fore subsequent price increases, no matter how great, might be expected to have less of an impact. In addition, since the absolute price increase in 1973-1974 was smaller than that in 1978-1979, it would not take such a great change in demand to result in the calculation of a higher elasticity. In other words, although an elasticity may be a good indicator of consumer response, it may fall short when one compares different periods of time with substantially different base prices and base quantities. The elasticities derived in this study, which are based on real price, are quite similar to the real-price elasticities from previous studies.

CONCLUSIONS

The purpose of this paper has been to present the results of an investigation of changes in motor-fuel consumption during a period in which significant changes in the supply of motor fuel have occurred. The examination was performed by using data for the state of Massachusetts during the 1967-1979 period. The focus of the research has been to relate the trends in fuel consumption to a number of factors related to its supply. These factors include price, fuel efficiency, and vehicle registrations. As might be expected, the number of vehicle registrations is the dominant factor, which indicates that the size of the vehicle fleet is the primary determinant of motor-fuel consumption. Price does play a role, and it is estimated that the short-term price elasticity of gasoline is between -0.18 and -0.44, depending on the price definition and the time period studied. Fuel efficiency relates to fuel consumption in that, as fuel efficiency increases, consumers can purchase less motor fuel without limiting the amount of vehicle miles of travel.

It would be useful to investigate further the specific ways in which consumers have changed their behavior in the face of rising gasoline prices and supply uncertainty (6). Monitoring of the overall fuel efficiency of the automobile fleet would be most useful in determining how consumers are adapting to rising fuel prices, and improvements in the procedure for collecting motor-fuel data would make possible a refinement of the analysis. Further research should also be performed by using more refined vehicle registration data. In short, while some conclusions as to the relative impacts of various factors on fuel consumption can be drawn, this study also points the way toward future research.

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Dual Price System for Management of Gasoline Lines

YOSEF SHEFFI AND VICTOR PRINS

The problem of crisis management during a shortfall in gasoline supplies is how to distribute the available gasoline in the most efficient and equitable fashion. Several approaches to this problem are reviewed, and particular emphasis is placed on a dual market scheme. The dual market system allows gasoline station operators to charge as much as they want for gasoline as long as for each high-price pump there is one pump operating at the regulated or controlled price. This creates a situation in which customers can either wait in line for the regulated-price gasoline or pay more and avoid queuing. The way in which this system actually creates a continuum of choices for each customer is described. Efficiency and equity criteria are emphasized, and some of the issues that may be associated with implementing the system are reviewed.

Most forecasts of energy availability in the near future include a provision for shortages in gasoline supplies for various periods of time. It is likely that the ongoing research into and development of alternative energy sources will not produce results in time to prevent such shortfalls. Thus, one of the questions confronting planners is how to best accommodate such a shortage. The focus of this paper is on one of the most visible consequences of a petroleum shortage--queues at gasoline stations.

This paper deals with some strategies for gasoline-line management.

The problem of emergency preparedness in the context of the gasoline market is different from the long-term issues of energy conservation. The fundamental difference is that the objective of crisis management is to best allocate the limited available supply to end users, not to reduce their consumption. This view of the problem objective leads to a set of criteria for judging various solutions based on comparisons between the scenario under each strategy and under the "do-nothing" alternative. These criteria are the subject of the first section of the paper. The next section concentrates on some specific crisis-management strategies and, in particular, the dual market mechanism that is the focus of the paper. Under such a scheme, the demand for gasoline is satisfied by having a portion of the population pay more in monetary units while others pay more in time units.

Examples of dual pricing in other markets are included in the third section, which also includes a simple model of the demand for gasoline and the queuing phenomenon. This model demonstrates numerically some of the topics discussed in this paper. The final section reviews some of the issues that may be associated with the implementation of the dual market system, including the required implementation effort, enforcement, and institutional and legal perspectives.

CRITERIA FOR MANAGEMENT OF GASOLINE LINES

The problem of managing gasoline lines is the problem of allocating limited supplies in the "best" way. In this section, we discuss criteria for ranking various solutions and judging the best one.

In order to evaluate any strategy, we must first describe a base case with which the strategies' effectiveness can be compared. The do-nothing alternative in this case is a gasoline shortage scenario in which queues form at every pump and regulated prices are similar to what they were in many states during the summer of 1979.

Thus, the situation is characterized by gasoline prices that are below the level that people are willing to pay. This creates the other mechanism for clearing the gasoline market--the queues. In queuing situations, people are paying in two forms: spending money to buy the gasoline and spending time waiting in the queue.

