Research on U.S. Crude Oil Market

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1 U.S. crude oil production and trade

After an attack on Saudi Arabia's key production facilities, which cut half of the kingdom's crude production, President Donald Trump has claimed to authorize the release of oil from the U.S. strategic petroleum reserve "to keep the markets well-supplied". Under the situation when U.S. briefly became the world's No.1 oil extractor and exporter after the shale oil revolution, there seems to be some irrationalities in America's urgent response to this oil shortage crisis. Why does America still need oil imports from the Middle East area to support supplies market when they've already held a rich domestic production?

First, let's take a deep look at the U.S. crude oil market. According to the U.S. Energy Information Administration (EIA), U.S. field production of crude oil[3] has increase from 5000 thousand Barrels per day in 2008 to 10990 thousand Barrels per day in 2018, attributed to the exploration of Shale Oil. After President Obama signed legislation to end a crude oil export ban in 2015, U.S. exports of oil[4] further grew 331.0% from 2015 to 2018.

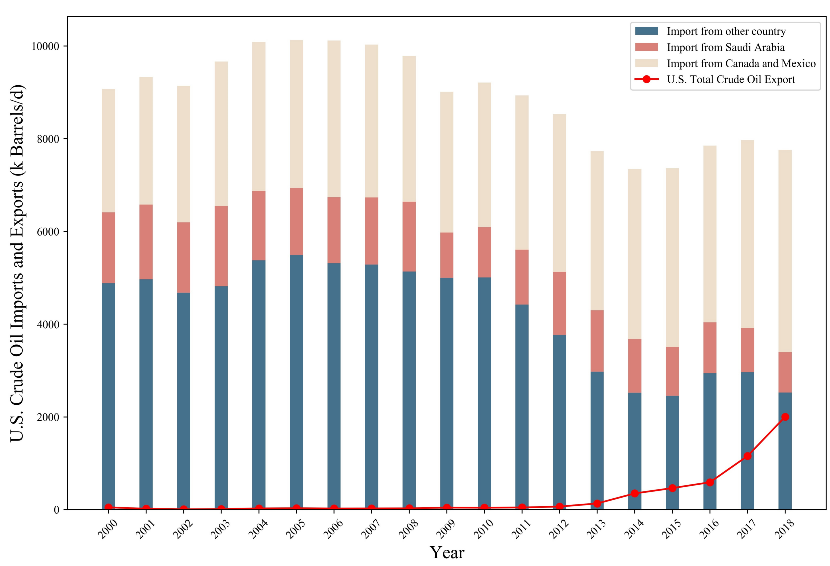

Figure 1: U.S. Crude Oil imports and exports from 2000 to 2018

[†]E-mail: ruoshui.li@duke.edu. This is an informal essay I wrote after the attack on Saudi oil facilities. Like I mentioned in the essay, I was interested in the reason why America still need oil imports from the Middle East area to support supplies market when they've already held a rich domestic production. So I did some analysis and wrote this casual literary notes.

Meanwhile, the total amount of crude oil imports[5] in America had an overall downward trend since 2008, only experienced a small increase in 2016. These trends indicate that the United States is pumping so much oil that it's gradually free of foreign oil dependence and is becoming a significant exporter of crude oil. However, if we further distinguish the source of crude oil imports, we can find that its share from Saudi Arabia has approximately kept same, and the amount of imports from Canada and Mexico is rising year by year, as U.S. total imports decreasing. There indeed have some economic factors in the market that influence import decisions, but admittedly, U.S. is, and remains, a significant importer of crude oil.

Another dataset also reveals part of the story. The United States uses most of its crude oil in the transportation industry (about 70% in 2018[8]). However, during the period from 2008 to 2018, U.S. total refiner motor gasoline sales don't show an upward trend. Rather, the volume has decreased 56.0%[6], which implies that crude oil consumption in America didn't follow its surge in production. Then where has the tremendous production increase gone?

