Measuring Market Transformation: Quantitative Analysis of Appliance Energy Efficiency Labeling Program Impacts in the European Union, Australia and India

Taylor Zhou and Michael McNeil, Lawrence Berkeley National Laboratory

ABSTRACT

Many economies and countries have or are implementing energy efficiency labels for appliances as a tool to identify and promote energy efficient products. The European Union and Australia are among those with the longest history of mandatory energy labeling programs. India, one of the largest rising economies and appliance consumption markets, has imposed mandatory efficiency labels for selected appliances since 2010. In this study, we focus on interpreting and comparing the labeling programs in these economies in order to evaluate the impacts of these programs. Applying a market-adoption model developed in earlier work of the authors, this study uses disaggregated appliance market share data together with statistical analysis to present a quantitative evaluation of the effectiveness of the mandatory efficiency labeling programs for a number of white goods, including refrigerators, dishwashers, washing machines and clothes dryers. Through cross-economy and cross-appliance comparisons, this study seeks to gain insight into the dependence of market efficiency transformation and improvement on appliances technology, as well as on label policy design. This paper ultimately hopes to contribute to the international knowledge base of best practices and lessons learned from labeling program design, as well as providing a guide for policymakers seeking to understand the impacts of various appliance energy efficiency policies.

Introduction

Increasing efficiency through appliance standards and labeling programs can mitigate greenhouse gas emissions and reduce energy demand. Many economies, including the European Union, Australia, Korea, China, Brazil and India employ categorical labeling programs, while the United States employs continuous labels (Energy Guide) and endorsement labels (Energy Star). In most cases nowadays, these programs act in concert with other policies such as minimum energy performance standards (MEPS) and endorsement labels to move appliance markets towards higher efficiency. MEPS can work with labels by removing the lowest efficiency categories, or can create a new 'market floor' at the time of a rescaling of labels.

The market impact from MEPS and comparative labels is different. The impact of the MEPS on a market is a direct and mostly complete elimination of the lowest-efficiency products[1]. The quantitative impact of labeling programs alone, however, is more diffuse, and until now not well-studied. Some studies discussed the mixed effects of MEPS and labeling (Lane, Harrington and Ryan, 2007) while others presented the impact of labeling programs in a more descriptive and less quantitative fashion (Egan and Waide, 2005). Part of the reason for the lack of quantitative studies of the impacts of labeling programs has been a lack of data – a problem that is diminishing due to the recent availability of market research data. New data and

[1] Not all products are eliminated due to incomplete compliance or held-over inventories of inefficient products. Furthermore, MEPS may cause an indirect shift in market shares towards higher efficiency.

recently developed methodologies allow for a more thorough investigation of the market evolution that has occurred as a result of labels and can therefore be expected by emerging labeling programs. It is reasonable to expect a variety in the effects of programs, and valuable to understand the cause of these differences. Variables that we could expect to make a difference include 1) different consumer disposition in different markets, 2) different technological configuration of product types and 3) program design (spacing of levels, label design, etc.).

In order to make cross-comparison possible this analysis uses data from the Australian, EU and Indian labeling programs as cases to study the market impact of labeling programs. Australia has a long history of energy labels. Labeling was first introduced in 1986 in Australia and is now mandatory for refrigerators, freezers, clothes washers, clothes dryers, dishwashers and air-conditioners in all Australian states and territories. On October 1st, 2000, the Australian government revised the energy labeling algorithms for all star ratings for appliances. The efficiency star level definition has been changed and rescaled from the original 1-6 star (1 star level being the base line), with single star increments to 1-10 stars with half star increments (EES 2010). The European Union established the energy labeling scheme in 1992 (EEC, 1992). Most white goods are required to carry the EU energy label that rated the appliance in terms of efficiency classes from A to G, A being the most energy efficient. India, as one of the fastest growing economies with a population over 1.1 billion, implemented a mandatory labeling for frost-free refrigerators, room air conditioners, fluorescent lamps and distribution transformers. In this study, we selected refrigerators and air conditioners in India in order to compare with programs for these products in other countries.