It should be realized that gasoline queues play more than one role in the crisis. On the one hand, they are an evil that government may be trying to eliminate by means of management schemes. On the other hand, they are a form of payment and thus one of the main causes for the aforementioned reduction in the demand for gasoline. This role of the queues may explain the limited effectiveness of some of the traditional queue-management schemes, a point discussed in the next section of this paper.

At the beginning of the shortage, there may be a transient phenomenon of "tank topping", which may exaggerate the crisis. Daskin and others (1) even argue that this panic buying is the main driving force behind the queuing. The view presented in this paper, however, is that it is the fundamental imbalance between prices and demand that drives the crisis. This view is similar to the approach taken by Dorfman and Harrington (2), Prins and others (3), and other researchers (4,5). Furthermore, based on data from California (collected during the summer of 1979), Goldstone (6) concluded that the queuing could not be explained by panic buying and is probably due to the above-mentioned supply-demand imbalance.

Let us now analyze this situation from two points of view: the economic and the social. The economic view gives rise to the efficiency criterion and, as noted by many authors (2,4), the do-nothing alternative scores poorly here. The queues are a very inefficient way of handling the gasoline payments. The main reason is that queues represent a loss of a resource (time) to the economy. The queuing time spent by the buyer cannot be enjoyed by the seller, and it cannot be taxed and used for public goods or income redistribution. The perfect solution to this inefficiency problem is, of course, to let the price rise to the point at which the market is cleared.

The social view of the problem leads to an equity criterion. Under the do-nothing alternative, people pay the difference between the controlled price and the market-clearing price by waiting in the queues. People with higher values of time "pay" more than people with lower values of time. This appears to be acceptable, since a higher value of time is typically associated with higher income and thus the queue may seem to serve as a direct income redistribution function. This is not the case, however, since even though high-income people may "pay", low-income people gain nothing from these "payments".

A second approach to the equity issue is from a regional perspective. Under the do-nothing alternative, some regions may suffer more than others because longer queues in one region do not provide any incentive to distributors to allocate gasoline to these harder-hit areas from areas where queues are shorter. This situation was apparent during the summer of 1979, when some states did not suffer any shortages while queues in other areas were getting longer and longer. The conclusion from these arguments is that the do-nothing situation is hardly equitable, even though all users pay the same monetary price for gasoline.

Letting the price rise may be economically efficient but is usually criticized as inequitable. This criticism is correct in the sense that low-income segments of the population will carry a large part of the burden and so will the segments associated with more driving. From the aforementioned arguments, it is clear that, under such a scheme, endogenous funds that may be earmarked for compensating those segments of the population can be generated. It seems, however, that societal values, as reflected in the political process, tend to discriminate against the economically efficient solution, mainly on the grounds of equity.

EXISTING STRATEGIES

The criteria discussed in the previous section did not include a conservation measure; i.e., no scheme for gasoline-line management is expected to save any gasoline. This means that no scheme is expected to include measures that effectively set the gasoline price above its market-clearing level (such as an extremely high tax or severely limited accessibility to the pumps). The role of gasoline-line management strategies is to distribute the limited available supply in the most efficient and equitable fashion. Before describing the dual market approach, let us review some of the existing approaches that have been used to solve the problem.

The first approach is the license-plate-based odd-even plan, which has been used in many states. This plan calls for gasoline purchases on either odd or even days of the month according to the last digit on the buyer's license plate. As noted by Prins and others (3), this plan may cause a small reduction in the average length of the queues, since the inconvenience incurred by the plan can be seen as some form of payment. In other words, the total price of gasoline under this plan includes the monetary price, the queuing time, and the inconvenience associated with not being able to join the queue on the spur of the moment.

This plan does not solve the problem on several counts. This may be due to the fact that a potential small reduction in the queues reduces the actual price paid for the gasoline. Since this price comprises money and queuing time, a reduction in the queue length may increase demand. Total consumption, however, is constrained by the supply so that the increase in demand shows in a higher propensity to wait and, thus, longer queues. The effect of such a plan may therefore be minimal. Furthermore, the transformation of one form of inefficient payment (waiting in line) to another (the mobility to buy gasoline when desired) cannot result in an efficient solution. From the equity point of view, this plan does not contribute much because the distribution of the burden remains as in the do-nothing alternative. Exemptions from the plan for some segments of the population can hardly be classified as equitable solutions, since they are based on making everybody else worse off rather than making the target population better off. (Without exemptions, this plan would discriminate against those users who have to fill up every day. Users who normally fill up every few days should not be affected at all by this plan, or they may decide to fill up when possible rather than when needed and thus aggravate the situation even more.) It seems that, although the odd-even plan may be effective against panic buying or the tank topping that follows the initial stages of the crisis, it does not bring about either a more efficient or a more equitable allocation as compared with the do-nothing alternative.

