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Government Budgets and Property Values

Lori L. Taylor

Methanol as an Alternative Fuel: Economic and Health Effects

Mine K. Yücel

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Contents

Page 1

Government Budgets and Property Values

Lori L. Taylor

Lori L. Taylor debunks several popular beliefs as she examines how property values relate to taxes, government services, and government debt. She finds that, contrary to popular belief, property values do not necessarily decrease when local governments increase taxes to pay for services. Her analysis reveals that taxpayers value all types of government services, including transfer payments such as welfare and health services. Taylor's work also suggests that people do not automatically prefer deficit spending to tax increases.

Page 9

Methanol as an Alternative Fuel: Economic and Health Effects

Mine K. Yücel

Methanol, because of its low pollution characteristics, is a possible alternative to gasoline as a motor fuel. In this article, Mine K. Yücel calculates the economic, pollution, and health effects of switching from gasoline to methanol fuels.

Yücel finds that use of methanol would lower oil demand and oil prices, while increased demand for methanol's natural gas feedstock would increase natural gas prices. Fuel prices would increase because methanol is more costly than gasoline. However, methanol use would reduce ozone pollution and some of the health risks associated with gasoline.

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Government Budgets and Property Values

Recessions force local governments to make difficult decisions. Generally, a weakening economy produces lower tax revenues and higher demand for government services. To cope with the fiscal demands that a recession induces, governments must raise taxes, cut nonessential services, or accumulate debt. None of these options is particularly appealing.

Ideally, governments would like to choose the option that residents or potential residents would most prefer. Economic theory suggests that people reveal their preferences for a government's mix of services, taxes, and debt by their choice of residence (Tiebout 1956). If the mix of services, taxes, and debt is particularly desirable in one town, then many people will want to live there. When the number of people who want to live in a town increases and the number of houses is limited, housing prices in that town increase. Thus, housing prices reflect preferences about the government's mix of services, taxes, and debt, all other things being equal. Therefore, the local government chooses the most desirable option if it chooses the option that has the smallest negative impact on property values.

A *hedonic model* of housing prices reveals the effect on property values of changes in the composition of local budgets. The analysis indicates that households have a taste for all types of government services and that increasing taxes to pay for those services need not decrease property values. The analysis also indicates that increases in taxes and increases in debt have the same effect on property values, suggesting that households view deficit spending as postponed taxation.

The Model

A house is a collection of desirable characteristics, such as shelter, comfort, and location. Therefore, the price that buyers are willing to pay for a house should equal the sum of the prices they are willing to pay for its component characteristics. A hedonic housing model treats a house as the sum of its parts and generates estimates of the shadow (unobserved) prices for each characteristic. When local government budgets are included as characteristics of the house's location, a hedonic housing model produces shadow prices for government services, taxes, and debt. From those shadow prices, one can calculate the impact on housing prices of changes in the composition of local budgets.

Following the literature on hedonic housing models (Linneman 1980 and Craig, Kohlhase, and Papell 1989), I model housing prices (P_i) as a log-linear function of house characteristics (H_{ij}) such as air conditioning and the number of rooms, nongovernmental location characteristics (L_{ij}) such as distance from the city center and neighborhood composition, government characteristics (G_{ij}) such as the size of the debt outstanding and the composition of the budget, and an error term (ϵ_i):

$$(1)\quad \ln(P_i) = \alpha + \sum_{j=1}^{n_H} \beta_j \bullet H_{ij} + \sum_{j=1}^{n_L} \delta_j \bullet L_{ij} + \sum_{j=1}^{n_G} \gamma_j \bullet G_{ij} + \epsilon_i .$$

The local government's budget constraint introduces a linear relationship between revenues, expenditures, and the deficit (if any). Previous analyses of housing prices have not dealt with the linearity problem because they have included only property taxes and a few other components of the budget constraint as explanatory variables. However, omitting aspects of the budget introduces specification error and generates regression

I would like to thank Stephen P. A. Brown, William C. Gruben, Joseph H. Haslag, and Fiona D. Sigalla for their helpful comments. Of course, all remaining errors are my own.

coefficients that are difficult to interpret. Therefore, I follow Helms (1985) by including all elements of the budget constraint except welfare expenditures as explanatory variables.

Because the regression coefficients in equation 1 indicate the effect on housing prices of a change in one right-hand-side variable, holding all other variables constant, Helms' approach produces easily interpretable results. The regression coefficient on the property tax variable indicates the effect on housing prices of a marginal increase in property taxes, holding nonwelfare expenditures, the deficit, and all other revenues constant. Because the budget must balance, any increase in property taxes that does not lead to an increase in nonwelfare expenditures or a decrease in the deficit or some other form of revenue must increase welfare expenditures. Therefore, the regression coefficient on the property tax variable indicates the effect on property values of an increase in property taxes that finances an increase in welfare expenditures. Similarly, the regression coefficient on the school expenditures variable indicates the effect on property values of an increase in school expenditures that is financed by a decrease in welfare expenditures.

The Data

I estimate a hedonic housing model using data on communities in the Hartford, Connecticut, metropolitan statistical area (MSA). I use Connecticut data because Connecticut is one of the few states in the nation with municipality-based government. In most states, government jurisdiction is divided between cities, counties, school districts, fire districts, and so on. Further, the jurisdictions tend to overlap irregularly, so that school districts straddle county lines and fire districts include parts of many towns. The data costs of sorting out government budgets are prohibitive when, for example, there are multiple school districts in a city and some school districts encompass parts of many cities. In Connecticut, municipalities carry out all local government functions, so the data costs are minimized. I use data on a single labor market—the Hartford MSA—so that I need not control for differences in property values that arise from labor market characteristics (Roback 1982).