Description of Data

To support this project, LBNL used Australia and EU data from GfK, a commercial market research company, over the period of 1993-2009 for Australia (E3, 2010) and 1995-2009 for the EU. The data includes number of sales by efficiency levels or by product classes, product capacity, unit energy consumption (UEC) and the Star Rating Index (SRI). In addition, we obtained the Indian refrigerator market share and sales data from the Indian Bureau of Energy Efficiency (BEE) through CLASP. The level of detail for each set of data varies. Table 1 provides the data characteristics for each country:

Table 1. Data characteristics by appliance and country

Country	Appliance	Sales	Market Share	UEC	Capacity	Efficiency index	Year	Source
AUS	Refrigerators	x	x	x	x	x	1993-2009	Gfk
AUS	Clothes washers	x	x	x	x	x	1993-2009	Gfk
AUS	Dryers	x	x	x	x	x	1993-2009	Gfk
AUS	Dishwashers	x	x	x	x	x	1993-2009	Gfk
EU	Refrigerators	x	x			x	1995-2009	Gfk
IND	Refrigerators		x			x	2007-2011	BEE

Table 2 summarizes the number of models for each product class that were reported in each year. Data from Australia and the European Union are shown. Model information is not available for India.

Table 2. Number of Models Reported

Country	Australia						European
Appliance	Washing		Dryers	Dishwashers	Refrigerator / Freezers		Refrigerator /
Product	Front	Top	All	All	Combi.	Freezer	All
1993	5	65	17	44	121	33	178
1994	6	47	18	41	125	30	178
1995	4	62	29	64	120	31	192
1996	3	48	14	71	113	25	164
1997	12	47	13	63	133	30	184
1998	11	55	15	53	111	25	166
1999	12	57	13	42	109	24	156
2000	15	56	10	69	121	25	174
2001	106	146	84	298	524	83	608
2002	131	155	82	331	636	97	734
2003	145	155	92	423	701	71	772
2004	182	169	101	488	813	83	905
2005	196	198	111	520	944	103	1047
2006	220	186	133	570	1055	134	1189
2007	228	157	126	616	1079	157	1236
2008	227	164	121	572	1079	181	1263
2009	217	138	117	599	1055	199	1254

There is a discontinuity of numbers of models surveyed before and after 2001. The number of models surveyed by GfK for each product increases drastically after 2001. For example, less than 10 dryer models were surveyed prior to 2001but around 100 afterwards. However, GfK claimed it covered 75%-90% (even with the limited number of model surveyed) of the sales in the market (E3, 2010b). A study conducted by the Australian government (E3, 2010a), using the same Gfk dataset, concluded that the incomplete dataset in earlier year did not affect estimates of the key parameters. Coincidently, the data discontinuity was in the same year as the 2000 policy of labeling rescaling. Unfortunately, we are not able to separate the impacts on the efficiency improvements due to data issue or the 2000 policy. The change of numbers of model surveyed may or may not affect our estimates of the efficiency improvements from 2000 rescaling policy.

Method

The method of projecting *cumulative market share* for each efficiency level is adopted from the previous work of the author (Lownthal-Savy, McNeil and Harrington, 2012). In this study, we evaluate the impact of a policy intervention by projecting the cumulative market share of a product at a specified efficiency level before and after a specific "policy intervention", which could include implementation of MEPS or rescaling of the label levels. Cumulative market share of a specified efficiency level is defined as the market share of all the efficiency levels equal and above that specified efficiency level. For instance, the cumulative market share in 2000 for a Level A refrigerator is 60% if 60% of refrigerators sold in that year had a rating of A or better in 2000. Defined in this way, cumulative market share represents the adoption level of a specific efficiency, assuming that the technology is incorporated into all efficiency designs beyond a specific level. One may expect the adoption rate to follow a standard "S-curve" model.

The policy intervention is determined by a shift in policy in a specific year during the data period. If so, the data is separated into two time periods, determined by the time of policy intervention. For example, the Australian data was separated by the labeling scheme rescaling in 2000, when the Australian government redefined the efficiency star level for products with

comparative efficiency labels. Since the EU and India do not have any policy shifts during our data period, we do not divide the data period and make projections.We then project the market share trend without the presence of the policy based on the pre-policy data. Statistical regressions were performed on the market share data of each star rating level to determine the efficiency improvement using the cumulative market share S-curve model. The general form of the cumulative market share relationship with time follows an S-shaped sigmoid function and is best described by the function expressed below (McNeil and Letschert, 2010):

$$F(t) = \frac{1}{1 + e^{-q*(t-t_0)}}$$

- where F(t) indicates the cumulative market share of a specified efficiency level in year,*t*;
- t_0 is such that $F(t_0) = 0.5$;
- and *q* is the adoption rate of a specific efficiency level.

