

# Closer to One GreatPool? Evidence from Structural Breaks in Oil Price Differentials

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Crude oil can vary significantly in some key physical properties, making them imperfect substitutes for each other and leading to the existence of price differentials among crude oils. These price differentials are important for many oil market participants. For refiners, they can affect profitability and influence investment decisions about specific equipment that could improve the profitability of processing lower grades of crude. Oil producers and fiscal authorities are concerned about these differentials because of the impacts they can have on revenues earned from producing or taxing certain types of oil. Finally, for academics, analysts and others interested in understanding the upstream and downstream oil markets, these differentials provide important signals about how supply and demand conditions change over time for one type of crude relative to others.

This paper investigates how the size of these quality-driven price differentials has changed over time. More specifically, we consider if these differentials have experienced permanent shifts, or structural breaks, in their average values. This research is motivated by the simple observation that in the data many differentials between high and low-quality crude oils appear to have become significantly smaller and less volatile since 2008.

We use a statistical test to formally document that price differentials between different grades of crude oil have become smaller over time. In particular, we show that many experienced a major structural break around the time of the Great Recession. Specifically, 25 out of 27 possible differentials in our daily price data, and 38 out of 42 cases when using monthly data. We then use these tests to investigate whether oil price differentials between crudes of the same quality experienced a similar set of breaks, which would suggest a broader change in the oil market not necessarily connected to crude quality. Overall, we do not find any evidence for such breaks.

As part of the paper, we document several fundamental, long-lasting changes in the oil market that we believe are consistent with the pattern of small differentials. One is the fact that the global refining sector has become increasingly complex over time, as upgrading capacity additions have increased the ability of the sector to transform lower-grade crude oil into high-valued petroleum products. The other is the shale boom, which has unexpectedly increased the relative supply of light crude oil, reducing, on the margin, the need for such complex refineries. This narrowing of the differentials has occurred despite the fact that increasingly stringent environmental regulations and a persistent decline in the use of residual fuel oil should be pushing them apart.

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## **Linking an Emissions Trading Scheme with a Renewable Credits Market in Korea**

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Korean government launched the Emission Trading Scheme (ETS) in 2015, which is a government-mandated market-based policy option to control greenhouse gas (GHG) emissions at the national level. The national target has been set as a 30% reduction of GHG emissions from BAU (business-as-usual) level by 2020 under the Framework Act on Low Carbon, Green Growth. The Renewable Portfolio Standard (RPS) which came into force in 2012 aims to increase the production share of renewable energy in electricity generation.

ETS allows companies to use offset credits generated from renewable power generations by up to 10% of total allowances, unless credits can also be used to comply with RPS in Korea. Therefore, even if two quantity-based regulation systems have different policy objectives, both mechanisms can be indirectly affected by credit conversions between the two, depending on their prices. This paper models an analytic partial equilibrium model and derives closed form market equilibria to demonstrate how the policies of one mechanism influence the other. This study mainly focuses on illustrating the interactions between the two regulatory markets as a consequence of changes in policy related to GHG regulation or RPS obligations. Furthermore, each system is administrated under different supervising agents, meaning that the decision of one regulatory agent may inadvertently affect the other's policy. Hence, it is necessary to pre-coordinate the effectiveness of the policy through this model.

We show that although any policy change would impact the same market directly incurring high price changes, the other market shows relatively small indirect responses in price. These unequal price responses from policy changes might give some comfort to policy makers unless they aim to influence the market they are not in charge of. Also, the calibrated results give policy implications on the degree to which the level of penalty and quota in carbon and renewable credit markets affects market participants' behaviour or prices. Policy makers can predict the effectiveness of regulatory changes across both markets through this model.

## **Cross-border Effects of Capacity Remuneration Mechanisms: The Swiss Case**

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European electricity markets are becoming more and more integrated as a consequence of internal market guidelines and the so-called Energy Union Strategy. Integration of the electricity markets is mainly driven by two intertwined processes: On the one hand, European markets are more tightly linked by implicit auctions and combined by the Price Coupling of Regions run by eight European power exchanges. On the other hand, the physical transmission grid is expanded

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and, in particular, the interconnectors will be further enhanced according to the 10-year network development plan of the European Network of Transmission System Operators.