The 1980 Census of Housing and Population and the 1977 Census of Governments provide data on the communities surrounding Hartford, Connecticut.[1] The Census of Housing and Population indicates the value of the median owner-occupied home in each community (MEDVALUE), the number of rooms in the median home (MEDROOMS), the proportion of the homes with air conditioning and sewer connections (AIR and SEWER, respectively), the age of the housing stock (STRUC70, the proportion of homes constructed after 1970, and STRUC39, the proportion of homes constructed before 1939), the proportion of housing units that are unoccupied (VACANTRT), the proportion of housing units that are owner-occupied (OWNERRT), and the characteristics of the residents.[2]

The Census of Governments indicates the extent of local government revenues from property taxes (PROPTAX), from any other taxes such as real estate conveyance taxes (OTHERTAX), from any other nontax revenue sources (OTHERREV), and from running a deficit (DEFICIT).[3] The census of governments also indicates the amount of debt outstanding (TOTDEBT), the value of any assets held by the local government (ASSETS), and the extent of local government expenditures on education (LOCLSCHL), police protection (POLICE), fire protection (FIRE), health and hospital services (HEALTH), highway repair and construction (HIGHWAY), public buildings (PUBUILD), welfare (WELFARE), parks and recreation (PARKREC), all utilities (ALLUTILS), and any other expenditures (OTHEREXP).

[1] Because its sheer size and urban nature make Hartford City an atypical community in the MSA, I exclude Hartford City from the analysis.

[2] Characteristics of residents refers to the proportion of the population that is over 65 years old (OVER65), the proportion of the population that is black (BLACK), the proportion of the population that graduated from high school (GRADHIGH), and the average household income of the population (HINCOME).

[3] With the exception of Hartford City, the municipalities in the Hartford MSA did not use sales or income taxes to finance local government activities.

For all types of expenditures, I calculate the level of locally financed expenditures by subtracting from the level of total expenditures in that category any user fees or dedicated transfers from other governments. Because dedicated transfers from the state or federal government may substitute for local spending, I include transfers from other levels of government as explanatory variables.[4] I control for size differences between communities in the sample by expressing all revenues and expenditures in terms of dollars per housing unit. I also use a map of Connecticut to calculate the commuting distance between each community and the center of Hartford City (DISTANCE).

After obvious outliers were removed, complete data were available for seventy-four communities in the Hartford MSA. Table 1 reports descriptive statistics for the variables used in this analysis.

The Results

Not surprisingly, the characteristics of the housing stock explain a great deal of the variation in median housing prices (*Table 2*). Adding a room to the median home increases property values by 19 percent. Prices also increase as the age of the housing stock decreases. A 1-percentage-point increase in the proportion of homes built after 1970 increases median property values by 0.5 percent. The proportion of homes with air conditioning or sewer connections, the proportion of owner-occupied housing, and the vacancy rate have no discernible effect on property values, all other things being equal.

The characteristics of the residents also explain a great deal of the variation in median home prices. One would expect home prices to increase as the ability to pay for housing increases, so it is not surprising that home prices increase as average household income increases. Home prices also increase as the percentage of residents over 65 years old in the community increases. The percentage of black residents and the percentage of high school graduates in the community have no significant effect on housing prices, given the level of average household income.

Distance from the city center has the expected negative effect on property values. Given two otherwise equal communities, the one with the shorter commute to the employment center has the higher property values. Each additional mile from the city center decreases property values by 0.3 percent.

Expenditures on education by the state and federal government (IGRED) have a significant negative relationship with property values, while all other dedicated transfers have no significant effect on property values. The negative relationship between education transfers and property values probably reflects an effort by the state to direct aid to the poorer communities in the MSA. The insignificant relationship between other dedicated transfers and property values may arise because government efforts to direct aid to property-poor areas (which would induce a negative relationship between property values and government transfers) offset the capitalized benefits of the aid (which would induce a positive relationship between property values and government transfers).

Only one element of the local budget constraint has no marginal effect on property values. Expenditures on health and hospital services are insignificant in the estimated equation, indicating that property values would remain unchanged if local governments were to transfer $1 per household from welfare services to health services, or vice versa. Households apparently consider public health expenditures a very good substitute for welfare expenditures.

Redistributing funds from health or welfare services to any other type of expenditures would have a significant negative effect on property values. For example, the analysis indicates that transferring $1 per household from welfare to education, fire protection or highways would decrease property values by 0.46 percent, or $291. Conversely, transferring $1 per household from one of those types of expenditures to welfare would increase property values by 0.46 percent.

[4] *Specifically, I control for state and federal transfers that are dedicated to education (IGRED), welfare (IGRWELF), health (IGRHLTH), and highways (IGRHWAY). I do not control for dedicated transfer from other local governments because I consider them payments for services rendered and unlikely to affect local expenditures.*

Table 1
Means and Standard Deviations

Variable	Mean	Standard Deviation
GRADHIGH	75.63	7.625
OVER65	10.69	3.856
BLACK	1.50	1.841
DISTANCE	21.09	12.227
HINCOME	23.91	3.827
STRUC70	23.85	9.845
STRUC39	27.72	12.761
SEWER	38.11	34.001
AIR	41.34	13.930
MEDROOMS	6.21	.375
VACANTRT	.07	.062
OWNERATE	.75	.109
TOTDEBT	578.87	527.244
ASSETS	32.47	96.069
PROPTAX	936.97	191.530
OTHERTAX	9.06	4.977
ELSEREV	147.06	107.747
DEFICIT	20.97	181.155
HEALTH	11.89	10.589
PUBUILD	11.43	21.894
POLICE	52.57	38.366
ALLUTILS	39.46	60.575
FIRE	28.79	25.779
HIGHWAY	76.75	33.228
LOCLSCHL	707.55	213.769
PARKREC	15.57	12.582
OTHEREXP	167.93	85.376
WELFARE	2.11	4.597
IGRHWAY	12.52	11.905
IGRHLTH	1.32	2.632
IGRWELF	3.61	4.306
IGRED	205.93	91.393
MEDVALUE	63,339.19	10,485.238