Other well-known schemes include minimum and maximum purchase restrictions. The analysis of all these schemes is analogous to the analysis of the odd-even plan. The maximum-minimum plans are clearly as inefficient as the do-nothing situation is and may be even less equitable. It seems, however, that these strategies are conceived as measures against transient tank topping, and thus it is not surprising that none of the above-mentioned schemes causes a measurable improvement in shortening queues or distributing the burden. (The usefulness of many of these schemes may be rooted in the restoration of public confidence in the government, which is obviously "trying to do something about the situation".)

None of these schemes fundamentally changes the situation in comparison with the do-nothing alternative and in fact can be viewed as minor variants of it. The only substantially different alternative discussed so far is letting the price rise to its market-clearing level, which gains much in efficiency and trades off some forms of inequity against others. Such a plan, however, is not politically feasible. This situation is the motivation for the dual market system proposed here, which combines some features of the do-nothing alternative with features of the economically efficient solution.

The dual market scheme allows each gasoline station to sell gasoline at two prices, each price associated with a distinct pump (or island of service). The operator may sell gasoline through one of the pumps at any price that he or she wishes provided that the other pump is operated at the regulated (controlled) price. In other words, for each free-price pump there should be at least one controlled-price pump operating.

Under this scheme, one can expect the price at the uncontrolled-price pump to rise. Gasoline stations will offer their customers two types of service to choose from: either wait in line and pay the regulated price, or avoid the long queue and pay more for the gasoline. Given the price at the controlled-price pump, the length of the lines at both pumps will be a function of the price set at the uncontrolled-price pump. In other words, the queue at the expensive (uncontrolled-price) pump may not be eliminated if the price differential is not high enough. It will, however, be shorter than the queue at the cheaper (controlled-price) pump. The key to the analysis of this scheme is the expected behavior of station operators. This subject is discussed in the next section, where we present a simple model that deals with operator behavior. In the remainder of this section, the dual market system is evaluated by using the efficiency and equity criteria.

At this point, let us assume that the price at the pump where gasoline is more expensive would rise to its market-clearing level. It is obvious that people who put a higher value on time (i.e., high-income people) will choose to pay for their gasoline in monetary units and avoid the queues while people who put a higher value on money (low-income people) will choose to wait. It can be expected that the prices at the uncontrolled-price pump will be higher than the prices that would have prevailed if the entire market had been allowed to clear in monetary units (the economically efficient approach). Similarly, the queues at the controlled-price pumps should be longer than in the do-nothing alternative. Both of these things happen because each market clears with a segment of the population that exhibits, by definition, a lower elasticity to the market-clearing measure. In other words, the uncontrolled portion of the market clears with a population segment that has a relatively lower value of money in comparison with the general population, whereas the controlled portion of the market clears with a population segment characterized by its relatively low value of time.

This scheme is clearly more efficient than the do-nothing alternative, since as much as half of the population will not have to wait in line at all or wait through a significantly shorter queue. The money paid by these people represents a transfer of resources rather than waste and thus leads to a more efficient solution than the do-nothing alternative. Furthermore, the population segment whose wait has been eliminated (or significantly reduced) is (by definition) associated with a high value of time, high opportunity costs, and probably high productivity. Thus, most of the waste is eliminated by reducing the wait time for this population segment. The time spent in the queue by people purchasing gasoline at the controlled market price is still an economic loss. It is, however, a much smaller loss than one may expect, since by definition the opportunity cost is very low for most of the people waiting in line. (In fact, according to neoclassical demand theory, most of these people would have preferred to wait even longer in exchange for even lower gasoline prices.) Thus, the dual market system is almost as efficient as the market-clearing price scheme.

The dual market approach may be at least as equitable as both the do-nothing alternative and the market-clearing price alternative. In comparison with the do-nothing alternative, the dual market scheme favors high-income people but requires them to pay more than they would have to pay under the market-clearing alternative. The people waiting in line for the controlled-price gasoline may have to wait somewhat longer than under the do-nothing alternative. This, of course, is a minus on the equity side, which may be somewhat softened by the fact that most people who choose to wait do not have a high value of time. In comparison with the market-clearing price alternative, the dual market system is more equitable since it allows low-income people to still obtain gasoline at the regulated price and not be priced out of the market. A population segment that may be disadvantaged by the plan (as compared with the free market system) includes those people who could have afforded the price and avoided queuing under the market-clearing price alternative but would not be able to afford the higher gasoline price under the dual market system. This group may not be a traditionally disadvantaged one and thus may not warrant special consideration; as we show next, however, the system offers a dimension of choice that may ease the aggravations of many population segments.

