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Short-Run Traveler Responses to Alternative Gasoline-Allocation Plans: Some Modeling Results

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The possibility that serious gasoline shortages may occur in the United States is prompting government agencies to give increased attention to the development of ways to allocate scarce gasoline supplies among travelers. A large number of allocation procedures are potentially available, including allocation by allowing the retail price of gasoline to rise to a market-clearing level, by means of queues at service stations (i.e., persons with the greatest desire or ability to spend time waiting in queues tend to receive the greatest allocations of gasoline), and by various rationing systems.

Quantitative estimates of the likely impacts on travel of gasoline shortages when different gasoline allocation procedures are in effect presumably could help government agencies and others to determine how the adverse effects of shortages can best be mitigated or equitably distributed. However, the development of such estimates has been impeded by a lack of satisfactory data and estimation methods. Virtually all of the data that are currently available for transportation forecasting studies in the United States were acquired before the 1973-1974 gasoline shortage and, hence, do not reflect any changes in travelers' tastes (e.g., changes in the value of travel time or in the extent to which the schedule inflexibility of carpooling is disvalued) that may have occurred as a result of or since this shortage. Nor do currently available data reflect transportation system changes (e.g., new transit systems) or changes in urban demographic and land use patterns that may have occurred since the large transportation studies of the 1960s and early 1970s. Moreover, transportation data sets typically pertain to urban weekday travel and, hence, do not include much of the recreational travel that may be most severely affected by gasoline shortages. Even if more recent and comprehensive data were available, their relevance for forecasting the effects of severe gasoline shortages could be questioned, as the forecasts almost certainly would require extrapolations to shortage conditions or allocation procedures that were not represented in the data.

The methodological difficulties of forecasting travelers' responses to gasoline shortages are also severe, although they may be more tractable than those resulting from data deficiencies. Past efforts to estimate the effects of gasoline shortages on travel and travelers have been based on surveys of travelers' responses to the 1973-1974 gasoline shortage (1-4) and on travel demand forecasting studies that have been predicated on disaggregate travel demand models (5-6). However, despite substantial differences in data and methodology, these survey and modeling studies have consistently indicated that, in the short run, most households tend to adjust to gasoline shortages or price increases by decreasing nonwork travel frequencies and nonwork trip lengths, whereas relatively few households change their modes of travel for either work or nonwork purposes. Although this consistency of results is encouraging, the survey and demand-modeling methods on which the results are based have important limitations. By themselves, the survey results cannot be used for forecasting, except in a very loose and qualitative way, and they are not suitable for comparing the impacts of various alternative gasoline-allocation procedures. The disaggregate demand models are, of course, designed for use in forecasting. These models permit treatment of a broader range of travel and policy options than can be dealt with by alternative modeling approaches. However, past disaggregate demand-modeling studies of the effects of gasoline shortages or price increases have not included certain potentially important short-run traveler responses (e.g., notably increased use of multidestination travel). The only gasoline-allocation method that has been treated in these studies is that of allowing the retail price of gasoline to rise to the market-clearing level. Thus, much of the potential value of the disaggregate demand-modeling approach to forecasting short-run effects of gasoline shortages remains unrealized.

The purpose of this paper is to present the results of applying an improved version of the disaggregate demand-modeling method in connection with a currently available data set to develop some exploratory estimates of the travel impacts of a gasoline shortage. The methodological improvements consist of including increases in multidestination travel among the modeled responses of travelers to gasoline shortages and of including several

gasoline-rationing procedures among the allocation systems that can be analyzed. The data set that is used was obtained from the 1968 Washington, D.C., area transportation study. Although this data set suffers from all of the previously mentioned data deficiencies, it is not substantially different in this respect from other available data sets. It does permit certain qualitative conclusions to be reached that may be applicable to current circumstances.

DEFINITION OF SCENARIOS AND QUESTIONS

It is assumed that the available supply of gasoline is less than the quantity demanded at the current retail price. (The reasons for this shortage are not addressed in this analysis and are not represented in the analytical framework.) It is further assumed that the responsible government agencies have decided to allocate the available gasoline supply among travelers by one of the methods noted below.