Although redistributing expenditures between welfare and all other expenditure types would significantly change property values, redistributing funds among the nonwelfare expenditures would have no perceptible effect on property values. For example, the estimation indicates that a $1 increase in police expenditures per household, financed by an equal decrease in welfare expenditures, would decrease property values by 0.44 percent, or $279. However, a $1 decrease in highway expenditures per household, financing an equal increase in welfare expenditures, would increase property values by 0.46 percent or $291. Therefore, increasing police expenditures by $1 per household while simultaneously decreasing highway expenditures by $1 per household would increase property values by an imperceptible $12. Statistical tests confirm

Table 2
Regression Coefficients

Variable	Coefficient	Standard Error
INTERCEPT	9.5902*	.208
GRADHIGH	.0013	.002
OVER65	.0106*	.004
BLACK	−.0025	.004
DISTANCE	−.0029*	.001
HINCOME	.0117*	.004
STRUC70	.0049*	.001
STRUC39	−.0009	.001
SEWER	−.0010	.001
AIR	.0012	.001
MEDROOMS	.1906*	.036
VACANTRT	.1475	.172
OWNERATE	−.1960	.113
TOTDEBT	.00002	.00002
ASSETS	−.00004	.0001
PROPTAX	.0045*	.002
OTHERTAX	.0064*	.003
ELSEREV	.0046*	.002
DEFICIT	.0046*	.002
HEALTH	−.0036	.002
PUBUILD	−.0043*	.002
POLICE	−.0044*	.002
ALLUTILS	−.0045*	.002
FIRE	−.0046*	.002
HIGHWAY	−.0046*	.002
LOCLSCHL	−.0046*	.002
PARKREC	−.0048*	.002
OTHEREXP	−.0049*	.002
IGRHWAY	.0008	.001
IGRHLTH	−.0013	.004
IGRWELF	−.0032	.002
IGRED	−.0003*	.0001
R-Square		.9426
Adjusted R-Square		.9002

* Significantly different from zero at the 5-percent level.

that the change in property values would be insignificant. In fact, testing the joint hypothesis that the coefficients on all of the nonwelfare expenditure types are insignificantly different from one another yields an F-statistic of 1.168 (significant at the 34-percent level), indicating that no marginal redistribution of funds among the nonwelfare expenditure types would change property values significantly.

Increasing taxes or deficit spending would increase property values, provided that the proceeds were spent on welfare services. For example, property values would increase by 0.45 percent if property taxes and welfare spending each increased by $1 per household. Increasing taxes to pay for any other type of spending would have an insignificant effect on property values. Adjusting the tax structure so that less revenue came from property taxes and more revenue came from some other form of tax or from deficit spending would also have no significant effect on property values.[5]

The Implications for Local Governments

Local governments can draw a number of conclusions about fiscal policy from the relationships indicated by this analysis. One striking implication of the analysis is that increasing taxes need not decrease property values. The estimation indicates that a marginal increase in taxes would increase property values if the proceeds of the tax were spent on welfare services. The estimation also indicates that a small change in taxes, coupled with a corresponding change in nonwelfare forms of expenditures, would have no effect on property values. Therefore, analysis of the Hartford MSA provides a clear example of a situation in which increasing taxes does not decrease property values.

Another interesting implication of the analysis is that Ricardian Equivalence appears to hold at the local government level. "The Ricardian Equivalence Theorem is the proposition that the method of financing any particular path of government expenditure is irrelevant" because deficit spending merely postpones taxes (Abel 1987). If the method of financing is truly irrelevant, then households should not care whether local governments finance their expenditures with taxes or deficit spending. The estimation shows that property values would remain essentially unchanged if local governments were to substitute a small increase in deficit spending for a decrease in taxes, indicating that households are indifferent between property taxes and deficits.[6]

A third implication of the analysis is that households have a taste for all types of government services, including transfer payments such as welfare and health services. If households were not willing to spend tax money on a particular government service, then property values could be increased by decreasing that form of spending and decreasing taxes accordingly. Given the spending levels in this data set, the estimation indicates that there is no form of government spending such that a small decrease in expenditures and taxes would increase property values. However, households could be unwilling to pay for levels of expenditures that diverge wildly from those in this data set.

Because small changes in both taxes and nonwelfare forms of expenditures would have no noticeable effect on property values, the analysis also suggests that local governments in the Hartford MSA were surprisingly successful at choosing their budgets so as to maximize property values within their jurisdictions. In general, local governments in Connecticut spent more than the national average on education, spent close to the national average on police services, and spent somewhat less than the national average on highways. Because health and welfare services are the only types of expenditures that the model indicates should be increased in the Hartford MSA, it is not surprising that local governments in Connecticut spent substantially less than the national average on health and welfare services. Local government spending per household on health and welfare in Connecticut was less than one-quarter of the national average.

Conclusions

By incorporating the complete budgets of local governments into a hedonic model of housing prices, this analysis debunks a number of myths about local government finance. The analysis indicates that, contrary to popular belief, increasing taxes need not decrease property values. Further, the analysis indicates that households do not automatically prefer deficit spending to tax increases. The analysis also suggests that households have a taste for all types of government services, including transfer payments like welfare and health services. Finally, the analysis indicates that local governments can be surprisingly successful at maximizing property values within their jurisdictions.

[5] *The F-statistic for the joint hypothesis that all of the revenue and deficit coefficients are equal to each other is 0.3672 (significant at the 78-percent level). Therefore, we cannot reject the hypothesis that the coefficients are equal.*

[6] *Because the localities in the Hartford MSA do not use local sales or incomes taxes as a source of revenue, the analysis cannot indicate whether or not households are indifferent between deficits and sales or income taxes.*

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Methanol as an Alternative Fuel: Economic and Health Effects

Air pollution is becoming an increasingly important problem for the United States. It is estimated that air pollution contributes to the premature deaths of more than 50,000 people a year and costs the nation $10 billion to $20 billion annually in health bills.[1] Motor vehicles currently contribute an estimated 40 percent to urban pollution.

