales assistants, particularly with rare purchases, such as white goods, that are bought in 'distress' because the old appliance has failed. If the retail chain has not trained their staff and discussed the importance of energy efficiency with them, the impact of the label will be much reduced.
- Given labels, rebates can dramatically boost the share of energy-efficient products kept in inventory and sold to consumers. Financial incentives can be offered at several points in the distribution chain for models with targeted energy performance, to manufacturers (to increase production) to retailers (to stock and promote) to consumers (to purchase).

There are key interconnections between actions:
- the upper level of label categories could be set by the results of new technology procurement, so that only products from or equal to the procurement exercise achieve an A rating.
- label categories can lead to definitions of standards (e.g. ABC survive)
- today's rebate levels (e.g. rebates for A and B), or procurement programmes (A) can provide valuable experience as one input into considerations about tomorrow's efficiency standard. The US refrigerator 'golden carrot' programmes complimented efficiency standards by stimulating the market to increase the average efficiency of appliances on sale (Geller and Nadel 1994), and provided a useful basis for discussion about what was technically and economically feasible.

There are obvious interconnections between the consequences of different actions, In particular, the question of whether savings are overlapping, or additive or synergistic. For example;
- could it not be argued that rebate programmes in 1997 are an expensive way of increasing market share of ABC appliances, when standards in 1999 will allow *only*ABC to survive? And who does the cost effectiveness calculations to justify such programmes?
- and, if models are eliminated owing to standards, what are they replaced with? Do manufacturers aim just to comply? Given the label is simultaneously revised to take into account the effect of standards, do manufacturers aim to avoid the new F and G label categories, and therefore move 10-20% above the standards line? Or if there are new rebates, do manufacturers aim for these incentives and move up to 30% beyond the standard?

Incentive and regulatory programmes are not, as they have often been presented, alternatives. Instead they should be seen as complementary. In terms of certainty and coverage, the impacts to be expected from advice, information, and labels are not certain and do not normally induce complete transformation, while efficiency standards provide the most certain and most complete energy savings. On the other hand, it is often claimed that minimum standards stifle innovation, becoming a de facto maximum efficiency rather than a minimum efficiency (building standards are a case in point). However, maintaining other incentives such as labels, rebates and procurement avoid this effect and ensure that there is always a clear incentive to improve efficiency.

In addition to having differing roles, policy instruments can be shaped at various political levels, including member state, EU level or through the IEA, for example:
- The extent of financial support (e.g. through rebates or through advertising and information) are national political decisions. Changes to the level of value added tax on appliances, within certain limits, are properly introduced by primary legislation in each country.
- EU labels and minimum standards require the support of member states, as well as separate implementing legislation in member states (on issues such as responsibility for verification, enforcement procedure and penalties for non-compliance).
- The International Energy Agency is devising a series of initiatives on technology procurement. Member countries inside and outside the EU can opt into these programmes.

It is important for optimising cost effectiveness that these options are developed and assessed together. A lack of co-ordination between policy-makers working on apparently separate elements of market transformation could lead to say, rebates and efficiency standards trying to make the same saving twice. It is clearly important to spend public money in the most cost effective way, and integrate these points. Without laying out aims, the net effect of the status quo -both in terms of costs and savings- is likely to be sub-optimal. The most appropriate combination of policies could achieve a synergetic effect and produce greater savings at lower costs than the sum of the individual initiatives.

For instance, if a model is taken off the market, because it is below an agreed standard, the manufacturer could decide to retain the existing, restricted range (with a shift toward increased volume of production of an existing model already in compliance) or (in response to other market transformation actions) to expand the range to include new and more efficient models. All of these factors affect the real cost of accessing efficiency, and this is now explored more fully.

4. Estimating the cost of additional efficiency

The future price to consumers for additional efficiency is very difficult to estimate. The traditional approach has been an engineering analysis to identify the increase in purchase price associated with improvements in efficiency. Weaknesses in current methods of evaluation of additional costs have been criticised by Krause *et al* (1995 p.15). An alternative approach might be to analyse the range in price and efficiency from the current market. A third might be to identify long term changes in efficiency and long term changes in price on the market. This discussion compares these three approaches, and suggests that traditional engineering analyses may tend to overestimate additional costs of efficiency.

The cost to the manufacturers of additional improvements in energy efficiency is different from, and in truth only loosely related to, the price the consumer pays for additional efficiency. In this analysis, the cost to the manufacturer of design changes is analysed separately from additional purchase price to the consumer.

While there is a varying relationship between purchase price and efficiency of appliances on the current market, ranging from a weak relationship for cold appliances, some relationship for washing machines, and a strong relationship for lightbulbs, it is argued that the relationship between price and efficiency is not a simple one of additional 'widgets', but in each appliance group the relationship is complicated by a number of additional factors,
- additional design costs,
- impact on the cost of tooling (e.g. tools for pressing stainless steel drums for washing machines are much more expensive than for vacuum forming plastic refrigerator linings)
- the speed of introduction of efficiency, with no real increase in fixed costs if normal tooling or design changes are not accelerated, so that several changes can be made simultaneously,
- the potential for economies of scale in production (e.g. the cost of CFLs are being eroded as economies of scale are accessed, and with improvements in production efficiency)
- uncertainty, especially about future policy, timescales, and levels of standards etc. (this was revealed particularly strongly with phaseout of CFCs where legislative timetables were speeded up several times).

