Working Paper

The Price-Induced Energy Trap

Exploring the Impacts of Transportation Expenditures on the American Economy

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Even though the U.S. economy grows at an anemic rate of perhaps 1.5 percent and 1.9 percent (or less) in this year and next, the world economy is likely to expand by well over 3 percent in that same two-year period. The world demand for oil is expected to increase, concurrently, by about 1.5 percent annually. The most recent projections by the U.S. Energy Information Administration (EIA 2011a) suggest that – absent major disruptions – the growing demand for energy worldwide will continue to push oil prices up in a slow but steady movement. Absent dramatic changes in U.S. energy policy, consumers are likely to continue to pay high and volatile prices.

Despite an anticipated 1.8 percent decline this year in gasoline consumption, for example, the overall expenditures for gasoline will increase 25 percent, rising from $391 billion dollars in 2010 to $489 billion dollars in 2011. Both the size of the U.S. gasoline bill, and its dependence on global events, impact the lives and well-being of individuals, families, and households – especially those from the middle and lower income levels. And as consumers' incomes, already shrinking in the after-effects of the recession, continue to be absorbed by high fuel costs, gasoline is becoming a drag on the economy.

How will U.S. policy makers navigate the future? For decades price has been the focus of policy-maker's attention. Policy-by-price has taken three approaches. First, policymakers have tried to keep prices low through subsidies for ethanol and biofuels, increased domestic oil production and an active foreign policy toward oil suppliers, while letting "the market" (i.e., rising prices), tell consumers when to change their habits or autos. Another approach has added CAFE standards for automobiles to the mix as a way of reducing demand in the fleet overall, while ensuring that consumers are steered towards more efficient vehicles in response to those prices.[1] A third approach wishes to make gasoline price more truly reflect its external costs through taxes, carbon fees, and highway use fees. All approaches emphasize the role of "the price signal" in providing incentives that encourage a smarter use of energy. All strains of policy assume that consumers can and do respond to higher prices by reducing demand in an economically rational fashion.

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[1] Earlier this year the Obama administration announced a new set of ambitious fuel economy standards for cars and light trucks that will double fuel economy in 14 years. The end result is the fleet average fuel economy for each automaker will be 54.5 mpg by the year 2025. While this is a critical long-run strategy (assuming an average vehicle life of 17 years, the full fleet of cars and trucks won't reach this average until perhaps 2042), many more short-term strategies are needed to deal with inefficient gasoline consumption.

However, a growing number of papers, and recent historical evidence, suggest that U.S. consumers respond to rising energy prices in a limited way (see, for example, Hughes, Knittel, and Sperling 2006; and Turrentine and Kurani 2007). As oil prices have risen, consumer response has been limited, providing a real-world simulation of the efficacy of price as a signal. Perhaps consumers cannot change their automobiles, or their commutes, or their habits quickly enough. If that is the case, then relying on price as a way to reduce oil consumption, or create "rational" allocations of resources, may be flawed. Furthermore, it's possible that a price-based policy itself may be paradoxically increasing, or at least freezing, energy consumption patterns and enabling the gas pump to capture more of U.S. workers' disposable income.

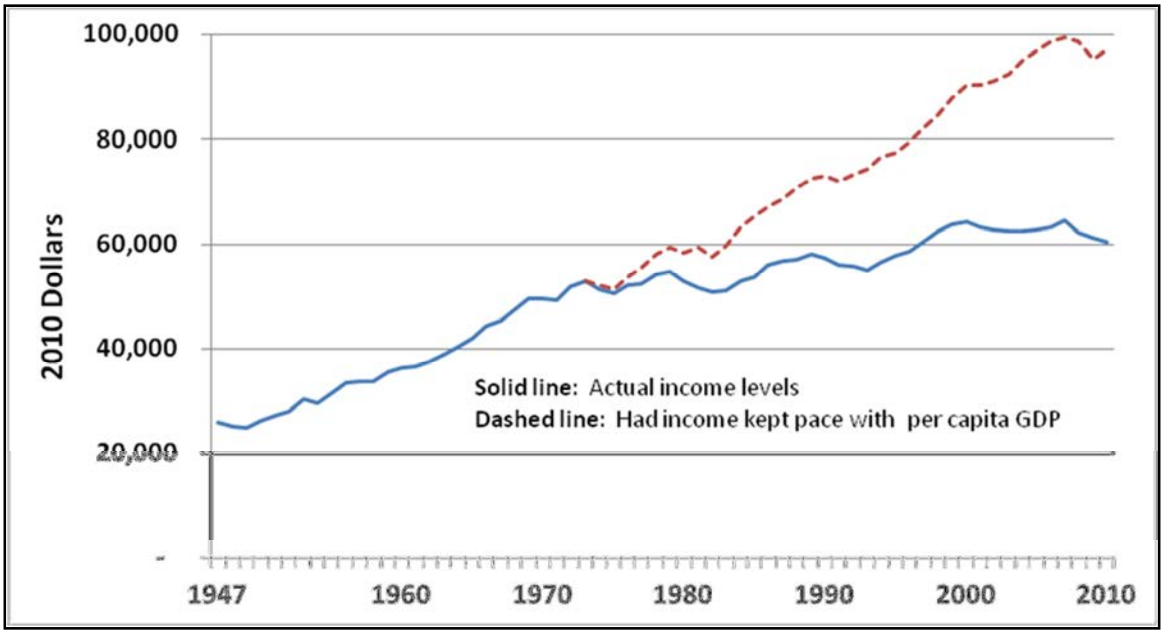
Better understanding why very high gasoline prices do not lead to dramatic reductions in gasoline consumption could lead to policies that more quickly, and less painfully, reduce gasoline demand and consumer spending. Data from the Bureau of Labor Statistics suggest that what households spend on transportation services, including expenses and payments for the car, is more than what they spend on both health care and taxes combined (Consumer Expenditure Survey 2010). Taking specific actions to reduce the cost of transportation, by improving the range of lower-cost choices, or increasing consumers' understanding of those choices, could allow households to act in an economically rational manner to reduce gasoline spending and increase their discretionary spending elsewhere in the economy.

At a slightly higher level, there is also reason to wonder whether persistent inability to make rational reductions in energy use is among those things which constrain overall U.S. economic activity.[2] In other words, higher oil prices not only increase the cost of energy services, but the on-going dependence on the inefficient use of oil (and other conventional energy resources) is likely to weaken the nation's improvement in per capita income. We are confronted with higher energy prices that increase consumer and business costs. At the same time, the lack of income or investment to improve our transportation system efficiencies locks us into a pattern that weakens the economy and reduces the prospect for future gains in income. Much research needs to be done to probe these larger questions and puzzle through this conundrum.

This paper, using widely-available economic data, is a first step at unraveling how current policies and consumers "lock-in" these costly spending patterns. In the sections that follow, we first will review emerging patterns of consumer income and spending to place energy and transportation expenditures into context. Next we will analyze existing data to evaluate the responsiveness of consumers and businesses to changes in incomes, prices and policies as they all impact energy consumption. Following that we will look at how consumer responses to energy prices appear to have changed over time. Then we will look at data on how different consumer income groups respond to energy prices. At that point we will examine how continued inefficiency constrains our economy. We will then conclude by generalizing about the policy insights--and much bigger questions--that emerge from the data.

[2] This point is discussed more fully later in the report, but for now, suffice to say that of all the energy resources used within our economy, only 14 percent are actually used to transform matter into goods and services. In other words, we waste 86 percent of the energy consumed in our economy. And that level of waste imposes a huge cost burden that constrains our economic well-being.

Figure 1. Median Family Income 1947-2010



Source: Author estimates based on U.S. Census Bureau, Current Population Survey, Annual Social and Economic Supplements and Bureau of Economic Analysis historical GDP growth rates.