This logistic is converted to a linear function, allowing us to determine all the parameters using statistical regression (Van Buskirk, 2012). The parameters include *q*, the rate of adoption and *c* the constant of the regression. The remaining constant, t_0, the year when the cumulative market share reaches 50%, was then determine by the values of *q* and *c*, where $t_0 = \frac{-c}{q}$

Results

In this section, we first present an international comparison of average annual efficiency improvement for washing machines, dishwashers, dryers and refrigerator; then we show the results of a detailed analysis of program impacts for four Australian appliances, European and Indian refrigerators.

For each product, we show the real cumulative market share based on the sales data, as well as the projected (counterfactual) cumulative market shares, which are the extrapolations using the S-curve model representing what might have happened without the policy intervention, if there is one. The results from the adoption curve regressions are provided in Table 3.We also show the index of actual and counterfactual price, energy, capacity and efficiency relative to the first year of available data. From these, we evaluate efficiency improvement rates with and without a policy shift, and offer some interpretation of the market response.

Table 3. Annual efficiency improvement rate by different periods and scenarios

	Scenario	Actual			Counterfactual	
Country	Product	1993-1999	2000-2009	1993-2009	2000-2009	1993-2009
Australia	Washing Machine	0.3%	4.8%	2.8%	3.1%	1.7%
Australia	Dryer	0.4%	0.0%	0.2%	0.5%	0.6%
Australia	Dishwasher	2.9%	2.2%	2.1%	3.3%	2.7%
Australia	Refrigerator	2.72%	3.10%	2.91%	1.7%[2]	1.9%
EU	Refrigerator	3.3%	NA[3]			
India	Refrigerator	2.9%				

Annual Efficiency Improvement Rate by Country and Appliance

We collected and compare the annual energy efficiency improvement rate among countries for each appliance. The Australian results use the GfK data and other countries' come from IEA-4E benchmarking studies[4].

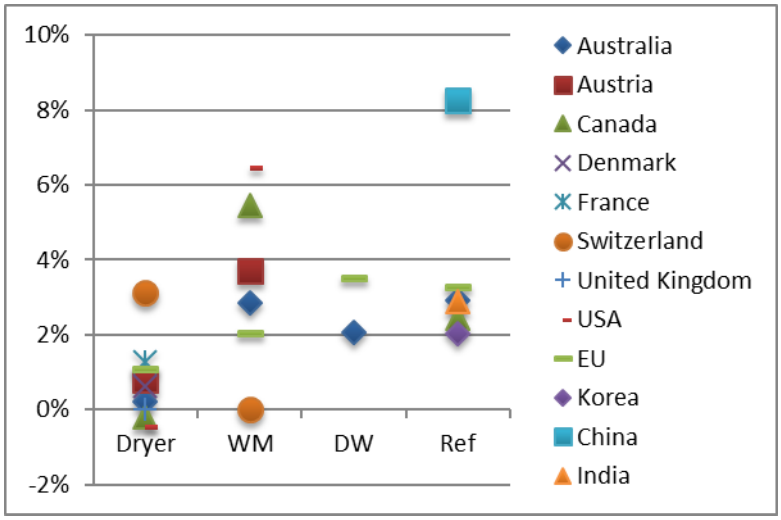

Figure 1. Annual efficiency improvement rates for major appliances.

Several observations can be made from Figure 1. First, a general clustering is visible across countries. Second, there are clear differences among appliance types. Dryers generally show low annual efficiency improvement – in the less than 2% range. The exception is Switzerland, where heat pump dryers have been promoted aggressively. Washing machines generally show much higher improvement rates, in the 2%-6% range. Dishwashers show improvement from 2%-4% but with limited samples. Refrigerator improvement generally also ranges from 2% to 4% but there are significant outliers, namely the UK and China, with much

[2] The counterfactual scenario for refrigerators is constructed using pre 1999 value by assuming no MEPS, 1999 or 2005, was implemented.