4.1 Engineering estimates

Engineering estimates examine fixed costs such as additional tooling, and variable costs such as extra electronics, plastic or foam. This estimate is then multiplied by representative fixed mark-ups for the manufacturer, distributor and retailer, to yield the expected consumer price. This is the approach commonly used by the Group for Efficient Appliances (GEA), a European group working to advise the EU Commission (DGXVII) on the costs and benefits of legislation under the SAVE programme to improve appliance efficiency. Reports have so far examined the cold appliances, wet appliances, and standby consumption in televisions and videos and there is a study currently underway looking at electric storage water heaters.

However there are several drawbacks with this approach:
- some of the figures are somewhat arbitrary: the GEA refrigerator study based estimates of design changes to fridges on data from Danish manufacturers. In discussion with the European manufacturers association, CECED, GEA agreed to multiply the cost estimates by a factor of 1.2.
- some studies have excluded fixed costs (Norgard 1989) while most, especially those undertaken by GEA make allowance for additional fixed costs (i.e. redesign, retooling etc.).

- mark-ups can vary. The cold appliance study did not state the mark-up factors it assumed in order to protect commercial data, but it was clear that different mark-ups were used for different products, but different mark-ups for different design options were not assumed (Pedersen 1992). On wet appliances, Van Holsteijn & Kemna assumed a mark-up of 3.3 for basecase, 4 for design options and 5 for visible features such as eco-buttons (GEA 1995 Background report V3 p3.5).
- account is not usually taken of economies of scale, where production costs can vary by a factor of 2. Engineering analyses quantify the cost effectiveness of the best technologies which almost invariably have low penetration, otherwise there would be no need for efficiency standards, and assume that the present cost differential for efficiency -if any- will be valid at much higher rates of penetration.
- no account is taken of the effects of additional cost with time: in the US, manufacturers implemented 3 rounds of standards with a 30% improvement in efficiency with no increase in consumer cost, but with additional investment in making production more efficient.
- It would be more true to say that the additional cost is to do with change or newness or innovation and NOT with efficiency. The industry is changing all the time.

4.2 Market estimates

Another, alternative approach is to examine the range of price and efficiency on the current market and attempt to draw out the determinants of price, including size, brand, efficiency and other attributes. This allows an estimate of the additional consumer price for the improved products compared to the average for a particular brand.

Engineering and commercial analyses for conventional fridge-freezers and larder refrigerators are presented in Figures 4.1 and 4.2. The engineering analysis data (the smooth curves) are taken from the GEA (1993) and apply to the average EU model. The raw data points are GB models offered on the market in 1996, through which an average has been drawn. There are several overall conclusions:

- we should be cautious in comparing data sets since the engineering data are EU 1992, and the market data are UK 1996. In addition, there may have been variation in exchange rates between £ and ECU,
- engineering estimates are based on an indicative model, and have not, by definition, taken into account the large variation on the market,
- the engineering analysis assumes, as its starting point, that there is a positive relationship between increased efficiency and additional engineering costs, and further, that these costs are passed on to the consumer in increased purchase price, while,
- analysis of the GB market shows no evidence of a relationship between efficiency and purchase price. Improvements in efficiency could be available at little or no cost to the consumer,

These points demonstrate the problems of converting between the costs to the manufacturer and the subsequent price to the consumer, particularly in a highly competitive market where the technology changes frequently, and mark-ups may vary between manufacturers and within a manufacturers product range.

There is some relationship on the UK market between price and efficiency for combined fridge freezers. In moving from an F to a B, average price per litre increases by around 20%. By contrast, in the larder market, there is no relationship between price and efficiency. In moving from a G to an A, there is if anything, a slight decrease in price per litre.

One key difference between the two markets is that in fridge freezers the range of prices is for the most part, both very low and very narrow, (between £0.8 and £1.20 per litre, compared to larder fridges (£1-£3 per litre). The implication is that competition in the fridge freezer market is focused much more heavily on price, with little room for competition on features or brand. The apparent additional cost of B rated fridge freezers is not efficiency: it is because they are relatively high value brand names such as Bosch or Zanussi: the cheaper brand-names are not represented in this market. The cost of efficiency is not therefore real, but due to a lack of competition. Chest freezers, upright freezers and one and two star fridges all follow the same model as larder fridges: there is a wide spread of price per litre, and no relationship between price and efficiency. Frost free fridge freezers are similar to fridge freezers.

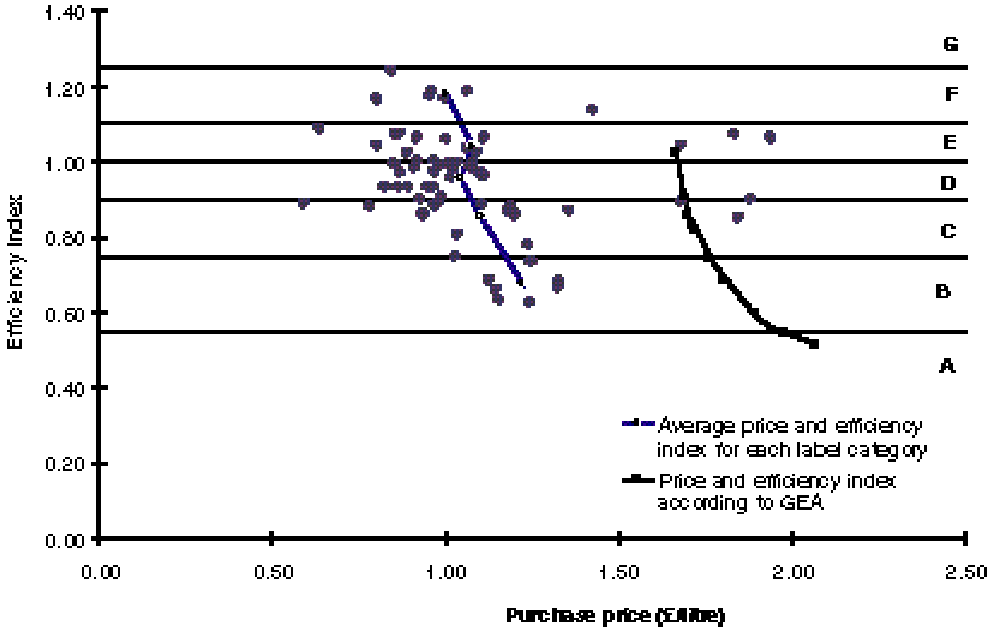

Figure 4.1 Efficiency Index and purchase price for fridge freezers (excluding frost free)