It should be realized that, even after equilibrium in both markets has been reached, consumer choice is not actually limited to two alternatives. In fact, over a long period, consumers can choose their optimal mix of money and queuing time by varying the frequency of choosing either alternative. Thus, any combination of length of queues (between zero and the length of the queue at the controlled-price pump) and price (between the controlled and uncontrolled prices) can be chosen. Moreover, by virtue of the frequency-of-choice mechanisms, the dual market system can account for varying values of time for the same individuals. In other words, individuals may either choose a combination of frequencies a priori, as described before, or choose based on their momentary value of time. For example, individuals may choose to avoid the queue and pay a higher price when going to work or to an important appointment and choose to wait in the queue at other times.

On the equity issue, then, the dual market system seems to be comparable to both the do-nothing alternative and the market-clearing price system. It may be more equitable than the do-nothing alternative in that it does not discriminate against people who have a high value of time and it may generate funds that can be used to compensate any severely affected group. It is, of course, more equitable than the market-clearing price alternative in that it does not discriminate against low-income population segments. Note that the segment of the population that is committed to a lot of driving will be hard hit under any scheme. Under the dual market scheme, some of the strain may be eased for some members of this group by providing them the opportunity to choose an optimal combination of time and money payments and by the possible availability of compensatory funds. At the same time, the dual market system is significantly more efficient economically than the do-nothing alternative and almost as efficient as the market-clearing price alternative.

DUAL MARKET SYSTEM

A dual market system is not a unique or a new idea. In fact, most of the existing markets are operating at multiple prices. One of the most vivid examples of this operation is the air-travel market, which offers first and coach classes as well as an array of lower fares associated with some restrictions (e.g., advance reservations, stay limitations, and standby status). In fact, the whole idea of different packaging (e.g., Oldsmobile Omega versus Pontiac Phoenix versus Buick Skylark versus Chevrolet Citation) may be viewed as some form of dual or multiprice market, where the same basic product is offered at several prices. Furthermore, a dual market in gasoline exists even now as gasoline stations offer the same type of gasoline at self-service or limited-service islands and at full-service islands but charge higher prices for the latter.

In all of these cases, the supplier of services tries to segment the market and charge each segment what it will bear. The motive of the private sector in practicing this approach is to convert some nonmonetary units of payment, such as prestige (or the lack of it), convenience, or time, into monetary units that can be translated into greater profits. In this case, the public welfare criteria would be very similar, since some forms of these payments, such as waiting time, induce waste (as argued in the preceding section). The conditions of the suggested dual market are much simpler than some of the aforementioned examples, and thus the situation can be modeled by using a very simplified approach.

The simple model developed below tries to demonstrate numerically some of the points mentioned in the discussion of the dual market system. It demonstrates the trade-offs faced by the gasoline station operator, including his or her optimal (profit-maximizing) price level and the length of both queues as a function of the price (at the uncontrolled-price pump) set by the operator.

Our model looks at the demand for gasoline at a single, isolated, two-pump station. The total number of customers is fixed, since we assume that all of the available supply is exhausted under any scheme. The choice between the two types of operation can be modeled by using a logit formula in which

$$Pr_c = e^{v_c}/(e^{v_c} + e^{v_u}) = 1/(1 + e^{v_u - v_c}) \quad (1a)$$

and

$$Pr_u = 1 - Pr_c \quad (1b)$$

where Pr_c and Pr_u are the probability of choosing the controlled- and uncontrolled-price gasoline pumps, respectively, and v_c and v_u denote the measured utility of buying gasoline at those respective pumps. [The theory and applications of the logit model and the choice models in general can be found in a variety of references (7,8).] In order to specify the measured utility functions, let R_c and R_u denote the controlled and uncontrolled prices, respectively; let W_c and W_u denote the associated waiting time; and let I denote the decision maker's income. Using these notations, let

$$v_c = -(R_c/I) - \alpha \cdot W_c \quad (2a)$$

and

$$v_u = -(R_u/I) - \alpha \cdot W_u \quad (2b)$$

where α is an estimated parameter [$(\alpha \cdot I)$ can be interpreted as the value of time for the decision maker with income I]. We further assume that income is distributed across the population according to the probability mass function $f_I(I)$ (a discrete density was assumed for purposes of clarity and simplicity), given by