[3] No counterfactual analysis due to no policy intervention

[4] It should be carefully noted that IEA-4E "normalized" the energy consumption for each country by adjusting the input parameters (such as ambient temperature, program time etc). As a result, the efficiency improvement rate that LBNL calculated may not be an exact equivalent to IEA-4E's calculation.

higher improvement rates. The annual efficiency improvement for dryers in Switzerland is the highest while that for the washing machines is the lowest. Efficiency improvement rates observed for different countries and products are related to the impacts, since most of these countries use comparative labels[5]. The picture is complicated, however, by the presence of multiple program types, particularly the presence of MEPS. Therefore, it is not always easy to isolate the impacts of just the comparative labeling program.

Australia Washing Machines

The labeling program for washing machines in Australia started in 1993 and was rescaled in 2000. Two main product classes are dominating: the more efficient front load and the less efficient top load. The annual efficiency improvement rate varies significantly from 0.3% before 2000 and 4.78% after 2000, the overall efficiency improvement is 2.84% from 1993 to 2009.

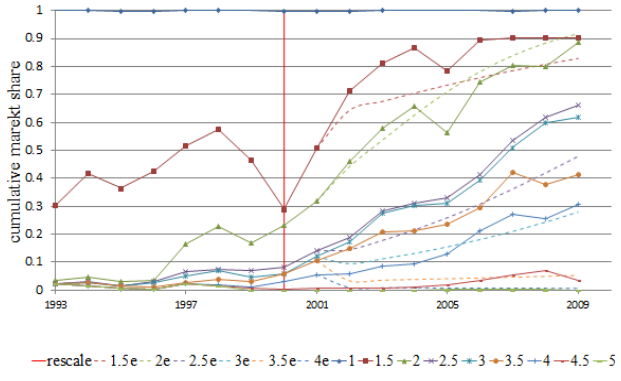

Figure 2a. Washing machine cumulative market share.

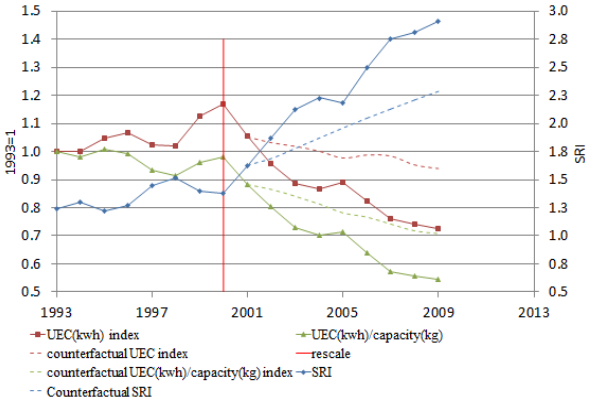

Figure 2b. Washing machines index trend.

Figure 2a shows the cumulative market share for Australian Washing Machines. Solid lines in these graphs represent cumulative market shares from the GfK data. Dotted lines are extrapolations of S-curves based on the pre-2000 data, and therefore represent a "counterfactual" scenario of what might have happened in the absence of the rescaling of labels in 2000. The actual cumulative market shares after 2000 were higher than the counterfactual, indicating an efficiency improvement relative to the business-as-usual trend. Figure 2b shows an efficiency index representing the relative change over years with 1993=1. The UEC/capacity trend shows a 45% improvement between 1993 and 2009, whereas the counterfactual only shows a 30% improvement in the same period. The average SRI (Star Rating Index) increase from 1.24 in 1993 to 2.91 in 2009, compared to 2.29 in 2009 in the counterfactual scenario. These graphs show that the energy efficiency of washing machines in Australia improves faster with the presence of the labeling program than without, but that in the later years, the trend toward higher efficiency is slower for front load vs. top load machines.

[5] The United States and Canada are the exceptions, although these countries use information labels.

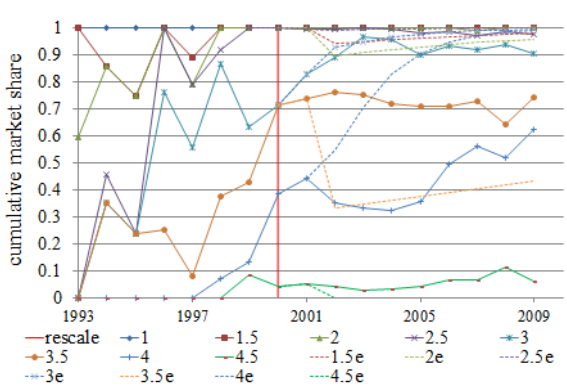

Figure 3a. Front load cumulative market share.