Answers lie in the reality that not all crude oil is the same. As said before, the surge of U.S. field crude oil production has come largely from increased exploration of shale oil. This is a type of light crude oil, with an API gravity normally higher than 31.1. Over the previous 10 years, major shale oil plays in Bakken (North Dakota), Permian Basin (Texas and New Mexico), and Wagle Ford (Texas) have extracted tremendous amount of crude oil, and the bulk oil production has an API gravity between 30.1 to 50[2].

However, this light shale oil does not meet needs of the market. Many Gulf Coast and Midwest refineries in America were designed to process heavy oil, which have an API gravity less than 22.3, imported from Canada, Mexico and some OPEC countries. Large light crude production already exceeds refiners' ability to process it at certain times of the year. Thus, to fully meet the demand of domestic production, importing heavy oil from foreign countries is inevitable.

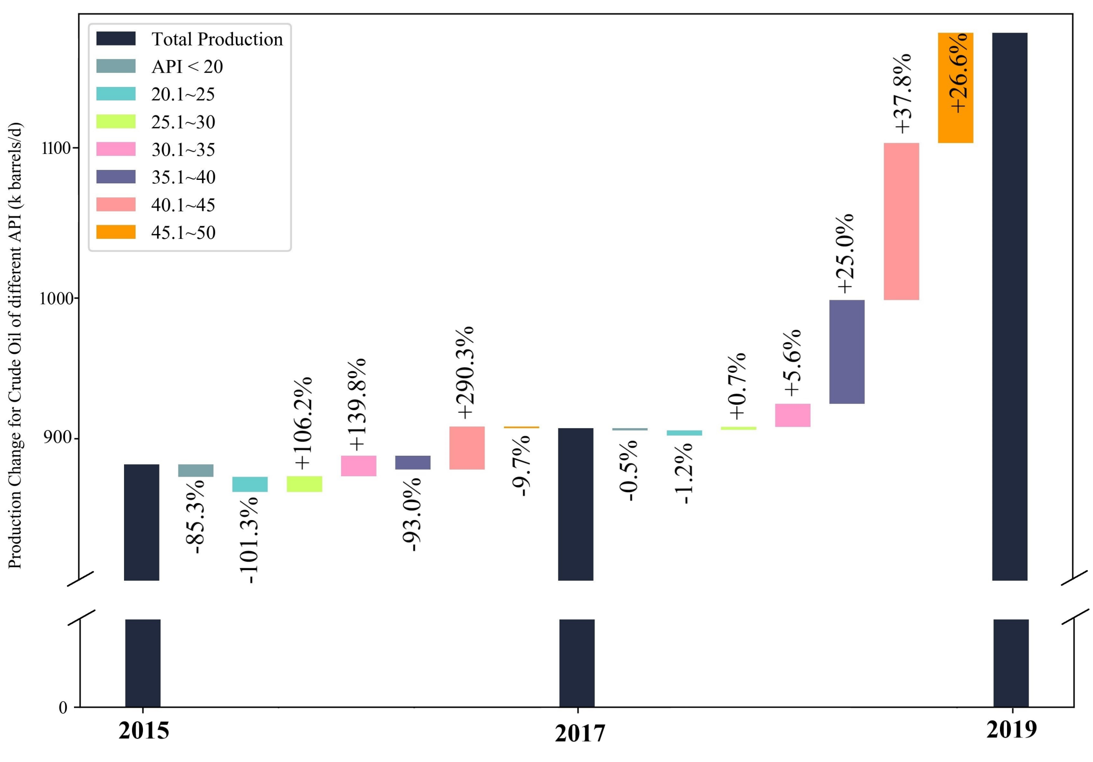

Figure 2: Components of U.S. Crude Oil production from 2015 to 2019

