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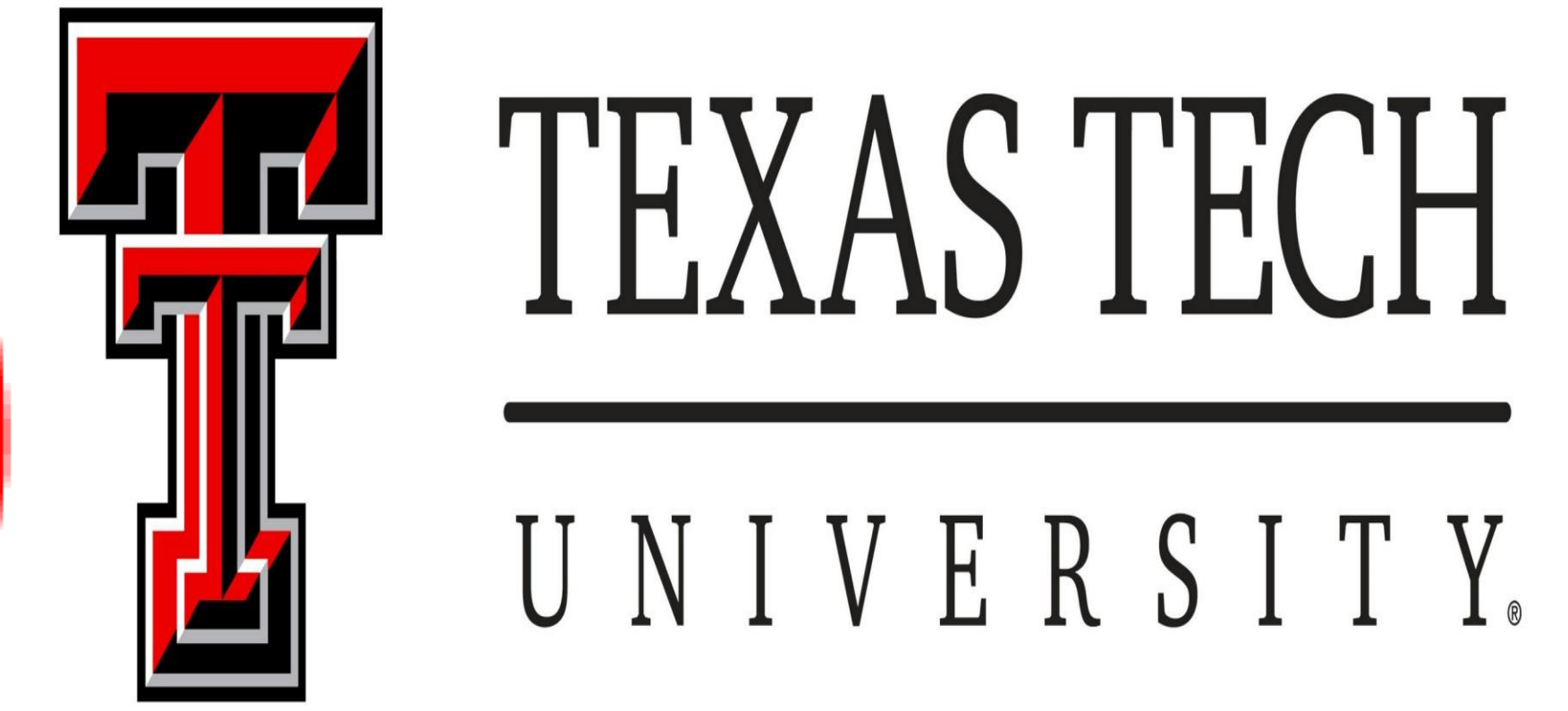
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Feasibility Study of an Onsite Multiproduct Biorefinery in West Texas From Using Cotton Gin Waste



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Introduction

According to the U.S. Energy Information Administration (EIA), Texas is the leading state for overall energy production and consumption. The state has a long standing tradition and experience in the energy sector. Renewable energy has emerged as a vital component of Texas' strategy for energy independence and leadership. Although renewable energy has a relatively small share in the energy consumption in Texas, this share is growing rapidly. According to the EIA, renewable sources accounted for 4.1% of all energy consumed in Texas in 2011. Wind energy comprises over three quarters of Texas' renewable energy usage, followed by biofuels and biomass (The Texas Wide Open For Business Report, 2014) The biomass and biofuels industry in Texas is growing in a very fast pace. According to the Texas Wide Open For Business Report, (2014) biomass and biofuels account for 36% of Texas' renewable energy consumption.