The new Clean Air Act, which President George Bush recently signed into law, restricts toxic emissions without mandating a specific fuel. The law mandates that all gasoline sold in the nine smoggiest cities in the nation must reduce emissions of hydrocarbons and toxic pollutants by 15 percent beginning in 1995 and by 20 percent beginning in 2000. By 1998, all car fleets in the nation's twenty-four dirtiest cities must run 80-percent cleaner than today's autos.

Methanol is one of several alternative motor fuels that have been studied as replacements for gasoline because of its low pollution characteristics. Other alternative motor fuels are ethanol, compressed natural gas, and reformulated gasoline. Some analysts at the Environmental Protection Agency (EPA) believe that methanol deserves special attention because it seems to have a significant advantage over the other fuels in terms of cost, potential supply, and vehicle performance.[2] The most popular methanol-based fuels are M85, which is a mixture of 85 percent methanol and 15 percent gasoline, and M100, which is pure methanol.

There is considerable debate about the benefits and costs of switching from gasoline to methanol. M85 seems to be a more feasible fuel alternative than M100 in the near future. However, the pollution-reduction benefits of M85 over gasoline are not as clear as those of M100. Moreover, there is concern about the adverse health effects of both methanol fuels.

In this article, I analyze the economic, pollution, and health effects of switching from gasoline to methanol fuels. The benefits of the policy will be a reduction in pollution and a reduction in the adverse health effects of vehicle fuels. The costs of the policy will be the distortions in the affected markets. Using a model of oil demand and supply, I first calculate the effects of a switch from gasoline to methanol fuels on the oil, natural gas, and fuel markets. Then I combine the estimated pollution and health effects with the model's predictions to calculate the health and pollution effects of a switch from gasoline to methanol fuels. Finally, I calculate the net benefit or cost of switching from gasoline to methanol fuels.

Economic effects of the switch to methanol

A switch from gasoline- to methanol-powered vehicles in the United States affects the oil, natural gas, and vehicle fuel markets. The motor fuel sector in the United States is a large oil consumer and makes up 43 percent of total U.S. oil consumption, which is about 12.1 percent of world oil consumption. Hence, any change in the demand for oil in the United States affects world oil prices.

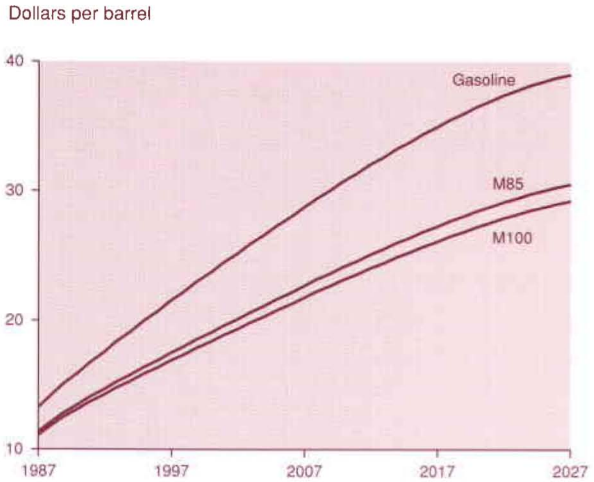
Replacing gasoline with methanol raises fuel prices because methanol is more costly than gasoline. The switch to methanol also increases

I would like to thank Kelly Whealan for excellent research assistance and Stephen P.A. Brown, John K. Hill, and Mark French for helpful comments.

[1] *See Gutfeld (1990).*

[2] *See Lorang (1990).*

Figure 1
Oil Prices
(Increasing Natural Gas Prices)



the demand for natural gas because natural gas is assumed to be the feedstock for methanol.

To calculate the effects of the switch to methanol, I utilize the results of my Dynamic Oil Model (*see the box titled "Theoretical Model"*), which calculates the world price of oil, the price of domestic motor fuels, and the demand for fuel before and after the switch to methanol. For simplicity, I assume that gasoline producers and methanol producers are the same. As we switch to methanol fuels, the refiners (that is, the producers of fuel) switch from oil as a feedstock to natural gas as a feedstock. The policy of changing to alternative motor fuels is applied evenly across the nation; the regional allocation of oil consumption is not considered.

Base case. The base case represents the oil market before the switch to methanol, in which motor fuel is 100 percent gasoline. The initial price of oil is $13.28 per barrel in 1987 and rises to about $40 per barrel over the forty-year time horizon. U.S. oil production satisfies 51 percent of total consumption at the beginning of the time period and decreases to 40 percent at the end of the time period. The average price of gasoline is 95 cents per gallon at the pump initially and rises to $1.56 per gallon as oil prices increase.

Phasing-in of M85 and M100. As the alternate fuels M85 and M100 are phased in, the demand for oil is reduced and oil prices fall. As a higher percentage of cars begin using the alternative fuels toward the end of the phasing-in period, oil prices fall further and the price differential between the base-case oil-price path (gasoline) and the M85 and M100 oil-price paths becomes larger (*Figure 1*).

Because domestic producers are price takers and have perfect foresight in this model, domestic production increases dramatically when alternate fuels begin to be phased in. Knowing that the demand for oil will be curtailed, producers try to take advantage of oil prices before they start falling. As gasoline is phased out, however, domestic oil production starts to fall. Oil imports also fall with the switch to nongasoline fuels.

The phasing-out of gasoline increases the amount of oil consumed in nontransportation uses because of the decrease in the price of oil. With the switch to methanol-based motor fuels, 85 percent of the oil used in vehicle fuels is replaced with methanol in the M85 case, and 100 percent is replaced in the M100 case. This replacement amounts to a 42.3-percent reduction in oil demand with M85 and a 50-percent reduction with M100. However, total oil consumed over the entire time horizon falls only 24 percent with M85 and 28 percent with M100. This reduction occurs because the world price of oil falls as U.S. demand for oil decreases. Oil and its cheaper products are substituted for the now relatively more expensive natural gas or other products in nontransportation uses.

