Biofuels

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Lecture notes for Econ 235

US biofuel policy

- US biofuel policy is mainly conducted through the Energy programs:
  - Energy Policy Act of 2005 first established Renewable Fuel Standards (RFS); which were quickly surpassed.
  - The Energy Independence and Security Act of 2007 expanded the RFS and included mandates for advanced biofuels.
  - The RFS under the Energy Independence and Security Act of 2007 are referred to as RFS2.
- Recent farm bills (Farm Security Act of 2002 and the Food, Conservation, and Energy Act of 2008) also play a role in biofuel policies.

References

- Renewable Fuel Standards (RFS): Overview and Issues http://www.fas.org/sgp/crs/misc/R40155.pdf.
- Biofuel Incentives: A Summary of Federal Programs http://www.fas.org/sgp/crs/misc/R40110.pdf.
- The Renewable Fuel Standard (RFS): In Brief http://nationalaglawcenter.org/wp-content/uploads/assets/crs/R43325.pdf.

Definitions

- *Advanced biofuels* are produced from non-corn starch feedstocks. These biofuels must also meet certain minimum thresholds of lifecycle greenhouse gas emission reduction to qualify as advanced biofuels.
- These notes focus mostly on ethanol produced from corn.
- In biofuel policy, a *mandate* defines the minimum quantity of a biofuel that must be blended into motor fuel.

Renewable Fuel Requirements (RFS2) in billion gallons

Year	Corn starch ethanol	Advanced biofuels			Total non-corn starch	Total renewable fuels
		Cellulosic	Bio-based diesel	Other		
2008	9.0	0.00	0.00	0.00	0.00	9.0
2009	10.5	0.00	0.00	0.10	0.60	11.1
2010	12.0	0.0065	1.15	0.29	0.95	12.95
2011	12.6	0.006	0.80	0.54	1.35	13.95
2012	13.2	0.00	1.00	1.00	2.00	15.20
2013	13.8	0.014	1.28	1.46	2.75	16.55
2014	14.4	1.75	a	1.00	3.75	18.15
2015	15.0	3.00	a	1.50	5.50	20.50
2016	15.0	4.25	a	2.00	7.25	22.25
2017	15.0	5.50	a	2.50	9.00	24.00
2018	15.0	7.00	a	3.00	11.00	26.00
2019	15.0	8.50	a	3.50	13.00	28.00
2020	15.0	10.50	a	3.50	15.00	30.00
2021	15.0	13.50	a	3.50	18.00	33.00
2022	15.0	16.00	a	4.00	21.00	36.00
2023	15.0	b	b	b	b	b

Notes: Before 2014 the numbers are the actual biofuel mandates. After 2014, the numbers are the volumes that were planned in the RFS.
The source of the table is Schnepf and Yacobucci (2013). *na* stands for "non-applicable" and *tbd* stands for "to be determined". a. means to be determined by EPA but no less than one billion gallon. b. means to be determined by EPA through future rulemaking.

Renewable Fuel Requirements (RFS2) in billion gallons

- There was a lot of controversy about the biofuel volumes for 2014.
- The final volumes for 2014 were only released in June 2015.
- At the same time EPA also released volumes for 2015 and 2016.
- We will discuss this more at the end of this section.

Table : Biofuel volumes for 2014-17

		Advanced biofuels				
Year	Corn starch ethanol	Cellulosic	Bio-based diesel	Other	Total non-corn starch	Total renewable fuels
2014	13.61	0.03	1.63	1.01	2.67	16.28
2015	14.05	0.12	1.73	1.03	2.88	16.93
2016	14.50	0.23	1.90	1.48	3.61	18.11
2017	15.00	0.31	2.00	1.69	4.28	19.28

Source: https://www.epa.gov/renewable-fuel-standard-program/proposed-renewable-fuel-standards-2017-and-biomass-based-diesel.

Tax credits and tariffs

- Volumetric Ethanol Excise Tax Credit (VEETC): Ethanol blenders were eligible for a 51 cents per gallon of ethanol tax credit. The 2008 farm bill amended the tax credit which was 45 cents per gallon between January 2009 and December 31, 2011. This credit is now expired.
- An import tariff of 54 cents per gallon for ethanol. The import tariff was set to offset the tax credit, thus effectively cancelling the tax credit for imported ethanol. As long as the import tariff is larger that the blending tax credit, on the net, imports are taxed. The import tariff expired on December 31, 2011.

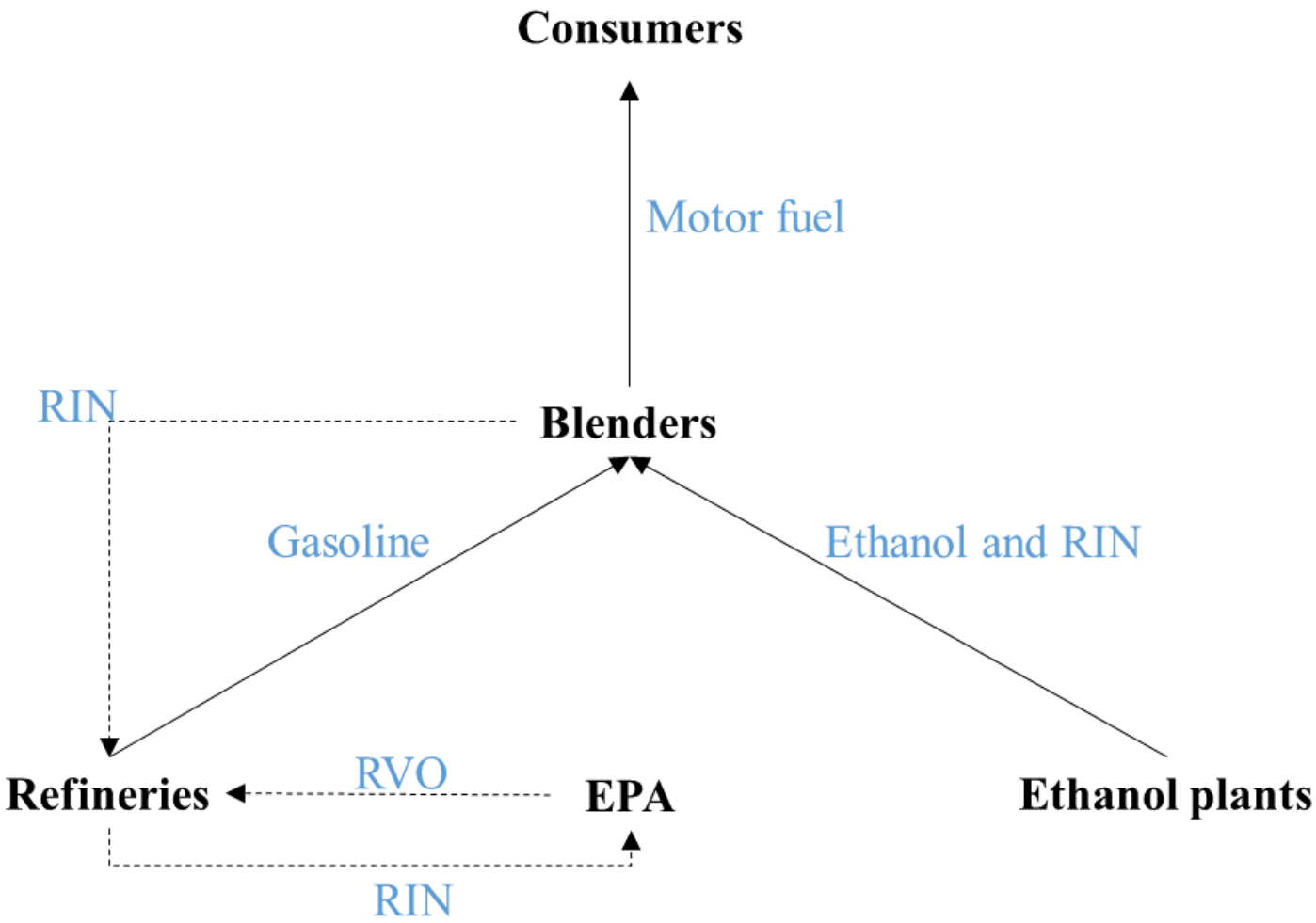
Who the mandates apply to?

- The implementation of RFS2 is done through annual requirements set by the Environmental Protection Agency (EPA) based on projections on the consumption of gasoline and diesel from the Energy Information Administration (EIA).
- Each November, EPA sets the percentage of fuel by category that must come from renewable sources in the following year.
- EPA sets those percentages using demand estimates and production capacity estimates. Note that EPA can, through rulemaking, modify the mandated quantities if the infrastructure to produce biofuel quantities does not exist.
- Gasoline refiners are obligated to obtain credit for a quantity of biofuel equal to a percentage of their total annual fuel sales, for each of the four biofuel categories. This requirement is referred to as the Renewable Volume Obligation (RVO).