As a result, various cross-border effects can be observed: Energy flows from market areas with higher prices to those with lower prices result in a convergence of electricity prices in connected market areas, given that sufficient interconnection capacity is available. Price convergence stops, if the available interconnector does not allow any further flow of electricity and, in this case, a certain price difference remains. However, an additional interconnection line between two market zones can increase price assimilation, resulting in positive welfare effects.

In this article, cross-border effects of different market design options are analyzed using Switzerland as a case study. Switzerland is largely influenced by surrounding (mainly large) electricity markets and needs to analyze political decisions regarding market design changes and to react to developments in the neighboring countries. The extent of this influence is studied with the help of an agent-based simulation model that is applied to two different scenarios describing possible developments. In one scenario all market designs are represented according to the current legislation (CRM Policies). In the other scenario energy-only markets (EOM) are assumed in all countries considered. Furthermore, two additional sensitivity scenarios based on the current legislation are applied to support the conclusions: First, with less capacity for the German strategic reserve and second, with a dry year regarding stored hydropower.

This study considers a long-term time horizon (until 2050) that allows to analyze generation adequacy not only for the current energy system with a comparably low share of intermittent renewables, but also for a time period with very large shares of intermittent sources in the energy system that may not be available when they are needed during peak demand hours.

In general, the model results indicate a strong price increase in the Central Western European electricity markets, which is mainly due to rising carbon certificate prices and increasing demand. Due to the planned larger interconnector capacities, this increase is evident in all simulated markets. However, the wholesale prices in the CRM Policies scenario are lower by up to 27 EUR/MWh than in the EOM scenario in the long term. This is caused by the introduction of national capacity remuneration mechanisms (CRMs) with high targets for domestic generation adequacy, which lead to higher installed capacities in the entire coupled market area. In the EOM scenario, by contrast, the capacities are scarce, resulting in price peaks.

Cross-border effects can strongly influence the investments in neighboring countries, thus increasing or decreasing the level of domestic generation adequacy. For this reason, it is essential to assess and anticipate these effects. The results indicate that the planned market design changes in the neighboring countries decrease investments in Switzerland. However, generation adequacy is still guaranteed due to the high Swiss hydropower storage capacity. Our results suggest that, under the current circumstances, a domestic CRM in Switzerland is not required.

Regarding the cross-border effects on the country without a CRM, in this case Switzerland, it is found that higher capacities in the neighboring countries lead to reduced domestic investments. In the CRM Policies scenario, the Swiss market can rely on higher import flows from neighboring countries. Hence, Switzerland remains dependent on neighboring countries, although it has a very limited influence on their market designs. However, it also found that sufficient generation capacity is available to serve the electricity demand in each time step in all scenarios. The reasons for that are large interconnector capacities and the high hydropower capacity in Switzerland. This means that although there is an influence on prices, generation adequacy in Switzerland is not adversely affected by market design changes in neighboring countries.

The results and subsequent conclusions are very interesting for countries that have large neighboring countries with highly interconnected electricity markets and are not limited to Switzerland. For the rollout of storage capacities due to falling battery prices, Switzerland may serve as an example, because these facilities (and flexible loads) have been used intensively in its market area for decades. Sensitivities with a dry year or with a reduced strategic reserve in Germany underlines that our conclusions are still valid even under difficult conditions, which is beneficial for a generalization of the results.

## **The Natural Gas Announcement Day Puzzle**

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The natural gas market has undergone massive changes throughout the last decades, starting with its deregulation in the 1980s, the inception of the futures market in 1990, the inflow of financial investors at the beginning of the twenty-first century, and recent shifts in supply and demand due to shale gas, a growing industry for liquefied natural gas (LNG) as well as increased attention related to climate change. Natural gas storage levels have always been an important indicator of changes due to their natural role as a buffer between supply and demand. As such, release of the Weekly Natural Gas Storage Report by the Energy Information Administration (EIA), which contains information about the current storage level, draws attention from all market participants. When new information is released to an efficient market, participants adjust their expectations and prices accordingly. More than 50% of the annual return of natural gas futures is generated on weekly EIA announcement days. Therefore, returns on natural gas futures are significantly different on EIA announcement days compared to non-announcement days. However, after controlling for the information of the announcement this difference should disappear.