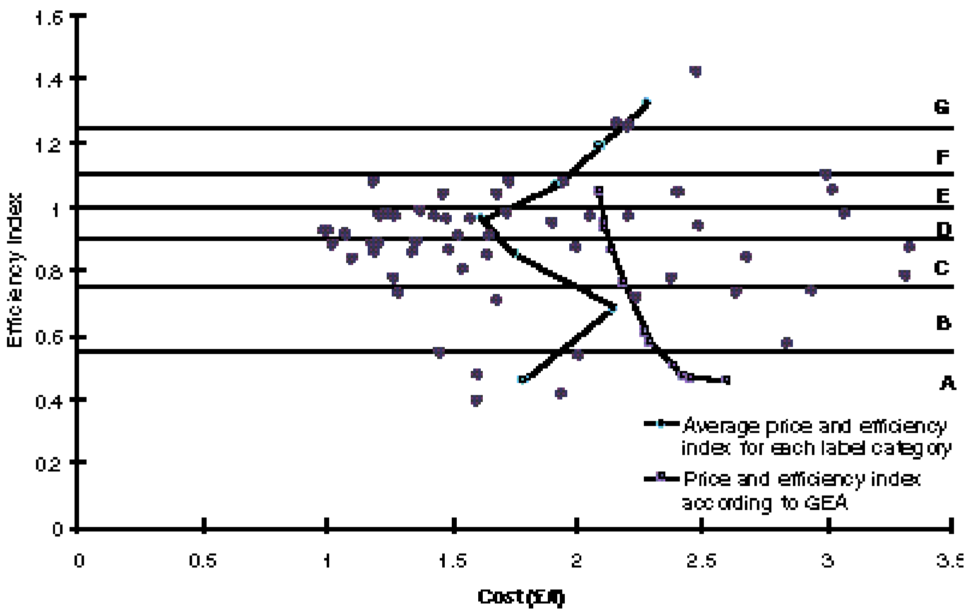

Figure 4.2 Efficiency Index and purchase price for larder refrigerators

4.3 Time series data on price and efficiency

This provides a snapshot on the current market, but what is the relationship between price and efficiency with time? Evidence in the US confirms that in at least one market there is little or no price increase with efficiency improvements due to standards. Greening et al (1996) analysed two rounds of refrigerator standards in the US using a dataset from retailers representing 2-3% of refrigerator sales, and actual prices paid before and after standards. The 1989 standards required a 10% improvement, and 1993 required a 30% improvement. As a result of the standards, average annual energy consumption in new refrigerators dropped from 974 kWh/year in 1987, to

653 kWh/year in 1994. Prices increased by between 1.4 and 1.5 percent per year from 1987/88 through 1993, and when increases in size are accounted for, the average annual increase was 1.25%. In general, the units meeting the 1990 standard levels had either similar level of features or an improved level of features, as manufacturers took the opportunity of redesign to update their product range. These results are consistent with a previously observed annual increase in current refrigerator prices of 1.1% between 1948 and 1983. This is an important conclusion, since analysis prior to standards (DoE 1989) had predicted that there was likely to be a cost penalty for improved efficiency.

However, Greening also found a doubling of capital investment over the period since 1989 and a decrease of 1/3 in labour costs over that time. In other words, manufacturers may have found efficiency improvements in production (less labour, different materials) while improving energy efficiency improvements in products. Since the actual costs to manufacturers are not publicly available, Greening was unable to ascertain the extent to which individual manufacturers were able to recover their costs, or whether their profits suffered (Greening pers. comm.).

In conclusion therefore, for the cold appliances, which represent 30% of the economic potential for efficiency from domestic lights and appliances, engineering analyses assume a monotonic and accelerating increase in price with increasing efficiency, whereas commercial analysis found both for the current market and for changes over time, no evidence to suggest that price will necessarily increase with additional efficiency, and strong evidence that price is determined by many things other than efficiency.

The hypothesis that market price is not so strongly related to efficiency as an engineering analysis would suggest appears similar for other appliance groups, for example washing machines and electric storage water heaters, at least in the EU. GEA suggested an increase in price for improved efficiency, but the wide range in price and efficiency can partly be explained by brand and spin speed which are important additional factors (GEA 1995). An engineering analysis of water heaters is attempting to identify the additional cost of design improvements but an analysis of market data shows little relationship between price and efficiency while brand is an important factor in variation in price (Orphelin pers. comm., and EVA forthcoming).

Having explored three different approaches for analysing cost and efficiency, the paper now explores how the real cost of introducing efficiency is different for different stakeholders under different actions.