1. The retail price of gasoline is allowed to rise until the quantity of gasoline demanded equals the quantity available.
2. Gasoline is allocated by white-market coupons. With this method, the retail price of gasoline is fixed below the market-clearing level, and travelers are issued coupons that entitle them to purchase set quantities of gasoline at the established retail price. Although the total number of coupons issued to all travelers is fixed, individuals can alter their allocations by trading coupons with other individuals at a price determined in an open market. [This allocation plan is analytically but not administratively equivalent to the alternative plans that (a) establish a tax on gasoline sales and rebate the tax receipts to individuals in a way that is independent of their gasoline purchases and (b) establish the nontax portion of the retail price of gasoline at a fixed level and set the tax rate at the level that clears the retail gasoline market. Since this latter tax plan is analytically indistinguishable from a white-market coupon plan, it is not analyzed separately here.]
3. Allocation is made by means of traditional rationing. In this method, the retail price of gasoline is fixed below the market-clearing level. Travelers are allocated fixed quantities of gasoline that cannot be traded to others. (The likelihood that a black market in gasoline would arise if this rationing method were implemented is acknowledged but is not treated in this analysis.)
4. Allocation by means of queuing at service stations is also possible but is not treated in this analysis. [See Mahmassani and Sheffi (7) and Prins, Wolfe, and Lerman (8) for discussions of analytic approaches to queuing.]

In the short run, travelers can respond to the gasoline shortage and the various gasoline-allocation methods by changing their travel habits and patterns. In the long run, they can respond by changing the numbers and types of vehicles they own (e.g., by purchasing automobiles with increased fuel economy) and by changing the locations of their residences and places of work. In this analysis, only short-run responses are considered. These include changing travel modes and frequencies, reducing average trip lengths, and linking individual trips together into multidestination tours. In general, it can be expected that different gasoline-allocation systems will cause gasoline shortages to have different impacts on travel and travelers, even if the supply of gasoline and aggregate gasoline consumption do not change.

The analysis of allocation systems discussed in this paper is based on four questions:

1. How do the three allocation methods differ in their effects across income groups?
2. How do the methods differ in their effects across trip purposes (work and nonwork)?
3. To the extent that gasoline shortages affect nonwork travel, does the effect consist mainly of reducing trip frequencies and lengths (which may have serious economic effects) or of increasing the use of multidestination tours (which may be economically neutral)? and
4. To what extent can adverse impacts of gasoline shortages on nonwork travel be mitigated through the implementation of measures aimed at reducing automobile use for work trips, such as work-trip transit improvements?

ANALYTIC METHOD

The analytic method used here consists of developing forecasts of travel demand in the presence of a gasoline shortage with alternative gasoline-allocation plans in effect. These forecasts are then used to compute various indicators of the effects of the shortage and the allocation plans. The travel demand forecasting models that are used consist of a disaggregate model of work-trip modal choice (9) and a disaggregate model of nonwork travel behavior (10). The work-trip modal choice model includes the drive-alone, carpool, and transit modes. The nonwork model treats multidestination travel and nonwork travel frequency and destination choice. Previous investigations have indicated that changes in modal choice for nonwork trips are unlikely to constitute significant responses to gasoline shortages. Therefore, to minimize the computational complexity and expense of the nonwork model, nonwork modal choice has not been modeled.

In the price-increase scenario, the effects of increases in the price of gasoline were represented in the work and nonwork models by increasing the values of the appropriate travel cost variables. In the white-market scenario, these variables were increased to reflect the sum of the pump price of gasoline and the price of coupons. In addition, household incomes were increased to reflect the market value of the white-market coupons allocated to them. In the traditional rationing scenario, the usefulness of each trip was reduced by an amount that is proportional to the quantity of gasoline consumed on the trip. The proportionality constant was chosen so that households would not consume more gasoline than was allocated to them.

The indicators of the effects of gasoline shortages and allocation plans that were modeled are total automobile vehicle miles of travel (VMT), total gasoline consumption, work-trip modal choice, automobile VMT on work trips, gasoline consumed on work trips, automobile VMT on nonwork trips, gasoline consumed on nonwork trips, nonwork-person sojourn frequency (a visit to a nonwork location other than home), nonwork-person tour frequency (a complete home-to-home round trip that includes one or more sojourns), number of nonwork sojourns per nonwork tour, nonwork trip length, remaining income (the difference between total household income and expenditures for transportation), and sales of white-market coupons. These indicators were computed as averages across the entire group of households whose travel behavior was modeled and as averages across separate income groups.

APPLICATION TO WASHINGTON, D.C., AREA

The model system was used to estimate the short-term responses of automobile-owning households in the Washington, D.C., area to a 15 percent reduction in the supply of gasoline available for weekday travel. Since non-automobile-owning households make few trips by private automobile, any impacts of a gasoline shortage on these households would occur mainly through the effects of the shortage on the performance of public transportation systems. (Because these effects are not discussed here, the impacts of gasoline shortages on non-automobile-owning households are not treated.)