This article documents a significant difference between the average returns observed on EIA announcement days and non-announcement days. Puzzlingly, this difference in returns between announcement days and non-announcement days cannot be explained by the information content of the announcement. Indeed, we find a strong significant negative relationship between natural gas futures returns and the announcement surprise, but we cannot explain the return difference between announcement and non-announcement days. This result is robust after augmenting the model with supply and demand measures, spillover effects from options, energy or equity markets as well as commodity specific variables such as the slope of the futures curve, hedging pressure, liquidity or volatility measures.

At the intraday level, we decompose the return within a two hour window surrounding the announcement into a pre- and post-announcement part. Curiously, the overall return divides equally into the pre-announcement part (49.4%) and the post-announcement part (50.6%). Albeit modest evidence for the leakage of information, this can only be a partial explanation as there is still a significant effect from the announcement. Lastly, we document that the pre-announcement return is entirely realized on days where the announcement surprise is positive, i.e., the published inventory exceeds analysts' expectations. The asymmetry of this result casts doubt on a simple explanation based on informed trading.

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From the perspective of an investor, this puzzling result raises the question whether the newly documented premium is economically large once transaction and funding costs are accounted for.

Our results show that the simple strategy of opening a short position 90 minutes before the announcement and closing it 30 minutes afterwards yields a significant annual return of 12% (t-stat = 2.93) translating into a Sharpe ratio of 1.76 after transaction and funding costs. However, the time series of strategy returns and the accuracy of analysts' forecasts suggests that the anomaly has decreased in magnitude and efficiency has returned to natural gas markets, leaving open the possibility that our strategy was new to investors who are now arbitraging it away.

## Why Has China Overinvested in Coal Power?

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While the Chinese government has sponsored a historically unprecedented expansion of renewable energy since 2005, China has, at the very same time, been investing heavily in coal power. From 2010 to 2015, China's coal power capacity increased from 660 to 884 GW, and China approved nearly 200 GW of new coal power capacity in 2015 alone, raising serious concerns of overcapacity in coal power and further crowding-out of renewable energy.

In order to understand why China engaged in such a massive expansion of coal power investment in the mid-2010s, we investigated key industry policies that have effectively subsidized and (over)incentivized coal power investment. We found that the rules under which China's coal power industry has historically operated made excessive investment extremely likely unless the central government served as a "gatekeeper," slowing and limiting investment in the face of incentives for socially excessive entry. However, this "gate" was lifted when coal-power project approval authority was decentralized from the central government to local governments at the end of 2014, which shortened approval time significantly and allowed investment to flood into the market.

We construct a simple economic model that captures key features of the policy regime influencing coal power investment, and then examine the model's predictions using coal-power project approval records from June 2013 to March 2016. We further hypothesize that provinces that already had a relatively large coal mining industry may be even more likely to permit the construction of new plants, because this could stimulate demand another important local industry, boosting measures of economic growth and increasing local officials' likelihood of promotion.

We find the approval rate of coal power is about 3 times higher after approval authority is decentralized, and provinces with larger coal industries tend to approve more coal power. We estimate that the presence of local coal production explains an additional 54GW of approved coal power in 2015 (other things equal), which is about 1/4 of total approved capacity in that year. While the central government has since taken measures to contain the coal overcapacity crisis, keeping the supply and demand of coal power balance in equilibrium will require more than a few *ad hoc* administrative orders. When it comes to the development of renewable energy and reform

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of the electricity sector, China is viewed as having very diverse development goals that often conflict with one another – including energy security, economic development, and environmental protection. Effective reconciliation of these conflicting goals will be a necessary but difficult step on the way toward a more socially efficient energy system.