In1999, the State of Texas adopted the Renewable Portfolio Standard (RPS) that required 2,000 MW of new renewable energy capacity to be installed statewide by 2009. In 2005, the Texas Legislature extended the RPS to expand the state's generating capacity from renewable energy sources to 5,880 MW by 2015 and included a target of 10,000 MW by 2025, with 500 MW coming from non-wind sources. The state's installed capacity reached the 10,000 MW target in early 2010, 15 years ahead of schedule.

Jackson and Mayfield (2007) estimated that 460,000 trillion Btu (134 trillion kWh) of electricity could be generated using biomass fuels in Texas. Of this amount, 23.7% would come from agricultural wastes. On average, Texas produced 5.527 thousand bales of upland cotton annually (USDA-NASS, 2000-2013), which equates to an estimated 1,658 thousand tons of cotton gin waste (CGW) based on a thirty percent gin trash rate during the ginning process. The region known as the South Plains of Texas is primarily an agricultural region, producing one of the nation's best cotton crops. The industry sector, like gins, often uses the biomass produced in its operations to generate electricity, heat and steam which are then used on site. Currently the main alternatives of advanced technologies for converting biomass to bio-energy are gasification and pyrolysis. Biomass based gasification eliminates heating, electricity consumption from the grid and waste disposal make it a valid investment (Craig and Mann, 1996). In the study region, small scaled gasifiers are commonly used to generate energy and heat for internal use or for sell back to the grid at the time it is generated, especially for those industries producing the biomass. Char produced in gasification process also is a potential for income as a fertilizer or additive.

Purpose

This study focuses on the economic feasibility of producing bioenergy from biomass in small onsite projects under energy market price uncertainty and inter-annual variability of CGW for a risk averse investor. Specifically, I have formulated a stochastic nonlinear mixed integer problem treating outputs prices and CGW quantities as random variables under with three different conversion technology to chose the optimal technology configuration. This investment focuses on smaller producer-investor projects to transform biomass into bioenergy at the \$2-8 million level. It shows very high returns from using only residual biomass at processing facilities and has the potential to encourage rural development locally under very conservative price conditions. Local investors are already interested in this project.

Sample

We use daily wholesale prices data for cotton, Ammonia (Tampa), biodiesel prices (Bloomberg Database), and day-ahead Electricity market for ERCOT South (EIA) from 2009 to 3013. These are data are extremely irregular, thus, we aggregate data to monthly means. All prices are in natural Logarithm. Cotton Gin Waste (CGW) data was provided kindly by Lui and Farmer. Using the available CGW data, we further estimate a Bayesian regression as a quadratic function of rainfall and cotton prices. We choose three chains for the MCMC sampling. Results show, after a period of burn-in, nice mixing properties and convergence. A beta distribution was the best fit to the CGW data.



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Methods

The Granger representation theorem and the Johansen Methodology

$$Y_t = \Phi D_t + \Pi_1 Y_{t-1} + \dots + \Pi_{p-1} Y_{t-p} + \hat{\alpha}_t$$
$$\Delta Y_t = \Pi Y_{t-1} + \Gamma_1 \Delta Y_{t-1} + \dots + \Gamma_{p-1} \Delta Y_{t-p+1} + \Phi D_t + \hat{\alpha}_t$$

$r=0$ $\Pi=0$ All component of Y_t are unit root processes and the VECM(p) reduces to a VAR(p-1)

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \dots + \Gamma_{p-1} \Delta Y_{t-p+1} + \Phi D_t + \hat{\alpha}_t$$