Consumer Income and Energy Spending Patterns

Over the past four decades the United States has undergone an economic transformation that has put middle and lower class families at financial risk. Expenses have increased and incomes have stagnated. Many households and families are now a pink slip or a bad medical diagnosis away from being newly poor (Warren 2006). Figure 1 on the previous page provides a sense of the stagnating incomes which have flattened significantly compared to continued growth in the economy.

In the period 1947 to 1973, the first U.S. energy crisis, real family incomes rose at a rate of 2.8 percent, about 0.3 percent above real per capita GDP, or Gross Domestic Product. Since 1973, however, the growth in median family incomes dropped to 0.4 percent—despite the growth in two income families—while per capita GDP grew 1.7 percent per year. Had family incomes increased at just the rate of per capita GDP since 1973, incomes might have risen to $97,000 instead of the current $60,000 level highlighted in Figure 1. Among the reasons for this trend is the lagging economic productivity of the U.S. economy, which we will show is partly the result of the growing costs of overall energy services.

By 2010, as shown in Figure 2 below, housing and transportation expenses consumed fully one half of the average set of household expenditures in the United States. Not surprisingly the lowest two income quintiles spent 55 percent of total expenditures on housing and transportation while the nation's highest income quintile spent only 47 percent on those same expenses. In another surprising statistic, for every dollar that a working family tries to save on housing, largely by driving further away from urban areas until they find a more affordable home, they spend 77 cents more on transportation (Lipman 2006). In other words for the lower middle class, spending more on energy became a work-around for the difficulty of buying a home close to employment. But this bargain became unstable when energy prices began rising seven years ago. Figure 2 demonstrates that the working poor and lower middle class, who have essentially traded transportation costs for housing costs, may be particularly at risk of losing a larger share of their income when gasoline prices soar. For some families the added gasoline dependence, which had offered them a chance at the American Dream of owning a house, could become another financially destabilizing factor—a variant on the "pink slip or bad medical diagnosis," that could push them towards being newly poor.

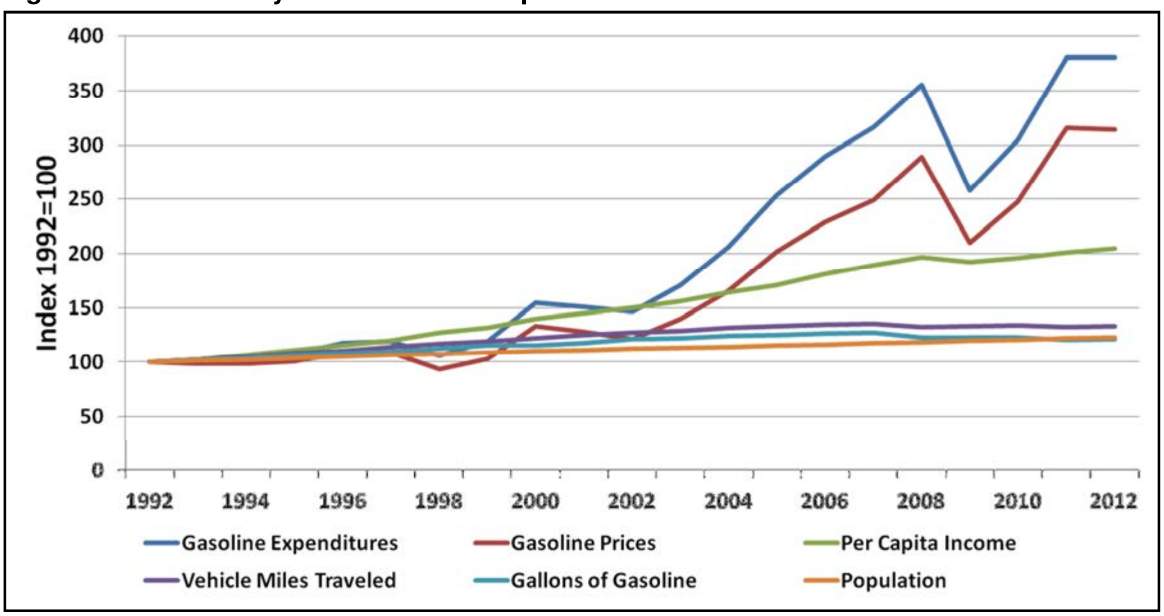
Figure 2. 2010 Allocation of Consumer Expenditures by Income Level

Expenditure	Average consumer household	Poorest 20 percent	Working Poor 20 percent	Highest Income 20 percent
Food	12.7%	15.8%	13.9%	11.5%
Housing	34.4%	41.4%	37.5%	31.9%
Transportation	16.0%	13.7%	16.5%	15.0%
Healthcare	6.6%	7.3%	8.7%	5.2%
All Other	30.3%	21.9%	23.3%	36.4%
Total	100.0%	100.0%	100.0%	100.0%

Source: Bureau of Labor Statistics Consumer Expenditure Survey 2010.

Over the past 9 years, the gas tank and the price of gasoline have become an ever more powerful, if enigmatic, factor in the U.S. economy. Rising from $1.39 per gallon in 2002, prices have been volatile, escalating to an average $3.31 per gallon in 2008, down to $2.40 per gallon in 2009, rebounding to $2.83 per gallon in 2010, and are now averaging about $3.61 per gallon through July 2011. Reviewing data from the Energy Information Administration's (EIA) Short-term Energy Outlook (2011b) suggests that gasoline expenditures in 2011 will rise 24.1 percent while per capita disposable income will increase by only 2.8% percent. Figure 3 below provides an index of key gasoline consumption variables, both historically from 1992 through 2010, with a short-term projection for both 2011 and 2012.

Figure 3. Index of Key Gasoline Consumption Variables



Source: EIA Short-Term Energy Outlook, September (2011b).

From this graph it is easy to see that whatever is going on with gasoline prices and flattening incomes is a dramatic and persistent resetting of the economy. In 2011 the United States will spend $488 billion dollars for gasoline (the top blue line), nearly $100 billion more than in 2010. That is about one-fourth of the increase in disposable income (the green middle line)—even as vehicle miles traveled, gasoline consumption, and population growth (the bottom three lines in that order) remain relatively flat (EIA 2011a). From this graph it's also clear that the economy-wide political bargains over energy use versus growth, as well as the household trade-offs between driving and home ownership that were made in the 1990's and early 2000's need to be reconsidered in light of the extraordinary volatility of energy costs now and in the future.

If a policy analyst were to study Figure 3 carefully, a new insight begins to emerge—that using price as a "signal" to encourage consumers to change their driving and buying behaviors may prove to be a dangerous game. Here the price of gasoline more than doubled, not once but twice in a five-year span, and while consumers did slightly reduce the number of miles traveled and gallons consumed, the overall dollar impact on the economy remained very high while incomes flattened. It raises the question that if we want consumers to "hear" the signal of high prices, how loud would that signal have to be? How much would it impact the rest of the economy? Or, will we find that price as a signal is somehow broken?

Understanding Elasticities

In order to probe how price signals impact consumers and the economy we have to look at historical trends in energy demand elasticities, which are indicators of how receptive consumers might be as they are forced to make new energy choices. To do this we explain the concept behind energy demand elasticities, focusing on the United States from 1970 to 2010. And as we shall see, focusing only on energy prices may produce a highly skewed sense of how choices about energy purchases are made, or what might be the better way to encourage smarter choices.

In brief, elasticities are a measure of how a change in one variable corresponds to a change in another variable. Hence, elasticities are a measure of responsiveness. More formally, elasticities measure the percentage change in one variable with respect to a percentage change in another variable. In this section of the paper we will review two categories of energy elasticities: price and income. We will also examine the importance of understanding how elasticities change over time.[3]

Why Are Elasticities a Big Issue?