Because data that would enable weekend travel behavior to be modeled are unavailable, the results given here pertain only to weekday travel. However, for the purpose of computing the effects of gasoline shortages on remaining

Table 1. Percentage change in impact indicators for the price-increase, white-market-coupon, and traditional rationing scenarios.

	Price-Increase Scenario				White-Market-Coupon Scenario				Traditional Rationing Scenario			
	Income Level				Income Level				Income Level			
Indicator	1	2	3	All	1	2	3	All	1	2	3	All
Gasoline consumption												
Work trips	-14	-4	-2	-3	-9	-3	-2	-3	0	-5	-9	-7
Nonwork trips	-87	-35	-4	-24	-85	-40	-0.2	-25	0	-15	-32	-22
All trips	-67	-20	-3	-15	-65	-22	-1	-15	0	-10	-22	-15
Automobile VMT												
Work trips	-15	-4	-2	-3	-10	-3	-2	-3	0	-6	-10	-8
Nonwork trips	-89	-38	-10	-28	-87	-44	-7	-29	0	-17	-37	-25
All trips	-67	-21	-7	-17	-64	-23	-5	-17	0	-11	-25	-17
Work-trip modal choice												
Drive alone				-6				-6				-8
Shared ride				+6				+7				+8
Transit				+31				+20				+40
Nonwork travel												
Sojourns	-84	-34	-7	-26	-82	-39	-3	-25	0	-5	-6	-5
Tours	-83	-17	+28	-6	-81	-23	+37	-4	0	-10	-22	-14
Sojourns per tour	-7	-20	-27	-21	-7	-21	-21	-22	0	+5	+20	+10
Average trip length	-32	-16	-16	-13	-32	-17	-18	-15	0	-15	-28	-18
Remaining income	+0.3	-11	-10	-9	+52	+5	-5	+2	0	+1	+1	+1
Effective gasoline price[a]				+468				+630				
Coupon sales[b]					+1.58	+0.12	-1.01	0				

Note: Income level 1 = less than \$11 500; level 2 = \$11 500-\$30 000; level 3 = \$30 000 or more; all are 1979 dollars.

[a]The effective gasoline price is the retail price plus the price (per equivalent gallon) of white-market coupons.
[b]The net sales (+) or purchases (-) of white-market coupons is expressed in units of gallons of gasoline per household per day.

Table 2. Percentage change in impact indicators for the white-market-coupon scenario with transit improvements.

	Income Level[a]			
Indicator	1	2	3	All
Gasoline consumption				
Work trips	-25	-17	-11	-15
Nonwork trips	-78	-23	-2	-15
All trips	-64	-20	-4	-15
Automobile VMT				
Work trips	-29	-17	-12	-15
Nonwork trips	-81	-6	-4	-19
All trips	-65	-22	-7	-17
Work-trip modal choice				
Drive alone				-16
Shared ride				-11
Transit				+330
Nonwork travel				
Sojourns	-64	-33	-1	-17
Tours	-72	-5	+33	+3
Sojourns per tour	-6	-19	-25	-20
Average trip length	-28	-13	-14	-11
Remaining income	+36	+2	-3	+1
Effective gasoline price[a]				+434
Coupon sales[a]	+1.59	+0.06	-0.93	0

[a]As defined in Table 1.

incomes (i.e., total household income minus transportation expenditures), it has been assumed that gasoline shortages cause percentage reductions in weekend gasoline consumption that are equal to the percentage reductions in weekday gasoline consumption for nonwork travel. Weekend nonwork gasoline consumption as a percentage of weekday nonwork consumption was estimated by using data from the Nationwide Personal Transportation Study (11). The assumption that the percentage reductions in weekday and weekend nonwork gasoline consumption are equal implies that the total reduction in gasoline consumption for all trip purposes and on all days of the week is approximately 20 percent in the cases noted here.

In the white-market-coupon and traditional rationing scenarios, coupons and gasoline have been allocated on a per-household basis. Incomes, prices, and motor vehicle fuel economy have been updated from 1968 to 1979 values. In other respects, the characteristics of the modeled population are as they were in 1968.

The results obtained by means of the three allocation scenarios are shown in Table 1. In all scenarios the main effect of the gasoline shortage is to cause reductions in nonwork travel. Sojourn frequencies and trip lengths are both reduced. Depending on the allocation scenario, reductions in nonwork travel account for 80-90 percent of the 15 percent reduction in total weekday gasoline consumption. In the pricing and white-market scenarios, households show no tendency to make increased use of multidestination travel as a means of compensating for the effects of reduced gasoline supplies. Rather, there is a tendency to make short, single-destination tours in place of longer, multidestination ones. This tendency is particularly apparent among high-income households. However, in the traditional rationing scenario, there is a tendency to make increased use of multidestination travel.