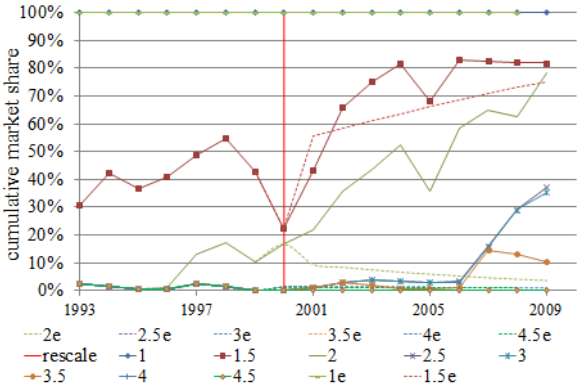

Figure 3b. Top load cumulative market share.

Figure 3a and 3b show the cumulative market share of two product classes. The top-load high efficiency models gained more market after 2000. The front load washer is somewhat more complicated. The high efficiency model shares were growing fast before 2000 but leveled off and remained relatively constant afterwards.

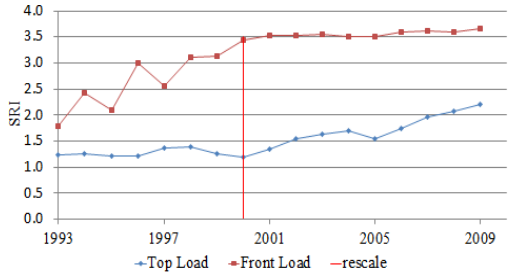

Figure 4a. Efficiency trend.

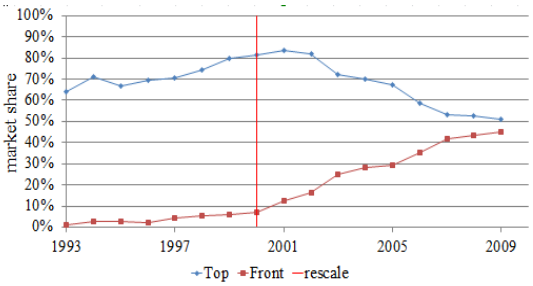

Figure 4b. Market share trend.

Figure 4a show the efficiency improvement within product classes. The SRI for the front load is significantly higher than the top load and it reached a plateau after 2000. In addition, the efficiency improvement for the Australian washing machine market is strongly affected by their relative market shares (Figure 4b). The front load market share grew dramatically since 2000—reached a market share of almost 50% in 2009 from less than 10% in 2000.

In conclusion, the combined effect of the product class market shift and efficiency improvement within the product type results in an increase in annual efficiency improvement from 1.6% to 5.3% before and after 2000. A parallel can be drawn to the 2006 MEPS in the U.S., which largely precipitated the introduction of front-loading washing machines in that country.

The average annual efficiency improvement for the washing machines for the EU is 2% in the same period based on IEA estimates, and that for Australian washing machine is 4.78% from the same period 2000-2009 based on our analysis. An EuP study in 2009 showed that the Level A washing machine increased from 5% in market share in 1997 to nearly 80% in 2003, leaving very little room for further efficiency improvement (AEA, 2009). The A+ level and above did not appear officially until 2010. The slow policy reaction to update the efficiency may have led to slow efficiency improvement.

Australia Dryers

The labeling program for dryers in Australia started in 1993 and was rescaled in 2000. The annual efficiency improvement is 0.22% from 1993 to 2009, which is relative slow compared to other appliances. The two main product classes for Australian dryers are auto vented and timer vented dryers, which together account for more than 97% of the market. We do not include condenser dryers due to the small market share (3%).

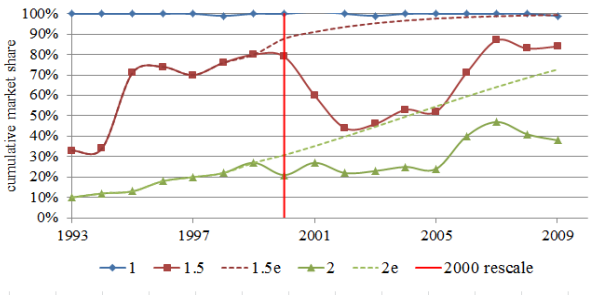

Figure 5. Australian dryers cumulative market share.