## **The Variation in Capacity Remuneration Requirements in European Electricity Markets**

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Capacity Remuneration Mechanisms (CRMs) arise to compensate providers of firm capacity for ‘missing money’ i.e. insufficient returns from the energy only market to recover capital costs and incentivise investment. EU energy market harmonisation objectives include implementing a process of open, transparent and non-discriminatory practices to allow foreign bidders to gain access to capacity markets. EU policy makers expect that harmonised capacity markets should ensure that overall costs are reduced, and that cross-border investment incentives and short-term merit order operation of the integrated electricity system are not distorted. Within the EU single energy market, competition is fair across countries because generators generally face the same input costs and state aid decisions have sought to avoid country advantages. However, with the introduction of CRMs, there is additional competition between generators benefitting from selective state aid, even if approved by the EU.

This paper provides the first EU wide analysis of the variation in Capacity Remuneration Requirements throughout Europe which aim to resolve the “missing money” problem in various member states. Under the assumptions of the European Commission Reference Scenario, pan-European power optimisation and investment models are specified for 2030. We consider and model the impacts of country specific climate policy targets, sovereign risks, fiscal measures and gas network legacy infrastructures on investor returns and therefore remuneration requirements. The results show that future investment in gas generators will depend on the availability of capacity payments. CRMs can provide this “missing money”, but we show that capacity remuneration requirements vary considerably across countries.

The research literature on this topic suggests that cross border capacity market participation between interconnected markets has many benefits, including welfare, efficiency and optimising the procurement of suitable capacity. These studies observe competing market structures and note that harmonisation has the potential to provide these benefits. However, externalities outside of the electricity market may create a harmonisation problem. If capacity remunerations vary due to sovereign risks, fiscal measures and legacy infrastructures, this could in itself distort competition. Rationally, generators in member states which operate in low risk markets could bid into high risk markets to receive the largest capacity payments to maximise profits. Generators in high risk member could then be unable to compete in low risk markets due to their higher cost base. In the context of harmonised energy trading, this raises questions of how generation adequacy should be achieved, particularly in the context of higher penetrations of renewables.

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## **In Light of Democracy and Corruption: Institutional Determinants of Electricity Provision**

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A large strand of previous research argues that democratic regimes provide more public goods and services than authoritarian regimes. Since political leaders are held accountable to the citizens in fair and regular elections, this literature argues, it creates strong incentives among political leaders to deliver broadly demanded public services. Indeed, long-lasting democratic institutions have been found to matter for, among other things, the universal provision of reliable electricity.

In this article we revisit this finding, suggesting that the effect of democracy on electricity provision is moderated by the quality of institutions shaping the implementation of public policies. We test the hypothesis positing the interaction effect between democracy and corruption using cross-national data on the share of population living in unlit areas. Our dependent variable is the percentage of the population living in unlit area, based on high-resolution satellite images capturing the concentration of outdoor lights around the globe. We use fractional logistic regression to estimate the relationship between democracy experience and the proportion of the population living in unlit areas.

The results show that democracy is associated with a higher electrification rate only in low-corrupt contexts. When corruption is widespread, democratic experience is not correlated with higher rates of electrification. These findings show that the effect of democratic institutions is conditional on the quality of the institutions that shape policy implementation. Our article thus provides a more nuanced understanding of the impact of democratic institutions on electricity provision.

## **Does Global Value Chain Participation Decouple Chinese Development from Co<sub>2</sub> Emissions? A Structural Decomposition Analysis**

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As the largest CO<sub>2</sub> emitter over the world, China accounted for 27.2% of global emissions in 2016. The Chinese government has pledged to peak its emissions before 2030. However, the prospect is not optimistic since China's emissions kept increasing in recent years due to economic resur-

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gence. Decoupling economic activities and CO<sub>2</sub> emissions is central to achieving the climate goals of China and the entire world. Global value chains (GVCs) have profound impacts on the economic growth and environmental issues, and China has increasingly participated in GVCs. Examining the impacts of GVCs on China's decoupling from emissions is of significance to identifying strategies to promote sustainability in China.