$r=n$ Π Is full rank and thus Y_t is stationary and not cointegrated

$0 < r < n$ Π Is of reduced rank and there are r cointegrating vectors in Y_t with $n-r$ common stochastic trends

$$\Pi = \alpha * \beta'$$
$$\lambda_{transverse}(r | r+1) = -T \log(1 - \lambda_{r+1})$$
$$\lambda_{trace}(r) = -T \sum_{i=r+1}^k \log(1 - \lambda_i)$$

Stochastic Programming *

$$\min_{x \in R^n} c^T x + E \left[Q(x, \xi) \right]$$
$$s.t. Ax = b, \quad x \geq 0$$
$$\min_{y \in R^m} q^T y$$
$$s.t. Tx + Wy = h, \quad y \geq 0$$

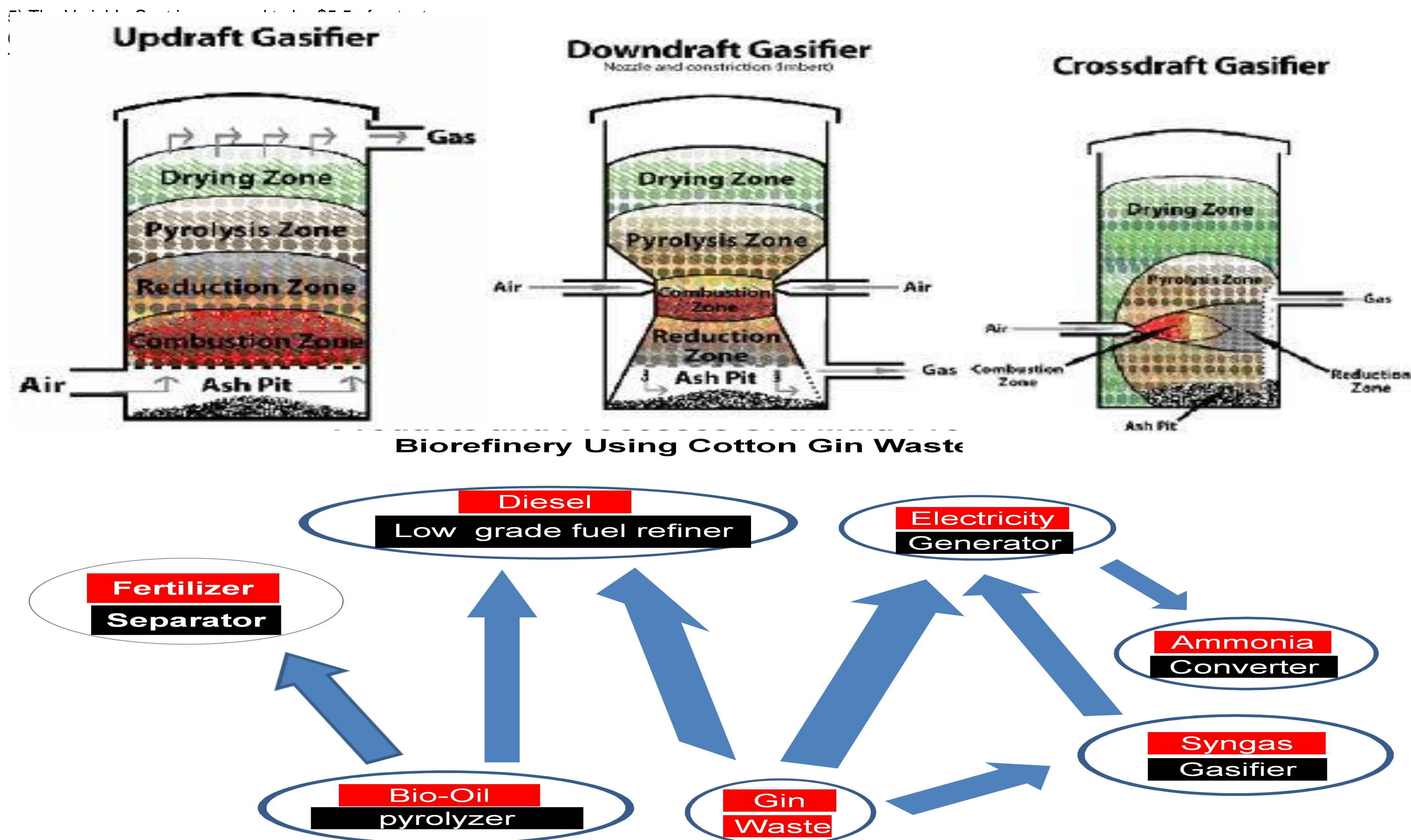
*Is the standard form of a stochastic program. In this study, we, instead maximize the profit function for a risk averse investor . We use both the expected value and the Conditional Value at Risk (CVaR). Our objective function is, then, a weighted average of the expected value of profit π and the CVaR. The objective function is:

$$\max \lambda * E(\pi) + (1 - \lambda) * CVaR(\pi)$$

Assumptions:

- 1)An adaptable technology platform where capacity C is endogenously determined. The proposed platform is made up of a pyrolyzer, a gasifier, and a power generator. Three technology configurations with the same pyrolyser and generator but differ by the type of the gasifier. We consider the Updraft, Downdraft, and crossdraft gasifiers. Below are figures that illustrates the conversion of biomass. The first figure shows the three types of gasifiers considered in this study. The second figure retraces possible process pathways to produce bioenergy. We discriminate among technologies using binary variables.
- 2) One ton of CGW yields one MWh of power.
- 3) The total bioenergy produced is less or equal the CGW quantity available given the rainfall of a given year.
- 4) The Fixed Cost (FC) has the empirical formula($\frac{4000000}{1.2 * C + 5} + 640000$)*C which gives an average fixed cost as a function of capacity C (Multer et al., 2010), financed assuming

a 12-year payback with a 10% interest rate in which 75% of total fixed cost fixed costs. We further assume a FC of \$700,000 for a biodiesel unit, and a FC of \$300,000 to produce ammonia all self-financed.



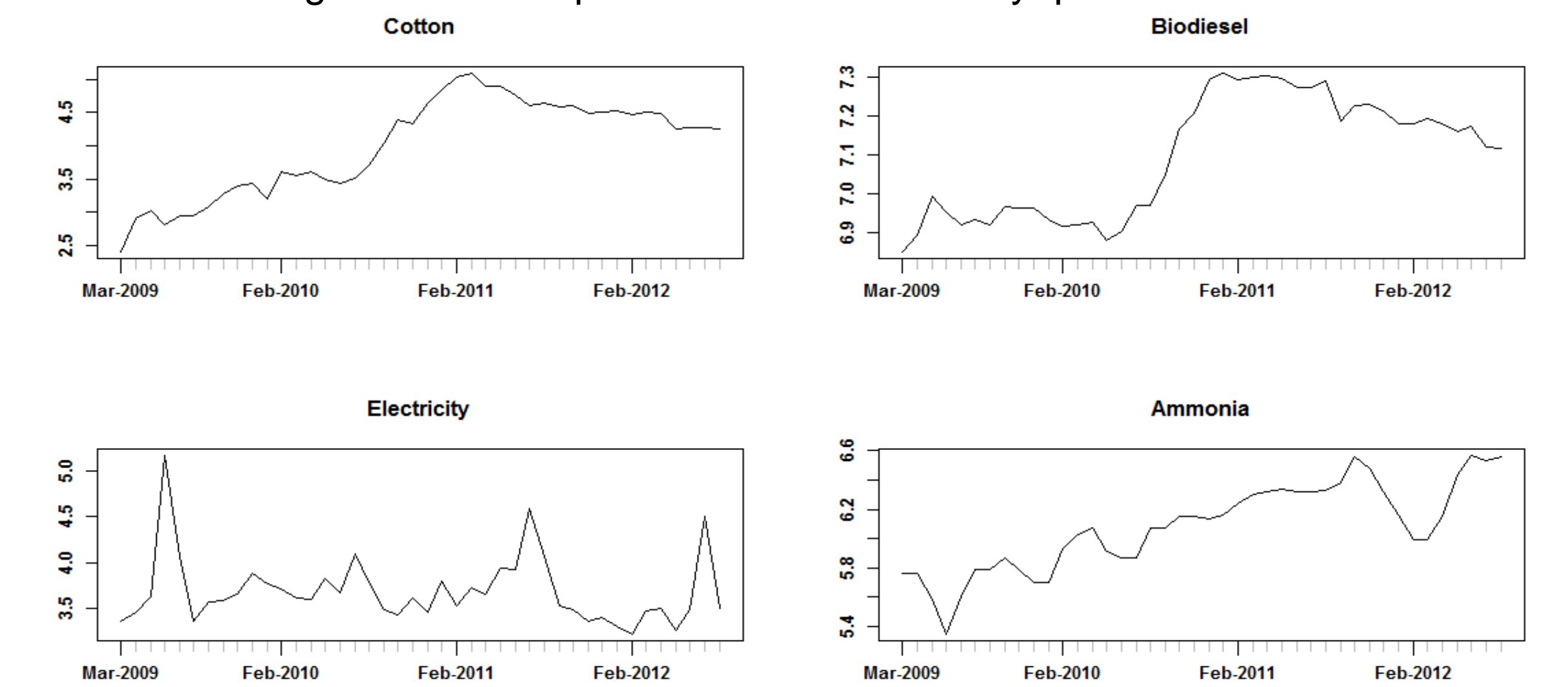
DCC-GARCH Model (Engel, 2002)

