Dynamic Dividend and Investment Decisions in Value Added Firms: An Application to Farmer Owned Ethanol Plants

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by
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Abstract

The paper analyzes the dynamic interaction between dividend and investment by adopting numerical methods in a growth framework. Two benchmark models are introduced and their modified version for ethanol production is particularly studied. The transition path supports the trend of smoothing procedure and approximately follows plant's life cycle. After ethanol plants achieve the mature size, impulse response functions and moment properties for dividend and investment associated with margin shocks and interest rate shocks are computed numerically. The result suggests that investment amount is adjusted in wide range and dividend decision is highly associated with cash flows available in ethanol plants.

Key Words: dividend, investment, and numerical method

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Introduction

In U.S. agriculture, there is an increasing interest, along with public support, in creating farmer-owned or controlled value added (VA) businesses as a means to increase farmer's income and economic activity in rural areas. The past decade has witnessed the rapid growth of ethanol industry, a typical type of value added business. According to the Renewable Fuels Association (Feb 2005), 68-ethanol production facilities are operating and other 16 plants are expanding or under construction in the United States. These plants achieve a total production capacity of more than 4.4 billion gallons annually in the United States, up more than 20 percent from the capacity in 2004. In 2004, the national ethanol industry will consume 1.35 billion bushels of corn, or 13 percent of expected 2004 corn production.

Two features distinguishing the VA business from others are outstanding. New VA businesses are almost always closely held and organized as closed cooperatives, LLC and S-corps, in which the new equity issues are highly limited in their amount often regarded as one type of financial imperfection. As a result, the financial debt borrowing subject to the optimal borrowing contract with lenders determined exogenously outside of VA businesses plays a critical role in their financial decisions. On the other hand, most of VA businesses produce a mix of commodities, such as ethanol, DDGS and other simple food products in ethanol production, with the primary agricultural yields, such as corn, soybeans, wheat, etch. Due to the uncertainty of commodities prices, we would expect a narrow margin business with a high level of volatility. Given the homogeneity of technology across industry, the margin shocks cause the uncertainty of income in the VA businesses to a large degree.

Since the motivation for farmers to invest in VA businesses is to increase current cash income, and since they are closely held, it is fairly reasonable to presume farmers would prefer dividends to capital gains even though the tax spread effect had not been taken into consideration. Furthermore, equity held in closely held firm is not very liquid. As a result, the relatively higher dividend payment ratio is expected in the steady state of VA business at which the investment decision and financial decisions, namely dividend and financial borrowing decisions, are undergoing no changes. A high dividend payout rate however, is likely to limit future earnings by curtailing investment and possibly productivity if there are economies of size and scope when the short-term debt affected by interest rate shock is not sufficient to satisfy the investment gap.

The paper focuses on resolving two questions. First, how does the dividend decision interact simultaneously with investment decision and financial borrowing decision when ethanol

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production businesses are undergoing growth from small scale to big scale? We could use transition trajectories they need to pursue associated with the growth of businesses to demonstrate the dynamic outcome. Second, how much degree of variability will the dividend payout ratio, investment amount and other key variables show respectively around the mature period? These two questions throughout the life of ethanol plants draw our attention extensively from the practical perspective of business management.

Keeping the forgoing properties of VA businesses in mind, we are attempting to apply the rational expectation model widely used in macroeconomics fields to study the dynamic behavior of dividend, investment decisions and other interesting flow variables during growth periods and their corresponding moment features around the steady state afterwards in ethanol production businesses. The impulse responses functions associated with 1 percent change in margin shocks or interest rate shocks help us better understand the essence of internally dynamic decisions as well. By making use of the Toolbox package, we are able to simulate many different sample shocks to analyze the effects the key variables are experiencing. However, all of the analysis and results obtained are on the bottom of the fact that we could exactly identify the steady states of linear rational expectation model.