The effective price of gasoline is higher in the white-market-coupon scenario than it is in the price-increase scenario. (In the white-market scenario, the effective price of gasoline is the sum of the controlled retail price and the price of coupons.) This is because in the white-market scenario, household effective income is increased by the market value of the coupons allocated to it. These increases in incomes enable a household to tolerate higher effective gasoline prices while maintaining given levels of travel than it can tolerate in the price-increase scenario in which income does not increase.

In the pricing and white-market-coupon scenarios, the greatest reductions in travel are among low-income households, and the smallest reductions are among high-income households. The large reductions in low-income household travel and the associated saving of travel costs cause the average remaining income of such households to increase in the pricing and white-market-coupon scenarios. The increase is especially apparent in the latter, as low-income households (and, to a much-lesser degree, middle-income households) sell gasoline coupons to high-income households. Households in the high-income group are both willing and able to pay the increased price of gasoline in the pricing and white-market-coupon scenarios. Therefore, high-income household travel is reduced considerably less than that of low- and middle-income households, and high-income households experience large reductions in remaining income. Middle-income households also experience large reductions in remaining income in the price-increase scenario. However, in the white-market

scenario, middle-income households sell coupons to high-income households and, as a result, experience an increase in average remaining income.

In the traditional rationing scenario, which is not price-based, the distribution of impacts of a gasoline shortage across income groups is significantly different from the distributions that occur in the pricing and white-market-coupon scenarios. In the traditional rationing scenario, all households receive equal allocations of gasoline. Because high-income households tend to travel more and to use more gasoline than low-income households, equal allocations of gasoline require high-income households to reduce their travel substantially but low-income households need not reduce their travel at all. Because the price of gasoline is fixed in the traditional rationing scenario, the average remaining income of low-income households is not changed by a gasoline shortage. However, the average remaining incomes of middle- and high-income households increase, owing to the reductions in travel by these households.

The ability of transit improvements for work trips to achieve reductions in work-trip gasoline consumption and, thereby, to mitigate the adverse impacts of gasoline shortages on nonwork travel was investigated for the white-market-coupon scenario. It was assumed that (a) transit in-vehicle travel times for one-way trips would be equal to the corresponding automobile in-vehicle travel times and (b) transit out-of-vehicle travel times (including both walk and wait times) would be no more than 7.5 min/one-way trip. This represents a considerably higher level of transit service than is likely to be available to most travelers. The impacts of a gasoline shortage with white-market-coupon allocation and the transit improvements in effect are shown in Table 2. Although the impacts of the gasoline shortage on nonwork travel are mitigated by the transit improvements, these impacts still are severe. Thus, it appears that the provision of even very high-quality transit service for work trips cannot prevent gasoline shortages from substantially reducing both nonwork sojourn frequencies and nonwork trip lengths.

CONCLUSIONS

Since the results presented in the preceding section are based on old data, it is useful to consider the extent to which these results might change if they could be rederived by using more recent data. Such data would reflect the changes in land use, transit service quality, and demographic characteristics of the Washington area population that have occurred since 1968, as well as any changes in tastes that may have occurred.

Clearly, any of these changes could alter the quantitative results that are presented in Tables 1 and 2. However, the major qualitative features of these results—notably the large impacts of gasoline shortages on nonwork travel, the inability of transit improvements to prevent these impacts, and the distribution of impacts across income groups—are determined primarily by tastes and by a household's ability to afford the costs of travel. Accordingly, these qualitative features are not likely to be highly sensitive to changes in land use, transit service quality, and aggregate demographic characteristics.

Changes in tastes—especially changes that would cause work-trip travelers to be more receptive to using high-occupancy modes and cause nonwork travelers to make greater use of multidestination travel—could substantially affect the qualitative features of the results presented here. The extent to which such taste changes may have occurred since 1968 is largely a matter of conjecture. However, the extreme differences between the impacts of gasoline shortages on work travel and nonwork travel that are exhibited in the results mentioned in the preceding section of this paper suggest that very large changes in tastes would be needed to achieve a significant redistribution of these impacts from nonwork to work travel. The previously cited surveys of travelers' responses to the 1973-1974 gasoline shortage suggest that this shortage did not cause substantial behavioral changes. Thus, it is certainly possible and, perhaps, even likely that the main qualitative characteristics of these results are as applicable now as they were in 1968.

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