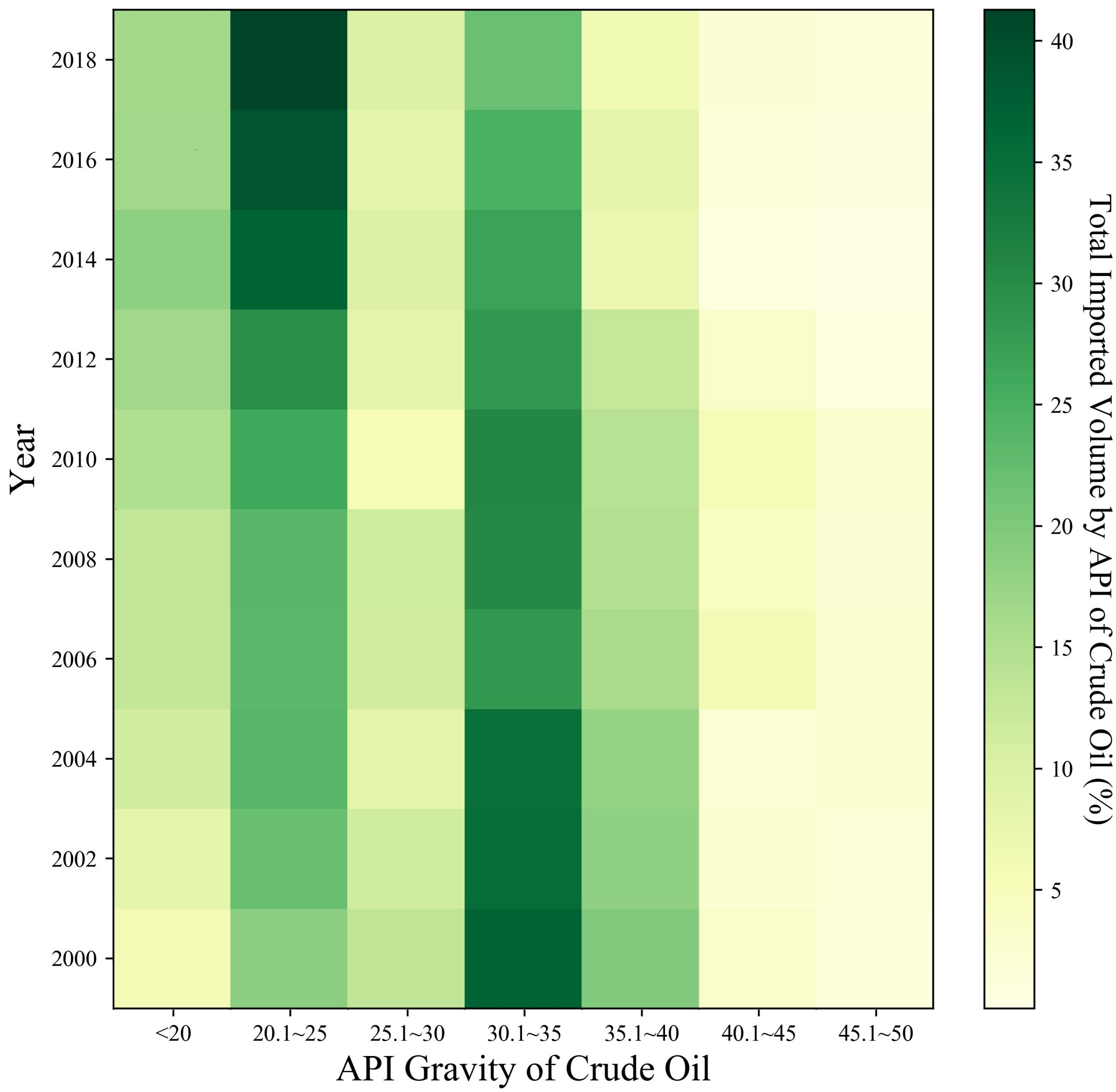

Figure 3: Components of U.S. Crude Oil production from 2015 to 2019

Accordingly, we can tell that the shortage in Saudi Arabia's crude oil market does influence supply in U.S. market. This further brings us to an assumption: if we were possible to reduce the use of gasoline by 30%, we may no longer have to depend on crude oil imports from the Middle East. It might be hard and infeasible to remove this part of crude oil imports instantaneously, but the development of electric cars can be a good entry point. Tesla is now a representative car and energy company in U.S. vehicle market, specializes in electric car and solar panel manufacturing. In 2019, Tesla vehicle sales in the U.S. increased from 8325 in January to 23025 in September, occupying an increasing part of market share. With the star products, Model 3, gradually becoming the best-selling plug-in car in America, it is reasonable to think that we could be entering a new era where the popularity of electric cars achieves significant reduction on gasoline product use in the transportation sector.

