Consumer Price Impacts of Efficiency Standards

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ABSTRACT

In this report we calculate the change in final consumer prices due to minimum efficiency standards, focusing on a standard economic model of the air-conditioning and heating equipment (ACHE) wholesale industry. The model examines the relationship between the marginal cost to distribute and sell equipment and the final consumer price in this industry. The model predicts that the impact of a standard on the final consumer price is conditioned by its impact on marginal distribution costs. For example, if a standard raises the marginal cost to distribute and sell equipment a small amount, the model predicts that the standard will raise the final consumer price a small amount as well.

Statistical analysis suggest that standards do not increase the amount of labor needed to distribute equipment—the same employees needed to sell lower efficiency equipment can sell high efficiency equipment. Labor is a large component of the total marginal cost to distribute and sell air-conditioning and heating equipment. We infer from this that standards have a relatively small impact on ACHE marginal distribution and sale costs. Thus, our model predicts that a standard will have a relatively small impact on final ACHE consumer prices. Our statistical analysis of U.S. Census Bureau wholesale revenue tends to confirm this model prediction.

Generalizing, we find that the ratio of manufacturer price to final consumer price prior to a standard tends to exceed the ratio of the change in manufacturer price to final consumer price resulting from a standard. The appendix expands our analysis through a typical distribution chain for commercial and residential air-conditioning and heating equipment.

Introduction

This report investigates the effects of energy efficiency regulations on the final price of the consumer good. A change in appliance energy efficiency regulations usually increases appliance manufacturing prices and this report describes a method to estimate the resulting change in the final consumer price. We focus on the example of air-conditioning and heating equipment, but this approach can be generalized to other appliances and equipment. We observe that a change in energy efficiency regulations increases manufacturing prices of a piece of equipment by a predictable amount. There is a distribution chain which the equipment passes through before it is sold to the final consumer. Each time the equipment changes hands, the price is increased by a certain amount. We will describe a method for predicting this "markup" in price for each step of the distribution chain.

We define two types of markups: (1) the "baseline markup", the ratio of final consumer price to original manufacturing price, and (2) the "incremental markup", the ratio of change in final consumer price to change in manufacturing price (also called cost of good). The incremental markup tends to be lower than the baseline markup because the labor component of marginal cost at the wholesale and retail level does not increase due to a standard, despite the increase in the cost of goods sold. Our analysis supports using the incremental markup to predict final consumer prices. Our method for predicting final prices using an incremental markup is described in detail in section 3. We focus on the air-conditioning and heating equipment (ACHE) wholesale industry, as an illustrative example.

This industry is characterized by a limited number of equipment manufacturers and a large number of wholesalers, general contractors and contractors to distribute and deliver appliances to final consumers. The Census of Manufactures suggests that the distribution chain in the industry is relatively competitive, with many firms at each distribution level. For example, over 5,500 ACHE wholesalers, 37,000 general contractors, and 84,000 HVAC contractors are listed in the U.S. Census (U.S. Department of Commerce, 1997). As a result, our basic model assumes perfect competition and constant marginal cost curves in the industry. We discuss the impact of different market and cost curve assumptions on the predictions of this model.

The model is used to estimate baseline and incremental markups using ACHE wholesaler survey information. This estimate indicates that the ACHE incremental markup is different than the ACHE baseline markup. Next, we estimate baseline and incremental markups using ACHE U.S. Census Bureau information. The markups estimated from Census Bureau information are remarkably similar to markups estimated using ACHE survey information. The similarity of the markup estimated using two different data sets supports the basic model and suggests the accuracy of the incremental markup approach described in this report.