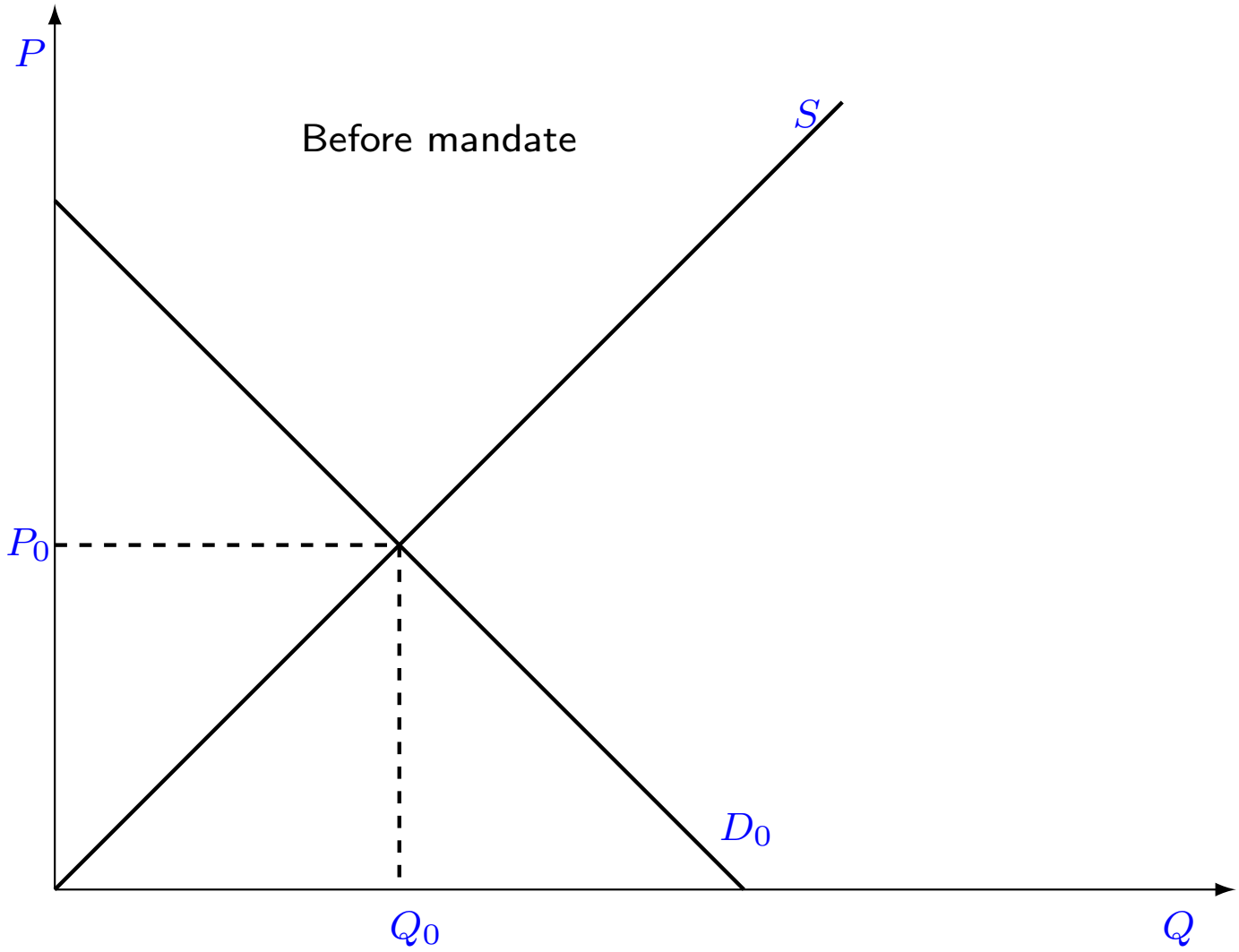
How does the ethanol policy affect farms

- It works in a way similar to pollution permits.
- To meet their RVO, refiners purchase a RIN from fuel blenders which is then submitted to EPA to show compliance with the RVO.
- A RIN shows that one gallon of ethanol has been blended in gasoline.
- Thus, as refiners demand RINs, blenders will demand ethanol to be able to sell RINs to refiners.
- As most ethanol is produced from corn in the United States, the increase in the demand for ethanol increases the demand for corn.
- The increase in the demand for corn causes the price and the quantity of corn to increase.

RIN and ethanol markets diagram



Shifts in demand for corn



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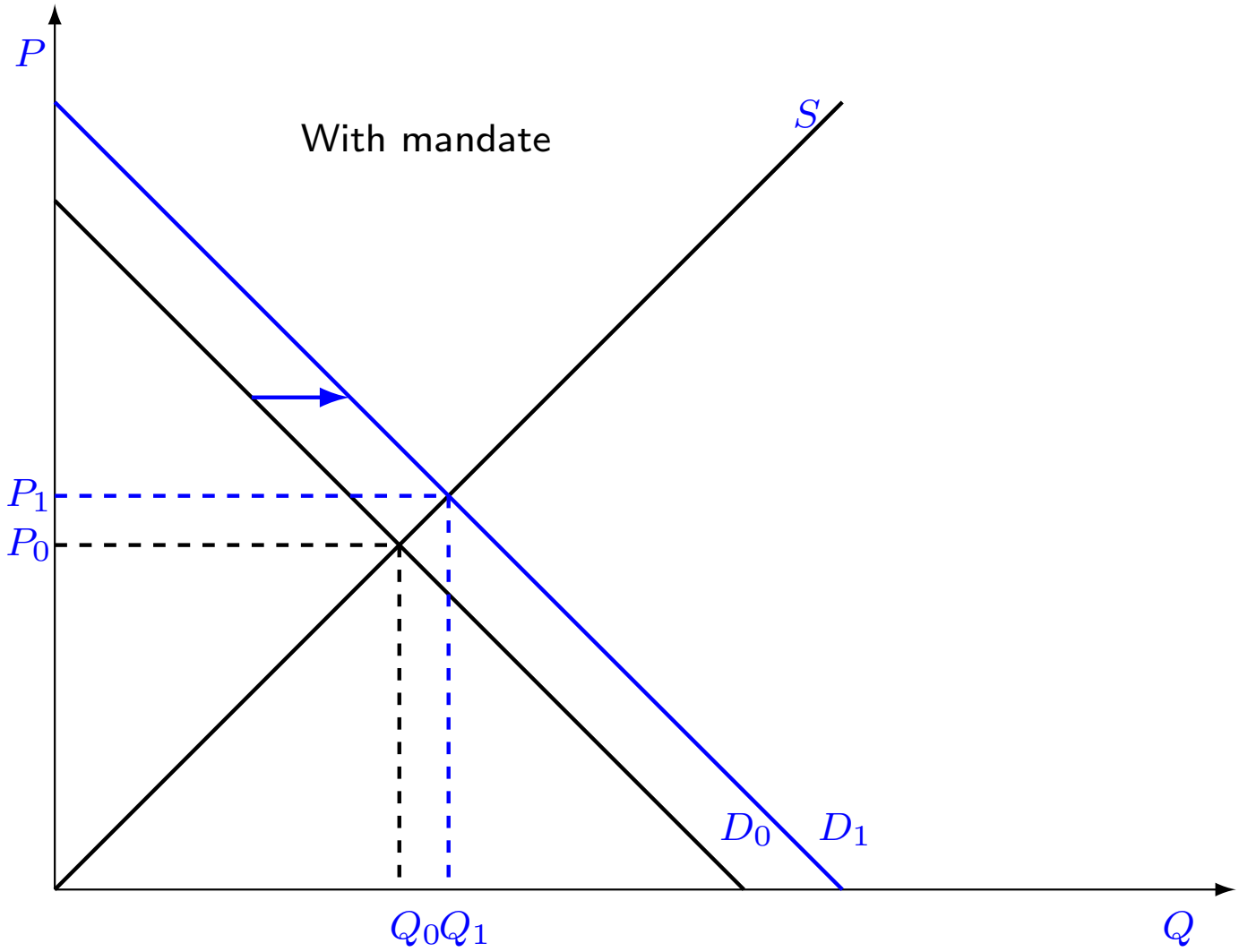


Were mandates really the reason for the growth of the ethanol industry?

- At the same time as EPA instituted the first ethanol mandates, Congress removed oxygenate requirements (which raises octane number) for gasoline.
- In response, refiners stopped using Methyl Tertiary Butyl Ether (MTBE) and instead started using ethanol to increase octane in gasoline.
- This means that refiners would use a certain amount of ethanol whether the ethanol mandates were in place or not.
- As ethanol is a substitute to gasoline, blenders would even use as much ethanol as possible in motor fuel if it is cheaper than gasoline.
- This means that blenders might use more ethanol then the mandated volume.
- Whether the growth of US ethanol industry is entirely attributable to the ethanol mandates is debatable.

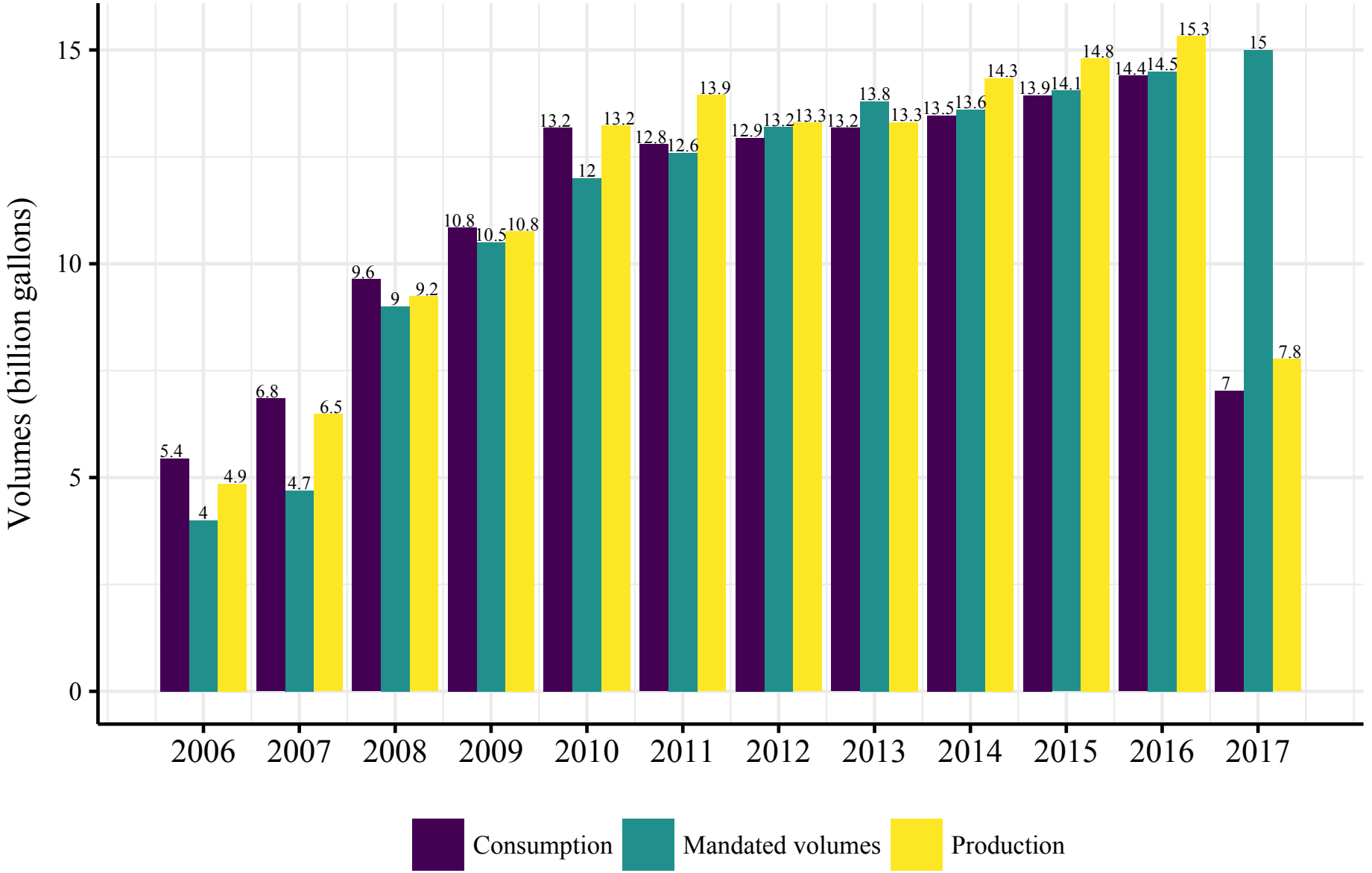
Price for corn, wholesale ethanol and wholesale gasoline

Sources: Prices for corn and gasoline are the daily settle prices of the nearest expiring futures contracts. The price of ethanol is the monthly F.O.B. ethanol rack price in Omaha, Nebraska given at http://www.neo.ne.gov/statshtml/66.html.