The switch to methanol fuels also affects the natural gas market. The demand for natural gas increases with the switch to methanol because it is assumed to be the feedstock for methanol. As natural gas becomes more expensive, however, consumers will substitute away from natural gas.

I make two differing assumptions about the cost of the natural gas feedstock. First, I assume that natural gas prices are the same as in the base case. This assumption implies that the demand for natural gas stays at base-case levels. Constant prices would be possible through the substitution of oil products for natural gas in nontransportation uses. For example, residual fuel oil would replace natural gas in industrial uses, and heating oil would replace natural gas in residential uses. However, the assumption of constant natural gas prices is quite restrictive because it means that 72 percent of natural gas

Theoretical Model

I use a dynamic optimal control model set in a partial equilibrium framework to simulate time paths for oil prices, oil production, and consumption. OPEC is modeled as a dominant firm facing U.S. total demand for oil, less U.S. domestic production and non-OPEC imports to the United States. Domestic producers are profit-maximizing price takers in the crude oil market. Both the United States and OPEC own reserves and maximize the present value of profits over a forty-year time horizon. I simulate the paths of the variables for a base case in which gasoline is based 100 percent on oil. The demand function for crude oil is an iso-elastic function with a price elasticity of –0.9 and an income elasticity of 0.8. The demand function is derived from domestic demand for products and normalized around 1987 demand. The cost functions for OPEC and the United States are also normalized around 1987 costs for these regions. I assume that U.S. income will grow at 2.5 percent per year. The discount rate is 8 percent.

After the base case, the model is solved with the demand for oil based on two different mixtures of gasoline and methanol most often discussed: an 85-percent methanol and 15-percent gasoline blend (M85) and 100 percent methanol (M100). M85 and M100 are phased in slowly over the average life of a vehicle. It is assumed that the use of methanol will be mandated by the government, and hence all vehicles will be dedicated vehicles and will be using methanol by the end of the phasing-in period.[1]

When methanol is blended with gasoline, methanol replaces a portion of gasoline, shifting the oil-demand curve inward. To obtain the new quantity of gasoline demanded, I calculate a new gasoline price and a new product-weighted average elasticity of oil. The process is repeated with M100. The price elasticity of fuel is assumed to be constant among the different fuels.

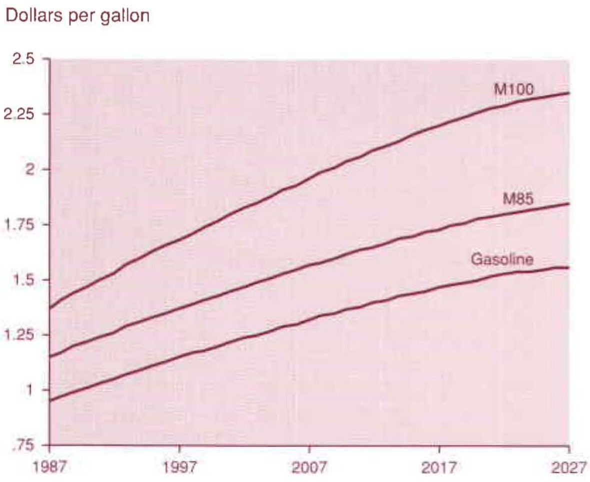
After the simulations are completed and price and output paths for oil are obtained, I calculate the price of gasoline, methanol (M100), and the methanol-gasoline blend (M85). I obtain the price of gasoline by dividing the per-barrel price of oil by forty-two (forty-two gallons in a barrel) and by adding various costs and taxes. When calculating the price of methanol, the feedstock is taken to be natural gas. Natural gas prices depend on oil prices in the base case. As gasoline is phased out, natural gas prices are kept constant in case 1 and allowed to rise with increasing demand in case 2. The methanol price is then converted to a gasoline-equivalent pump price by an adjustment factor, because methanol has one-half the energy content of gasoline but is more fuel-efficient. The M85 blend is calculated as a weighted average of methanol and gasoline prices.

[1] The results reported in this study overstate the effects of any switch to alternative fuels because it is assumed that all vehicles will be using either the M85 blend or M100 at the end of the phasing-in period. In reality, the numbers will most likely be much smaller. However, complete vehicle dedication is a necessary assumption to highlight the qualitative effects of the switch to methanol.

consumption must be replaced by oil or other substitutes in the switch to M85. With M100, 85 percent of natural gas consumption must be replaced.

If the increase in demand for natural gas in transportation uses is not offset by an equal decrease in nontransportation uses, the price of natural gas will rise. Given the secular increase in demand for natural gas and a long-run price elasticity of demand for natural gas of –0.7 and assuming that one-half of natural gas consumption is replaced by cheaper oil products, natural gas prices would increase 52 percent with M85 and about 61 percent

Figure 2
Fuel Prices
(Increasing Natural Gas Prices)



with M100 if supply was completely inelastic.[3] Hence, in the second case, I assume that natural gas prices increase 50 percent from the base case. This level is an upper bound, given that natural gas supply is not perfectly inelastic.

In the motor fuel market, the relative prices of gasoline, methanol, and the M85 blend change as alternative fuels are phased in, as shown in Figure 2. Pure methanol is more expensive than pure gasoline, hence, the price per gallon of M85 (gasoline equivalent at the pump) is higher than a gallon of gasoline throughout the time horizon. Even though gasoline prices fall with the switch to methanol, the reduction in gasoline prices is not enough to offset the price differential between gasoline and methanol. At the end of the forty years, methanol fuel consumption is 8.5-percent less than gasoline with constant natural gas prices and 17.5-percent less with increasing natural gas prices.

The results are stronger with M100. M100 is less efficient than M85 because M100 is pure methanol, and hence it is more expensive on a gasoline-equivalent basis. The price of fuel in this case is higher than both gasoline and M85. Consequently, the total amount of fuel consumed with M100 over the forty-year period is 26.3-percent less with constant natural gas prices and 35.4-percent less with increasing natural gas prices.