The Model

Notation

We consider two cases, a base case which represents the existing situation, and an efficiency case. The latter assumes that existing equipment is modified to improve efficiency, but otherwise retains the general characteristics that define it in the market. The modification leads to an increment in the manufacturer selling price. The incremental markup, α, is the markup on this manufacturer price increment. The markup is the ratio of the final customer selling price to the manufacturer price. The markup in the base case is also referred to as the baseline markup. In symbolic form we have the following definitions:

- P_0 = manufacturer unit price/cost of good sold (CGS) in the base case.
- P_0' = manufacturer unit price/CGS in the efficiency case.
- $\Delta_0 = P_0' - P_0$ = change in manufacturer unit price
- P_F = final consumer unit price in the base case
- P_F' = final consumer unit price in the efficiency case
- $\Delta_F = P_F' - P_F$ = change in the final consumer unit price
- $m = P_F / P_0$ = markup in the base case = baseline markup
- $m' = P_F' / P_0'$ = markup in the efficiency case = modified markup
- $\alpha = \Delta_F/\Delta_0$ = incremental markup, increase revenue per dollar increase CGS.

It is also useful to represent the increment to the manufacturer price as a percentage:

$$\varepsilon = \Delta_0 / P_0 \text{ or equivalently } P_0' = P_0 \bullet (1 + \varepsilon).$$

It is then easy to show that the relationship between the baseline and modified markups is

$$m' = (m + \alpha \bullet \varepsilon) / (1 + \varepsilon).$$

By definition $\alpha \leq m$, so that $m' \leq m$. If ε is sufficiently small we have the approximate relationship

$$m - m' \simeq \varepsilon * (m - \alpha).$$

This shows that the difference in markup between the base case and the efficiency case may be relatively small, being the product of two small quantities.

Economic Theory of Markups Under Different Assumptions About Market Structure

In this section we indicate the impact of different assumptions about market structure, including markets that face rising marginal costs, exogenous demand shifts, and oligopoly power.

Wholesale Incremental Markups Assuming Perfect Competition with Constant Costs

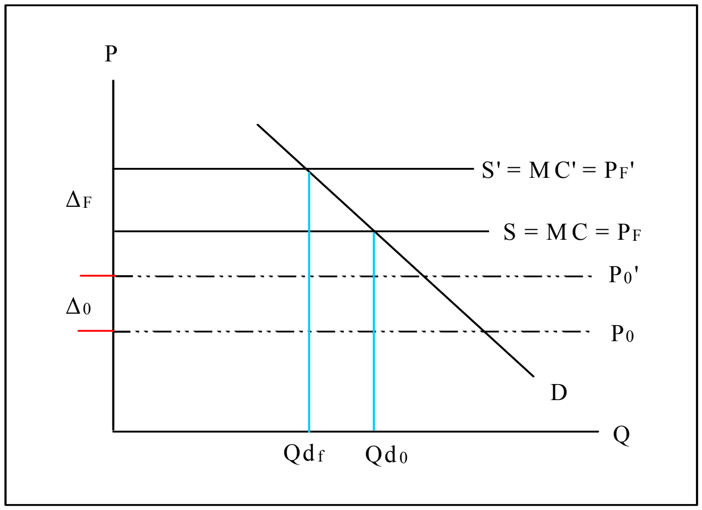
Under perfect competition with constant costs, products are priced at marginal cost (Pindyck and Rubinfeld, 1998). Assuming constant costs (perfectly elastic supply), marginal cost equals average unit manufacturing price plus average unit wholesale cost. This implies that the customer price (P_F) is set equal to unit costs faced by the wholesaler. As represented by the following equation, the change in customer price (Δ_F) due to an efficiency standard, equals the change in unit manufacturing price (Δ_0) added to the change in unit wholesale cost (MC_w):

$$\Delta_F = \Delta_0 + MC_w.$$

This change in customer price due to an efficiency standard assuming perfect competition and constant costs is illustrated in Figure 1.

This model of markup determination in the case of perfect competition and constant costs implies that the increase in final price that a consumer sees will equal those changes in costs associated with the increasing cost of a good. Some wholesale/retail costs, such as insurance and equipment financing costs, are likely to increase when appliance efficiency goes up and will contribute to the increase in the final price. Other costs, including labor and occupancy costs, are not likely to increase when appliance efficiency goes up and will not contribute to the increase in final price or be included in the incremental markup.