Mandate vs production and consumption

- After the adoption of the first mandates (RFS1), the industry quickly outpaced the ethanol mandate.
- RFS2 increased the biofuel mandates but still refiners blended more ethanol than what was required by the mandates until 2012.
- Early on, the US was a net importer of ethanol and then became an net exporter of ethanol.

Mandate vs production and consumption (up to May 2017)



Profit of producing ethanol

- Let's look at what affects the profitability of ethanol plants.
- Several websites offer measures of profitability:
  - CARD: http://www.card.iastate.edu/research/biorenewables/tools/hist_eth_gm.aspx;
  - ISU extension: https://www.extension.iastate.edu/agdm/decisionaidsall.html.
- We will calculate profits by an ethanol plant using the assumptions of ISU extension, with the excel sheet available here.
- This gives a good idea of the profit of a representative ethanol plant.

Profit of producing ethanol

- The excel sheet clearly states the main assumptions to calculate profitability by an ethanol plant:
  - Built in 2007;
  - Capacity of 100 million gallons;
  - ...
- We will look at the profitability of such a plant located in Iowa.

Revenue of ethanol plants

- A typical corn ethanol plant gets revenue by the production of three outputs:
  - Ethanol;
  - Dried Distillers Grains with Solubles (DDGS);
  - Corn oil.
- DDGS is a by-product of the production of ethanol. It is a closed substitute to corn as a feed and as such its price follows the price of corn.
- I do not have data about corn oil and will ignore its impact on revenue in what follows. It has become a small but significant part of ethanol plant total revenue.

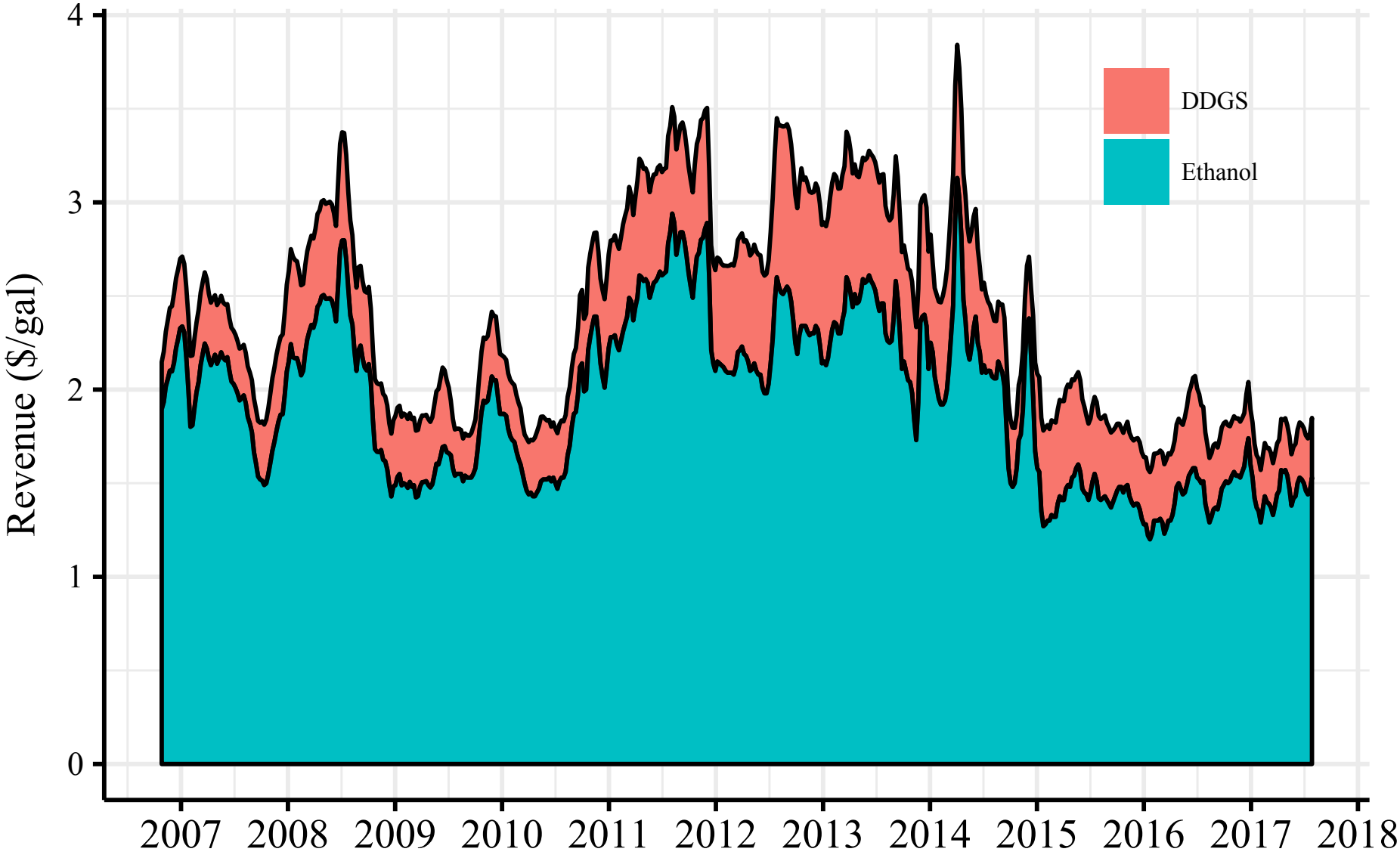
Prices for corn and DDGS

Sources: Price data were obtained from AgMRC.

Revenue of ethanol plants

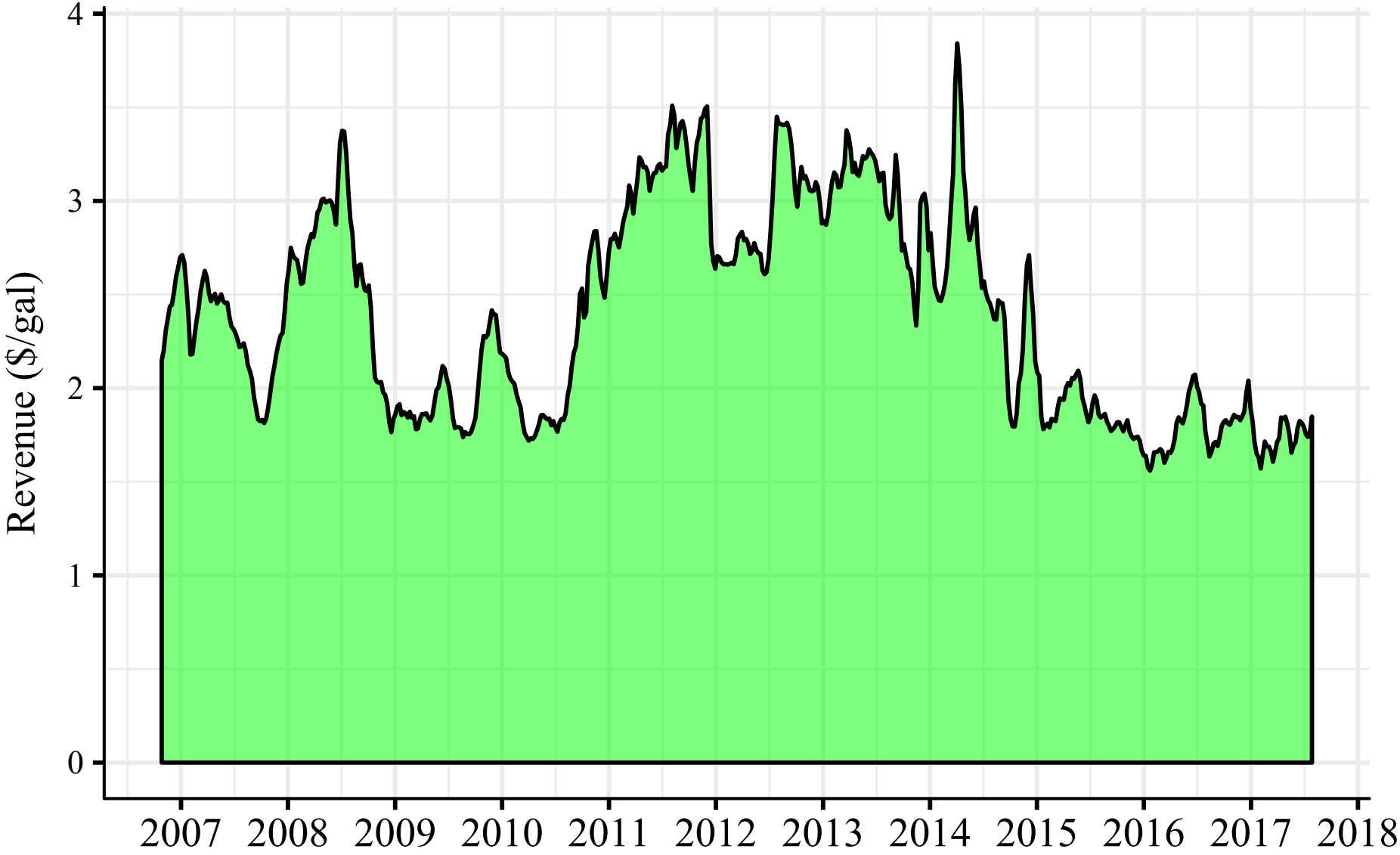
- One bushel of corn yields about 2.8 gallons of ethanol.
- One bushel of corn yields about 16.5 pounds of DDGS.
- This is means that for each gallon of ethanol produced, the ethanol plant produces 5.9 pounds of DDGS.
- For a price of ethanol of \$2.10 per gallon and a price of DDGS of \$0.10 per pound, the revenues of an ethanol plant for the production of one gallon ethanol are:
  - \$2.10 for ethanol;
  - \$0.59 for the production of DDGS;
  - Thus a total revenue of \$2.69 for the production of one gallon of ethanol.

Ethanol plants revenues from corn and DDGS



Calculations done using price data from AgMRC.

Ethanol plants revenues from corn and DDGS



This is the same graph as on the previous slide but removing detail of the source of revenues. Calculations done using price data from AgMRC.