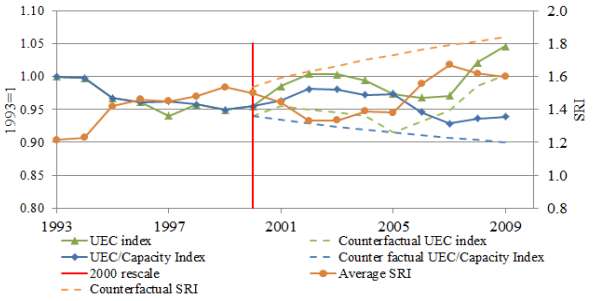

Figure 6. Australian dryers efficiency index.

At first glance, the efficiency improvement situation for dryers in Australia is puzzling, since in general, the trend after the label rescaling shows less efficiency improvement than before, and the behavior of individual levels shows abrupt changes towards less efficiency (Figure 6 and 7). After 2000, the actual cumulative market share for both 1.5 and 2 star levels are below their counterfactuals, indicating that the actual efficiency improvement is slower than the projection in that period. The efficiency trend was disturbed in 2000 due to a sudden increase market share of the baseline (1 star) products. The sudden change of efficiency distribution market share may accurately describe the market, or it may be caused by the change of GfK survey model, shown by the sudden increase of dryer models surveyed in Table 2. Unfortunately, it is very difficult for us to distinguish between these possibilities based on our data.

The picture becomes clearer, however, when we look at the improvement around the world, which is very small for dryers (Figure 1). The improvement for EU dryers was little since 1996, when the mandatory labeling program was implemented on dryers. Most of the EU dryers are in efficiency level class B or C and it is very hard to make significant improvement without changing the drying technology, the heat pump dryer (Bertoldi, 2001).

These observations lead to the conclusion that there exists a technological barrier to dryer efficiency improvement (Werle, et al. 2011). As noted above, significant dryer efficiency improvement may depend on adoption of heat-pump dryers and other ‘disruptive’ technologies.

Australia Dishwashers

The energy rating label for dishwashers was introduced to Australia in 1992 and revised in 2000. The annual efficiency improvement is 2% from 1993-2009. It slows down from 2.9% to 2.2% before and after 2000. Figure 8 shows that the counterfactual cumulative market share for each efficiency level moves faster than the actual data. Similar to the cumulative market share of

the Australian dryer, the sales of lower efficiency models (1 and 1.5 stars) increased in 2000-2005, resulting in a slowing of market-averaged efficiency.

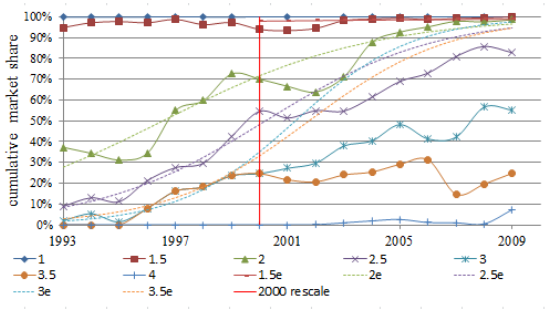

Figure 7. Australia dishwashers cumulative market share.

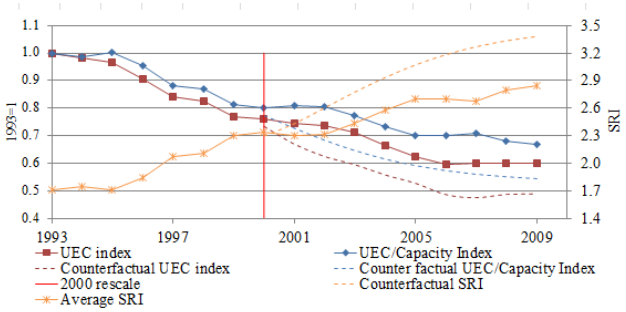

Figure 8. Australia dishwashers energy index.