In next part of the report, I will design a model to compare total cost of owning and operating a Tesla Model 3 and another popular fuel vehicle in the market, the Toyota Camry, to test whether it would be cheaper to use an electric car.

2 Modeling levelized cost of owning and operating electrical vehicles or internal combustion engines

The cost of owning and operating a car is highly related to performance of the car (like capital cost, battery size of electricity car and fuel economy of gas vehicle), variable and fixed cost of operating the car, depreciation, finance cost, fuel or electricity cost etc. The performance data of each type of car are obtained from Tesla[14] and Toyota[16] official website, while fuel economy of Toyota Camry L is estimated by EPA combining city/highway economy[9]. Cost data are obtained from AAA Your Driving Costs report (2018 Edition)[10]. The social cost of environmental externalities (like carbon emissions) is not included in either models.

The Tesla model is designed to allow selection between different size of battery (thus different capital cost), to increase the robustness of our model. Besides, a great reason for people to turn to electric vehicles is the availability of federal sales tax incentives. It can provide a total $1,875 tax credit for a new Tesla Model 3 buyer[15]. However, since this tax incentives will be expired after Dec. 31st, 2019, we include both case with or without tax credit in the Tesla model. Conversely, in the Camry model, we propose a hypothetical emission tax to capture the effects of different government regulation intensity on the cost of operating an internal combustion engine. We think that significant emission tax disadvantages for high-emission gasoline engines can also have a strong influence on consumer choice. In both models, users can deviate between different gas price and electricity price scenarios. So, we can evaluate the cost sensitivity to these two variables. Another interesting point is that unlike Toyota Camry, which cost $461 per year in operation and maintenance[11], Tesla Model 3 requires no traditional annually cost on oil change, fuel filters, spark plug replacements or emission checks. And its majority possible maintenance expense comes from a replacement battery pack, which happens in rare cases. These has led to a zero fixed OM cost of Model 3[13]. Finally, we assume that both vehicles can serve an average of 15 years. Users can choose between different annual driving miles from 10,000 miles to 30,000 miles. We use the annual average miles estimated by U.S. Department of Energy as default mileage in both models (12,330 miles per year)[12]. The specific contents of two models are shown below.

Telsa Model 3	
Car performance	
Capital cost ($)	32815
battery range (mile/charge)	240
battery size (kWh) ◉ 50 kWh ○ 75 kWh	50
vehicle service time (yrs)	15
Cost	
Variable O&M ($/mile)	0.0076
Fixed O&M ($/mile)	0
Depreciation ($/year)	5471
Insurance and Finance charge ($/year)	1898
Liscense, registration, tax credits ($/year)	-552
☑ Subsidies expired (after Dec.31th,2019)	
Variable	
Miles driving per year (mile)	12330
12330 (Estimated annual average miles)	
Electricity price ($/kWh)	0.1317
Electrical cost ($/mile)	0.027438
Levelized cost of a Tesla Model 3 ($/year)	7249.012

Toyota Camry L (8th generation)	
Car performance	
Capital cost ($)	24095
vehicle service time (yrs)	15
Fuel economy (mile/gallon)	34
Cost	
Variable O&M ($/mile)	0.00858
Fixed O&M ($/year)	461
Depreciation ($/year)	3580
Insurance and Finance charge ($/year)	1932
Liscense, registration, tax credits ($/year)	690
Variable	
Miles driving per year (mile)	12330
12330 (Estimated annual average miles)	
Gasoline price ($/gallon)	2.681
Emission tax	0.000
Fuel cost ($/mile)	0.07885
Levelized cost of a Camry ($/year)	7280.048