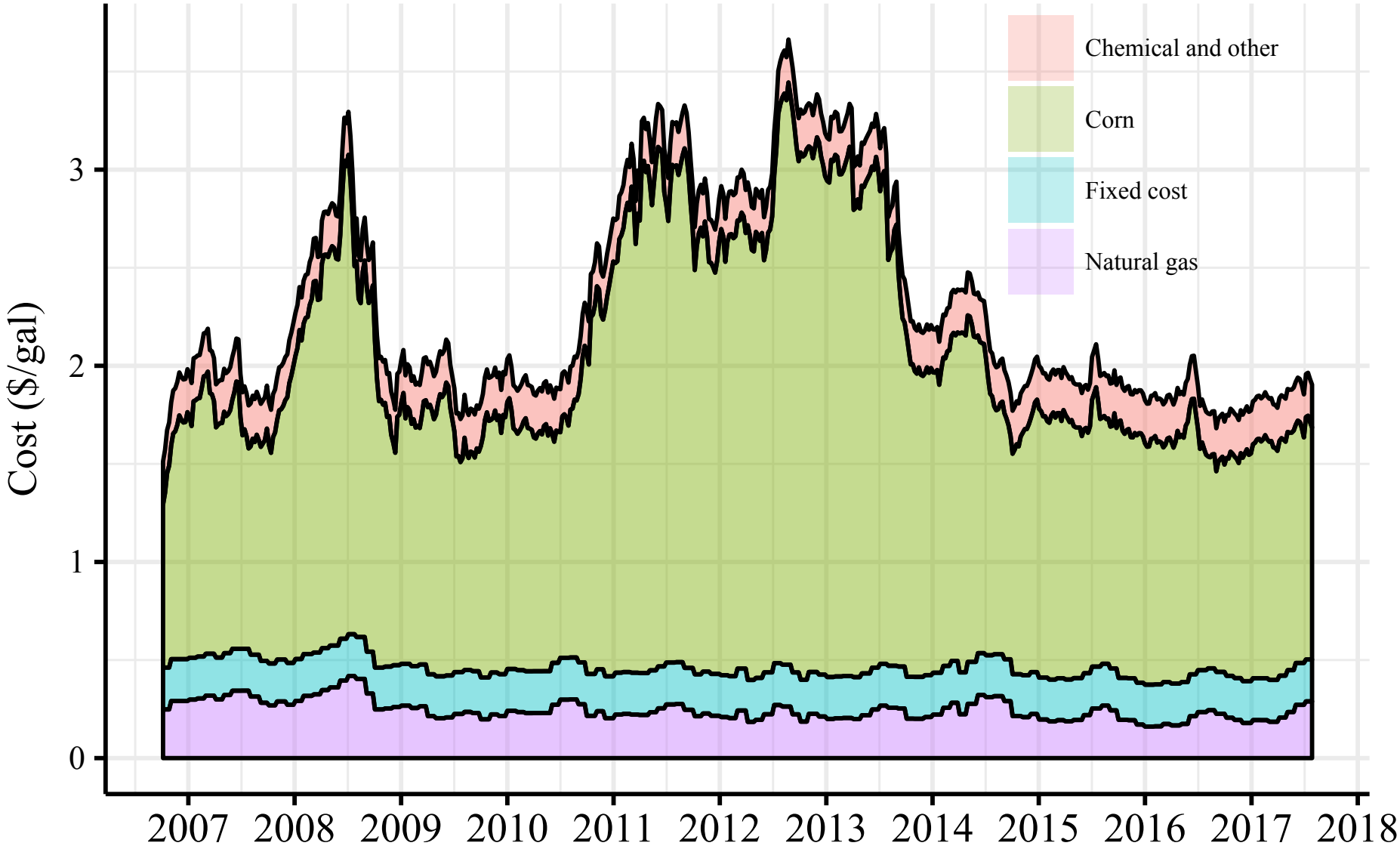
Cost of ethanol plants

- A small share of the costs to an ethanol plant is relatively constant and predictable:
  - Chemicals: enzymes, yeasts, chemicals and denaturants;
  - Other direct costs: repair & maintenance, transportation, water, electricity,...;
  - Fixed cost: Depreciation, interest, labor & management and property taxes.
- I would not put labor & management in the fixed cost category as the excel sheet does but let's leave it there for this exercise.

Cost of ethanol plants

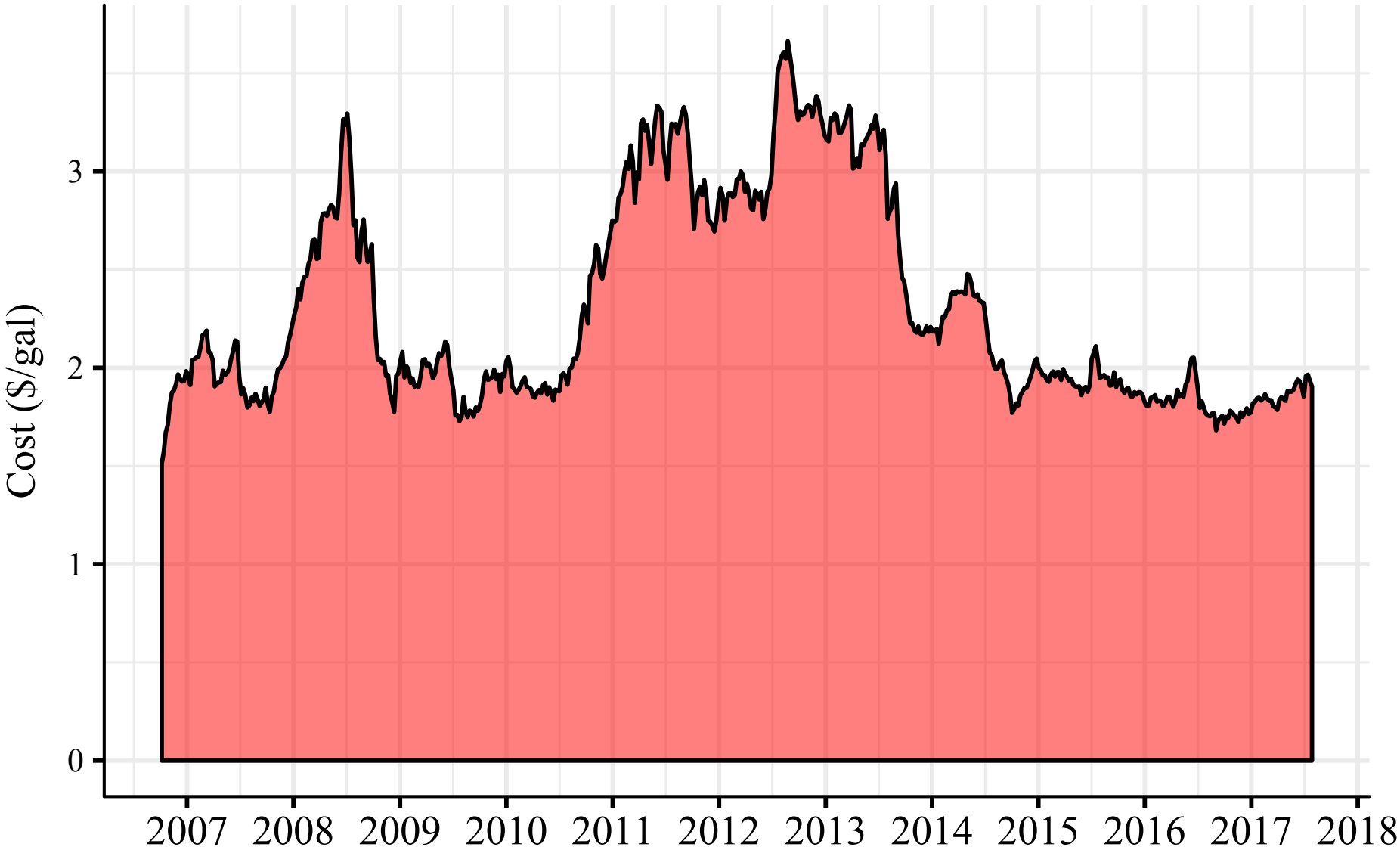
- The largest share of the costs to an ethanol plant are from corn and natural gas.
- The prices of these inputs, especially corn, are highly volatile.

Ethanol plants costs from corn and DDGS



Calculations done using price data from AgMRC and from EIA.