5. The real costs of efficiency

5.1 Actors and stakeholders

When analysing the real costs of efficiency, one has to ask, costs to whom? Actors are those who can have a direct influence on the market, and could include the EU Commission; national energy ministries or agencies, and utilities or agencies who deliver DSM. Stakeholders have an interest in the process, but may have a less direct influence on the policy framework and include manufacturers retailers and consumers. Among these groups:

- Governments bear most of the costs of developing, initiating and maintaining programs and policies. Eventually any cost to government is converted to a cost to the consumer through some sort of direct or indirect tax.
- Manufacturers incur costs in making changes in individual products or to the set of products offered for sale, and attempt to recover costs through pricing. Manufacturers differ dramatically in costs and in the markets they serve. This variability and its implications for competition in the marketplace are important and difficult to study from publicly available information.
- Retailers are important in setting factory and consumer prices. Manufacturers and retailers gather information from consumers, which influences the set of products offered for sale.
- Consumers (including builders and contractors) in turn make purchase decisions among the products offered by the array of retailers and manufacturers. Consumers ultimately operate the appliances and lighting and pay the energy expenses (sometimes directly, and sometimes through rent).
- Utilities incur costs to supply energy at the time the consumer demands it, and have an interest in reducing or moving demand at peak times.

- The environmental impacts are not always captured in the economics and thus may arise as externalities. the role of government, many would argue, is to concern itself with societal interests.

Actors such as the EU Commission and national agencies are motivated by reducing barriers to trade by harmonising standards, aiming for economic optimal, and environmental impact reduction. Actors who deliver DSM might be interested in these objectives or in reducing peak load to avoid new investment.

- some programmes (like standards) deliver savings at low cost to consumers.
- some programmes (like rebates for efficient ovens) might deliver savings at 20-30 pp kWh but avoid peak generation.

In the UK, the average cost of generation is 2.9 pp kWh, peak can be up to 20-30 pp kWh. The cost to buy is 7.5 pp kWh. The external environmental and social costs are in addition to these.

Both are economic, but to different groups for different reasons. Nowhere is there a strategy which lays out what is economically optimum. Other objectives are often ignored, but might include:

- reduced uncertainty for manufacturers, through clarity about the long term objectives, instead of implementing only what is politically feasible in the short term,
- economies of scale, shared R&D costs,
- equity between stakeholders and within income groups.

Actors are often not aware of the actions or intentions of other actors implying a lack of integration of thinking. In the UK, the Energy Savings Trust who might be developing rebate programmes would not normally know about an EU study group on hot water heaters, or the Commissions thinking on efficiency standards for cold appliances. Yet another agency, in the UK (Energy Technology Support Unit) is involved in the IEA DSM Annex on technology procurement. In the US, some utility rebate programs were not co-ordinated with manufacturers' production plans, leading to inadequate supplies of energy efficient products. Further, the definition of "efficient" products, qualifying for rebates, varied from one region to the next, creating confusion. Other stakeholders (manufacturers and consumers) often receive policy rather than participate in it (though the appropriate industry organisations -CECED and EACEM- are increasingly involved in EU study groups on appliances).

In this analysis, 'cost to whom' principally involves the manufacturer and the consumer, i.e. stakeholders rather than actors. It is assumed that costs to retailers, governments and utilities are, on the whole, a second order of magnitude, and are largely passed on to consumers.

5.2 Cost to manufacturers of introducing efficiency

There are many factors that will vary the true costs for manufacturers of introducing efficiency. Uncertainty, speed, the cost of innovation and economies of scale are all crucial.

Uncertainty includes uncertainty about future policy, timescales, and levels of standards etc. This was revealed particularly strongly with phaseout of CFCs where legislative timetables were speeded up several times.

The introduction of efficiency with sufficient lead time may imply no more than reasonable increase in fixed costs if normal tooling or design changes are not accelerated. Analysis of data from market research firm GfK shows that half the models on the market survive only 2 years, but these modifications may only be slight. Every few years, the whole range is likely to undergo substantial redesign to optimise manufacturing processes. If efficiency is an element in an existing process -rather than the exclusive trigger for a new cycle of redesign- then there is no reason why redesign and retooling should be a significant additional cost (DECADE 1997).

The cost of innovation when new features are introduced is likely to include the full costs of additional R&D, new tooling and additional marketing. After a reasonable payback, say 3 years, the start-up costs will have been written off and overhead costs will go down (features move from a luxury to a commodity). A mark-up of 5 for new products or features could be reduced to a mark-up of 4 or 3 after a few years.

Some options will become standard practice, giving the opportunity for reduced production costs through optimising the design, economies of scale and automation. For example, in the UK vented tumble dryers retail for on average about £180. A product specification for a new heat pump tumble dryer has been developed under the IEA Technology Procurement programme and is under discussion with manufacturers. If sold in relatively small quantities, the dryer would be assembled almost by hand, resulting in a purchase price of some £300. If production could be increased above 30,000 units per annum, manufacturers would consider setting up a separate, automated, production line and retail price could fall to £250, almost halving the additional cost of the heat pump (Jeffcott pers. comm.). Thus the traditional economies of scale described by economists is, in truth, not smooth, but has discontinuities. This picture is further complicated by uncertainty. If manufacturers could be certain of a projected market share they may make changes in production sooner, whereas with uncertain sales, investments will be delayed (Figure 5.1).