$$f_I(I) = \begin{cases} f_L & \text{for } I = I_L \\ f_M & \text{for } I = I_M \\ f_H & \text{for } I = I_H \end{cases} \quad (3)$$

where subscripts L, M, and H designate low, medium, and high income, respectively. Thus, if the total number of users (per unit of time) purchasing gasoline at the station under consideration is N, the number purchasing the gasoline at the controlled price (N_c) is given by the weighted sum of the choice probability (Equations 1a and 1b) with the corresponding income levels. In other words, if we let

$$(v_u - v_c)_j = (1/I_j)(R_c - R_u) + \alpha(W_c - W_u) \qquad (4a)$$

for j = L, M, H, the number of gasoline buyers at the controlled-price pump is given by

$$N_c = N \cdot \sum_j \{f_j/1 + \exp[(v_u - v_c)_j]\} \qquad (4b)$$

and

$$N_u = N - N_c \qquad (4c)$$

The prediction of the number of users at each pump is not completely straightforward because of the dependence between N_c, N_u, and the waiting time. In other words, the more people who want to purchase a certain type of gasoline, the longer will be the queue in front of this pump (at a given price). This side of the system is modeled by using a simple M/G/1 queuing model, which can be viewed as nothing but a formula relating the average waiting time at a certain pump to the number of users at this pump; i.e.,

$$w_c = N_c \cdot (\mu^{-1} + \sigma^2)/2(1 - N_c/\mu) \qquad (5a)$$

and

$$w_u = N_u \cdot (\mu^{-1} + \sigma^2)/2(1 - N_u/\mu) \qquad (5b)$$

where μ is the average service rate at which gasoline is filled and σ^2 is the variance of the service rate.

It should be noted that a queuing formulation may not be an appropriate representation for the controlled-price pump, since the queue there is most likely to persist continuously. In other words, in this queue customers enter service at a rate that equals the service rate. According to queuing theory, such a queue should be of an infinite length, a phenomenon that does not occur in reality due to the balking effect as the queue grows. This leads to queuing systems with state-dependent arrival rates, which are mathematically complicated to handle and represent fine tuning that is meaningless in the absence of data. We thus chose to ignore this difficulty and use a relatively simple queuing formula. [This approach may also be justified if one looks at the pump including a certain length of the queue (such as the steady-state length) as the "server" in this system.] A similar approach has also been used by others (9).

In order to solve simultaneously for the waiting times and the number of users (per time unit) choosing each pump type, Equations 1 and 5 have to be solved simultaneously. This problem parallels the well-known equilibrium problems of traffic assignment (10,11) or of transportation in general (12, 13). A similar problem in the context of mode choice has been discussed by Sheffi (14), who also recently suggested a mathematical-programming-based formulation of the general problem of equilibrium with logit models (15) and an efficient solution algorithm. The focus of this paper is on the model results rather than on solution techniques, and these results are discussed next.

The following numerical values were used for this model: $I_L = 1$, $I_M = 2$, $I_H = 3$; $f_L = 0.25$, $f_M = 0.50$, $f_H = 0.25$; $R_c = 1.50$, $\sigma = 0$, $\alpha = 2$; and $N = 45$, $\mu = 45$. Since we are interested in the general shapes of the resulting functions rather than specific values or units (which would require data and model estimation), the specific numerical values are not important. It should be noted, however, that having three income levels serves as a sensitivity analysis on most of the model parameters.

Figure 1 shows the percentage increase in the operator's revenue as a function of the percentage change in the uncontrolled price over the controlled price (the operator revenue is proportional to the sum of the quantity sold at each pump times the price at which it is sold). As expected, the curves at all income levels show a steep increase as the prices rise, since users are shifting to the high-price pump. Beyond a certain point, however, people cannot pay the price and go back to the low-price pump. The higher the income, the less price sensitive the population is and the higher the optimal price and profits are.

This means that the price charged at the unregulated pump may vary quite substantially among neighborhoods. The price at the unregulated pumps should be higher in the high-income neighborhoods, since this market may be clearly with higher-income populations. Such price variations may be seen as another positive attribute of the dual market system from the equity perspective in comparison with the do-nothing alternative. (Similar price variations may also occur to some extent under the market-clearing price alternative.)

The waiting time at the controlled-price pump will increase as the gasoline price at the uncontrolled-price pump is increased, as shown in Figure 2. This is obvious since, the higher the latter price is, the more people will join the queue for cheaper gas. Figure 3 shows the (expected) decrease in the average waiting time at the uncontrolled-price pump as a function of this price.