Ethanol plants costs from corn and DDGS

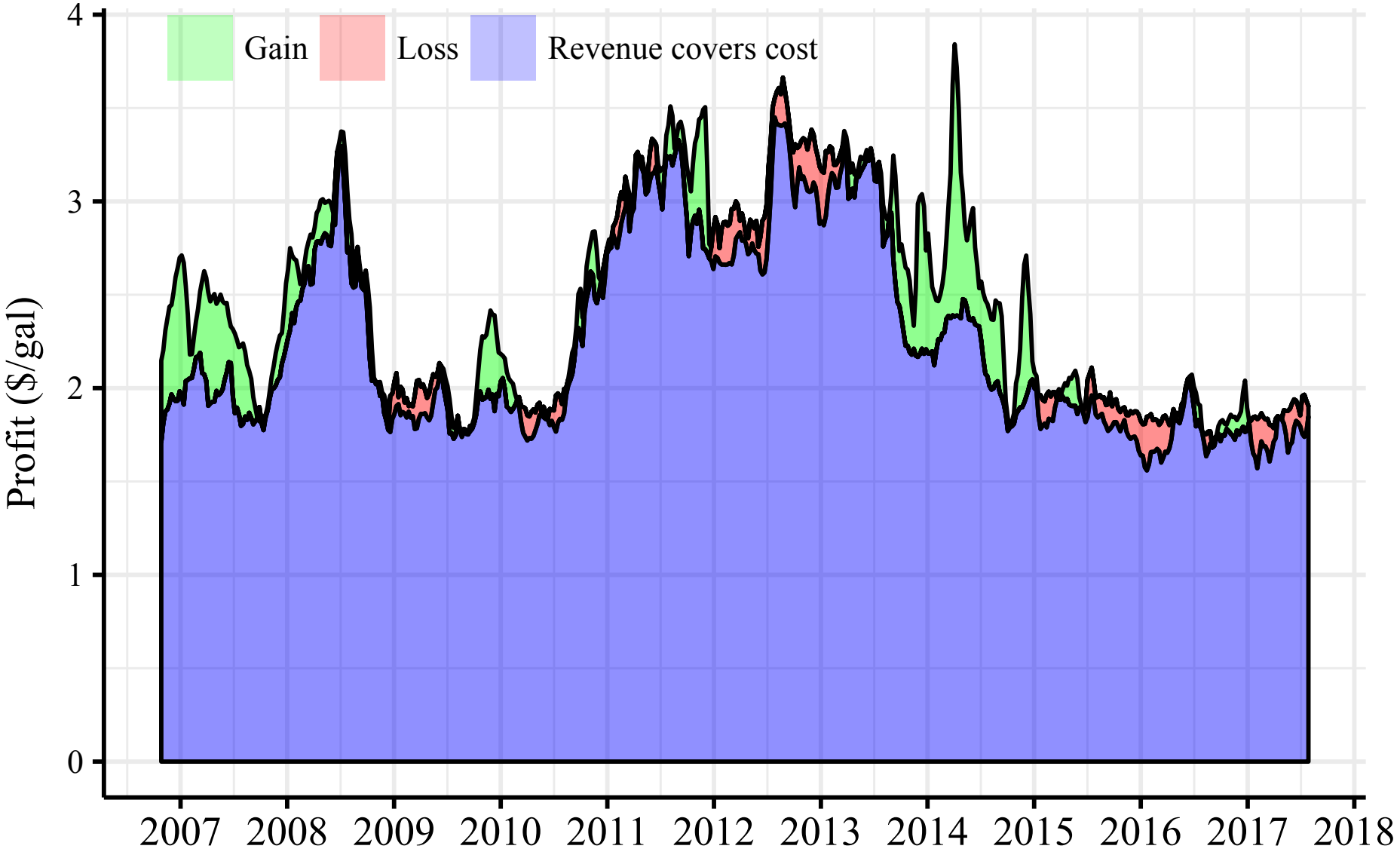


This is the same graph as on the previous slide but removing detail of the source of costs. Calculations done using price data from AgMRC and from EIA.

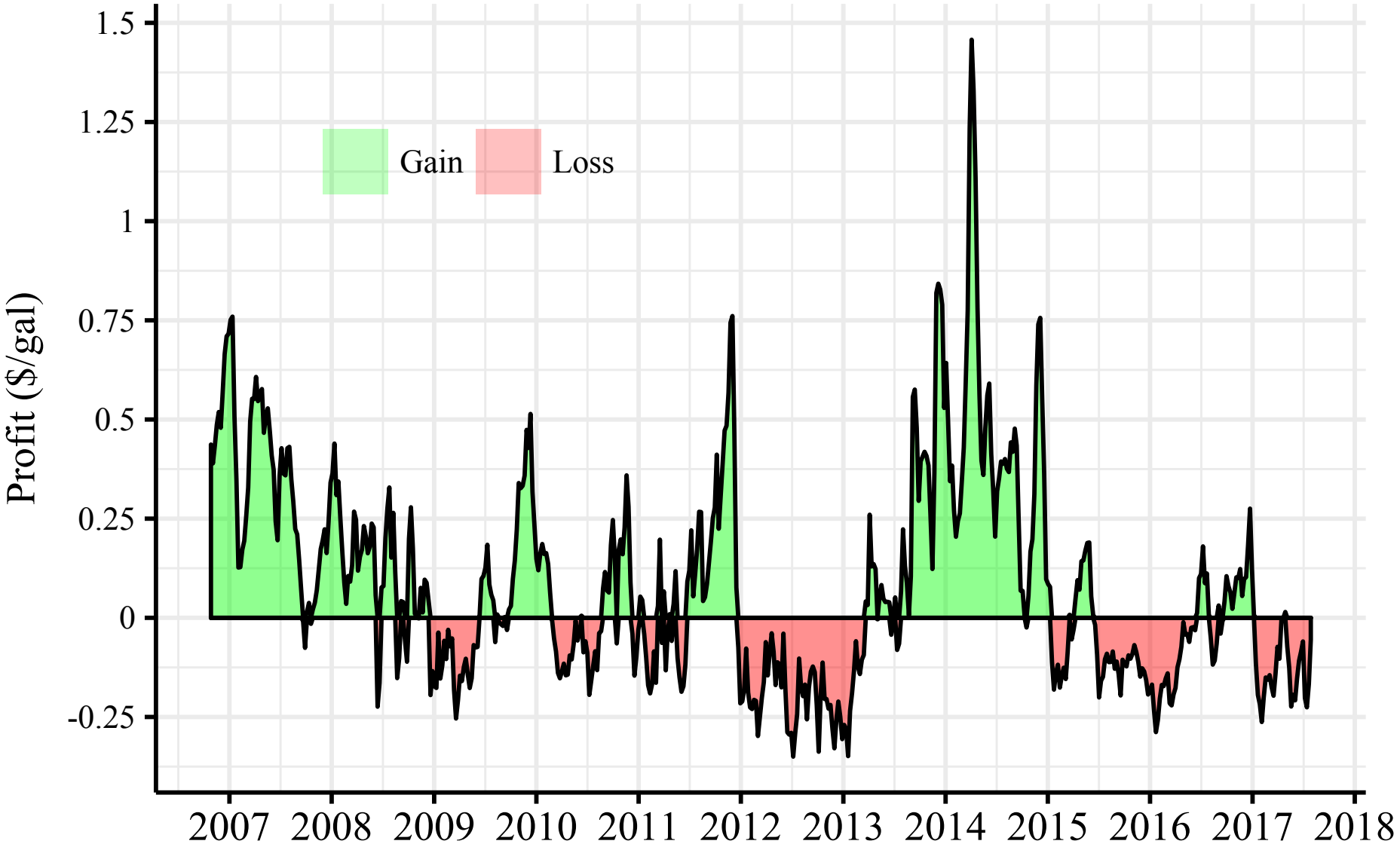
Profit of ethanol plants

- We can now calculate the profit of a plant as simply the difference between revenue and the cost.
- Note that it likely underestimate profit because revenue from corn oil are not added.