This paper shows that both the production and consumption of China were on the trajectory towards decarbonization in 2007-2012, though both were relative decoupling from CO<sub>2</sub> emissions. The final consumption of China was greener than its production activities. But the production related activities decarbonized more evidently than the activities induced by China's consumption in 2007-2012. The structural decomposition analysis (SDA) results reveal that GVCs were the primary source of China's decoupling from emissions during this period. Compared to the international value chains between China and foreign countries, domestic value chains within China played a more important role in greening Chinese economy. Sectoral emission intensity improvement was the main contributor, while the key barriers to further decoupling were the regional shift of global final demand and outsourcing structure of intermediates along GVCs. The progress in decoupling along GVCs slowed down after the financial crisis. Despite the considerable improvement, GVCs remained the main obstacle to environmental sustainability of China at the end of the study period.

Efforts from both the production and consumption sides are clearly needed to further decouple China's development from CO<sub>2</sub> emissions. Our results suggest that promoting green consumption and stimulating the diffusion and transfer of advanced production technologies within China are vital to further decarbonization. In particular, moving up GVCs is deemed important to emissions mitigation as well as economic growth, which relies heavily on fostering industrial competitiveness.

## **An Experimental Study of Monthly Electricity Demand (In)elasticity**

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The price elasticity of demand for electricity is a key parameter for analyzing the costs of climate change mitigation, the incidence of carbon pricing, market power, and electricity market design. This paper reports results from a field experiment designed to estimate this elasticity at the monthly level. In our experiment, we partnered with an electricity retailer to randomly provide households discounts of up to 95% off of their per-unit electricity price for two months. We provided different levels of discounts, some very large, which allows us to document highly inelastic demand at the monthly level across the entire range of the demand curve.

Combining our experiment with billing, smart meter, and survey data, we find that residential electricity demand is unresponsive to large reductions in both marginal and average prices. Our preferred own-price elasticity of demand estimate is -0.003. The estimate is statistically insignificant, but economically important as it points to perfectly inelastic demand. With 95% confidence, we can rule out households in our sample having a price elasticity more negative than -0.04.

We believe that the most likely explanation for our findings is that an intermediate, month-long time horizon is both too long to allow for significant inter-temporal smoothing of electricity

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use, and too short to change habits or household appliance stock. Over this time horizon, adjustment costs in behavior and technology can rationally justify non-response.

Our research design and data allow us to consider numerous other possible explanations for our finding of highly inelastic electricity demand in the medium run. These include households being unaware of our experimental discounts or confused, sample representativeness, price salience, appliance stocks, customer absenteeism in the home, and experimenter-goodwill. Given our experiment and data, we show that it is unlikely that these alternative explanations drive our results.

Our paper differs from the recent body of experimental evidence on electricity demand primarily in our choice of time horizon. We consider price shocks that are much longer in duration than is common in the experimental literature. In the context of this literature, the unique time frame of our experiment and magnitude of the price shocks that we study is policy relevant. Monthly price variation reflects changes in wholesale costs due to commodity price volatility and seasonality in both demand and supply. Indeed, previous research demonstrates that there are significant potential efficiency gains from passing through this variation to households, but the magnitude of the gains depends critically on the price elasticity of demand. Furthermore, monthly price elasticities have implications for the incidence of a price on carbon. In light of our null result, if households are inelastic over the medium-short run as we find, they will bear the full cost of carbon pricing over this period. Our findings directly point to this possibility, and any related distributional and political consequences.

## **Institutions and Geography: A “Two Sides of the Same Coin” Story of Primary Energy Use in Sub-Saharan Africa**

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The existing literature on energy use, in addition to investigating the direction of causality in the energy-income relationship and estimating their long-run dynamics, discusses the main determinants of energy demand. Thereby, very little attention has been given to factors such as institutional and geographical characteristics of countries. In Sub-Saharan Africa in particular, stylized facts suggest that relatively intense economic activities and primary energy use are observed in coastal located countries, raising questions on whether geography matters to endowment in energy resources and in primary energy use. Moreover, institutions shaping economic production activities might also play a similar role in energy use as in the comparative development literature. In this paper, using data on primary energy use and socio-economic indicators, we empirically provide insights into the “two sides of the same coin” role played by institutions and geography in primary energy use across Sub-Saharan African countries. On the one hand, our results show that good political institutions shaping economic performances also intensify energy consumption. On the other hand, geographical characteristics of SSA countries likely affecting endowments in fossil energy resources matter as well to primary energy use.