Welfare effects

By lowering the price of oil and increasing the price of vehicle fuels, the switch from gasoline to methanol fuels has implications for consumer and producer welfare in many markets. The fall in the price of oil is beneficial to consumers of oil but hurts producers of oil. If natural gas prices increase, producers benefit, but consumers of natural gas are hurt. In the vehicle fuel market, both consumers and producers of fuel are hurt.[4]

Domestic oil producers are worse off with the change to methanol fuels because both the price of their product and their sales decrease after gasoline is phased out. Profits are reduced 46.3 percent from the base case with M85 and 51.7 percent with M100. On the other hand, oil consumers who are in the market for products other than motor fuel are better off. The gain in consumers' surplus is forty times greater than base-case domestic producer profits with M85 and fifty-six times greater with M100. Gains in consumer surplus are large because the world price of oil falls with the switch to methanol. Therefore, not only domestic oil but also imports are cheaper. Because domestic production increases until gasoline is fully phased out, consumers enjoy an abundant supply of cheap oil for the first eight years. Even though supply is decreased after phasing-in is completed, oil prices are always less than in the base case. Overall, there are gains in the oil market.

The situation is reversed in the fuel market; there are losses to both consumers and producers of fuel. Producers are hurt because the cost of producing methanol is higher than the cost of producing gasoline. Moreover, because of the higher price of fuel, fuel consumption is less with methanol fuels than with gasoline. Higher input costs along with lower sales pinch producer profits. With constant natural gas prices, profits fall 15 percent with the switch to M85 and 19.3

[3] *See Bohi (1981).*

[4] *The measure of producers' welfare is the present value of total profits over the forty-year time horizon. The losses or gains to consumers are calculated by the changes in consumer surplus using Hausman's (1981) measure of compensated variation.*

percent with the switch to M100. The fall in profits is more dramatic in the case of increasing natural gas prices. The losses rise to 30 percent of base-case profits with M85 and 35 percent with M100 if natural gas prices are increasing.

Higher fuel prices hurt consumers; there are losses in consumers' surplus with the switch to methanol fuels. As with producers of fuel, the highest losses on the consumers' side are when natural gas prices are increasing. To put consumer losses in perspective, we can express them as a percentage of refiner profits before the switch to methanol. The losses range from a low of 2.2 percent in the constant natural gas price case with M85 to a high of 23.4 percent with increasing natural gas prices and M100.

The natural gas market is also affected by the switch to methanol. If natural gas prices are constant, there is no welfare loss or gain in the natural gas market. In the case of increasing natural gas prices, producers are better off, but consumers are worse off. A rough approximation of consumer losses shows that losses in the natural gas market are twice consumer losses in the fuel market. Producer gains in the natural gas market do not make up for the consumer losses. Producer gains are about one-tenth of consumer losses in the natural gas market.

If we analyze the three markets separately, we see that there are gains in the oil market but losses in the fuel and natural gas markets. However, the gains in the oil market are large enough that if the losses and gains in the three markets are combined, the switch from gasoline to methanol fuels appears to have net gains for the economy (*Table 1*).

The gains in the oil market arise from the United States' monopsony power in the world oil market. The fall in demand for oil in the United States causes a decrease in the world price of oil. However, there are more efficient policies, such as a tariff, that could capitalize on this monopsony power.[5]

Hence, if we do not include the gains in the oil market but concentrate only on the fuel and natural gas markets, the switch from gasoline to methanol fuels would result in welfare losses.

Adverse health effects of vehicle fuels

The switch from gasoline to methanol is expected to have considerable health benefits. Methanol use will reduce ozone pollution and some of the health risks associated with gasoline. The health effects of vehicle fuels can be separated into two types: indirect exposure to the fuel through evaporative and exhaust emissions (pollution) and direct exposure through ingestion, inhalation, skin and eye contact, and fuel fires.

Effects of indirect exposure

Pollution. One of the most important contributors to urban pollution is ozone. Ozone is a very reactive gas found naturally in the earth's atmosphere that becomes dangerous at high levels. The Clean Air Act classifies ozone as a criteria air pollutant, which has "an adverse effect on public health and welfare...and results from numerous or diverse mobile and stationary sources."[6]

Ozone is not directly emitted by the pollution-causing sources but is produced by the reaction of nitrogen oxides (NO_xs) and reactive organic compounds (ROCs) in sunlight. Ozone-causing NO_xs and ROCs escape from fuels mainly because of combustion through the exhaust or tailpipes of automobiles. ROCs are also emitted from automobiles through evaporation and spillage.

Exhaust emissions are the largest portion of total emissions. The ROCs released through the combustion of gasoline are certain hydrocarbons containing no methane or oxygen (nonmethane, nonoxygenated hydrocarbons—NMHCs), formaldehyde (a hydrocarbon containing oxygen), carbon dioxide (CO_2), and carbon monoxide (CO). Methanol emits all these reactive organic compounds emitted by gasoline plus methanol, but in different concentrations.

There are various estimates of the gases emitted in the combustion of gasoline and methanol.[7] To be able to compare gasoline and methanol emissions as contributors to urban air pollution, it is important to obtain a measure that calculates

[5] *See Brown (1982).*

[6] *See Tilton (1989).*

[7] *See Environmental Protection Agency (1989), Austin (1990), and Gold and Moulis (1987).*

Table 1
Welfare Losses or Gains from Switching to Methanol (Increasing Natural Gas Price Case, Billions of Dollars)

	Consumers	Producers
M85		
Oil Market	8,595.6	–99.4
Fuel Market	–883.3	–320.7
Natural Gas Market	–2,177.2	196.3
M100		
Oil Market	12,127.1	–111.1
Fuel Market	–1,248.4	–376.8
Natural Gas Market	–2,263.0	201.3

NOTE: The losses/gains are the discounted value of total losses and/or gains over the forty-year time horizon. A negative number denotes losses.

the ozone-forming potential of these gases and to standardize emissions test results. The emissions estimates used in this article are taken from a study by Krupnick, Walls, and Toman (1990), referred to as the *RFF study* from now on.[8] The RFF study computes a reactivity measure that includes nonmethane hydrocarbon emissions, methanol emissions, and formaldehyde emissions, from gasoline, M85, and M100. The extent to which health problems related to ozone pollution are reduced with methanol depends on the amount of ozone reduction caused by the switch from gasoline to methanol.