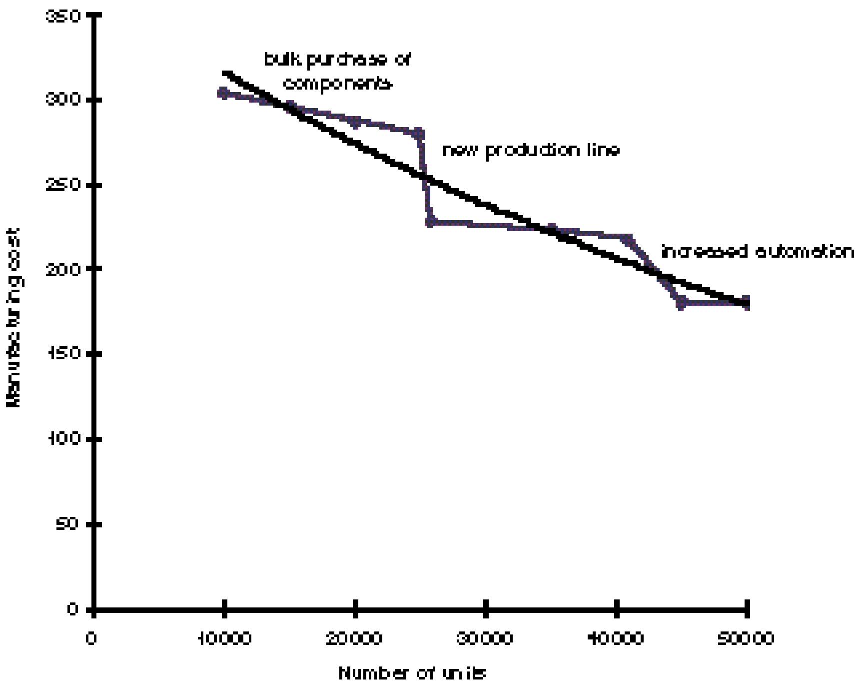

Figure 5.1 Theoretical and real economies of scale

Sometimes improving efficiency will not imply additional design, but reducing unnecessary variety, which will cut, not increase production costs. The Electrolux group has bought more than 100 brand names in the last twenty years or so, and many components were unique to each factory. Electrolux now produces the necessary variants from a minimum number of base components. Two examples are given below:

- Cold appliance manufacture is now concentrated in Mariestad in Sweden. The number of alternative cabinets has been reduced from 12 to 5, the number of inner cabinet liners reduced from 32 to 19. The smallest number of units that can be made in one batch is now 10 (Stevens 1995). One cabinet and liner combination may produce very thick insulation and an efficient appliance whereas the same cabinet with a different liner may maximise the inner cabinet space at the expense of very thin insulation and poor energy efficiency. Improved efficiency may mean reducing the number of combinations of cabinet and liner. For ease of production management, the range of compressors used should be minimised, though from an energy efficiency perspective, poor sizing reduces efficiency. Standards may mean that compressors are better sized for the heat load in any one cabinet so the number of compressors needs to be increased.
- The Porcia factory in northern Italy manufactures washing machines for the entire Electrolux group, a total of 32 different brands and 800 different model variants (Stevens 1995). These machines appear to the consumer as if manufactured by competing companies. The flexible manufacturing system allows a minimum batch size of 12 units, and a change of model some eight to ten times a day. Products include perhaps eight points of differentiation:

- washing machines as well as combined washer/dryers;
- different sized units with a 32 cm wide product for restricted spaces, as well as a large capacity 6 kg machine;
- a range of about 65 different tub models, some plastic and some stainless steel tubs,
- a range of about 45 different cabinet designs;
- spin speeds from 400, 500, 600, 800, 1000, 1100, 1200, 1500 rpm, each step increase in speed requiring a different thickness of stainless steel in the drum and different bearing and motor design to resist spin speed forces;
- with or without shower wash paddles;
- with or without semi-automatic detergent dispensers;
- and using hybrid electro/mechanical controls on simpler models as well as fully electronic controls.

Improving energy efficiency, may, in production terms, simply mean not making certain variants, rather than adding new and innovative products. This may actually cut production costs by reducing tooling changes. It may however, have some impact on the variety of products (and prices) offered to consumers.

5.3 Price to consumers of buying efficiency

There are many factors that intervene between production costs and final purchase. Price-pointing, apparent value rather than real cost, varying mark-ups at different ends of the market, brandnames, and the level of competition in a particular market segment all affect purchase price.

In the UK, four major, national retail outlets dominate the market, and selling power is concentrated in their hands. National advertising has meant that prices can be compared relatively easily across the major chains, and prices are not a continuum. There are a limited number of ‘price points’ at which products are available (e.g. washing machines sell at £299, £329, £399, £449, and £499) rather than a price based on production costs with a fixed profit margin for the manufacturer, distributor and retailer. It should also be noted that models can move from one price point to another, in a limited time period, and there is often substantial additional discounts, special offers, trade-ins available. Figure 5.2 shows the large (30-50%) variation in purchase price across up to 40 units of the same brand and model in the same retail outlet in Oxfordshire in the first quarter of 1995. The data are ranked in order of increasing price, and show that a single product in a single outlet can move in a very short time period from one price-point to another, and that this effect of stiff competition on price is large compared to, say, the difference between an average priced B and an average priced F. This again implies that efficiency is not a significant component of price.