Elasticities change over time. Indeed, the magnitudes of all elasticities are influenced by changes in technology, consumer preferences, beliefs and habits. However, looking at the historical and the current pattern of U.S. energy demands is highly revealing.

Using published data from the 2009 *Annual Energy Review* (EIA 2010) and updated to 2010 using the EIA *Short-Term Energy Outlook* (EIA 2011b), Figures 4 and 5 show a series of both short-run and long-run price and income elasticities for total primary energy consumption in the United States. These elasticities of total energy consumption are based on year-by-year changes in the nation's Gross Domestic Product (GDP) and average energy prices. In this case the average energy price is found by dividing total annual energy expenditures within the United States divided by total primary energy consumption. Both GDP and energy prices are expressed in constant 2005 dollars. The data are for the period 1970 through 2010.

In Figure 4, we can see the changes over time with the set of short-run elasticities. Short-run generally means changes in energy use that are limited to the stock of existing equipment and technologies. In the case of automobiles, for example, a household may use the same car but share more rides, or reduce the amount travel during their vacations. Or they may walk more to take care of personal errands. For practical purposes we can also think of short run elasticities as temporary or interim changes that take place within the period of a year.

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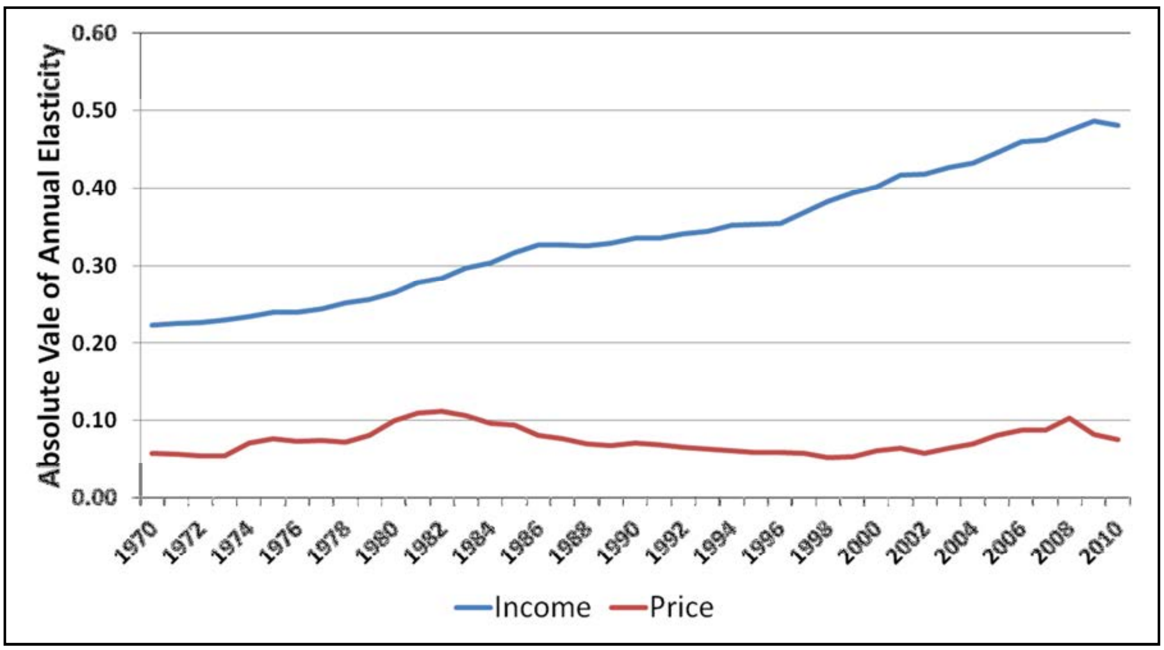
[3] For a more complete overview of energy demand elasticities and an extensive review of previous studies and estimates of elasticities, see Dahl (2006).

While we normally expect to see price elasticities expressed as a negative coefficient, here we highlight their absolute value to provide a consistent indexing and comparison. The patterns in Figure 4 reveal a set of short-run price elasticities which vary, but which show little volatility. They peak in the early 1980s and declining steadily through about 2002, and then showing a very moderate uptick in 2008 when oil prices increased dramatically. Overall, though, price elasticities are small and relatively flat. Economists would point to the red line in Figure 4 and say that, indeed, the demand for gasoline is relatively inelastic with respect to prices.

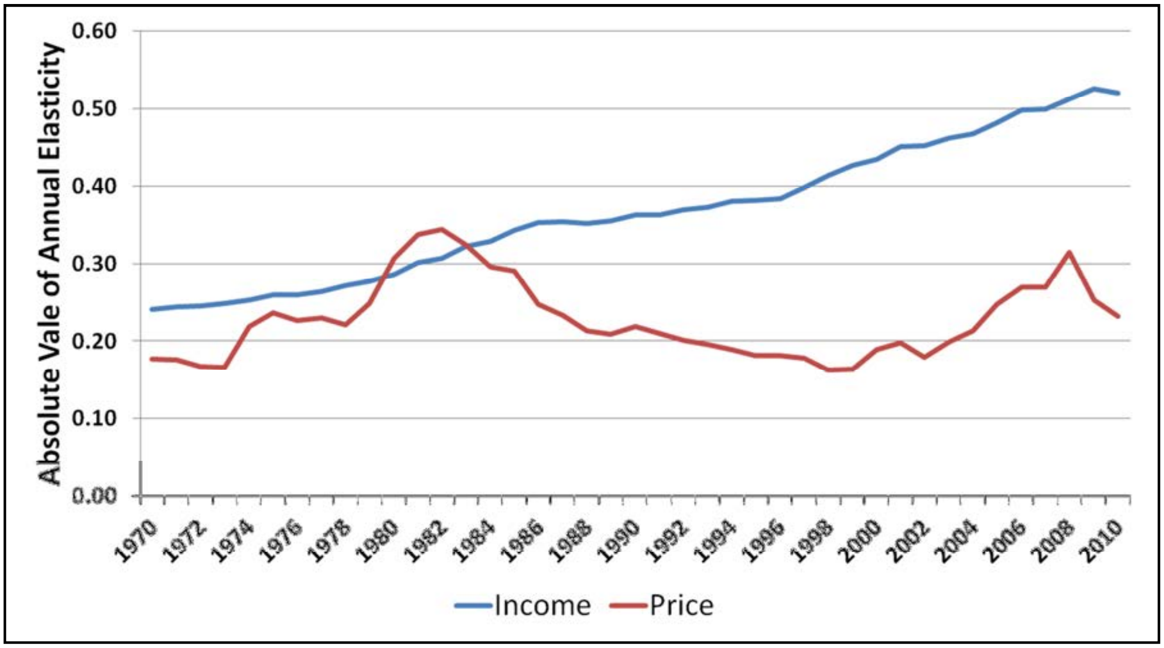
What is more striking, however, is the upper blue line which shows the energy demand elasticity with respect to changing incomes over time. The short-run income elasticities in Figure 4 are shown to rise steadily over time. The gap between income and price elasticities in 2010 is about 65 percent bigger as it was in 1970. In other words, since the year 1970, income has become a far more influential driver of increased energy consumption, while the impact of price has stayed relatively flat. Thus, policies based solely on price, without regard for the more pervasive influence of income, may produce a less than satisfying outcome than is normally believed or understood.

Figure 4. U.S. Short-Run Energy Elasticities with Respect to Income and Price



Source: Author calculations from EIA Annual Energy Review, 2010.

Figure 5. U.S. Long-Run Energy Elasticities with Respect to Income and Price



Source: Author calculations from EIA Annual Energy Review, 2010.