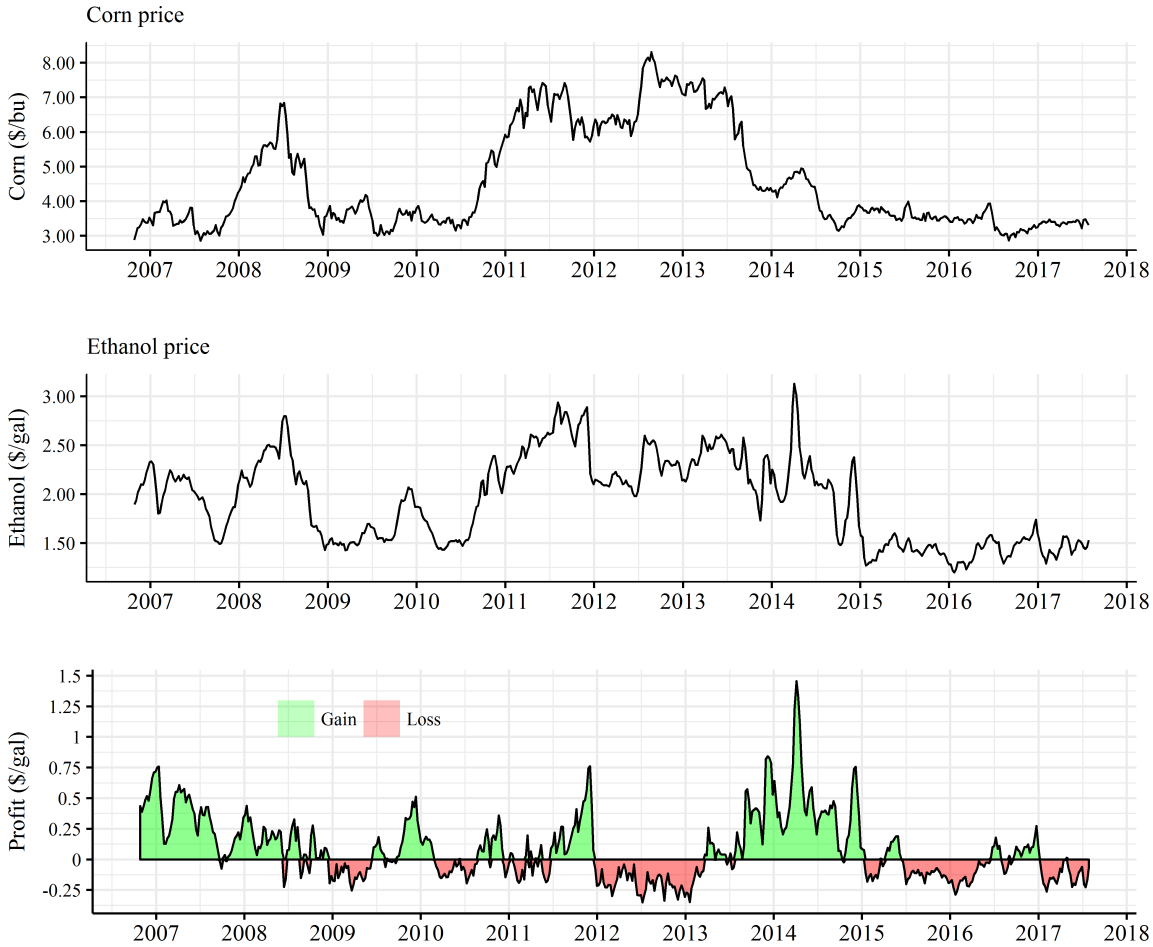
Profit of ethanol plant



Profit of ethanol plant



Profit of ethanol plant: corn and ethanol prices



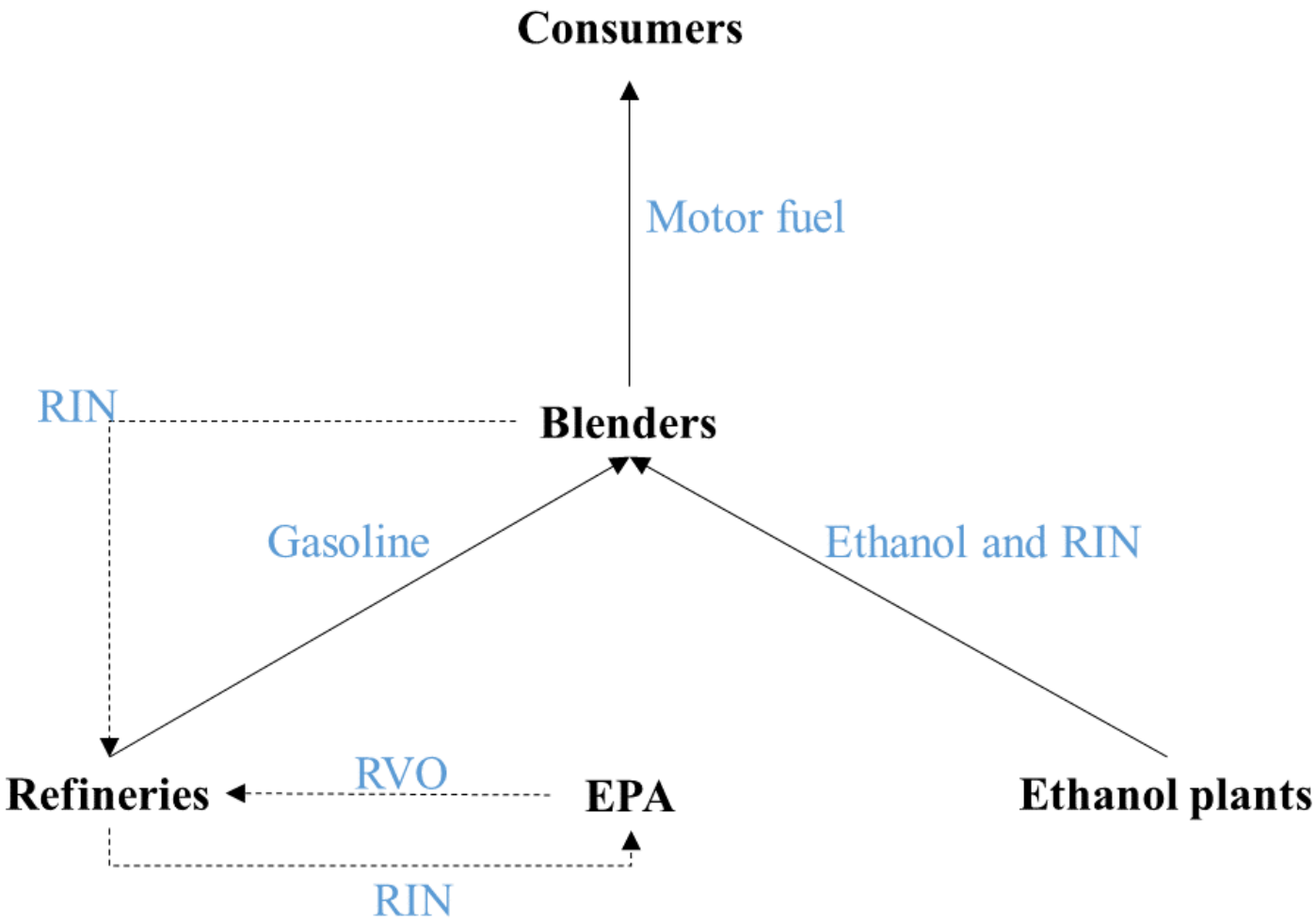
Profit of ethanol plants - volatility

- The previous figure shows that the profit of an ethanol plant is highly volatile.
- The calculation of the profit of a representative ethanol plant assumes that the plant does not hedge.
- A plant that hedges on the corn and the ethanol market will have much less volatile profits.

Renewable Identification Numbers (RIN)

- A RIN is a 38-character number that is attached to one gallon of ethanol produced or imported in the United States.
- The RINs remain "attached" to biofuels until the biofuel has been blended or sold.
- After being detached, RINs are tradeable and then effectively become a commodity available for purchase by refiners.
- A RIN is valid in the current and the following year.
- The objective of RINs is to enforce biofuel mandates and minimize the cost of meeting the mandate.
- At the end of the year, each supplier must have enough RINs to show compliance with their RVO.
    - This means that a supplier may never sell any biofuel but still meet its RVO through the purchase of RINs.

RIN and ethanol markets diagram



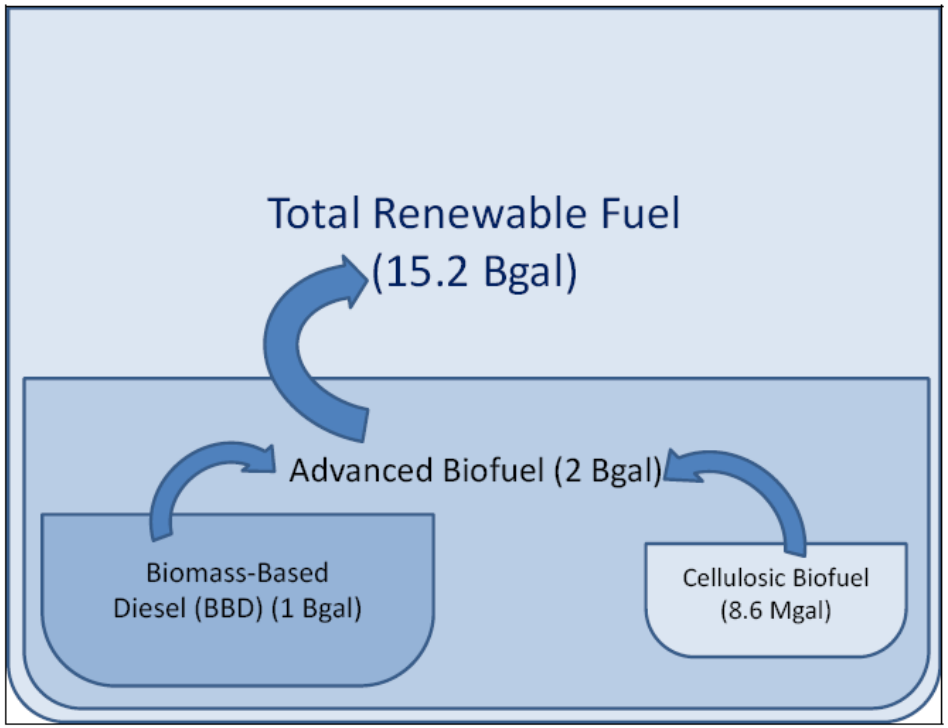
Renewable Identification Numbers (RIN)

- RINs differ depending on the type of biofuel they apply to:
  - Conventional ethanol RIN (D6);
  - Advanced ethanol RIN (D5);
  - Biodiesel RIN (D4);
  - Cellulosic RIN (D3).
- D# identifies the type of biofuel within the RIN 38-character number.
- The RINs of some biofuels are worth more.
- RIN for one type of biofuel qualifies for the type of biofuel above it (see next figure).
  - A D5 RIN can be used as a D6 RIN; same with other RIN types.
  - This creates an ordering in RIN prices.

Nested RFS and RINs

Figure 1. Nested RFS Mandates for 2012

(Not to scale)



Source: CRS.

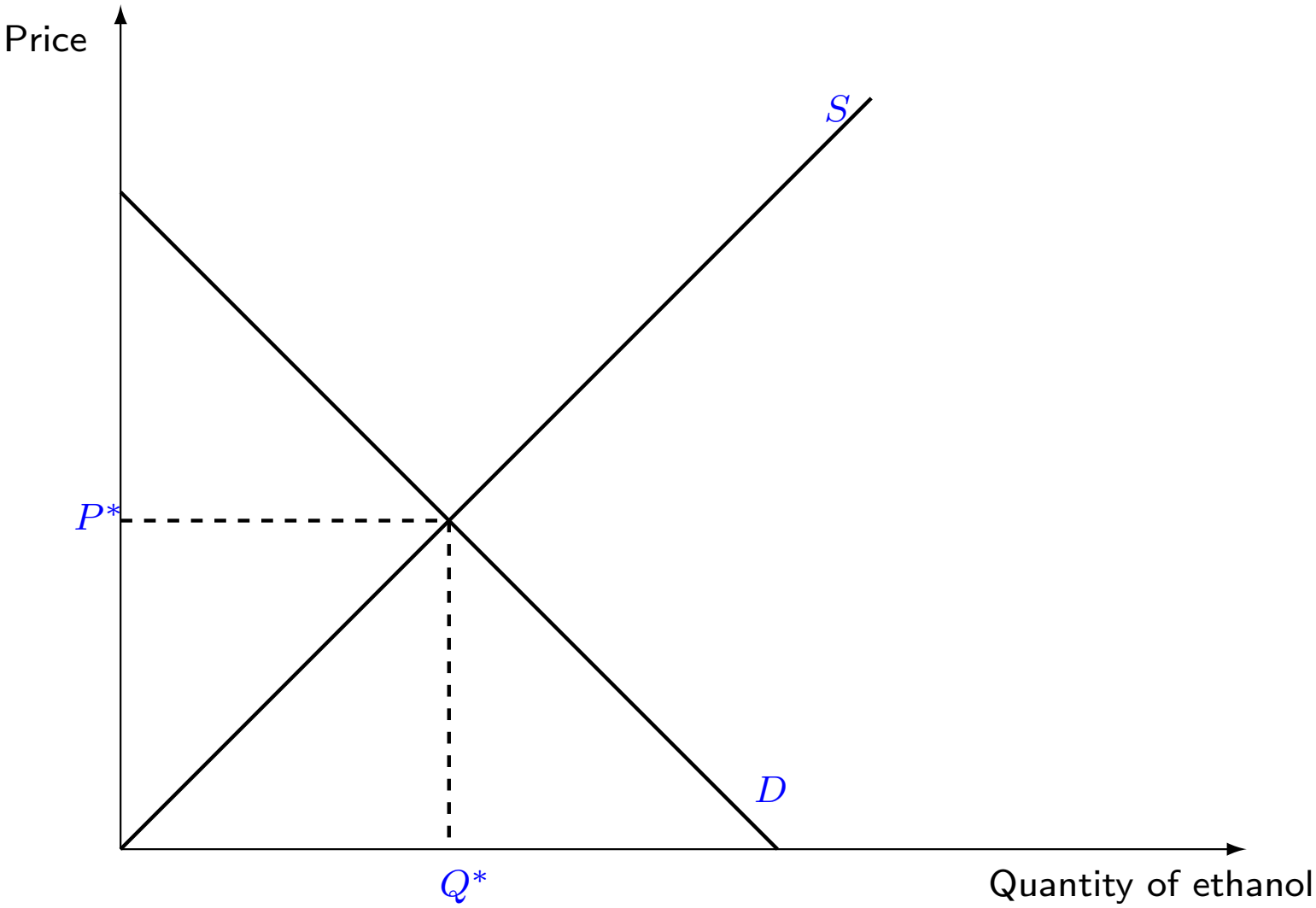
Notes: As noted by the arrows, fuel qualifying as one type of biofuel in the RFS qualifies for all levels above it. For example, cellulosic biofuel may also be used to meet the advanced biofuel mandate and the overall RFS mandate. However, non-cellulosic advanced biofuel (e.g., sugarcane ethanol) may not be used to meet the cellulosic or BBD mandates. Likewise, corn starch ethanol may only be used to meet the total RFS mandate (and not the advanced, cellulosic, or BBD mandates).