Figure 4: Levelized cost model of a Tesla and Camry

To determine the effect of residential electricity price, gasoline price and emission tax on cost of owning two types of vehicles. We use different scenarios to show the sensitivity of cost and plot them in a same graph. We can see that under this model, in the most case electrical vehicles have clear advantage in saving total operation and maintenance cost. If we use the current electricity price (\$0.1317/kWh) and gasoline price (\$2.681/gallon) data (for Sept. 2019) from EIA, with a 15-year total \$1875 tax credit incentive for Tesla Model 3 to calculate levelized cost, we can find that people are able to save \$156.04 operation and maintenance cost annually by using a electrical vehicle. Even if the sales tax incentive expired, electric vehicles can still save \$31.04 per year under the current electricity and gasoline price. Besides, according to EIA, even though in the short term both residential electricity price and gasoline price can slightly increase[7], the long run price of crude oil is projected to increase 3.5%, while price of electricity may only grow 2.3% (both use nominal \$ per unit)[1]. This implies that the gap between cost of using electrical vehicles and internal combustion engines can grow even larger. Meanwhile, we cannot omit the huge influence of emission tax. According to the modeling results, a hypothetical emission tax of 15% of gasoline price can greatly enhance the life-cycle cost of internal combustion engines. Moreover, as gasoline price increase, unit fuel cost can increase non-linearly under the help of emission tax, thus increase the advantage of zero-emission electric vehicles. This can be a useful tool for government to lift cost of gasoline engines and produce incentives for potential electrical vehicle buyers.