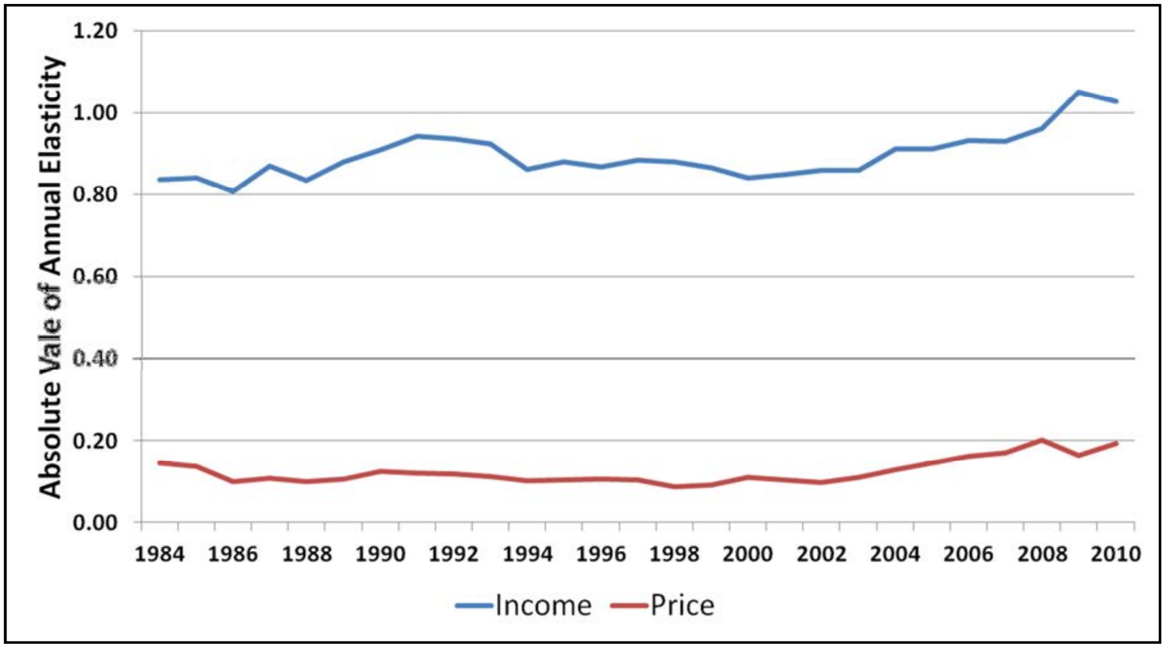
Obviously, short run elasticities are only part of the story. Over time, people react to the impact of high prices and invest in new ways that reduce their need for high-priced energy. They might, for example, move closer to work or transit, or buy a different car, or invest in technology that allows them to work with less fuel. Turning to Figure 5 above, we now examine the long-run elasticities—tracking the changes in energy use in roughly an 18-month period following the change in prices and income. Presumably, many consumers and businesses will have changed out their older or less efficient cars and trucks and begun to buy more modern vehicles and appliances. It's immediately obvious that in the long run, price elasticity has greater magnitude and volatility than in the short run. This makes sense when we realize that consumers and businesses have a bigger opportunity to respond as the result of newer equipment, and perhaps even a greater sensitivity to the economic circumstance of a given period. This is encouraging and economically rational.

However, a more curious insight appears when we compare the long run income elasticity over time. As the world adjusted to the economic realities following the two oil price shocks of the 1970's – the embargo imposed by the Organization of Petroleum Exporting Countries (OPEC) and the Iranian Revolution -- and moved to reduce the petroleum intensities of their economies, oil prices fell as did the long run energy price elasticities. During these decades the income elasticity, however, rose steadily and grew in importance. Though the gap between price and income elasticities narrowed and even flipped during the late 1970s and early 1980s to the point that the magnitude of price actually exceeded income, this was impossible by 2010. By 2010 income elasticity held sway, and the gap was about 65 percent greater than in 1970. The dramatic response to price that the world saw in the early 1980's has not been repeated. This may be, in part, because consumers have had little choice as some kind of lock-in or economic gridlock has constrained their ability to change cars or patterns of behavior.

At the same time, in the spirit of exploring future opportunities, it may be worth considering whether consumers in the late 1970s were "shocked" into changing by a political and market establishment that treated high gasoline prices as a crisis, while this time around consumers may have been lulled into the likely wrong belief that prices either "should" or would soon return to "normal" price levels which, in turn, made conservation behaviors or energy efficiency investments seem unnecessary or even economically foolish.

To get a better look at the interplay between income and price elasticity, it's helpful to isolate transportation spending elasticities that take into account all of the costs involved in owning and operating a car, in addition to the fuel. Figure 6 highlights these differences as we examine income and price elasticities based on consumer expenditure survey (CES) data for 1984 to 2010. Here, again, a story unfolds which shows income to be far more persuasive than price.

Figure 6. U.S. Average Transportation Spending Elasticities



Source: Author calculations from energy prices (EIA 2010) and the full transportation expenditures (BLS 2011).

While there is variation in these short-run elasticities, it seems transportation expenditures are more influenced (and consistently so) by income rather than price. Here transportation spending includes the average of all transportation expenditures in the CES data—including the purchase costs of cars and light trucks (both new and used), insurance and other operating costs as well as the purchase of motor oil and gasoline by households (all expressed in constant 2005 dollars). Income reflects average consumer expenditures by household and price is the price-per-gallon of gasoline with both values again expressed in constant 2005 dollars). Whereas the average short-run energy income elasticity shown in Figure 4 begins in 1984 with a value of 0.30 and rises to 0.48 by 2010, the transportation income elasticity starts at a much higher value of 0.84 and rises only slightly to 1.03. The differences are likely attributable to a greater system of transportation expenditures, though this warrants further investigation. Interestingly, after price elasticity peaked in mid-2008, income elasticity seemed to have a brief growth spurt. Still, the overall story of this graph aligns with a greater economic and cultural reality: Income lures or locks households into a set of transportation expenditures from which gasoline prices do not seem to dislodge us.

It's also worth noting that while graphs of elasticities tend to prejudice us towards thinking that increases in income are driving demand for energy, in fact the relationship may be more reciprocal or puzzling. As Kurani and Turrentine (2004) reported, some of their informants chose vehicles they believed would increase their income. "I earn more by presenting myself as successful than I could save driving an economy car," said one. In a less baroque example, a worker may driver further in search of a higher salary.

Comparing Differences in the Impact of Elasticities

Having demonstrated that historically, and currently, income plays a far greater role in determining energy demand, it's important to take this out of the abstract and look at it more practically. What do these differences in elasticity really mean? At this point we can illustrate the relative magnitudes between income and price elasticities to highlight the significance of rising incomes compared increasing (or decreasing) changes in energy prices – in this case comparing gasoline prices with gasoline consumption. Figure 7 provides the backdrop for this discussion.

Figure 7. Illustrating the Price Increase Necessary to Hold Gasoline Use Even As Income Rises

	Assumed Elasticity	Income Change	Price Change	Net Change in Energy Use
Income	+0.50	3.0%		1.5%
Price	-0.10		16.0%	-1.5%
Net Impact of both price and income =				0.0%

Source: Author's calculations with elasticity estimates drawn from Figure 4.

In this example above, a short-run income elasticity of 0.50 will increase energy use by 1.5 percent when incomes are increased by a typical 3 percent change within a given year. With this infrastructural bias, any upward change in income will also result in an increase in energy use. In order to hold energy use at the same previous level, energy prices (all else equal) must increase by 16 percent. So if gasoline today costs $3.65 per gallon, then prices must increase to $4.23 per gallon – or an average increase of 58 cents per gallon. It is difficult to imagine a situation in which Americans would accept a 58 cent per gallon additional tax on gasoline, yet the energy bias in our economy may demand that we pay it, simply so that our increased need for energy does not further stress the world's oil markets.