Source: Analysis of Renewable Identification Numbers (RINs) in the Renewable Fuel Standard (RFS) http://www.hsdl.org/?abstract&did=726857.

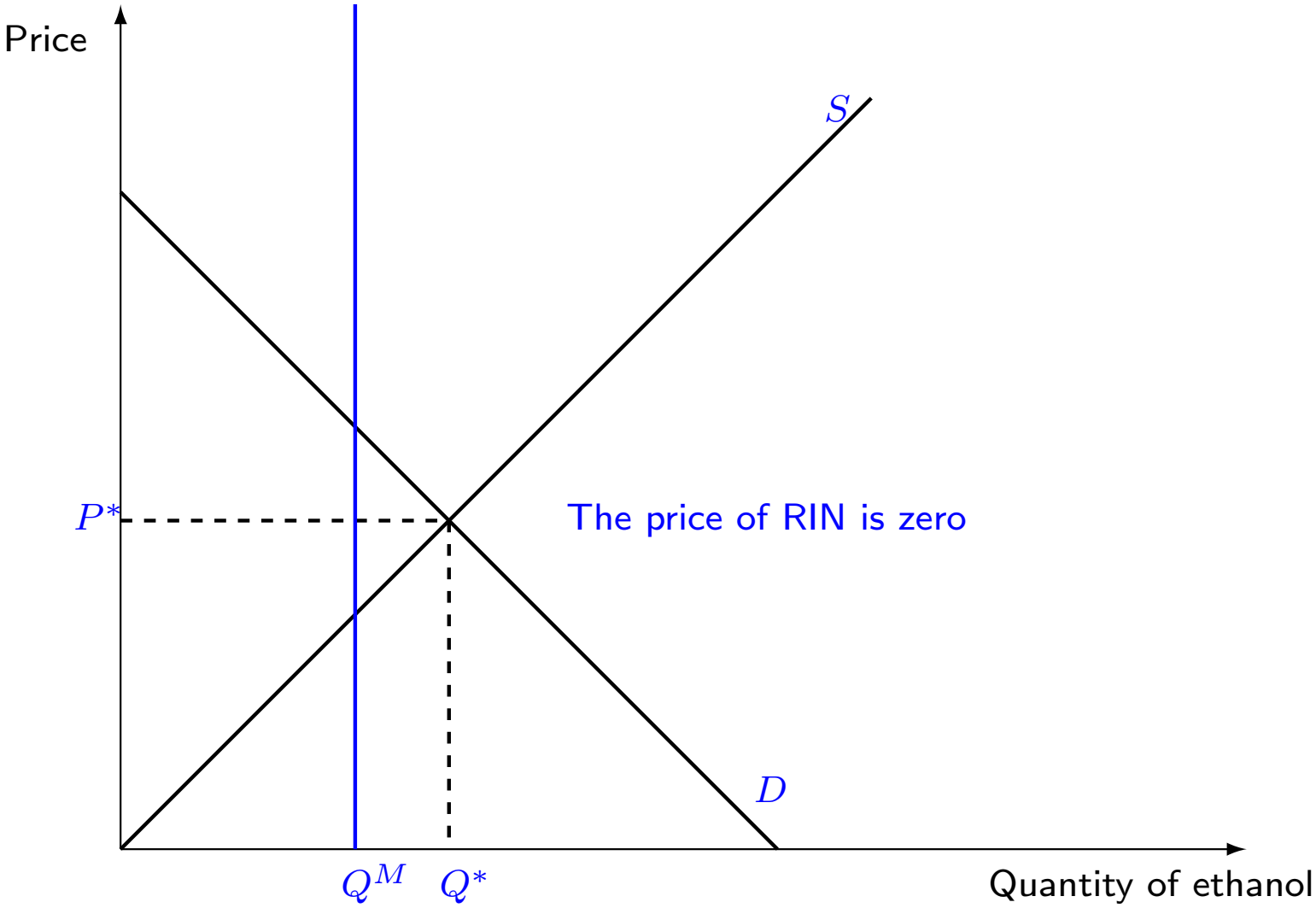
The price of RINs

- The price of RINs is determined by the vertical distance between the supply of ethanol and the demand for ethanol at a given mandated volume.
- If the mandate (Q^M in the next figure) is below the market equilibrium, then the price of RIN equals zero.
- If the mandate is above the market equilibrium, the price of RINs is positive.
- For a given demand and supply, an increase in the mandate causes an increase in the price of RINs.
- Note that a small corn crop increases the price of corn, thus increasing the cost of producing ethanol which then increases the price of RIN.
- See Irwin and Good at http://farmdocdaily.illinois.edu/2013/04/speculation-driving-up-price-rins.html for more explanations of RIN prices.

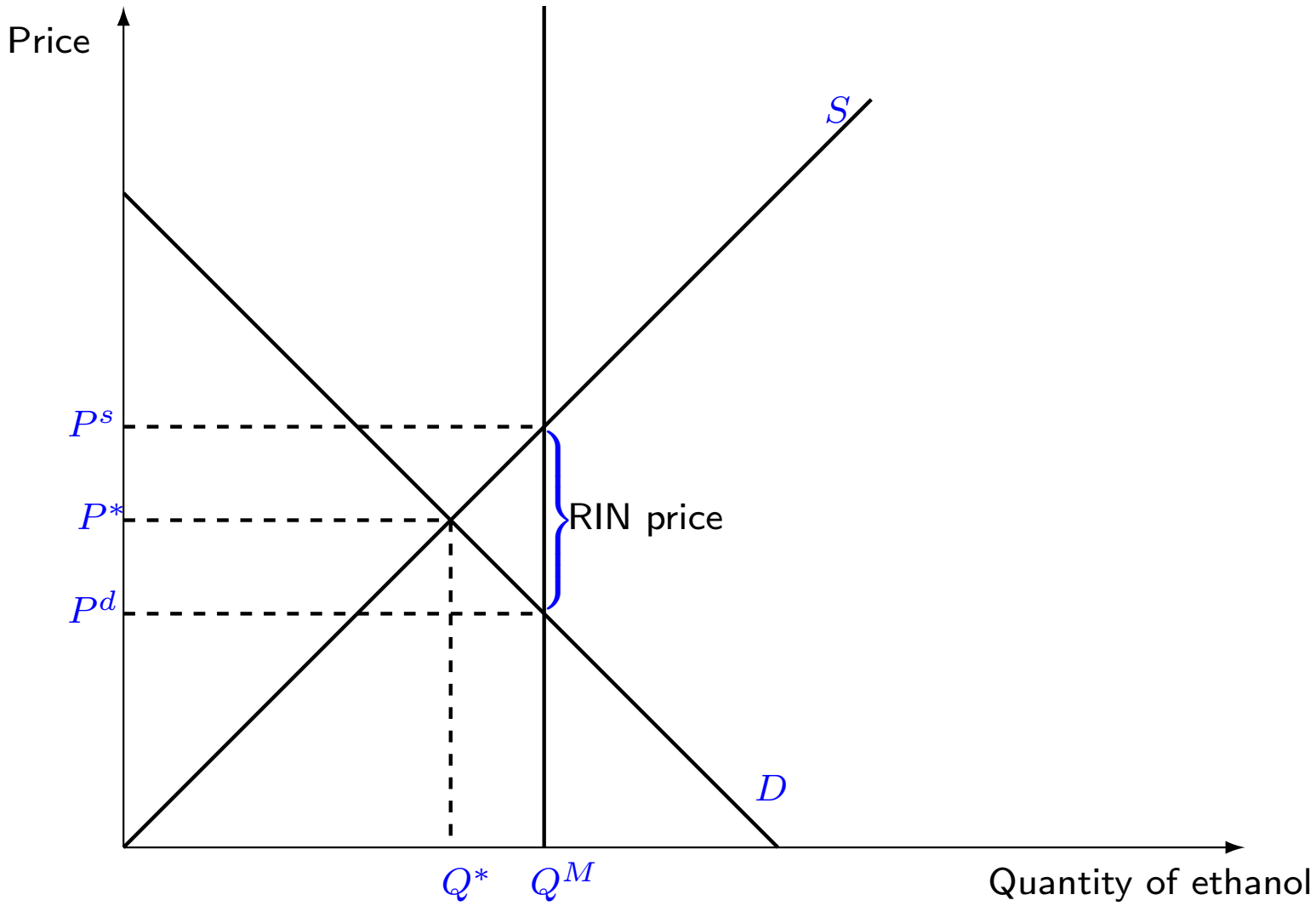
RIN prices



RIN prices



RIN prices



Price of RINs in 2012-13

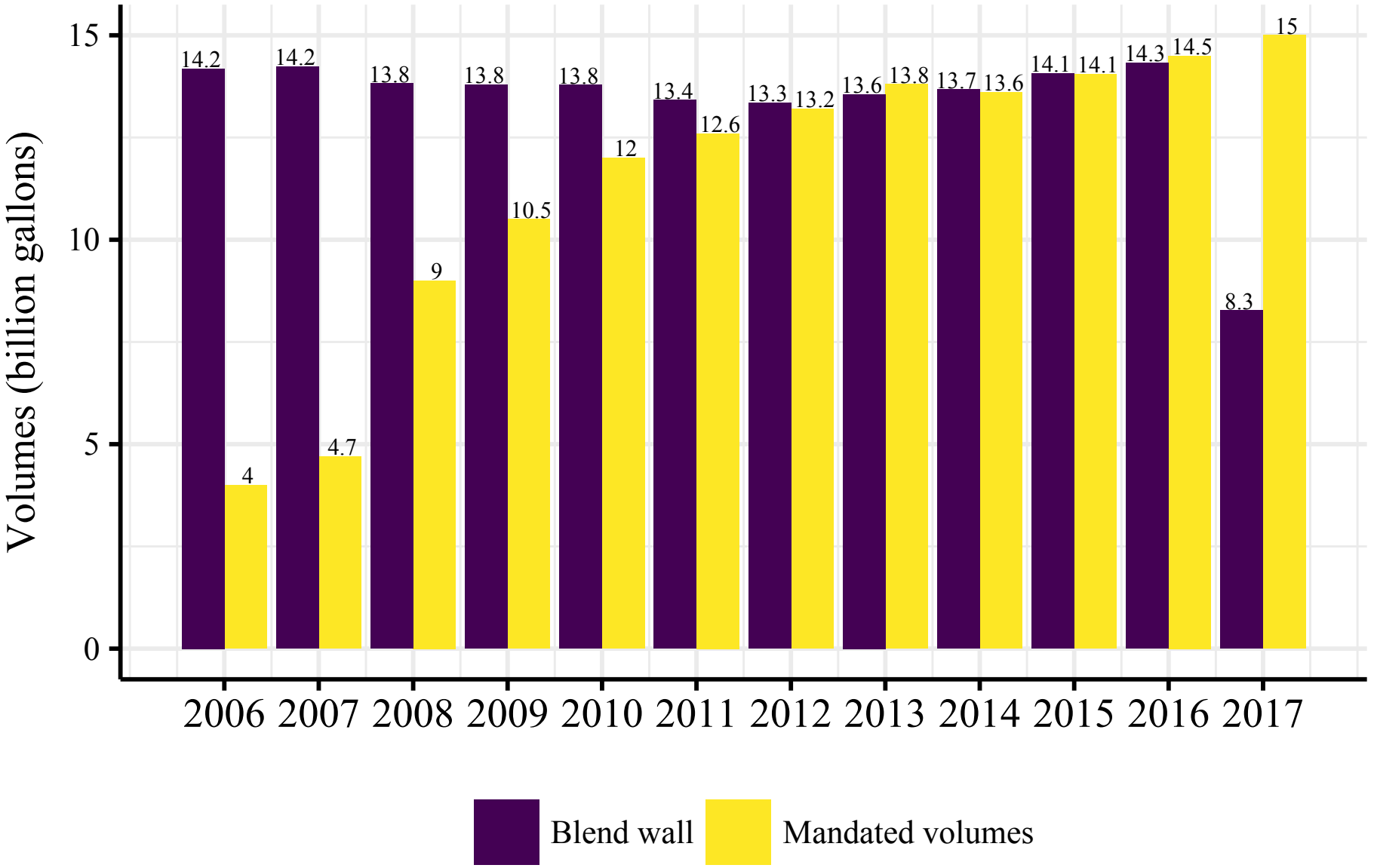
- The 2012 drought caused an increase in the price of corn shifting up the cost of producing ethanol therefore shifting to the left the supply of ethanol.
- At the same time, the mandate on conventional ethanol increased following schedule.
- This caused the price of RINs to increase.
- Fuel suppliers used RINs from the previous year and reduced their purchase of ethanol.