Figure 1. Relationship between Customer Price and Marginal Cost

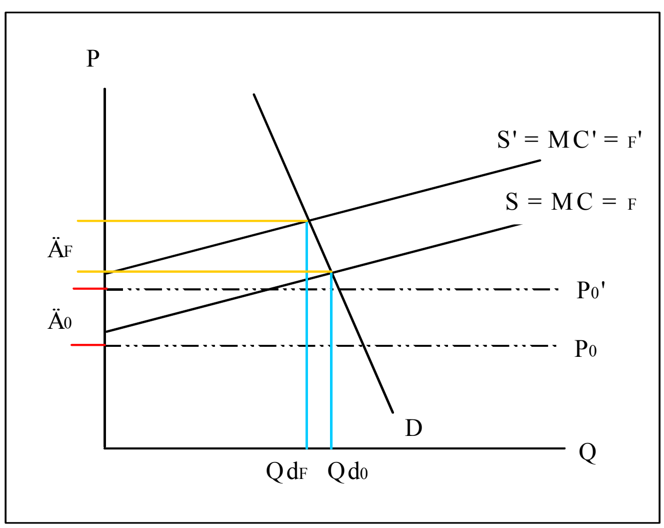


Impact of Rising Costs on Markups

As shown in Figure 2, under perfect competition with rising costs, products are priced at marginal cost. In this case, the upward shift in marginal cost (the supply curve) caused by standards is shared between the producers and the consumers such that Δ_F could be less than the shift in marginal cost. Thus, in this case, the final price to the consumer rises less than the upward shift in marginal cost. The fraction of the shift in marginal cost which is paid by the consumers, called the pass-through fraction, is dependent on the elasticities of supply and demand (Pindyck and Rubinfeld, 1998):

Pass-through fraction = E_s / (E_s – E_d), where, E_s = supply elasticity and E_d = demand elasticity.

Figure 2. Price as Function of Marginal Cost with Upward Supply Shift



Thus, the fraction of the upward shift in marginal cost that is passed through to the consumer varies inversely with the market wide elasticity of demand, and varies directly with the elasticity of supply.[1]

Impact of Demand Shift on Markups

It is likely that efficiency standards would create no shift, or a small upward shift in the demand curve as the quality of the good increases due to the efficiency standard (Hausman, 1979; Fredrick et. al., 2002).[2] While the size of this shift is hard to predict, we can gauge its effects by examining the quantity of goods demanded by consumers. If there is no shift in the demand curve, the quantity of goods demanded falls depending on the elasticity's of demand and supply.

We could define a small upward demand curve shift as one that leaves the quantity of goods demanded at or below pre-standard levels, but greater than the quantity demanded assuming only a shift in the supply curve. In this case we would find the pass through fraction to be larger than seen under just the supply curve shift, but it would still range from zero to one. If there was a large demand curve shift, the quantity demanded would increase to a level greater than that demanded before the standard was implemented. In this case the pass through fraction would be greater than one, and would depend on the size of the increase in demand.

We can summarize the effects of elasticity and demand shift based on one measurement. If, after the standard is implemented, the quantity of good demanded falls the pass through fraction will range from zero to one. If, after the standard is implemented, the quantity of good demanded increases, the pass through fraction will be greater than one. If, after the standard is implemented, the quantity of good demanded stays the same then the pass through fraction will equal one.

In a situation with rising marginal costs, where the market demand is extremely elastic, we might see very little change in price due to a given shift in marginal cost. In this situation, provided most of the cost increases seen by the firm came in form of an increase in cost of good, we might find an incremental markup of less than one. In a situation where demand shifted outwards due to increase appreciation of the benefits of efficient appliances, we might see a larger incremental markup. However, this effect is due to changing consumer preferences as opposed to increased costs to manufacturers, wholesalers, and retailers.