On the other hand, if a change occurred in the oil supply markets that required us to reduce consumption by 5 percent over the next year, then prices would have to nearly double to ensure that change over a short period of time (in less than a year). Prices, in other words, are an extraordinarily blunt instrument—a bludgeon really—for an economy that needs to fine tune its energy use to correspond with world events in a rather agile manner. It's also worth noting that when U.S. demand dropped dramatically as the 2008 recession began, so did oil prices—and so the inflexibility of price-driven demand may be a factor in higher oil prices themselves.

Figure 7 illustrates the first policy trap of relying too heavily on price signals: If the economy-wide goal of raising incomes is tied to increasing energy demand, and consumers have difficulty responding to high prices by reducing demand, then future growth may be undercut by a feedback loop of crippling energy expenditures.

Since neither doubling prices nor slashing incomes is an economically effective or efficient way to reduce energy demand, it would be smarter, and more politically reasonable to more actively sever the relationship between income growth and energy consumption. This requires long-term changes in mortgages, city planning, transit lines, etc. But short term changes could be enabled by pushing for strategic investment in shared infrastructure as well as personal infrastructure— that is to say, cars—

that consume less fuel. The key to creating price response is to offer people choices beyond simply gritting their teeth and paying more for gas.

Many of the efforts to change our nation's oil consumption patterns have focused heavily on "getting the prices right," *but that overlooks the importance of other signals that consumers are getting*. It is important to note here that consumer preferences can change over time so that what may require a doubling of energy prices today may require a substantially smaller price signal tomorrow. Perhaps, for example, clearer signals from political figures which acknowledge that high and volatile gas prices are a part of a likely future, could "magnify" the signal of moderate prices. As families and businesses respond to growing concerns about energy security or economic well-being, and as information about alternatives becomes more available, they may be more responsive to changes in energy prices—especially over a longer period of time, or as incentives and financial tools are made more widely available. But price signals on their own, without an ability to respond to those rising prices, punish the consumer rather than enabling him or her to change energy consumption or energy spending.

Comparing Elasticity Differences by Income

A second concern about the efficiency of price as a signal to change energy demand arises around the issue of how much leeway different economic classes have to react and change their vehicles, equipment, homes, jobs or schedules for short or medium term reductions in energy demand. Is it possible that a price signal that changes behavior in one income level—say those with high incomes would have either cash or access to credit to purchase a hybrid or electric vehicle—but less of one among those who buy used vehicles and may have less choice among their purchases?

To explore differences in how consumers respond to changes in incomes and prices as a function of their income group, we used CES data that is conveniently arrayed in quintiles according to their average level of income. The first quintile is those households with incomes in the upper 20 percent earnings distribution. In 2010 their pretax income averaged $157,369 while their consumer expenditures totaled $92,870. The "average consumer income" in that same year was $62,481 with expenditures of $48,109. The fourth quintile, which we refer to here as the working poor, had incomes of $26,777 with consumer expenditures totaling $30,285. Those households with incomes that were generally below poverty had average earnings of $9,906. But they actually spent $20,953 as a result of gifts, borrowing, and other sources of monies to maintain their households. For purposes of determining income and price elasticities by income, we use total consumer expenditures as the income surrogate in the discussion that follows. Figure 8 below compares both income and price elasticities for these consumer groups for the years 1984, 1990, 2000, 2008, and 2010.

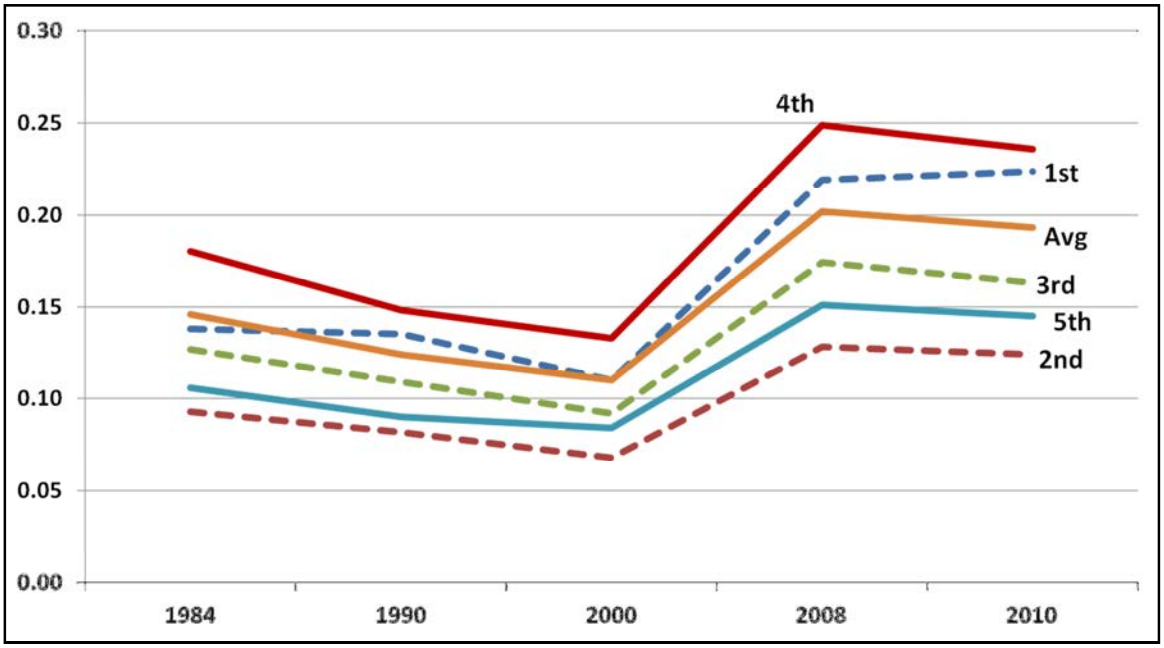
Figure 8. Short-Run Elasticities for Transportation Expenditures by Quintile

	1st Quintile: The Well-off		2nd Quintile: Upper Middle Class		3rd Quintile: Lower Middle Class		4th Quintile: Working Poor		5th Quintile: Below Poverty		The Average Consumer	
Year	Price	Income	Price	Income	Price	Income	Price	Income	Price	Income	Price	Income
1984	-0.138	1.362	-0.093	1.060	-0.127	1.076	-0.180	1.050	-0.106	0.691	-0.146	0.838
1990	-0.135	1.560	-0.082	1.153	-0.109	1.152	-0.148	1.112	-0.090	0.767	-0.124	0.910
2000	-0.110	1.377	-0.068	1.095	-0.092	1.063	-0.133	1.064	-0.084	0.751	-0.110	0.842
2008	-0.219	1.603	-0.128	1.167	-0.174	1.171	-0.249	1.174	-0.151	0.827	-0.202	0.963
2010	-0.224	1.801	-0.124	1.259	-0.163	1.238	-0.236	1.227	-0.145	0.888	-0.193	1.028

Source: Author's calculations with data from the Bureau of Labor Statistics Consumer Expenditure Survey.

When we look closely at the quintile data in Figure 8, there are two things that jump out almost immediately. The first is, again, there are very big differences between price and income elasticities—almost regardless of which level of household incomes we might examine. The second is that there are some very curious patterns which might be better seen in Figure 9 that follows. There we follow only the price elasticities of these same quintiles over time.

Figure 9. Transportation Price Elasticities (in absolute values) by Quintiles Over Time



Source: Author's calculations with data from the Bureau of Labor Statistics Consumer Expenditure Survey.