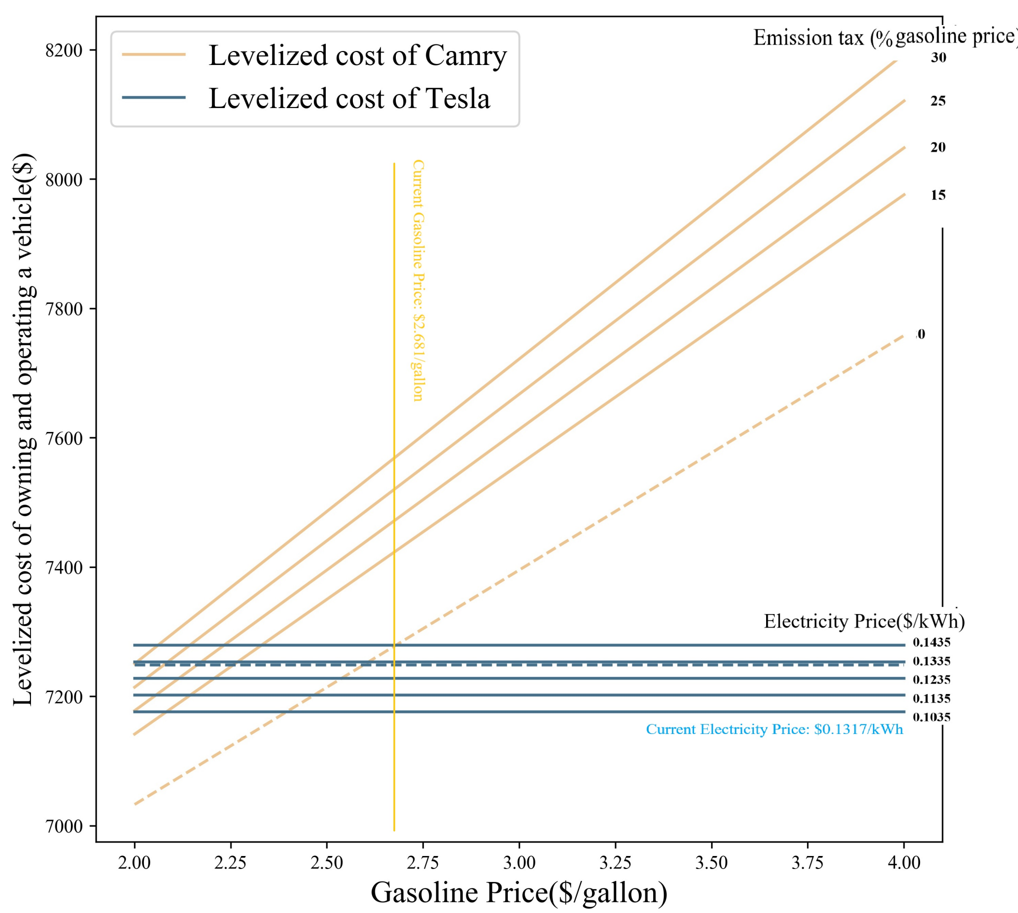

Figure 5: Levelized cost of Camry and Tesla under different scenarios of gasoline price, residential electricity price and emission tax (assume no federal tax credit)

The story is quite clear here. Owning and operating an electric vehicle rather than a internal combustion engine can save people a lot of money during the time they own it. If federal government is able to propose regulations to further enhance the cost of high-emission gasoline engines, coupled with the fact that crude oil price can increase faster than electricity price in the future, it is fair to say that making an investment in electric vehicles will continuously be a smart decision in both saving money, and further saving gasoline consumption. Admittedly, electric vehicles are not suitable for all people's life (because of charging periods or cruising range problems), the low total cost can serve as a strong incentive for customers to leave combustion engines market, and gradually help us achieving significant reduction on gasoline consumption in the transportation sector.

Reference

[1] U.S. Energy Information Administration. Annual projections to 2050–energy prices by sector and source. https://www.eia.gov/analysis/projection-data.php#annualproj.

[2] U.S. Energy Information Administration. Crude oil and lease condensate production by api gravity. https://www.eia.gov/dnav/pet/pet_crd_api_adc_mbblpd_m.htm.

[3] U.S. Energy Information Administration. Monthly crude oil and natural gas production. https://www.eia.gov/petroleum/production/.

[4] U.S. Energy Information Administration. Petroleum other liquids–imports/exports. https://www.eia.gov/petroleum/data.php#exports.

[5] U.S. Energy Information Administration. Petroleum other liquids–imports/exports. https://www.eia.gov/petroleum/data.php#imports.

[6] U.S. Energy Information Administration. Refiner motor gasoline sales volumes. https://www.eia.gov/dnav/pet/pet_cons_refmg_d_SCA_VTR_mgalpd_a.htm.

[7] U.S. Energy Information Administration. Short-term energy outlook. https://www.eia.gov/outlooks/steo/report/prices.php.

[8] U.S. Energy Information Administration. Oil: crude and petroleum products explained–use of oil. https://www.eia.gov/energyexplained/oil-and-petroleum-products/use-of-oil.php, 2018.

[9] U.S. Environmental Protection Agency. Toyota camry fuel economy. https://www.fueleconomy.gov/feg/PowerSearch.do?action=noform&path=1&year1=2019&year2=2019&make=Toyota&baseModel=Camry&srchtyp=ymm.

[10] AAA Association Communication. Your driving costs – how much are you really paying to drive? https://exchange.aaa.com/wp-content/uploads/2018/09/18-0090_2018-Your-Driving-Costs-Brochure_FNL-Lo-5-2.pdf, 2018.

[11] Your Mechanic. Toyota camry annual maintenance costs. https://www.yourmechanic.com/estimates/toyota/camry.

[12] U.S. Department of Energy. Vehicle annual mileage splits between city and highway driving. https://afdc.energy.gov/calc/cost_calculator_methodology.html#sources.

[13] Tesla official website. Car maintenance. https://www.tesla.com/support/car-maintenance.

[14] Tesla official website. Design your car. https://www.tesla.com/model3/design#batter.

[15] Tesla official website. Electric vehicle solar incentives–federal tax incentives. https://www.tesla.com/support/incentives.

[16] Toyota official website. Camry. https://www.toyota.com/camry/.