Impact of Market Power on Markups

Unlike a firm in competition, a firm with market power is not a "price taker." A firm may choose its quantity that it sells and charge the maximum price given the demand. The profit maximization rule--marginal revenue equal to marginal cost--applies when firms with market power maximize their profit. Under market power, price will be greater than marginal cost. Here, we define a "economic markup", m_e, as:

$$m_e = \Delta_F / MC_w.$$

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[1] E_d is defined as negative. (Price increases resulting in lower quantity demanded.)

[2] The sources cited support high implicit discount rates and thus low demand shift (due to a low consumer value time discounted energy savings).

Figure 3 shows such firms facing a highly elastic residual demand. This is a case where a firm has very limited market power. Such firms will see an economic markup of less than one. In Figure 4 we see an example of a firm that faces an inelastic residual demand. In this case, the economic markup is greater than one (Pindyck and Rubinfeld, 1998). The economic markup is estimated as a function of the elasticity of market demand in the following equation (Bhuyan and Lopez, 1995):

$$L = (P_F' - MC_w) / P_F' = (H + \alpha (1-H)) / E_d$$

In this equation, P_F', MC_w , H, α and E_d represent the price, marginal cost, Herfindhal-Hirschman index, collusion parameter, and absolute value of the demand elasticity, respectively. The collusion parameter (α) represents the degree of industry wide collusion, where Cournot and perfectly collusive behavior are represented by α = 0 and α = 1, respectively. The Herfindahl-

Figure 3. Elastic Residual Demand

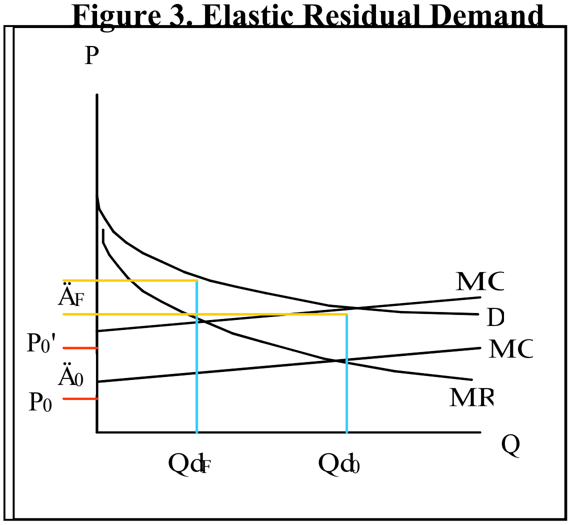
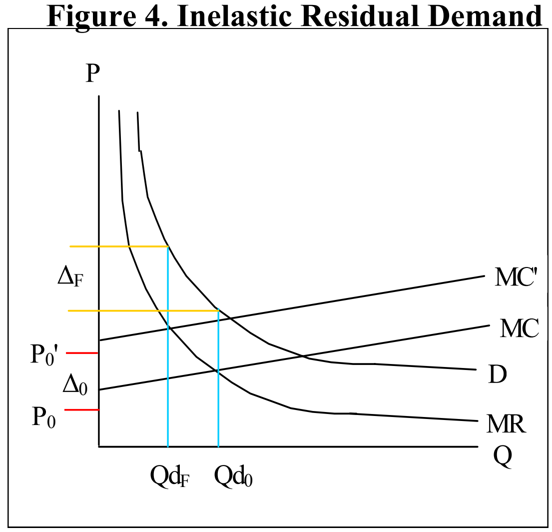


Figure 4. Inelastic Residual Demand



Hirchman index (H) measures industry concentration (H approaches 0 under perfect competition and exceeds 1000 for moderately concentrated industries). The market demand elasticity (E_d) indicates the responsiveness of production to changes in the price ($E_d < 0$). The other variables in the equation are defined above.

Solving for P_F' gives,

$$P_F' = MC_w \bullet [E_d \; / (E_d - (H + \alpha (1-H))]$$

This expression demonstrates how marginal cost, demand elasticity and other variables interact to determine the consumer price. When firms have market power as described by this equation, our method for calculating markups needs to be adjusted. In the equation, price equals marginal cost times a multiplier (E_d / (E_d - (H + α (1-H))). Since the multiplier is itself a function of the price elasticity, the economic markup varies according to price elasticity value.