The most curious aspect of this data set is that it does not seem to follow any expected pattern. If we isolate income elasticities we do see an orderly change in response as incomes move from the top quintile to the 4th and 5th quintile of the "working poor" and the "below poverty" households. Yet the chart in Figure 9 shows a highly irregular pattern. Ignoring the average set of elasticities show above, from top to bottom the lines go 4th, 1st, 3rd, 5th, and finally 2nd. An immediate question is why the fourth quintile has a slightly bigger response among all the quintiles? And why is the first quintile unexpectedly and so closely following the fourth? We can imagine different interpretations. But one might think the working poor have little choice but to forego some driving, and quite possibly because of the loss of a job, or the reduction in working hours. The first quintile, with an even greater income elasticity, and a greater array of choices, may have comparably higher price elasticity because they have more immediate choices. And those below poverty have the lowest price elasticity precisely because they are already at the bottom and cannot as easily trim back their already very low consumption. Two potential policy insights are reinforced in this last regard.

First, while there are different patterns of price elasticities among the quintiles, all of the quintiles show very large income elasticities compared to their respective price elasticities. This point was first noted in comparing Figures 4 and 6. And the data clearly reinforce the earlier hypothesis that if we want to achieve significant and beneficial changes in patterns of energy consumption, smart energy policies will tend to focus more on the income rather than the price side of the equation. This seems to be especially true for transportation expenditures in which it appears there is more "lock-in" because of the system of expenditures necessary to support household travel. Second, not all households are equal in their circumstance or ability to respond. Hence, an investment led solution to break free of the energy trap may be appropriately different for the middle and lower middle class households compared to those in the upper quintile. More research clearly needs to be done to tease out income enabling rather than price punishing solutions.

Lagging Efficiency, Diminishing Incomes, and Rising Prices

There is an emerging crop of reports and studies suggesting both the need and the opportunity to dramatically increase our nation's ability to turn energy consumption into GDP, as a means to a more stable economic growth path. A representative sample of these studies might include the Interlaboratory Working Group (2000), the American Physical Society (2009), the Committee on America's Energy Future (2009), McKinsey & Company (2009), and Laitner et al (2006 and 2010). While several included both transportation and non-transportation assessments, Cambridge Systematics (2009), looked exclusively at transportation system efficiency improvements and found an array of some 50 options that might help achieve significant efficiency gains and cost reductions. These included pricing options like taxes, tolls, congestion pricing, and fees to induce changes in travel behavior. The majority of the policy suggestions, however, focused on non-price innovations: improved vehicle fuel economy, improving overall land-use and system efficiencies that reduce unnecessary idling and start and stop driving, and reducing the need for vehicle travel.

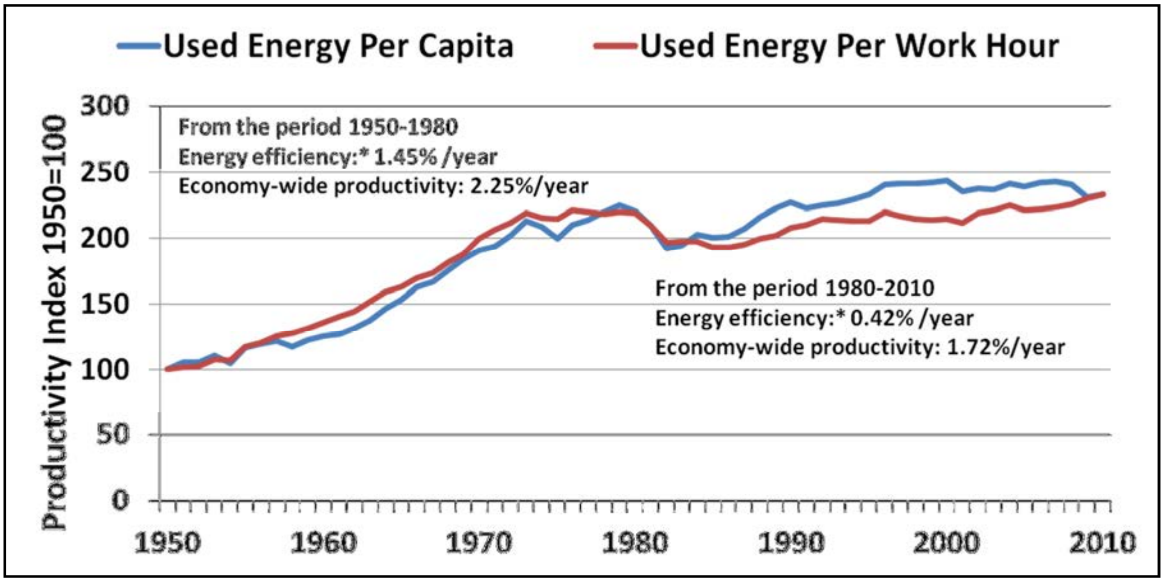
But in addition to reducing waste, making the system more efficient can play a role in boosting larger economic productivity. Building on the work of Ayres and Warr (2009), a working paper by Laitner (2011) documents a lagging improvement in U.S. overall economic activity that, in turn, may be a reason for the slumping income documented in Figure 1.

Charting annual data for the U.S. economy over the period 1900 through 2010, the findings suggest that the United States may convert only 14 percent of the total energy used to drive the economy. In other words, we now waste about 86 percent of the energy necessary to transform matter into goods and services, and that huge level of waste imposes an array of very large costs what actually constrain the development of a more robust level of economic activity. Figure 10 underscores critical aspects of this picture by examining two major periods of time, the years 1950 to 1980 and the years 1980 to 2010.

Examining "Used Energy"

In Figure 10 we index the amount of "used energy" over the period 1950 through 2010 that was necessary to maintain economic activity on both a per capita and working hour basis. By 1950 the nation had increased its energy conversion efficiency from about 2.5 percent in 1900 to about 8 percent. If we assume that the amount used energy per capita or per work hour held a value of 100, then 1980 we better than doubled that ratio, arriving at an index value of about 225. Since 1980, however, we've barely moved the needle, pushing the index up to a value of about 235 by 2010. As the two major data texts on Figure 10 indicate, the lagging uptake of used energy per capita or per work hour may be among the critical reasons why our nation's income has been lagging.

Figure 10. Critical Role of "Used Energy" to Drive U.S. Economy-wide Productivity



Source: Author calculation from Ayres and Warr (2009) and EIA (2010). See also Laitner (2011).

The good news in Figure 10 is that we increased the conversion efficiency in turning energy into useful work from about 8 percent to 12 percent over the period 1950 to 2010. We improved our conversion efficiency at about 1.45 percent per year. And that allowed us to increase overall economic productivity by about 2.25 percent per year—in effect, allowing us to increase per capita income by roughly that same amount.[4] Since 1980, the flattened curve of "used energy" has weakened our larger economic productivity. The annual rate of energy efficiency improvement fell to just 0.42 percent per year. Our economy wide productivity declined to 1.72 percent annually. As we previously highlighted, lagging improvements in converting total energy into useful work appear to have constrained economic activity. This, in turn, weakens opportunities for increased household income – holding constant the concerns about growing income inequality.

Increasing Energy Consumption and World Oil Prices

Looking ahead, the United States is faced with a challenge. Taking into account income and price indexes, together with the indicated elasticities and the anticipated demands for goods and services, U.S. energy consumption is expected to increase from 98 quads in 2010 to 111 quads in 2030. Thus, the combined effects of income and price elasticities suggest that energy use will increase 14 percent over baseline levels in 2010.[5] In fact, this is about same scale otherwise projected in the EIA's *Annual Energy Outlook* for 2011 (EIA 2011a). This result suggests that, given the technology characterization and market dynamics embedded within the AEO2011 projections, the elasticities used in this example are reasonable estimates of the relationship between price and income as they impact total energy consumption within the United States. But if this future unfolds, what might we expect about future energy and especially world oil prices?