This simple model shows that there is an optimal price that the profit-maximizing operator will charge and this price will be finite even under a shortfall situation. Furthermore, it is likely that most operators will charge less than this price due to the competition effect. Under the dual market system, operators will have to compete in setting the price level of the unregulated gasoline. Thus, the equilibrium price under competitive situations may be somewhat lower than that indicated by the model. Moveover, under the dual market system, operators have less discriminatory power and opportunity for unfair practices (e.g., forcing oil changes or spare automotive parts on customers or accepting other forms of bribes). Many station owners may also choose to charge less than what the market will bear in order not to alienate good customers if the shortage is perceived as a transient phenomenon.

OPERATIONAL ASPECTS AND VARIATIONS

The dual market system has been evaluated so far on the basis of two criteria only: efficiency and equity. This section discusses some of the operational issues associated with the plan and some variants on it. The operational issues can be broken down into four categories: (a) the ease of implementation and cancellation of the plan, (b) the question of enforcement, (c) institutional issues, and (d) legal constraints.

In order to put the dual market system into effect, one would require a public information campaign, one that should not be more extensive or complicated than, say, an odd-even plan. The dual market scheme, however, has a built-in "sunset" mechanism of fading away on its own, unlike license-plate-based strategies or other schemes. As gasoline supplies return to preshortage levels, station hours will get longer and the price at the uncontrolled-price pump will start to decline. This is caused by competitive pressures from stations that suddenly (as the shortfall eases) do not sell all their allotment at the given prices.

The enforcement of this scheme should not require

Figure 1. Increase in operator revenue versus increase in uncontrolled price over controlled price.

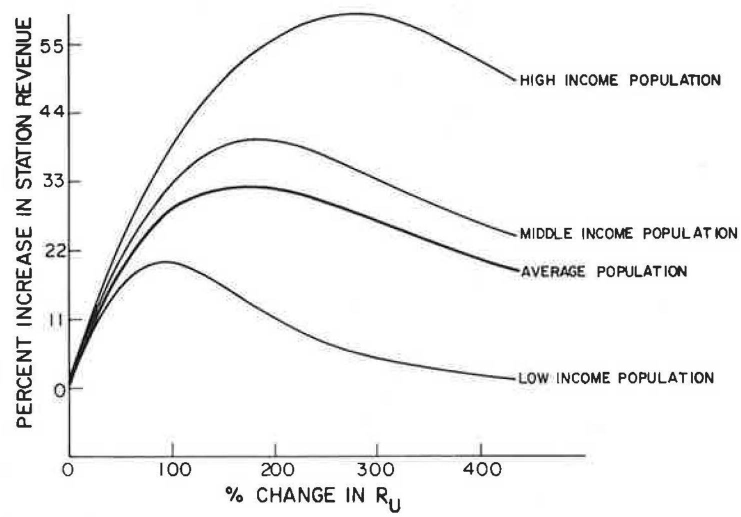


Figure 2. Increase in waiting time for users of controlled-price pump versus increase in uncontrolled price over controlled price.

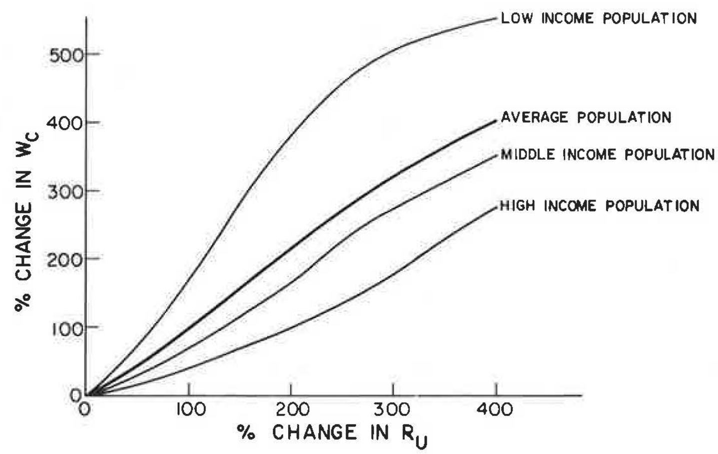
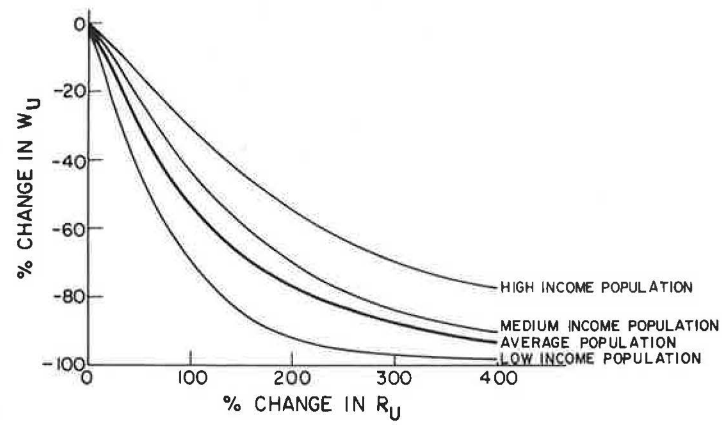