Depending upon the size and potential changes in elasticity value, the multiplier may be larger or smaller than one as illustrated above (Figure 3 and Figure 4).[3]

Estimating Markups

Estimating markups using balance sheet data. The wholesale ACHE markup is based on firm balance sheet survey data obtained from the trade associations representing ACHE wholesalers. Wholesalers reported median data in a confidential survey conducted by the Air-conditioning and Refrigeration Wholesalers Association (ARW). These balance sheets break out the components of all costs incurred by wholesale firms that handle ACHE (Air-conditioning and Refrigeration Wholesalers Association, 1998).

The wholesale cost data are summarized in Table 1.[4] The data show that for every $1.00 spent by the wholesaler on equipment costs, $1.00 in sales revenue is earned to cover the equipment cost, $0.20 is earned to cover labor costs, $0.05 is earned to cover occupancy expenses, $0.07 is earned for other operating expenses, and $0.04 is earned in profits. This totals to $1.36 in sales revenue earned for every $1.00 spent on equipment costs. This tells us that the wholesale baseline markup is 1.36, since the wholesaler earns $1.36 in sales revenue for every $1.00 spent to purchase the equipment. In other words, for every $1.00 taken in as sales revenue, $0.74 is used to pay the direct equipment costs. Labor expenses represent $0.15 per dollar sales revenue, occupancy expenses represent $0.04, other operating expenses represent $0.06, and profit accounts for $0.03 per dollar sales revenue.

Table 1. Wholesale Expenses and Markups

Description	**Firm Revenue** Per Dollar Cost of Goods Sold
Cost of goods sold: Primarily ACHE manufacturing cost	$1.00
Labor Expenses: Salaries, Payroll, Benefit plans	$0.20
Occupancy Expenses: Rent, Utilities	$0.05
Other Operating Expenses: Insurance, Depreciation	$0.07
Profit	$0.04
Baseline Markup: Revenue per dollar CGS.	1.36
Incremental Markup: Increase revenue per dollar increase cost of goods sold.	1.11

Source: 1998 ARW Wholesale Profit Survey Report.

In order to interpret the cost data we must first understand the structure of the wholesale industry. Past studies on market power have found a variety of results based on the method used and the industry surveyed. We have found some results supporting the idea of low market power

[3] Here we need to adjust the method used to calculate incremental markups. Unlike the case of perfect competition, firm profits are positive and firm income exceeds the opportunity cost of capital. As long as the firm makes as much or equal to the opportunity cost of capital, it will continue to produce. Thus, the opportunity cost of capital (the profit section of the survey) would not be not included in markup calculations using the Lerner index.

[4] The data in Table 1 were converted from costs per dollar revenue to revenue per dollar CGS by dividing each cost category in the survey date by $0.74 (i.e., the CGS per dollar revenue).

in the appliance wholesale market (Norrbin, 1993). The competitive nature of the market is also suggested by the large number of ACHE firms listed in the 1997 Census of Manufactures. For example, there are over 5,500 ACHE wholesalers, over 37,000 general contractors, and 84,000 HVAC contractors listed in the 1997 Census (U.S. Department of Commerce, 1997). In addition, wholesale and retail appliance markets are considered to have few barrier to entry so that even new firms that wish to enter these markets can do so without making large up front capital investments, acquiring expensive patents or overcoming government regulations. Markets with limited barriers to entry, termed contestable markets, behave like competitive markets, even when the number of firms is small (Mansfield, 1997). Finally, we have no data about the shape of the marginal cost curve, but a conservative assumption in this case would be to assume that the cost curve is horizontal. Thus we expect to see firms set prices set at marginal cost as shown in Figure 1.