The remaining of the paper proceeds as follows. Section 2 summarizes the literature review on dividend policy. Three types theoretical models are developed and their numerical growth solutions are calibrated as well in Section 3. Section 4 does the post optimality analysis on the moment effects around the steady state. Finally, concluding remarks are presented in section 5.

Literature Review on Dividend Policy and Investment Decision

The earliest dividend research in the common corporate firms yields several seemingly conflicting principles and theories with respect to the influence of dividend payment behavior on share prices and investor's wealth. Standing in the middle position, the most distinguished theory developed at that time is Miller-Modigliani dividend irrelevance proposition (1961) in that dividend policy should not affect firm's value in a perfect capital market given the fixed investment policy. One of the key implications is the independent relation between optimal investment decision and financial decisions in a firm, particularly the dividend decision and debt evaluation. The underlying support for the independence comes from the fact that the firm can search for the outside financing without transaction cost to fund the remaining investment opportunities. Deviating from the perfect capital market, many other researchers try to disclose the certain interdependence or contingency between them. This paper focuses on studying the dividend and investment decisions from the point view of practical management to attain the achievable numerical solutions rather than discover possible theories.

The residual dividend model derived from the practical management is an outgrowth of the irrelevancy of dividends in MM's world. It presumes that a firm will pay out dividends to outside investors only when its internally generated earnings are not completely consumed for potential investment opportunities. The firm has to determine the amount of equity needed given investment requirement and target capital structure in the first place. Under the residual model, dividends are set as follows: Dividends = Current Net Earnings - Target Equity Ratio * Investment Requirement. The better the firm's investment opportunities implies the lower the dividend payment, which would lead to high volatility of dividend payment inconsistent with the empirical dividend smoothing fact. To overcome the disadvantage of instability, the modified residual model applies future earnings and investment opportunities to adjust long-term target payout ratio so as to generate smoothing dividends. Consistent with the pecking order argument of Myers and Majluf (1984), firms experiencing high growth rates should also be characterized by low payout ratios in line with residual model.

The earliest practicable dividend decision model could be found in Lintner's survey (1956) in which the dominant patterns of dividend decision making observed in field work was characterized simply by fixed target pay-out ratio and standardized speed-of-adjustment factor. The paper revealed the fact that the managers are much more concerned with changes of dividends than their magnitude, which indicates the dividend smoothing policy of changing dividends by only part of the amounts as a result of changes in current financial figures. It has also been shown that net earnings should serve as the primary financial determinant of the volume of dividends due to its publicity and reasonable persuasiveness. Hence, the proposed simple model takes the following form: Dividend Changes = Constant Adjustment Factor * (Target Payout Ratio * Net Earnings – Last Dividend Payment). The statistical tests have been done subsequently producing significant results as to the adequacy and reliability of this model. Lintner asserted that the maintenance of established stable dividend policy was a much more important task than fulfilling working capital requirements and investment opportunities. A clear distribution sequence came into being under his context in the sense that the remaining indispensable investment projects have to resort to external financing after dividends have been increased in line with established policies. It is obvious that this sequence is exactly converse to that of residual dividend model by weighting dividend smoothing much heavier. But he did not consider the case in that the outside financing is completely restricted and then the competition among different uses should be anticipated. From our intuition, this competition will incur the simultaneous interaction among dividend smoothing, optimal investment and other financial decisions.

By retrospection on the question why firms pay dividends, free cash flow hypothesis (e.g., Easterbrook (1984), Jensen (1986), Lang and Litzenberger (1989), Zwiebel (1996)) that addresses the agency problem between insider controllers and outside investors comes to be a better explanation for the functional role of dividends policy. It highlights the phenomenon that when faced with free cash flow, inside managers can engage in non-profitable investment on self-serving projects rather than distribute the cash to shareholders. The agency approach presumes the interdependence between investment policy and dividend payout, moving away from the assumptions of dividend irrelevance theory. It renders us the theoretical cornerstone to investigate the simultaneous interaction between optimal dividend policy and investment decision given the external financing constraint and the growth desire. Furthermore, due to the relative intimate relation among members, board of directors and managers, it is generally true that use of dividends as information content signal is much more expensive and costly. Hence, concentrating on the pattern of dividend payment in closed cooperatives, we consider free cash flow hypothesis to be more appropriate than dividend signaling theory or other related theories.