The net amount of pollution reduction with the switch to methanol can be calculated by combining the reactivity estimates in Table 2 with fuel consumption numbers from the simulations. The reactivity estimates in Table 2 show that in 2000, M85 will reduce the reactants in the air (given by grams per mile) by 11 percent with completely dedicated vehicles and by 25 percent with flexible fueled vehicles. By 2010, M100 will reduce reactants by 42 percent.

The decline in ozone-forming potential with methanol is greatly enhanced by the accompanying decline in fuel consumption. The simulation results indicate that fuel demand with M85 and M100 are less than with gasoline throughout the time horizon because fuel prices are higher than with gasoline in both the constant and increasing natural gas price cases. If natural gas prices are constant, reactivity in 2000 will be reduced 20 percent with dedicated M85 vehicles and 30 percent with flexible fueled vehicles.[9] In 2010, use of M100 reduces reactivity by 53 percent with constant natural gas prices. If natural gas prices increase with the switch to methanol, reductions in reactivity are even greater, ranging from 35 percent in 2000 with M85 to 63 percent in 2010 with M100. It is evident from these calculations

[8] *The study calculates emissions using test results from the American Petroleum Institute database for flexible fueled vehicles (FFVs) and dedicated vehicles using M85. There were too few M100 results in the database, therefore the emissions for M100 are adjusted numbers from the literature. From their five scenarios, I take only the "most likely" scenarios, which are the following: year 2000, FFVs; year 2000, dedicated M85s; year 2010, dedicated M100s.*

[9] *I focus on the years 2000 and 2010 to facilitate the use of the RFF study, which calculates a reactivity measure for gasoline and methanol fuels for these years.*

Table 2
Gasoline versus Methanol Vehicle Emissions (Grams per Mile)

	2000			2010	
	Gasoline	FFV	M85	Gasoline	M100
Exhaust					
REACT	.542	.50	.59	.270	.178
NMHC	.53	.0	.0	.263	.05
HCHO	.004	.042	.06	.003	.015
NO_x	.52	.67	.72	.20	.50
CO	3.94	2.74	4.79	3.50	.0
Evaporative					
REACT	.41	.216	.257	.023	.003
Total					
REACT	.952	.716	.847	.408	.237

NOTE: REACT = Reactivity measure
NMHC = Nonmethane hydrocarbons
HCHO = Formaldehyde
NO_x = Nitrogen oxides
CO = Carbon monoxides
FFV = Flexible fueled vehicles
M85 = Dedicated M85 vehicles
M100 = Dedicated M100 vehicles

SOURCE: Krupnick, Walls, and Toman (1990)

that the ozone-forming potential of vehicle fuels is greatly reduced with the phasing-out of gasoline.

To translate the emissions reductions into specific numbers relating to health benefits, I use the estimates of *avoided days of adverse consequences* from U.S. Congress, Office of Technology Assessment (1989). The publication reports that, on average, a 1-percent reduction in ROCs reduces restricted activity days due to pollution by 240,000 days and reduces respiratory symptom days by 514,000 days and asthma attack days by 17,100 days (for the total population). Assuming that a 1-percent decrease in reactivity would result in the same reduction in adverse health days, the reduction in adverse health days ranges from 15.7 million days in 2000 with M85 and constant natural gas prices to 48.3 million days in 2010 with M100 and increasing natural gas prices.

The gain to society from the reduction in health days is quite large. If we assume that one person in four misses a day of work from an adverse health day, the present value of wages gained by the switch to methanol, over the forty-year time horizon, ranges from $3.5 billion with M85 and constant natural gas prices to $10.5 billion with M100 and increasing natural gas prices.[10]

The reduction in emissions, however, is not the only factor that affects air quality. Emissions

[10] *If one person in 100 misses a day of work from an adverse health day, the present value of wages gained would range from $140 million with M85 and constant natural gas prices to $550 million with M100 and increasing natural gas prices.*

test results are entered into large photochemical air-quality modeling studies to analyze the effects of emissions on air quality.[11] The studies suggest that the conversion of gasoline-fueled vehicles to methanol-fueled vehicles will reduce ozone levels in urban areas. All the studies emphasize that the hydrocarbon–NO_x ratios (HC/NO_x) in the atmosphere in a certain locality are very important in determining whether a switch from gasoline to methanol will improve air quality. The switch is most beneficial when HC/NO_x is low. Hence, in certain urban areas, such as Houston, where this ratio is consistently high, the benefits of switching to methanol-fueled vehicles will be much less than in areas with low HC/NO_x.

Air toxins. In addition to ozone pollution, gasoline also emits several air toxins, including fuel vapor, benzene, 1,3-butadiene, polycyclic organic materials (POMs), and formaldehyde, which are classified by the EPA (1989) as known or probable carcinogens. The switch to methanol should reduce most of these air toxins.

Methanol does not contain benzene and POMs, and it has minute amounts of 1,3-butadiene. Hence, there would be no adverse health effects due to these compounds with M100. The EPA (1989) estimates that M85 would reduce the level of benzene by 70 percent, POMs by 72 percent, and 1,3-butadiene by 64 percent. The EPA suggests that chronic effects related to methanol vapor are not likely with M100, but the combined effects of gasoline and methanol would be expected with M85.

The cancer incidence estimates from gasoline's air toxins range from 379 cases to 727 cases (see Adler and Carey 1989, and EPA 1989). Table 3 shows that there would be a reduction of a minimum of 254 cancer incidences with M85 in 2000. The reduction in cancer incidence from air toxins could be as high as 633 cases in 2010.