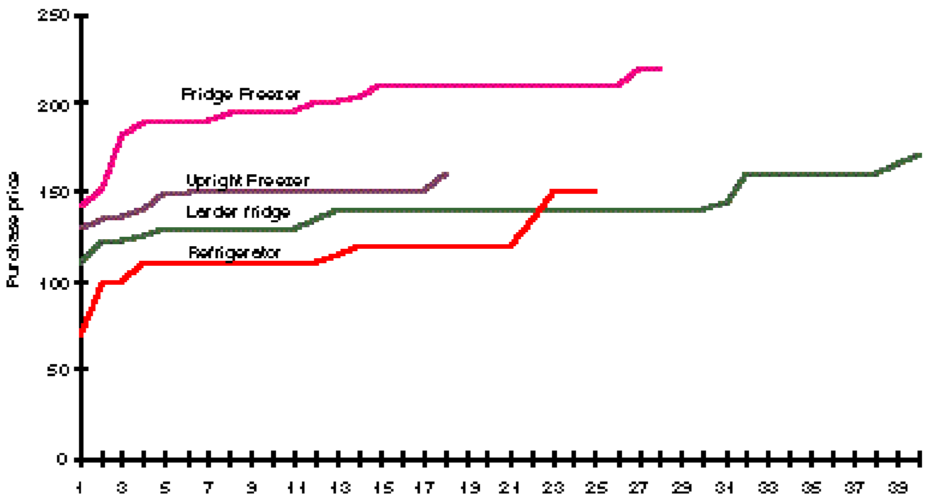

Figure 5.2 Purchase price of one model in one retail chain in Oxfordshire (1st Q 1995)

Manufacturers often express resistance to efficiency improvements forced through legislation because adding a particular design option to, say, a lower price machine (or taking a particular set of features out of production) may mean it has to move above its traditional price-point. Since the market is extremely sensitive to purchase price, this may threaten a loss in market share. Alternatively, manufacturers could absorb the increase in cost themselves in order to preserve the price-point, but they are -understandably- equally reluctant to do this. Any threat of uncertainty or additional cost puts the system under pressure.

Price points are not reflective of the cost of manufacturing. Clearly, manufacturers and retailers are taking different mark-ups on different products. At the bottom end of the market there is fierce competition on price, but substantial sales volume. At the top end, added value features, such as frost free or energy efficiency, are considered more important than price, so there is less pressure on margins. Little profit is taken per unit at the lower end with high sales volumes, and higher profit per unit is taken at the higher end with low sales volume.

Sometimes efficiency -or rather certain features which improve efficiency- are provided at the top end of the market, and the additional cost is not a simple multiple of the cost to manufacture, but equal to the apparent value to the consumer. For example, it costs only a few pence to add an extra button on a washing machine for an 'economy wash'. In most machines this merely reduces the time the heating element is switched on by 25%, but it adds a good deal of value to the consumer. It also costs relatively little to have a design variant on a fridge liner which allows for much thicker insulation which, again, benefits the consumer. Yet, in both these cases, the added cost to the consumer is around £20-£30. This may be because market research shows that a segment of the market is willing to accept a payback period of up to three years and so the manufacturers price according to what consumers will accept, rather than what the engineering cost may be. It may also be that manufacturers are amortising a tooling change over a smaller number of units or a shorter time period.

There are certain markets where an efficient appliance (those that survive the 1999 standards, i.e. A B or C on the EU Energy label, except for chest freezers which is a-E on the label) *appears* to cost more to the consumer. Table 5.1 illustrates this. It can be seen that A-E rated chest freezers appear almost twice the price of F-G rated appliances. However, deeper analysis of the market shows that the market for chest freezers is dominated by a few very small, inefficient and cheap G models that are large sellers. The category A chest freezers are substantially larger as well as more expensive.

Since brand and size are two important elements in pricing, models from several brands have been plotted, and a regression line drawn through the data (Figure 5.3). The four brands illustrated are similar to many others, and the ones included are indicative. There are several conclusions:

- models are concentrated on less than 350 litres and less than £400,
- taking the conventional fridge-freezer market as a whole, there is some relationship between price and size (r^2= 0.45). The relationship is better for some brands than others, and brands vary between 0.14 and 0.79,
- there is some relationship between brand and price. Brands from German and Swedish parent companies (-though not necessarily manufactured in those countries) are higher value than UK brands. UK 2 above is competing in a similar price and size range to several Italian brands. The effect of switching brand from UK2 (at £250) to Germany 1 (at £400), given the same adjusted volume (of for example, 300 litres), implies a price increase, equal to 60%.

High value products can therefore have several common characteristics: they are German or Scandinavian brandname; they are larger, they may use hydrocarbon refrigeration technology (rather than HFC 134a) and to some extent they have higher efficiency.

Table 5.1 Price efficiency and size for cold appliances (GB, 1995-6)

		Sales weighted average price (£)	Adjusted volume (litres)	cost adjusted volume (£/litre)
Fridge-freezers	A - C	316	255.3	1.24
	D - G	289	251.8	1.15
Frost-free fridge-freezers	A - C	635	437.3	1.45
	D - G	461	321.2	1.44
Refrigerator	A - C	154	114.3	1.34
	D - G	161	111.8	1.44
Larder refrigerator	A - C	223	139.9	1.60
	D - G	205	134.6	1.52
Chest freezers	A - E	336	459.0	0.73
	F- G	160	249.2	0.64
Upright freezers	A - C	246	108.8	2.26
	D - G	228	215.4	1.06
Frost-free upright freezers	A - C	679	516.5	1.32
	D - G	333	196.4	1.69