Figure 3. Decrease in waiting time for users of uncontrolled-price pump versus increase in uncontrolled price over controlled price.



more resources than the enforcement of the regulated price in the do-nothing alternative. Furthermore, the plan is self-enforcing to a large degree because it is so simple: There should be one pump operating at the controlled price for every uncontrolled-price pump. Violations of this scheme should be easy to spot (e.g., when a station operates only the high-price pumps). It may be harder to spot and enforce another type of violation: When the rate of gasoline flow is not equal at both pumps, operators may try to increase the service rate at the uncontrolled-price pump by using more attendants, processing payments faster, etc. This should be noticeable both to customers and to law-enforcement agents. It implies, however, that the dual market scheme should specify that the rate of gasoline flow at both types of pumps should be equal rather than that the number of pumps should be equal.

An institutional analysis of the dual market system may include identification of all of the actors involved in implementing this plan and those who may be affected by it. On the face of it, it seems that no major population segment may be adversely affected by the plan because it offers, basically, a continuum of choices, as explained in the previous section of the paper. The plan should be presented as a compromise between the do-nothing alternative and the market-clearing price alternative in that it has most of the better aspects of both and offers more choice. The only population segment that may be discriminated against under this plan is operators of small, one-pump stations, who will have to sell at the regulated price. Thus, the system may include a provision for such stations by letting them apply for the higher prices and evaluating such applications ad hoc. Other provisions may also be possible, such as collaboration between two adjacent one-pump stations so as to alternate the pricing between them. At any event, this is a small, well-defined group that should not present any particular problems.

Opposition to the dual market system may also be rooted in people's objections to any one group (gasoline station owners) making a substantial profit from a crisis situation. Inasmuch as this may impede implementation, the law may include provisions for a "windfall profit" type of tax or a similar mechanism to extract these profits from the station owners. The regulated price level may even be set below the operator's costs. This, in fact, forces the operator to cross subsidize the lower price directly. Such a scheme represents an effective income transfer to low-income groups, since no transaction costs are involved.

The legal situation concerning the implementation of a dual market plan is not certain at this time. Currently, the act that gives the federal government the right to control prices is the Emergency Petroleum Allocation Act of 1974. This act is due to expire on September 30, 1981, and it is unclear whether it will be renewed. Should it be renewed, the implementation of a dual market system is an open legal question, since under the act such a mechanism is neither prohibited nor specified as a possible alternative. Should the act not be renewed, it is up to Congress or to each individual state to enact a law that would make possible the implementation of a dual market in gasoline.

The basic dual market system presented in this paper can be implemented with many variations. For example, instead of letting each operator charge whatever the market will bear at the uncontrolled-price pump, the government may designate special stations that would be allowed to raise their prices. Under this alternative implementation plan, the taxing of these profits would be much simpler. Furthermore, the gasoline sold at these special stations could be taxed on a per-gallon basis. This plan, however, does not offer as much choice as the original one because of the spatial distribution of gasoline stations (i.e., some people may perceive that the controlled- or uncontrolled-price gasoline is not available in a certain locality). Yet, basically, this variation is similar to the original one in terms of efficiency and equity.

Other variations on the original plan include the imposition of traditional measures, such as an odd-even arrangement or maximum-minimum purchase restrictions, in conjunction with the dual market system. This is not recommended because there does not seem to be any potential benefit from such "add-ons".

The relative rate of flow of the controlled- versus uncontrolled-price gasoline can be changed from the equal amounts specified under the original plan. In other words, the rule can be two controlled-price pumps for each high-price pump or any other combination instead of the "one-for-one" rule. Such rules will affect both the uncontrolled price and the length of the queue at the controlled-price pump. As more controlled-price pumps are needed per each uncontrolled-price pump, the price at the uncontrolled-price pump will go up and the length of the queue at the controlled-price pump will shrink and get closer to the queue length that would prevail under the do-nothing alternative. As more uncontrolled-price pumps are allowed to operate (per each controlled-price pump), the uncontrolled price will come down toward the prices that would have prevailed under the market-clearing price alternative. Again, this alternative does not fundamentally change the situation because of the continuum of choice that is actually available to consumers, as discussed in the preceding section. The simplicity and ease of implementation associated with the original scheme should thus make it the most attractive alternative from this perspective.