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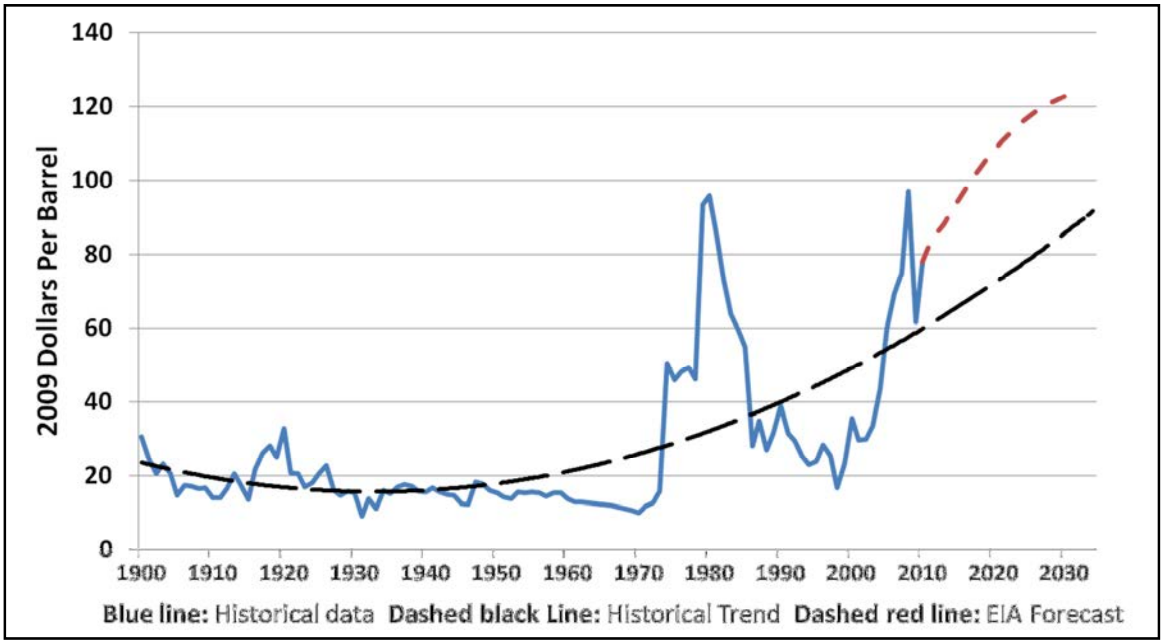
[4] Perhaps obvious to some, but increasing national income does not automatically translate in to household or family income.

[5] See the discussion in the appendix on the use of *combined elasticities* to illustrate how one might imagine the growth in energy consumption to occur given assumptions about changes in income and energy prices. At the same time, however, there are many other influences and drivers, as well as interacting effects, that will change the demand for energy services. Here the intent is only to suggest a likely outcome given current economic trends. The good news is that it roughly corresponds to the standard projections as suggested in the main text of the report.

Figure 11. World Oil Prices



Source: BP Statistical Review of the World 2010 with EIA Annual Energy Outlook 2011.

As shown in Figure 11 above, we can examine the likely costs of producing more oil by tapping into the *BP Statistical Review of World Energy*, supplemented by standard forecasts of world oil prices that are published by the U.S. Energy Information Administration (2011a). Some useful insights emerge here as might be told through the story of 3 lines. The first solid blue line provides a century long context for world oil prices as they are presented in 2009 dollars per barrel. The second dashed black line provides an expected trend of what those historical prices might look like as they are extended into the future. And in this case, the answer is that the oil prices are clearly moving upward.

The third red dashed line shows what the EIA now believes will happen to world oil prices through the year 2030. And the answer is up! So the bottom line? World oil prices since 1970 have been showing a decidedly upward trend. This trend is unlikely to abate as the world-wide demand for petroleum will only increase—absent a greater emphasis on the more efficient use of all energy resources, and in the absence of alternative energy resources that might displace some of the demand for oil.

Following this discussion, the first big policy question becomes: Might we grow household incomes faster if we severed the strong relationship between energy consumption and the inefficient use of energy that limits productivity and enables a highly volatile set of energy prices? The findings of the Interlaboratory Working Group (2000), the American Physical Society (2009), the Committee on America's Energy Future (2009), and McKinsey & Company (2009, among many other assessments, all clearly suggest a resounding "yes!" It can be done. The second question then follows: Will we choose to get it done?

The Conclusion

So working our way backward, energy costs are likely to rise faster than incomes—unless we make the kinds of investments that will be required to ensure a more robust and energy-efficient future. Second, unless we transform our use of energy to be more productive, we will see not only greater costs associated with energy production and consumption, but it is very likely we will continue to see a significant flattening of family incomes. Third, energy prices over the next several decades, led by an increase in world oil prices, are going to rise almost regardless of how the future unfolds. Given that context, and recalling the earlier discussion on the contrast between income and price elasticities, the more productive use of resources will depend on an investment-led and more energy-efficient economy. Energy prices can provide a useful market signal, but the means to actually achieve the transition to a more robust economy will depend on investment strategies that help families and businesses improve their overall incomes. Prices matter, but they are not all that matter.

How might we think beyond price in helping shape a more productive outcome? Broadly speaking, we want to encourage smart investments in technologies and infrastructure to drive down the cost of energy services—not just compared to tomorrow's expected energy prices, but compared to the costs we are now seeing today. And in the next decade and beyond, we need to provide households and businesses with the means to move toward more energy-efficient cars, technologies and behaviors.

Philosophically, the change from a price-driven policy towards one that focuses on income and investment will require moving into unfamiliar areas. Obviously there's a need for public infrastructure investment, but we'll also need to invest in personal infrastructure, cars perhaps, or broadband to enable telecommuting. And while previous energy policies have focused on national energy supply, future policies may need to focus on providing the tools for consumers to respond in geographic areas that are particularly hit by high fuel costs. Thirdly, an income-based approach will require investing in consumer education and finding incentives for behavior changes to turn the national conversation away from energy price and towards its costs. The good news is that an income-focused investment approach may yield far faster and greater magnitude of changes in demand than the *de facto* price approach on which we've been relying almost exclusively.

Obviously, going forward price will continue being a significant part of an energy policy package. There are strong reasons to make gasoline prices more clearly reflect their true costs with a carbon price. Undoubtedly, part of the reason consumers and political leaders oppose adding these charges is that they fear that consumers will not be able to respond and, therefore, will be punished by high prices. Strategically, increasing consumer's range of choices may make more accurate pricing more feasible and more practical.

With transportation clearly at the forefront of this paper—and rather than thinking of only one or two possible solutions, it means that we think about the full array of 50 different cost-effective transportation options suggested by Cambridge Systematics (2009). Equally critical it means we shape those policy options to reflect the unique circumstances and opportunities within each of the income quintiles, within each of the different regions of the country, and within each of the different sectors of the economy. Yes, those options might include things like taxes, tolls, congestion pricing, and fees to induce changes in travel behavior. But those signals alone are far from enough to imagine a new path that reduces the burden of transportation expenditures as it also increases incomes for the middle class through greater economic productivity.

Clearly, we are in different times. George Mason University economist Tyler Cowen suggests in his book from last year that we are in the midst of what he calls, *The Great Stagnation* (2010). This is the result, he suggests, from "living off low-hanging fruit for at least three hundred years. We have built social and economic institutions on the expectation of a lot of low-hanging fruit, but that fruit is mostly gone." Oil was that low-hanging fruit during most of the 1990's and early years of this century. But as its economic, political, and environmental costs have risen, it is clear that we need more than a price signal (even if it is a very loud signal) if we want to effectively and more equitably move consumers out of their ruts—both in terms of their thinking, and more literally, their driving habits.