Figure 9 shows that the efficiency improvement in counterfactual scenario is higher than the actual efficiency improvement. The counterfactual UEC/kg is 10% lower than its actual line. The counterfactual SRI goes up to 3.3 in 2009 while the real average SRI only reached to 2.9. The slowing efficiency improvement after 2000 could be due to the change in sampling method from GfK that the data was not as representative as they declared.

Australian Refrigerators

The picture for Australian refrigerators is somewhat different than other appliances due to the presence of a MEPS program in addition to the labeling program. MEPS for refrigerators where implemented in 1999 and 2005 for all product classes. Freezer-only units were subject to MEPS, but not a labeling program. The average efficiency improvement rate for refrigerators and freezers are 2.9% and 2.1% from 1993-2009. Figure 9 shows the strong market impact of two MEPS on Australian refrigerators. The market share for each efficiency level was relatively flat in between the MEPS, from 1999 to 2002, when the 2005 MEPS was announced. The flat cumulative market share in this period shows little efficiency improvement. This indicates a weak short-term impact of the labeling program on refrigerators when MEPS was presented.

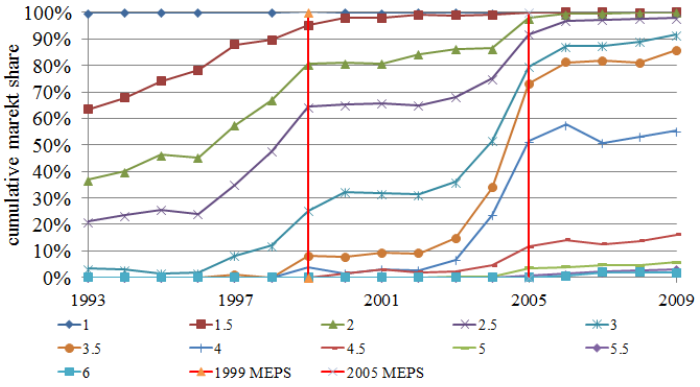

Figure 9. Australia refrigerators cumulative market share.

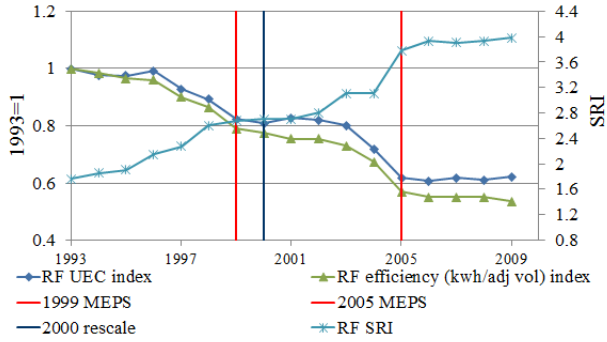

Figure 10a. Australia freezers only efficiency index.

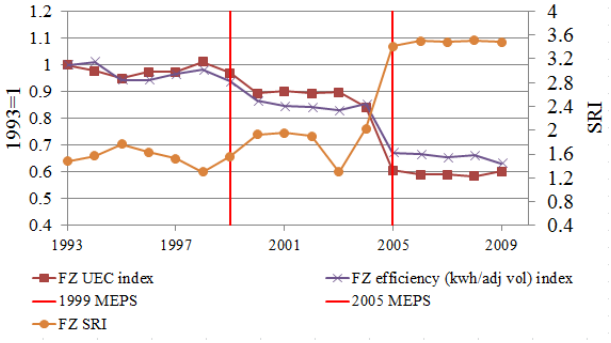

Figure 11b. Australia freezers only efficiency index.

Figure 11a and 11b show a similar efficiency trend for freezer only units, despite the fact that this product class does not have an energy labeling program. The efficiency increased significantly after the time when MEPS were announced, but remained relatively flat after the MEPS were implemented. There was a significant jump in SRI for freezers from 2003 to 2005, while that for the refrigerator-freezer was less dramatic during the same period. There is some evidence to suggest that where energy performance labels have already been introduced, the short-term impact of MEPS is reduced. This may due to the fact that the market is already prepared to some extent (at the very least, manufacturers already knew the relative performance of their models) (IEA, 2007).

Indian Refrigerators

The BEE imposed a mandatory labeling program for the Frost Free (FF) refrigerators and a voluntary labeling program for the direct cool (DC) type. The market share between product classes shifts from the FF to DC from 2009 to 2011.In 2009, the market was split half and half between FF and DC, In 2011, DC counted as 80% of the market.