In addition, among the drivers of energy use, our analysis also points to aggregate economic production, exports and urbanization (measured by urban population share and its access to electricity). Conclusively, energy consumption being largely an urban phenomenon across Africa, factors such as ongoing population growth, cities enlargement and economic performances in Africa

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will probably foster energy demand (fossil energies use in particular) which obviously have adverse environmental consequences. In terms of policy implications, our results encourage African political actors to further think of alternative energy strategies.

## **Energy Cost Information and Consumer Decisions: Results from a Choice Experiment on Refrigerator Purchase in India**

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Research shows that energy-efficient appliances are cost-effective, yet they are not widely adopted. The phenomenon is commonly referred to as the “energy-efficiency gap”. Most studies find that inadequate information is an essential factor contributing to this gap. While deciding to buy a product, the capital cost information is more salient than operating cost information. Labels on appliances are being used globally to provide energy use information to consumers. In the majority of countries, these labels give information in physical energy units such as kilowatt-hour. Several researchers have studied whether financial information, such as annual operating cost can be more useful for consumer decision-making. A review of these studies shows that there is a difference in the impact across appliances within studies. A difference in the impact is also observed for the same appliance across studies. Recent studies on refrigerators show that annual operating cost information on labels increases the probability that consumers compare products based on costs and benefits of alternatives and are more likely to choose energy-efficient options. These studies are limited to the European markets. Moreover, these studies do not estimate consumer willingness to pay for a product in a higher energy efficiency category.

In this study, we extend the work by examining the impact of annual energy cost information on labels of refrigerators in the Indian market. We estimate the change in consumer willingness to pay for a higher category of energy efficiency when the annual operating cost information is provided on labels. We conducted a stated preference survey in a metropolitan city in India. In this survey, we interviewed households on their choice of refrigerators from two alternatives differing in their characteristics such as energy efficiency category, brand and price on a series of choice-sets. We divided the sample of 302 households randomly into control and experiment group. In the choice sets shown to the respondents in the experiment group, the annual energy cost of the refrigerator was also presented alongside the label. We specified a mixed-logit model so that we could estimate the magnitude and the distribution of consumer willingness to pay for a higher category of efficiency in the two groups.

Our results confirm the findings of past studies that unlike the existing label, the labels with annual operating cost information allows consumers to compare products based on energy efficiency categories. Using the operating cost information on labels, consumers differentiate between different classes of energy efficiency and place a higher value on a higher category of energy efficiency. In the absence of energy cost information, consumers are indifferent to categories of energy efficiency. We find that the willingness to pay for a higher category of energy efficiency is insignificant in the control group. However, in the experiment group, the consumer willingness to pay for the higher efficiency category is estimated to be US\$200 at a 95% confidence interval of \$104–296. To place these values in perspective, the mean price of the refrigerators considered in the study is \$285, and

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the associated lifetime savings in the operating cost due to increase in energy efficiency for a range of assumed discount rate (1–10%) is \$102–66. The share of the sample placing a higher value on the highest energy efficiency category as compared to a lower category increased from 54% in the control group to 76% in the experiment group.

Despite the growing research and evidence on a positive impact of monetary cost information on the effectiveness of appliance labeling, it is rarely used. The estimates of operating cost estimates based on average national energy prices could vary among consumers incurring different electricity costs. Hence, such information may still be inadequate for effective decision-making. It is essential to look at the mechanism by which the operating cost information operates on consumer decisions. Several studies have shown that consumers do not have the right knowledge about the energy costs of products. Hence, it is likely that the energy cost information on labels is operating by either providing or correcting the knowledge about the energy cost. Following this, we suggest that policy interventions to enhance consumer knowledge on energy costs of energy-using products through labels or other communication channels can help consumers make cost-effective decisions and address one of the causes of the energy-efficiency gap.