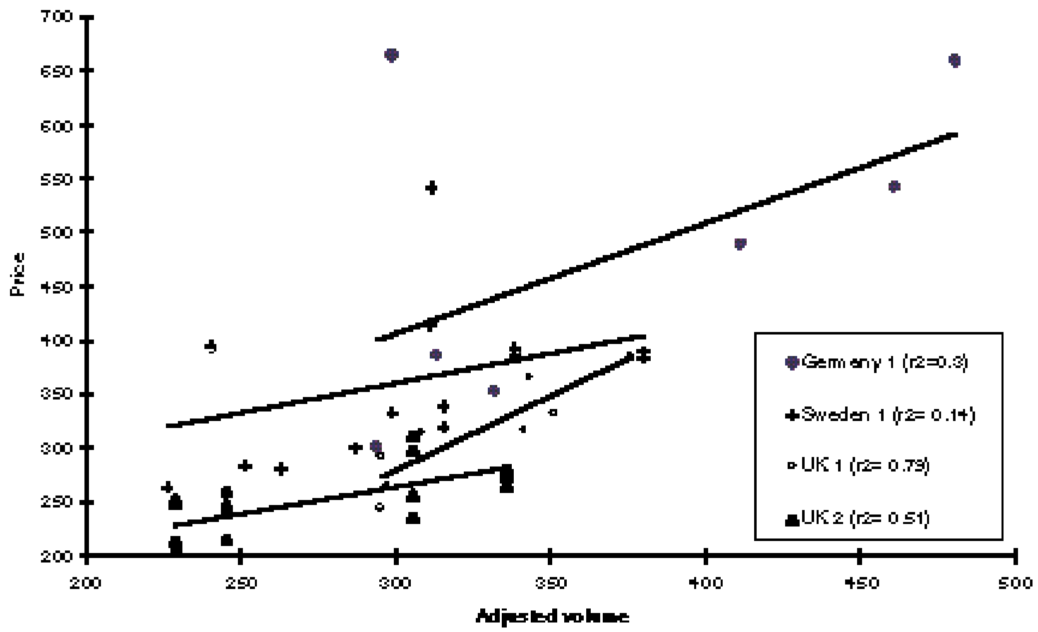

Figure 5.3 Size and price for a number of brands of conventional fridge- freezer

It is clear therefore that both cost and price are influenced by many factors, and efficiency has little influence. What does all of this mean for market transformation strategy?

6. Conclusions, implications and recommendations

There are several major conclusions and policy implications to flow from this paper.

First, all market transformation actions may be used for any given technology, but at different stages in the development of the technology and the market. Different instruments are appropriate for encouraging a technology to move from one stage of Roy's innovation curve to another, i.e. exploration, consolidation, minor innovation, decline and replacement.

Second, some appliances are greater priorities than others. Lighting, cold appliances, water heating and ovens are particular priorities.

Third, several tools for analysis of additional cost for future efficiency are compared, including an engineering analysis, analysis of price and efficiency on the current market, and time series analysis of price and efficiency. Engineering analyses assume, as a starting point that additional efficiency costs increasingly more money, and aim to identify how much more. The other two approaches show that this assumption may not be valid, price being determined by many things other than efficiency, and gains in efficiency not necessarily implying additional purchase price in practice. Thus future efficiency may be accessed at much lower costs than previously thought, at least for the cold appliances, and potentially, for other appliance groups.

Third, there are many factors that affect the cost and price of future efficiency, that act to modify any theoretical additional cost: innovative products of any sort (including innovation on energy efficiency) carry higher development, tooling and marketing costs. On the other hand, economies of scale from increased production volume would reduce the cost of efficiency improvements. Additional price is determined by the extent of novelty, rather than by the extent of efficiency.

Fourth, and as a consequence, the actual cost of future efficiency is not fixed, but is policy dependent. Policy instruments affect price therefore in different ways.

- Technology procurement programmes, by bringing a manufacturer and a large purchaser (e.g. a housing association) together to develop a specification and guarantee a market, reduce the marketing costs and most especially the risk associated with a new product launch and thereby access savings at a lower cost to the manufacturers. Because start-up costs are amortised more quickly and more securely, costs to consumers are reduced, and a new technology is introduced more quickly and with lower risk than it would have been.
- Policy instruments which access improvements through the operation of the market using instruments such as energy labelling and rebates, will make savings at their apparent value, rather than at their real cost to manufacturers. They allow manufacturers to make a larger profit from something relatively new. Innovative products may carry a higher mark-up than commodity products, and this includes innovation on energy efficiency. They may also subsidise or persuade consumers to buy a high value item (German, larger volumes, alternative refrigerants) which has efficiency as part of a package. They also accept and preserve diversity, even if diverse products include inefficient products.
- Efficiency standards constitute the most effective means of making savings. They are geographically widespread, not restricted temporally, and not restricted to whether consumers understand efficiency. They are the most certain approach in making CO_2 savings. They deliver savings at the lowest cost to the consumer given economies of scale in manufacturing and avoiding the additional marketing costs of the new design option. The true costs of standards to consumers will be less than the prices identified in reports to the Commission (GEA 1993, GEA 1995), and may -especially in the longer term- tend towards zero. The timing of possible actions is an important consideration in their actual cost, given the need to inform manufacturers and not to interrupt the timing of major redesigns, (e.g. standards revisions could follow those in the US, e.g. 1989, 1993, 1998 or in the EU for cold, 1999, 2004, 2008).

Efficiency could be accessed at lower cost for the manufacturer if:

- uncertainty is reduced, timescales for implementation are clearer, implications for design and tooling are known, and speed is in line with normal rates of product redesign,
- R&D can be shared either within an industry or with government,

Efficiency could be accessed at lower price to the consumer if:
- economies of scale, optimisation and automation can be introduced,
- efficiency is not just a point of differentiation for higher value products,
- pricing of certain features (such as eco-buttons on washing machines) is based more on engineering costs rather than apparent value, and
- the market provides efficient appliances across all brands, and all sizes so that genuine choice exists.

Fifth, the net cost to manufacturers and consumers will depend on the policy or mix of policy which bring about the improvement. It would seem rational to minimise the effects on both groups, and therefore, to develop a strategic transition by some mix of incentive and regulation to minimise the risk that one group in particular would benefit from, or bear the cost of, improved efficiency. It should be accepted that procurement may make savings sooner at 6pp kWh, but that this is necessary to get the technology on the market, and understand its costs and benefits, before standards can make savings at close to zero cost. All of these policy options are parallel to Roy's description of the several stages of innovation, namely exploration, consolidation and maturity, minor innovation, and decline and replacement.