$$h_t = \alpha_0 + \sum_{i=1}^p \beta_i h_{t-i} + \sum_{j=1}^q \alpha_j \hat{\rho}_{t-j}^2$$
$$H_t = Var(u_t | F_{t-1})$$
$$H_t = D_t R_t D_t$$
$$D_t = diag \left(\frac{1}{h_{1t}}, \dots, \frac{1}{h_{nt}} \right)$$
$$R_t = (I_n \otimes Q)^{1/2} Q (I_n \otimes Q)^{1/2}$$
$$Q_t = (1-a-b)Q + a \xi_{t-1} \xi_{t-1}' + b Q_{t-1}$$
$$a+b < 1$$
$$\xi_{it} = u_{it} / \sqrt{h_{it}}$$
$$R_t = Q_t^{-1} Q Q_t^{-1}$$
$$\bar{Q} = Cov(\hat{\alpha}_t^T) = E[\hat{\alpha}_t^T \hat{\alpha}_t^T]$$

Results and discussion

Unit Roots tests: ADF, PP, KPSS

Cotton and biodiesel are non-stationary under ADF, PP, and KPSS. While both electricity and ammonia are stationary under ADF test, they are not the PP test. The KPSS test gives a clear cut answer that electricity and ammonia are stationary. To see this we go back to the plots of these commodity prices.



From these plots it is clear that both cotton and biodiesel have stochastic trends. The electricity is rather mean-reverting, and thus stationary, while ammonia is trend-stationary .i.e. deterministic trend. These confirms results of the ADF and KPSS unit root tests.

Johansen Cointegration tests:

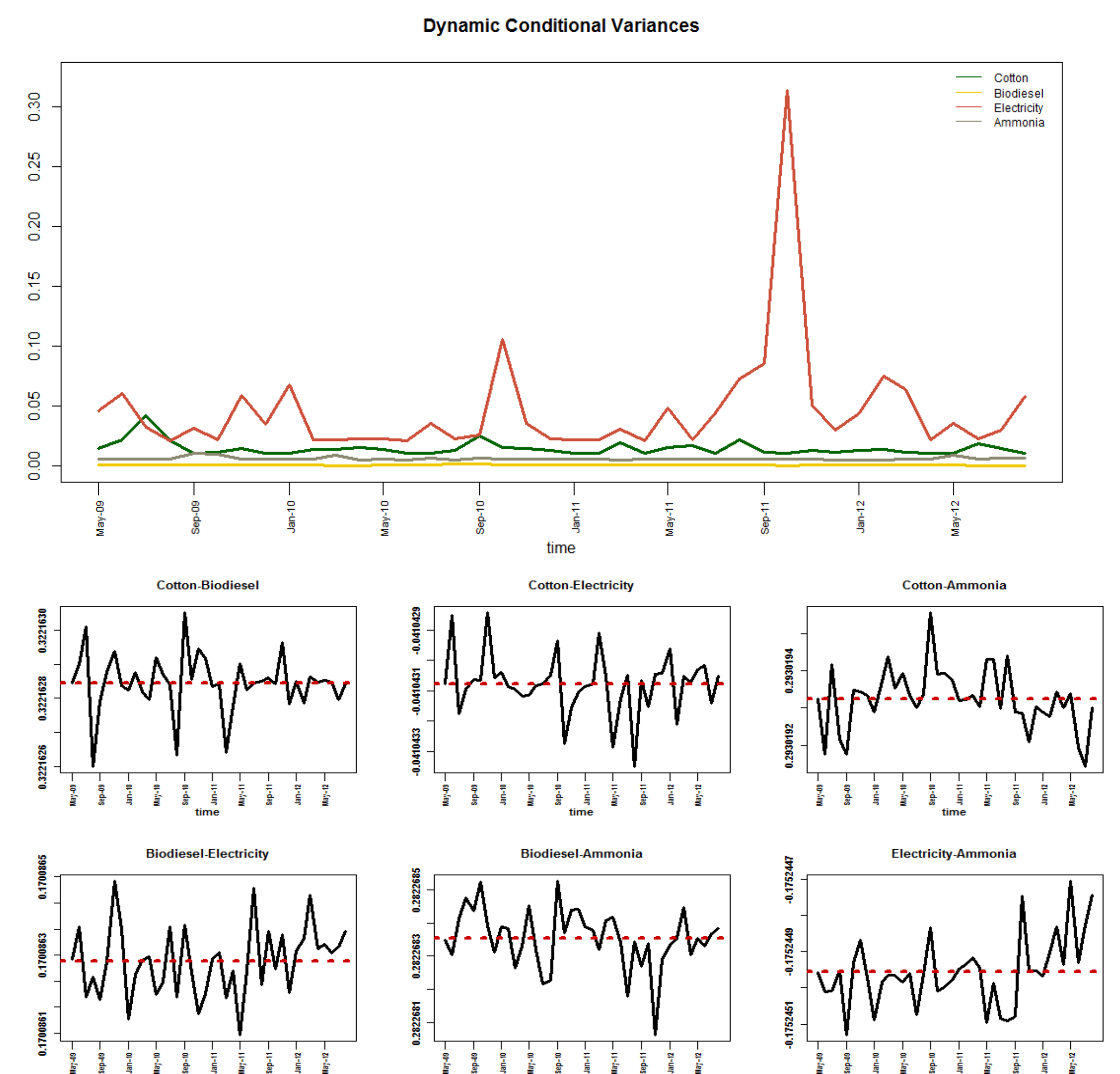
The trace test (49.42) is significant at the 5% CV (48.28), while the max eigenvalue test (26.12) is weakly significant at the 10% CV (24.78)

DCC-GARCH

Stability DCC $a+b < 1$

$\alpha + \beta$ is far less than 1 this implies low persistency in variances. The spikes in electricity variance are due to seasonality.

The following graphs show the development of variances and DCC



Stochastic Optimization

We draw 50 samples from the estimated VAR, each with 100 observations. This accomplished the convergence of our pregame: The optimal capacity was 11 MW. With an objective function of \$2,252,674. The optimal products mix are: 1,232 MWh for peak load, 5,464 MWh for base load, 2,235 ton for biodiesel, and 2,117 ton for ammonia. The average CGW input was 2,127,494 ton

Conclusions

Taking into account the variability of CGW in West Texas due to recurrent droughts and the uncertainty of market prices of outputs. A risk averse investor, with a reasonable investment, would have all benefit to invest in green energy to take advantage of local market opportunities given the weak comovement of the four markets, and low variances and contagion through low DCC of products portfolios



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