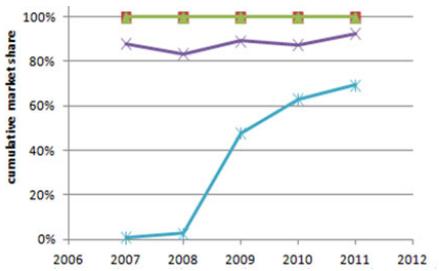

Figure 11. Frost Free cumulative market share.

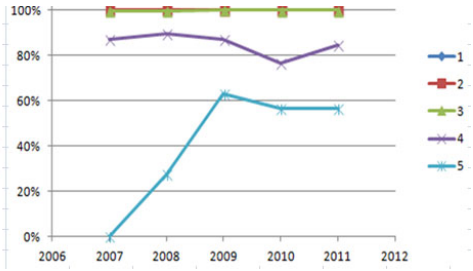

Figure 12. Direct Cool cumulative market share.

Figure 12 and 13 show that the level 5 (the most efficient) of India refrigerators for both types is rapidly increasing and has gained most of the refrigerator market by 2011. The sales for level 5 refrigerators for both types increased drastically from 2007-2009 and slowed down afterwards. The increasing sales of the DC refrigerators and the dominating level 5 efficiency call the need for update for the Indian refrigerator labeling standard.

Interestingly, the annual efficiency improvement for refrigerators in Australia, the EU and India is quite similar. As Figure 1 indicates, that the average annual efficiency improvement for refrigerators in all three economies is at around 3% despite variations in baselines and target definitions.

Conclusions

This paper uses a new methodology to quantify the rate of market transformation towards energy efficiency appliances under comparative labeling programs. The most obvious result of the study is that appliance markets in which comparative labeling programs are in place show significant improvements in market average energy efficiency. While it is impossible to precisely quantify the impacts of labeling programs alone from market effects and other programs where they exist, it is reasonable to assume that at least part of the improvement is due to the labeling program. In addition, in the case of Australian appliances, the labels were rescaled in 2000, providing a disjuncture where the change in market behavior can reasonably be attributed to the policy move.

A second important result is that there exists a significant amount of variability among countries and appliances. In spite of this variability, when in comparing like appliances across countries, some patterns emerge. For example, market average dryer efficiency improvements are quite small across the world. The detailed data from Australia allows us to see that no dryer models exceed the 2 star rating, although in principle the labels should encourage a full range of efficiencies. This clear ceiling of efficiency implies a technological barrier. Heat pump dryers are 'discontinuous' technology that overcomes this barrier and provides a big jump in efficiency. The Swiss government has targeted heat pump dryers and has strongly encouraged their adoption, including through MEPS. It is not surprising, then, that the improvement rate for dryers in Switzerland is of a different scale than other countries.

A second example where interesting dynamics can be seen are washing machines in Australia. From the results, we can observe that although front-loading and top-loading are both regulated by comparative labeling programs, most of the market average efficiency improvement arises from the shift between product classes, not increases within them. This shift seems to have been enhanced by the rescaling in 2000, indicating that that policy change was effective in accelerating a market transformation.

Interestingly, the observation of market average efficiency improvement for refrigerators is similar across countries. Despite the different design of the labeling programs (e.g the efficiency difference between each level or the MEPS), the average annual efficiency improvement for refrigerator around the world is about the same—around 3% per year. In Australia, the MEPS shows a strong short-term impact on pulling the efficiency up, but the long-term impact of MEPS and labeling program is similar to other countries. Refrigerator markets show evidence of saturation effects in the case of Indian refrigerators and EU dishwashers. For these products, the labeling moves the efficiency in the market until most of the available product is rated at the highest efficiency level. As a result, manufacturers and retailers do not benefit more to sell more efficient appliance and improvement slows down. This market phenomena calls for a policy update in order to avoid a deceleration of the efficiency improvement.

In conclusion, this study provides new quantitative evidence of the impacts of labeling programs and starts to shed light on some important dynamics of these by using a cross-country multi-appliance dataset. These interesting but somewhat limited findings could be further developed if more data becomes available. In addition, significant insights of the dynamics of markets under a program could be accessed if cost data were to be added to this analysis in the future.

References

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