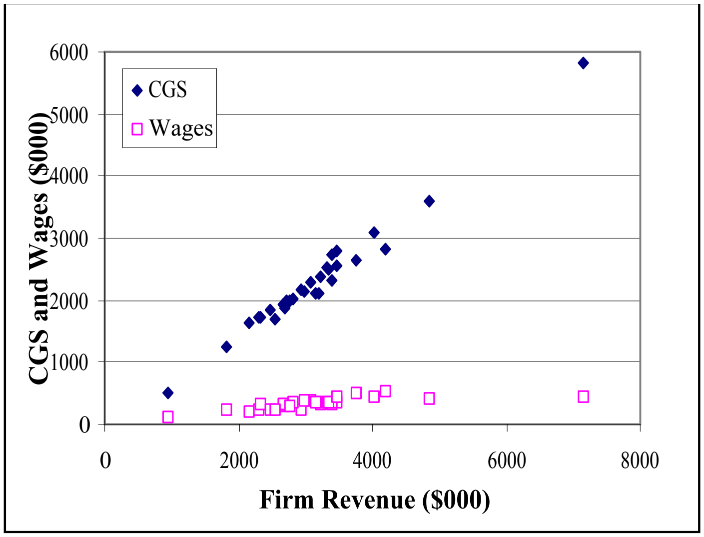
We use the data in Table 1 to calculate baseline markups on existing equipment (prior to efficiency changes resulting from enactment of efficiency standards) by making assumptions about changes in labor and occupancy expenses resulting from changes in appliance efficiency. The incremental markup will depend on which of the costs in Table 1 are variable with respect to cost of good, and which are fixed with respect to cost of good.

For example, for a $1.00 increase in the manufacturer equipment price, if *all* of the other costs scale with the manufacturer price (i.e. all costs are variable), the increase in wholesaler price will be $1.36, implying that the incremental markup is 1.36, or the same as the baseline markup. At the other extreme, if none of the other costs are variable, then a $1.00 increase in the manufacturer price will lead to a $1.00 increase in the wholesaler price, for an incremental mark-up of 1.0. Actually, we expect that the labor and occupancy costs will be fixed and that the other operating costs and profit will scale with the manufacturer price (i.e. are variable). That is because in our judgment it requires no more labor to handle high efficiency equipment than it takes to handle existing, lower efficiency equipment. In this case, for a $1.00 increase in the manufacturer price, the wholesaler price will increase by $1.11, giving a wholesale incremental markup of 1.11.

Estimating markups using U.S. Census Bureau data. The ACHE census data includes firm revenue, the CGS, and labor wage data for ACHE firms in different U.S. States (U.S. Department of Commerce, 1997). The data allow us to compare the trend in average firm CGS in different states with the trend in average firm payroll, both as functions of firm revenue (Figure 5). Each diamond shape in Figure 5 indicates average firm payroll and revenue in one State. The diamond shapes in the Figure indicate that average firm payroll increases across States as a rough linear function of average firm revenue. Each square shape in the Figure indicates the average firm CGS and revenue in one State. The square shapes in the Figure suggest that average firm CGS increase across States as a rough linear function of average firm revenue.

We calculated the national baseline markup of ACHE firms by dividing total firm revenue (summed across all States) by total firm CGS (summed across all States). The national baseline markup calculated in this manner is 1.39. Note that this markup estimate is very close to the 1.36 baseline markup calculated using ARW survey data.

Figure 5. CGS, Wages and Firm Revenue



We calculate the incremental markup of ACHE firms from a regression analysis of the revenue, CGS, and payroll census data. First, we use the data to estimate the following regression equation of firm revenue as a linear function of the CGS and firm payroll:

$$\text{Firm Revenue} = \underset{(1.7)}{181.4} + \underset{(26.5)}{1.1} \bullet \text{CGS} + \underset{(3.1)}{1.3} \bullet \text{Payroll}$$

(R2 = .98)
(N = 30)

In the above equation, 181.4 is a constant term, 1.1 is a coefficient associated with changes in the CGS and 1.3 is a coefficient associated with changes in firm payroll. For example, average firm revenue in a State with CGS averaging $1,000 and wages averaging $200 is estimated using this equation to be $1,541. The statistical fit (R^2 equal to .98) and significant t statistics associated with the coefficients for CGS and Payroll suggest that the equation is accurate and well specified.