The increase in formaldehyde emissions with methanol is more problematic. Aside from increasing the ozone-forming potential of fuels, formaldehyde causes metabolism problems in certain population groups and is also a probable carcinogen. Studies with rodents have shown that inhalation of formaldehyde leads to nasal tumors and its ingestion (mixed in drinking water) leads to increased leukemia and gastrointestinal cancers (Beyaert, and others 1989). Adler and Carey (1989) estimate that formaldehyde from gasoline led to forty-three to eighty-one incidences of cancer in 1986. Switching to M85 would increase cancer incidence, while switching to M100 would decrease cancer incidence.[12] Table 3 shows that the increase in cancer incidence with M85 can be as high as seventy-seven cases in 2000 and ninety-five cases in 2010. With M100, cancer incidence could fall by sixty-three cases in 2010.

Overall, the switch from gasoline to methanol lowers health risks from indirect exposure. The pollution potential of methanol, as measured by total reactivity, is less than gasoline. Although methanol emits higher levels of formaldehyde, emissions of both reactive organic compounds and air toxins are less with methanol than with gasoline.

Effects of direct exposure

The relative safety of direct methanol exposure as compared to gasoline is much debated. The switch to methanol seems likely to decrease the risk of vehicle fires and the incidence of ingestion, inhalation, and skin or eye contact. However, methanol use could increase the number of lethal cases of inhalation, ingestion, and skin or eye contact.

If methanol fuels are not used in nonautomotive uses, health risks due to inhalation of fuel will be reduced. Machiele (1990) estimates that 50 percent of inhalation cases arise from nonautomotive uses of gasoline. Combined with the chemical properties of M85 and M100, the incidence of inhalation cases would be 80 percent of gasoline with M85 and 20 percent of gasoline with M100.

Although the number of cases of inhalation would decrease with methanol fuels, the number of serious injuries or deaths could increase. Litovitz (1988) reports that the mortality rate with methanol fuels is 0.375 percent as compared to 0.0157 percent with gasoline. As shown in Table 3, the number of deaths with methanol fuels

[11] See, for example, Russell (1990, Table 1), Chang and Rudy (1990), and Sillman and Samson (1990).

[12] The EPA (1989) assumes that there will be improvements in methanol-engine and emission-control technology and thus reductions in indirect formaldehyde emissions with M100.

Table 3
Health Effects of Gasoline versus Methanol (Increasing Natural Gas Prices)

	2000			2010		
	Gasoline	M85	M100	Gasoline	M85	M100
Air Toxins						
Cancer Incidence*	502–921	248–413	0	627–1149	310–516	0
Formaldehyde						
Cancer Incidence*	55–102	95–179	0	68–128	118–223	34–65
Inhalation						
Incidence	2,660	1,775	386	3,322	2,214	478
Deaths	0	7	1	0	8	2
Skin/Eye Contact						
Incidence	10,135	4,226	3,686	12,656	5,273	4,564
Deaths	2	16	14	2	20	17
Ingestion						
Incidence	19,642	3,670	1,246	24,532	4,881	1,542
Deaths	3	5	5	4	6	6
Vehicle Fires						
Injuries	6,318	2,057	198	7,836	2,579	248
Deaths	1,071	349	34	1,328	438	43

*These numbers indicate a range of possible cancer incidence.

could increase by one to eight cases.

As calculated from Machiele (1990) and Litovitz (1988), 8.8 percent of gasoline ingestion cases in 1987 were due to automotive uses of gasoline. Assuming the same percentage of ingestion would result from methanol's automotive uses and combining with simulation results, I obtain an increase of two to three mortality cases due to methanol use.

Fifty percent of skin or eye contact cases with gasoline result from automotive uses. Estimating the incidence per gallon of gasoline used and assuming 50 percent would apply to methanol, the incidence of skin or eye contact with methanol can be calculated. Table 3 presents these results. The fourteen to twenty deaths reported are the maximum that would result, using Litovitz's mortality rate estimate.

Machiele (1990) reports an average of 858 deaths and 5,060 injuries related to vehicle fires involving gasoline in 1986. Combining Machiele's estimates for death and injuries for M85 and M100 with fuel consumption from the simulations, I obtain a 60-percent reduction in deaths and injuries with M85 and a 96-percent reduction with M100 if natural gas prices are constant. With increasing natural gas prices, the reduction in deaths and injuries is 67 percent with M85 and 97 percent with M100 (*Table 3*).

Overall, it is evident that the incidence of direct contact with automotive fuels is greatly lessened with methanol mainly because of its lack of nonautomotive uses. However, because methanol has a higher mortality rate and contains a larger percentage of formaldehyde than gasoline does, the number of serious injuries and deaths from direct methanol contact could be higher than that from gasoline.

Conclusion

Switching from gasoline to methanol fuels has important economic and health effects. Replacing gasoline with methanol will affect oil markets by lowering the demand for oil and thus lowering oil prices. Increased demand for the natural gas feedstock will increase natural gas prices. Because methanol is more costly than gasoline, fuel prices will also increase. On the other hand, methanol use will reduce ozone pollution and some of the health risks associated with gasoline.

Are the costs worth the benefits of switching from gasoline to methanol? Although there are welfare losses in the fuel and natural gas markets, the gains in the oil market more than offset these losses. Considering all three markets affected by the phasing-out of gasoline, the switch to methanol results in net gains. The health benefits from lower pollution and the lives saved from the switch from gasoline to methanol are in addition to these gains. Overall, the benefits of the policy far outweigh the costs.

However, the gains in the oil market, arising from the United States' monopsony power in the world oil market, can be captured by other, more efficient policies. If we exclude the gains in the oil market from the welfare calculations and consider only the vehicle fuel and natural gas markets, the policy will result in welfare losses. The present value of these losses would total $3,687 billion over the forty-year time horizon.

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