RIN price

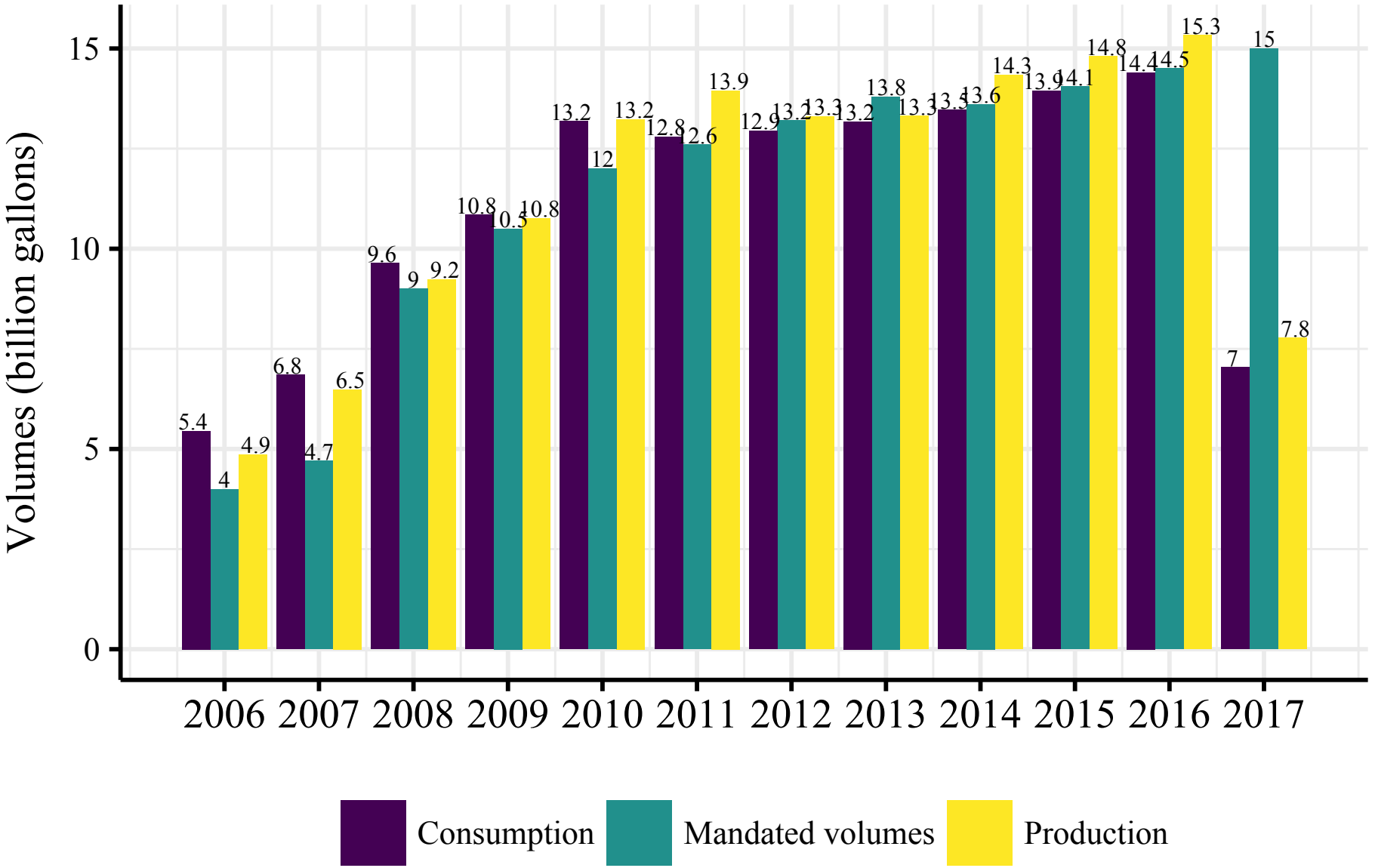
Blend wall

- Currently, most ethanol is distributed through motor fuel that contains 10 percent ethanol (87-octane).
- This is the established maximum amount of ethanol in fuel that most engines can run on, without damage.
- Flex-fuel vehicles can run on fuel that contains more ethanol.
- In 2013, the mandate on ethanol blending slightly exceeded the blend wall for the blending of ethanol in regular 87-octane gasoline.

Ethanol blend wall (up July 2017)



Mandate vs production and consumption (up to May 2016)



2014 ethanol mandate

- In November 2013, EPA announced the ethanol mandate for 2014.
- EPA proposed an ethanol mandate for 2014 to 13 billion gallons, far short of the scheduled 14.4 billion gallons.
- The main reason that the EPA gave is that there was no distribution capacity for more ethanol.
- This was a very controversial decision:
  - Farms and the ethanol industry voiced strong objections to the proposed rule. To them, more ethanol means more money;
  - The oil industry was very happy with the proposed rule as the burden of meeting the ethanol mandate falls to them.

2014 ethanol mandate - oil industry argument

- In 2013, the oil industry, in particular the American Petroleum Insitute (API), organized a strong lobby for the EPA to reduce the ethanol mandate for 2014.
- The oil industry correctly pointed out that with a larger ethanol mandate, the price of RIN increases.
- The oil industry then claimed that this increase in cost would be passed to consumers, who would then decrease their consumption, which would make meeting the mandate more difficult.
- If the mandate keeps on increasing every year, the price of gasoline keeps on increasing, putting a significant dent on US economic growth.
- API even predicted that this will result in another recession.

2014 ethanol mandate - oil industry argument

- Were the arguments of the oil industry correct?
- Let's calculate the impact on the price of gasoline of a price of RIN \$1 per gallon of ethanol:
  - Currently, the ethanol mandate requires blenders to acquire about 0.1 RIN for every gallon of gasoline;
  - This means that the purchase of a RIN for each gallon of gasoline increases the cost of gasoline by 0.1 x \$1 = \$0.1 per gallon of gasoline;
  - With a wholesale price of gasoline of about \$1.50 per gallon, this means that the cost of RIN increases wholesale gasoline by \$0.1 per gallon, or by about 6.7%.
  - The retail price of gasoline would also increase by about \$0.1 per gallon.
- Thus, a small increase in cost would result in a small change in consumption because the demand for gasoline is inelastic.

2014 ethanol mandate - oil industry argument

- At first glance, increasing the ethanol mandate would cause a small increase in gasoline price.
- I show with a colleague in a paper available here that the ethanol mandate might even cause a small decline in the price of gasoline.
- Our argument is that as the mandate increases, the value of ethanol going in gasoline will go down. This means that the price of motor fuel that contain a large share of ethanol (E85) will go down.
- E85 and E10 (regular gasoline), are substitute products.
- Thus, as more consumers purchase E85, the demand for gasoline shifts down, thus causing a decline in the price of gasoline at retail.
- That is, we find that the increase in the cost of producing gasoline is offset by substitution with other fuel blend.

How to get over the blend wall?

- At the current volumes, it is possible to increase the ethanol mandate. However, US car fleet cannot accommodate much ethanol beyond the blend wall currently.
- There are many possible solutions to the blend wall:
  - The EPA can modify the ethanol mandates;
  - Other types of biofuel can be used to meet the mandate.
  - Distribute ethanol through blends that contain more than 10 percent ethanol (e.g. E85). Is there really a demand for E85?

How to get over the blend wall?

- Out of about 245 million vehicles, about 20 million can fuel with gasoline that contain more than 10 percent ethanol (flex vehicles).
- Out of about 110,000 fuel stations, less than 5 percent of them offer E85.
- The distribution capacity is a more limiting factor than the number of flex vehicles in increases sales of E85.
- Fuel stations do not have an incentive to increase their offering of E85 if the ethanol mandate does not increase.
- EPA did not increase the mandate because there was not enough distribution capacity for ethanol.
- This is a chicken and egg problem.
- I discuss this in a policy paper in more detail here.

Is the future of US ethanol policy dead?

- EPA finally released the final rule for the 2014 ethanol mandates in June 2015.
- At the same time, EPA released mandates for 2015 and 2016.
- The mandate volumes are shown on slide 6.
- EPA took a conservative approach by lowering the mandates but setting an increase in the mandates for the upcoming years.
- Those mandated volumes were much smaller than those that were scheduled.

Conclusions

- US biofuel policy has an important impact on US energy supply and on US agriculture.
- Corn crop will influence the price of RINs.
- Current controversy regarding biodiesel.

References

Schnepf, R., and B.D. Yacobucci. 2013. "Renewable Fuel Standards (RFS): Overview and Issues." CRS Report for Congress No. R40155, Congressional Research Service.