We estimate the incremental markup using this equation from the coefficient associated with CGS. The coefficient associated with CGS in this equation indicates the change in firm revenue associated with a change in CGS, holding payroll constant (the partial derivative of CGS). Following our assumption that labor and occupancy costs are fixed, this coefficient provides an independent estimate of the ACHE wholesale incremental markup. We note that the value of this coefficient (1.10) is almost identical to the incremental markup calculated from ARW survey data as discussed earlier (1.11).

Conclusion

In this report we establish an approach for estimating incremental markups based on a reasonable set of assumptions about costs that vary with changes in appliance efficiency and costs that do not vary with changes in efficiency. We apply this approach to calculate ACHE wholesale incremental markups using two sets of data—ARW survey data and U. S. Census Bureau data. Following this approach these two data sets gives almost identical estimates of

ACHE incremental markups, increasing our confidence in our estimation approach and methods. In addition, we show in each case that the incremental markup is significantly lower than the baseline markup under perfect competition.[7]

Following our focused discussion on the wholesale ACHE industry, we evaluate markups under different market structures, including markets characterized by rising marginal costs, exogenous demand shifts and market power. We conclude that rising marginal costs tend to lower markups, demand shifts may lower or increase markups and market power tends to increase markups, compared to markups in the base model case under perfect competition. This approach can be easily duplicated for other appliance industries that might be subject to regulation to increase energy efficiency standards.

Appendix A: Correlation Between Appliance Labor and Efficiency

The correlation between wholesale labor and appliance efficiency is evaluated with a regression analysis and correlation matrix of appliance efficiency, shipments, and wholesale labor trends between 1990 and 2000. Labor is total labor in the retail home appliance sector (thousands) (U.S. Department of Labor, 2000). Shipments are total refrigerator, freezer, home air-conditioning, cloths washer, and dishwasher shipments in each year (thousands) (Association of Home Appliance Manufacturers, 2000). Efficiency is the weighted average change in the efficiency of these appliances (average change in efficiency since 1981, weighted by appliance shipments) (Association of Home Appliance Manufacturers, 2000).[8]

The correlation matrix suggests that there is a negative correlation between labor and efficiency (Table A.1).

Table A.1. Correlation Matric of Appliance Variables (N = 10)

	Year	Efficiency	Labor	Shipments
Year	1.00			
Efficiency	0.93	1.00		
Labor	-0.83	-0.70	1.00	
Shipments	0.94	0.86	-0.67	1.00

The regression equation specified for the regression analysis is:

$$\text{Labor} = A + B_1 \bullet (\text{Shipments}) + B_2 \bullet (\text{Efficiency}) + B_3 \bullet (\text{Year}) + e$$

In this equation, Labor, Shipments, Efficiency and Year are defined above, B_i are coefficients to be estimated and e is the error term. All coefficients in the regression analysis show the expected relationship between the variables and labor (Table A.2). No significant relationship is established between wholesale labor and appliance efficiency.

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[7] A table of our results can be seen at the end of Appendix B (Table B.6). These results show that a standard will have a less than proportional impact on final ACHE consumer prices.

[8] Note, for the efficiency value, we examined the yearly change of percent change of efficiency from 1980. We took the weighted average of this based on the relative number of shipments for each year of each appliance to create a final value for yearly total change in efficiency in the home appliance sector.

Table A.2. Regression Summary for Dependent Variable (N = 10)

Variables	Coefficients	t statistics (six degrees of freedom)	R^2
Intercept	5005	3.49 **	
Efficiency	-0.028	-0.177	
Total Shipments	0.00104	1.97 *	
Time	-1.83	-3.41***	

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