# *SURVEYING ENERGY DEMAND ELASTICITIES: WHAT DO THEY TELL US ABOUT THE PAST AND WHEN CAN THEY PORTEND THE FUTURE?*

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## Overview

Since the Arab oil embargo and even before, the study of demand elasticities for aggregate energy as well as energy products has held a certain fascination. Such elasticities are helpful in determining how energy consumers respond to the energy product price, economic activity, income, other prices, and a variety of other factors, providing valuable information to energy forecasters, planners, advisers, consumers, producers, service companies, and policy makers. What these elasticities are and how they change over time will help us to better understand, predict, and manage structural change and adapt to the latest energy transition.

What is particularly challenging about the current transition is the rapid speed of the transition. We aspire to get to netzero carbon emissions into the atmosphere by mid century, likely requiring huge changes in many decades old habits and infrastructure in just a few decades. All the while, we strive for more energy justice by increasing energy services to the now disadvantaged (more than 2 billion people still do not have access to clean cooking fuels, and more than half a billion people still do not have access to electriciity (https://unstats.un.org/sdgs/report/2023/). All the while, the digital revolution and AI are providing amazing technical changes but much uncertainty. Will data centers and AI services along with electric vehicles put even more stress on the grid and non-dipatchable fuels or will they give the needed boost to technology and make this needed transiton possible? Further what policies will be needed to nudge markets into making these goals a reality. Understanding energy demand elasticities are now even more crucial tools for analysts and lawmakers when crafting policies aimed at achieving net-zero in the most efficient and equitable means possible.

To attain this desired future, it is first good to consider the multitude of already completed demand studies to understand the past. Our contribution will be to help provide this understanding by collecting energy demand elasticities and cataloging them in the most extensive ongoing open access energy demand elasticity database. We will consider what we have learned from the many completed studies, indicate perils and pitfalls in current methodologies, and suggest productive areas for further research. Even more difficult will be the challenge of discerning what—if any—conclusions from the past studies will provide insights for the changes yet to come.

## Methods

The ongoing database dubbed (Dahl Energy Demand Database (DEDD) and accompanying survey work that we are updating began with a report to the U. S. Department of Energy in support of their National Energy Modeling System (NEMS) Dahl(1993). That report was the most extensive survey at the time and built on 12 previous energy demand elasticity surveys supplemented with close to 200 additional individual studies. Price and income elasticities were surveyed by product demand including total energy, electricity, electricity by time of day, natural gas, coal, oil, oil products, distance travelled, distance per unit of fuel, and transport. The estimates were done at various levels of aggregation, using models and data that varied by methodology, place, time, and sector. In most categories, there was significant variation in elasticities but often patterns emerged with suggested summary elasticities. Most often these price elasticities were less elastic than -0.5 in the short run and less elastic than -1 in the long run. Similarly, short and long run income or activity elasticities were typically in the inelastic range. More uncertainty surrounded long run than short run elasticities and patterns of adjustment were not readily apparent.

Again in a report for EIA modeling efforts, Dahl (2010) provided an extensive update to the database and previous survey work. By then the survey included around 18,000 econometric equations in about 1,000 studies. The energy products were the same as in the earlier survey but with the addition of demand for biomass. Included was any available study with demand elasticity estimates for energy products for any aggregate, for any sector, for any region or sub-region in the world. Although EIA was mostly concerned with price and activity elasticities for the sixteen world regions in their international modelling, all additional demand elasticities reported were included in the database (e.g. cross price, temperature, demographic variables, etc.) Both good and bad studies were included to know what to trust and emulate (the good ones) and, like the Titantic, what to distrust and avoid (the bad ones).

From the summary discussion of the database completed to 2010, Dahl found the 1980s to be the decade that saw the most energy demand studies (around 40% of the total), when energy security, cost, and the environment were ongoing concerns. Electricity, oil, and aggregate oil products had been the most studied, in this period. Although heterogeneity was found across studies for all the elasticities, careful scrutiny suggested a number of patterns. Some examples follow. Clustering still suggested that energy demands tended to be price and income inelastic. Estimates on monthly and quarterly data did seem to find smaller long run income and price elasticities than those on annual data as were estimates on household data. Aggregate income elasticities seem to fall as countries get richer, but the patterns diverge across sectors. Commercial energy GDP elasticities increase as countries get richer and the commercial sector grows; industrial income elasticities are low for very poor countries, increase as the countries take off and build up infrastructure, and then fall back again as countries' economies move towards the commercial sector. Transportation fuel demand tends to grow at a more predictable rate than either gasoline or diesel fuel, especially where strong policies have been aimed at the fuel mix. Moving forward, we have found numerous studies pooling times series across countries for gasoline and for diesel with no or rather blunt instruments to account for policy. Given the importance of the transportation sector for climate policy, it will be important to investigate further the role of policy is playing in transportation as well as other sectors.

Dahl found model and estimation technique matter. The studies with the largest outlying elasticities seemed to be on models with lagged endogenous variables or translog models where an energy product share is small. By the 1990s, the older classical estimation techniques were starting to be replaced by newer time series techniques that investigated whether equation variables were cointegrated or not (e.g. error correction models). Cursory comparison suggested that although earlier studies did not check for co-integration, this condition likely held.

## Results

The first order of the day, will be to update the database with more recent work. Critical interest in energy security, cost, and environmental effects has intensified since 2010. These issues are now more often referred to as the Energy Trilemma https://www.worldenergy.org/transition-toolkit/world-energy-trilemma-framework but with cost incorporated into energy justice, and environment broadened into energy sustainability. With the increase in interest in the Trilemma, the decade of the 2010s has proven to be even more fruitful study-wise than the 1980s. We have located and added 101 more studies into the database from this time period with another 422 yet to process. Twelve studies conducted since 2020 have been added to DEDD with another 225 yet to process. By the conference we expect to have completed the literature review, processed all the new finds into DEDD, and made online open access beta databases for vetting and to support others work on energy demand modeling.

Results of the study will include these online open access databases by energy product with our updated available demand elasticities by study. Parts of DEDD completed as of 2010 were the first to be made open acces with demand elasticities for gasoline, diesel fuel, electricity, distance travelled (M=miles or meters), and vehicle efficiency as measured by distance travelled divided by fuel use (q) designated as Mpq. These files can be accessed at https://dahl.mines.edu/courses/dahl/dedd/index.htm. The newer databases will include these categories plus coal, oil and oil products, natural gas, biomass, and biofuels.

As we move forward to complete the survey portion of this study, we will continue to watch for new studies, consider results from other survey work, look for best-in-class studies to emulate, provide warnings of the perils and pitfalls from worst-of-class studies, conclude whether summary elasticities or ranges present themselves to us, watch for structural changes, and look for questions and controversies that suggest future research agendas. The trend towards more sophisticated statistical techniques with canned programs has continued, sometimes to the detriment of underlying economics principles. Mindless time series is much in vogue and we will provide examples for young researchers of how to avoid this particular trap. Ultimately, we will ponder what these past elasticities and results may tell us about the future. For example, demand for vehicle miles travelled as functions of cost may still hold, whereas electricity and fossil fuel use for vehicle travel may not.

## Conclusions

Our hope is that by collecting, processing and evaluating the accumulated knowledge from the past, with our related future speculations, we can gain the economic intuition needed to meet our ambitious energy related goals.

## References

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