SUMMARY AND CONCLUSIONS

This paper describes a dual pricing mechanism of distributing the burden of a shortfall in gasoline supply. This scheme is compared with the do-nothing alternative on the one hand, which is characterized by controlled prices and queues at the pumps, and a free market system, in which the price is allowed to rise and clear the market. The comparison is based on the two criteria of efficiency and equity, and the dual market scores well in both of these.

The main problem with the do-nothing alternative is the gross inefficiency associated with the queuing. This inefficiency can be eliminated by letting the market price rise to a level that would clear the market. Such a solution discriminates, however, against low-income population groups and therefore is perceived as inequitable. The dual market system can be viewed as a compromise that is better than either of the extremes. It is almost as efficient as the market-clearing solution, since the people who choose to pay and not wait place a high value on time. The discrimination against low-income groups is minimal and may be eliminated altogether if so desired.

In order to understand the plan and why it may work, it is important to realize two concepts. First, the total number of buyers in the market is fixed, and the question is mainly who buys. Thus, for example, no aspect of any plan can be criticized as encouraging consumption and no plan can be advocated as conserving gasoline. Under the dual market system, the high-income groups are better off (since they can pay with monetary units that they have) and the low-income people are not particularly hurt (since they can pay in terms of waiting time, which does not cost them as much).

Middle-income groups are not adversely affected by the plan because of the second concept associated with it--the continuum of wait-time/price combination that may be chosen by each individual in the long run. This means that most of the population is going to be better off under this plan, which is almost as efficient as the market-clearing alternative.

The paper also mentions several implementation issues and concludes that the major impedance to the implementation of the plan is legal. Currently, only the federal government has the authority to alter the price of gasoline, and it is not clear if the dual market system is legal under current laws. The current law is due to expire shortly; if it is not renewed, it may be left to each state to set the gasoline price, and the states could enact a law that would make it possible to implement a dual market system. Alternatively, this may be provided for in a new congressional act.

This paper does not cover all the issues that are associated with a dual market system and all the complications that may follow. For example, we do not deal with the question of multiple gasoline types and their pricing, nor do we predict the role that the oil companies may play under such a system. These issues and others are left for further investigation.

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Projections of Changes in Vehicle Technology and Characteristics to Improve Fuel Economy

RICHARD L. STROMBOTNE AND STEPHEN LUCHTER

Probable changes in the technology and characteristics of vehicles in the 1985 new-vehicle fleet, as well as some possible changes for the period after 1985, are discussed. In the 1975-1985 period, the designs and characteristics of new passenger automobiles are changing radically. The same can be said about the designs and characteristics of light trucks but to a lesser extent. By 1985, the average weight of all new vehicles and of four-, five, and six-passenger cars will have dropped by about 800-1200 lb. In addition, the recently initiated conversion to front-wheel drive will be virtually complete, sophisticated electronic controls to reduce emissions and improve fuel economy will be used almost universally, and all passenger cars will have automatic restraint systems.

Revolutionary changes in the design of automobiles and light trucks are expected between now and 1985. Vehicles will weigh less, there will be more small vehicles in the fleet, and the technology of engines, transmissions, tires, aerodynamics, and emission controls will be at a much more advanced level. These trends are expected to continue after 1985.

AUTOMOBILES

Typical new automobiles in 1985 will differ from today's automobiles in many respects. With few exceptions, they will be "downsized", have front-wheel drive, and make greater use of lightweight materials. Other anticipated improvements include smaller, more efficient engines, reduced aerodynamic drag, tires with lower rolling resistance, and improved transmissions. As a result of these changes, average fuel economy will increase to more than 27.5 miles/gal. Beyond 1985, further increases in fuel economy are expected.

Vehicle Changes

Three major trends are foreseen in vehicle design by 1985, all resulting in significant weight reductions: Automobiles are expected to (a) be downsized, (b) have front-wheel drive, and (c) use lightweight materials to a large degree. Beyond 1985, further applications of lightweight materials are expected, and a two-passenger "urban car" will be introduced by most manufacturers.

Downsizing means that an automobile's external dimensions are reduced without changing the interior volume. Figure 1 shows the main dimensions of the 1977 General Motors (GM) large cars compared with those of the corresponding 1976 model. Overall length was reduced from 223.3 to 212.1 in, and the width was reduced by 3.5 in, from 79.5 to 76 in.