As we noted earlier, this working paper is a first step in unraveling how current policies and consumers "lock-in" these costly and inefficient spending patterns. Indeed, there are many further questions raised by this project. To that extent we invite additional work that might focus on the five topics below:

1. Elasticities are a very compressed way of expressing the complex set of decisions by which consumers drive demand. Clearly, we need to decompose these elasticities to understand more exactly and precisely how consumers actually do respond to signals around price and other influences that determine how and why they purchase gasoline.

2. We need a better understanding of the relationship between income and energy use. As we emerge from a recession with high unemployment and falling wages, how do workers make decisions about their household and personal energy spending?

3. We need to understand the "lock in" or energy trap as it affects households and the economy as a whole. Is it driven by infrastructure, by access to credit, or by responsibilities to family members or other factors?

4. We need a better understanding of how long-run price sensitivity works. Are there ways to magnify its impact by offering information, other motivations, greater transit choices, or access to credit?

5. There has been a general policy and investment focus on interruptive technology such as biofuels and electric cars as a way to reduce oil dependence. However, most of the incentives for electric and hybrid cars have been tax breaks aimed at high income households. Policy makers should explore making technology available to lower income classes as a way of reducing gasoline expenditures and increasing their financial stability.

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Appendix Material

Own Price Elasticity of Demand

Price elasticity measures the change in demand for a given quantity (such as gallons of gasoline or kilowatt-hours of electricity) that might result from a change in its own price. To avoid the measure of elasticity being sensitive to the units measured, the elasticity of demand is expressed as the percentage change in demand that occurs in response to a percentage change in its own price.

$$\varepsilon_{price} = \frac{\Delta\, gasoline\ quantity}{\Delta\, gasoline\ price} * \frac{gasoline\ price}{gasoline\ quantity}$$

Because the change in the quantity demanded usually is negative, price elasticity is shown as a negative. By way of example, assume that current gasoline consumption (*gasoline quantity*) is now 500 gallons per year and that gasoline price (*gasoline price)* is now $3.65 per gallon. If the price of gasoline increases by 50 cents (*Δ gasoline price*) and the demand for gasoline falls by 10 gallons (*Δ gasoline quantity*), we can estimate the price elasticity of demand for gasoline as:

$$\varepsilon_{price} = \frac{-10\, gallons}{\$0.50 / gallon} * \frac{\$3.65 / gallon}{500\, gallons} = -0.15$$

In this case, a price elasticity of -0.15 means that a one percent increase in price will tend to lower the demand by 0.15 percent. In the alternative, one percent decrease in price will tend to raise demand by 0.15 percent. If we know that: (i) gasoline has a price elasticity of -0.15, (ii) current consumption is 500 gallons, and (iii) prices will rise from, say, $3.65 to $4.15 per gallon, then we can estimate the effect on consumption as:

$$Demand\ Change = \left(\frac{\$4.15}{\$3.65} - 1.00\right) * -0.15 * 500 = -10\, gallons$$

One further note is at this point is to distinguish between short-run and long-run elasticities. As the prices increase, the short run response is dominated by changes in the way households and businesses use their existing cars or appliances. On the other hand, if a consumer is able to buy a different car or find new ways to get to work through carpooling or mass transit, the changing out of old equipment, appliances, and vehicles allows a potentially greater response which can be tracked using long run elasticities.

Income Price Elasticities

Income elasticity measures the responsiveness of the quantity demanded of one good to a change in household income or Gross Domestic Product (GDP). An increase in per capita income, for example, will tend to increase the consumption of gasoline. The relationship between income and the demand for gasoline might be expressed as:

$$\eta = \frac{\Delta\, quantity\ gasoline}{\Delta\, income} * \frac{income}{quantity\ gasoline}$$

Cross Elasticities

Not as often discussed, the cross elasticity of demand measures the responsiveness to a price of one good (say, the price of gasoline) to the resulting quantity demand of another or different good (for example, the use of mass transit). Assuming households can easily access bus or rail transit, an increase in gasoline prices, will tend to increase the use of mass transit by a smaller or greater amount. This change might be represented in the following way:

$$\varepsilon_{cross} = \frac{\Delta\, quantity\ mass\ transit}{\Delta\, gasoline\ price} * \frac{gasoline\ price}{mass\ transit}$$

Combined Elasticities

Typically, we are interested in the influence of both price and income elasticities as they might affect the consumption of a major commodity like gasoline, or perhaps more broadly, total primary energy consumption. Generally, the value of income elasticities tends to be greater than the absolute value of energy price elasticities. To illustrate how we might evaluate the effect of combined elasticities, we might use the following equation:

$$Demand_{2030} = Demand_{2010} * IncomeIndex^{IncomeElasticity} * PriceIndex^{PriceElasticity}$$

To actually calculate potential changes in overall energy consumption within the United States let us adopt the 2010 demand of 98 quads[6] of total primary energy as estimated by Annual Energy Outlook 2011 (EIA 2011a). Following the AEO 2011, let us also assume that income (in this case, measured in constant dollars of GDP) will rise by 72 percent and that real energy prices will rise by only 18 percent, respectively, by the year 2030. Finally, using historical data from the Energy Information Administration's Annual Energy Review 2010 (EIA 2010), over the period 1949 through 2010, let us also assume that income and price elasticities are 0.28 and -0.15, respectively. Hence,

$$Demand_{2030} = 98\, quads_{2010} * 1.72^{0.28} * 1.18^{-0.15} = 111\, quads_{2030}$$

Based upon these anticipated change in the income and price indexes, together with the indicated elasticities, energy consumption is expected to increase from 98 quads in 2010 to 111 quads in 2030. Thus, the combined effects of income and price elasticities suggest that energy use will increase 14 percent over baseline levels in 2010. In fact, this is about same scale otherwise projected in the AEO 2011. This result suggests that, given the technology characterization and market dynamics embedded within the AEO2011 projections, the elasticities used in this example are reasonable estimates of the relationship between price and income as they impact total energy consumption within the United States.

Other Elasticities of Interest

Although energy demand price and income elasticities are the primary elasticities of interest (perhaps together with cross elasticities), there are two others which, if properly evaluated in context, may also inform policy makers about appropriate policy implications.

The first are elasticities of substitution. On an energy basis, these typically estimate the responsiveness of households and business sectors as they might substitute more productive capital (in the form of newer, more energy-efficient technologies) for

[6] A quad, or one quadrillion Btus of energy is roughly the heat energy contained in 8 billion gallons of gasoline. Assuming an average fuel economy and average distance traveled per year, one quad is sufficient energy to power 15.3 million cars on U.S. roads and highways for one year.

their current or anticipated energy use. As an example, if prices rise by, say, 50 percent, over some period of time, and if there are known improvements that are also cost-effective and available to them, consumers might invest in more money in energy-efficient technologies to reduce energy use by 10 percent (assuming a long run price elasticity of -0.25). This might pay for itself with these new prices in about three and one-half years. But to actually achieve that level savings, they might have to increase cost-effective investments by 15 percent over the cost of less efficient technologies and equipment (assuming, in this case, a positive elasticity for capital of 0.35). The absolute value of both elasticities is roughly the equivalent of a substitution elasticity of 0.60. Indeed, it is the ability to substitute productive or more energy-efficient capital for costly energy use that will enable consumers to respond more effectively and in bigger ways to the cost of energy.

The second set of elasticities that are of interest are those for energy supplies. These provide the level of responsiveness for the exploration and production of new energy resources given changes in incomes and especially energy prices over time. While we don't provide any further assessment of substitution and energy supply elasticities we want at least make people aware of them, and especially when evaluating long term energy policies, they should become part of the tool kit used in those assessments.

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