Sixth, there are key interconnections between actions:
- labels are necessary for rebates,
- label categories can lead to definitions of standards
- today's rebate levels or procurement programmes can provide valuable experience as one input into considerations about tomorrow's efficiency standard.
- There are obvious interconnections between the consequences of different actions, In particular, the question of whether savings are overlapping, or additive or synergistic.

Seventh, Standards play a unique role in ensuring least cost to consumers and greatest certainty. A complete market transformation strategy must include framework legislation for efficiency standards. EU legislation could be based on the experience of three pieces of US legislation: the Energy Policy and Conservation Act 1975 (EPCA); National Appliance Energy Conservation Act 1987 (NAECA); and the Energy Policy Act 1992 (EPACT) which extends standards legislation to cover commercial and industrial equipment (Millhone 1992, Adams 1992). Figure 6.1 shows one possible plan, with 17 different levels of standard for 7 appliance groups, and could for example assume:
- for cold appliances, wet appliances, water heaters and ovens, short term standards are based largely on a statistical analysis, resulting everything moving up at least to the average of the current market. Long term standards (2004 onwards) assume everything meets the economic and technical potential which may be up to 40%. A third round of standards could be based on new technologies like vacuum panels, and could be an 80% saving compared to the current market.
- fleet-average standards for lighting could in the first instance aim to increase penetration of CFLs and integral ballasts, and longer term, increase sales of electronic ballasts.
- generic standards for smaller appliances could include maximum standby losses, maximum rates of heat loss for small cooking appliances, and minimum efficiency for small motors in appliances.

Given the resistance there has been in the EU to standards, the regulatory committee given the power to set standards should be asked to discuss the appropriateness of voluntary agreements, or sales weighted average efficiencies (similar to corporate average standards, like the US CAFE standards for automobiles).

Eighth, there are, amongst actors, common basic prerequisites for intervention, and the same analysis should be common to all actors:
- the ability to measure efficiency in a reproducible way through test procedures influenced more than at present by the needs of market transformation policymakers,
- knowing where the market is now, and how it changes with time: in other words, monitoring both before and after policy intervention. In the UK, data on sales by model is available four times a year, and can be integrated with a database on size, consumption and efficiency of appliances. Such a database can be used for monitoring the effectiveness of policies, and analysis of costs over time (DECADE 1997), and
- knowing what the potential for improvement is, together with an understanding of the relationship between

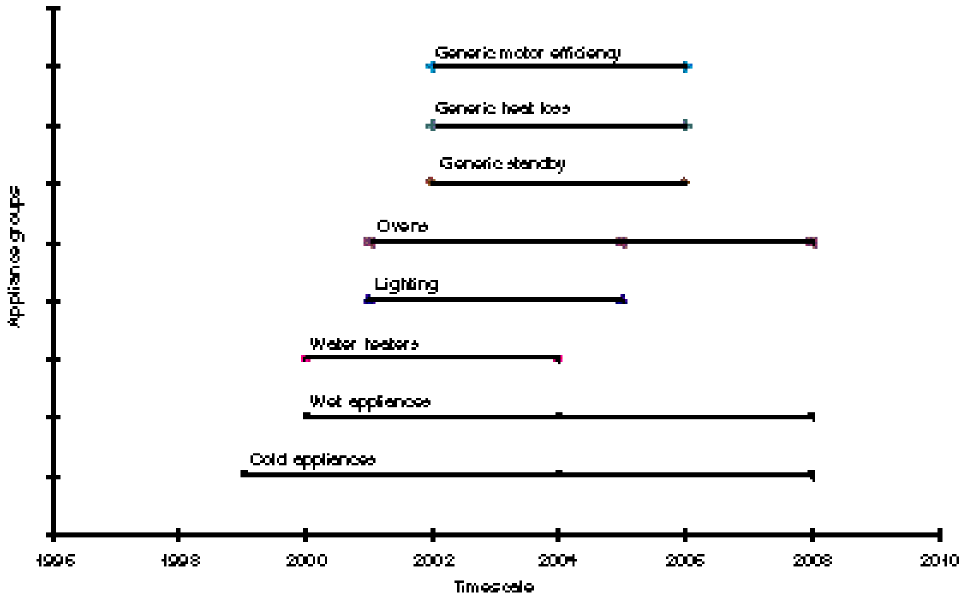

Figure 6.1 A possible timescale for EU efficiency standards

price and efficiency including both engineering and market analyses. Retrospective analysis of individual programs, much less comparative studies, are rare. Reliance solely on prospective, forecasting analysis approaches cannot lead to an understanding of the actual merits or shortcomings of policies as implemented.

In summary, Market Transformation could thus be a much more integrated process, based on a wider and deeper analysis of costs and benefits, and not a collection of uncoordinated instruments implemented by different actors with different motivations. DECADE suggested that the Economic and Technical Potential in appliances was 39% of projected consumption in the UK in 2020. We may need to access much of that potential given IPCC scenarios of climate change and consequent decision about targets for CO_2 reduction. Any single or uncoordinated approach, whether it be labels, rebates, or standards, is likely to be sub-optimal and potentially costly. It will only be through an integrated strategy for market transformation that we can generate the political consensus amongst stakeholders, and the understanding of the relative costs and benefits for each of those stakeholders, to permit access to savings at the least net cost, with the least uncertainty.

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