Appreciating the interdependence between dividend and investment, the recent Fairchild's paper (2003) employed the Gordon growth model to examine the trade-off between level of dividends and optimal re-investment under deterministic and stochastic cases by maximizing the firm's value. It postulated that all of the remaining income was re-invested after paying dividends and the optimal retention ratio was fixed each period, given strictly constrained external financing. Hence, the dividend payment and investment varied correspondingly to changes of net income in each period. The simplified assumptions and value function made it easy to derive the optimal level of dividends and investment as a function of the cost and expected return of equity. The paper did provide obviously a practical management tool for dividend policy, but the assumptions of constant retention ratio and simple value function appeared too strong and naive without involving required dynamic considerations.

The optimal dynamic growth model starting from Ramsey is widely applied to macro growth analysis on an economy with the aim to find the transition trajectory to the steady state. Its stochastic counterpart is adopted to demonstrate the real business cycles theories. The challenging work of this paper is to establish a consolidated framework that involves the smoothing dividend competing simultaneously with other uses of earnings under the uncertainties of income. We are employing the rational expectation model particularly adaptable for the closed ethanol cooperatives to derive numerically the transition path for optimal investment and smoothing dividends. The post optimality analysis around the steady state of ethanol production such as impulse response functions associated with margin shocks and financial interest shocks are numerically calibrated as well. The simultaneous interaction among smoothing dividends, optimal investment and financial borrowing under external margin shocks is highlighted effectively in our framework.

Dynamic Models and Numerical Results

In this section we adjust the one-sector neo-classical growth model of optimal capital accumulation to the ethanol production by taking external financial borrowing and margin uncertainties into account. Two benchmark models are introduced and numerically computed first and their preliminary results provide us useful information for further modification in ethanol production.

Benchmark Model without Financial Borrowing

Our benchmark model comes from the slight modification of the stochastic growth example of Brock and Mirman (1972), which turns out to be the cornerstone in the macroeconomic field. It is a problem of a central planner in a closed economy populated by a large number of identical households and endowed with a production technology that transforms capital into consumption and investment goods. The planner seeks to maximize the expected lifetime utility of the representative household by choosing a sequence of consumption and capital stock. Its mathematical representation is summarized as follows:

$$\max_{\{D_t, i_t\}_{t=0}^{\infty}} \left[E_0 \sum_{t=0}^{\infty} \beta^t \frac{D_t^{1-\sigma}}{1-\sigma} \right] \tag{1}$$

$$\theta_t k_t^{\alpha} \geq D_t + i_t \tag{2a}$$

$$i_t = k_{t+1} - (1-\delta) k_t \tag{2b}$$

$$\ln \theta_{t+1} = (1-\rho^{\theta})\theta + \rho^{\theta} \ln \theta_t + \varepsilon_{t+1}^{\theta} \tag{2c}$$

$$k_0 \text{ Given} \tag{2d}$$

The discrete lifetime utility function in equation (1) indicates that the representative agent derives utility only from the consumption of dividend goods in each period. Households discount future utility at the rate implicit in the discount factor δ. The cash flow budget constraint in equation (2a) says that at any time, the sum of dividend and investment, $D_t + i_t$, must not exceed the total amount of output arising from exploiting the Cobb-Douglas technology. The output depends on the capital share in output α, and the productivity shock θ_t. The investment equation (2b) specifies the law of motion of the capital stock with δ indicating the rate at which the stock of capital depreciates in every period. Equation (2c) is the forcing process governing the productivity shock's dynamics whose log value follows one period lag AR process with a normal distribution residual error.

Identifying the strict equality of budget constraint at the optimum, we could derive the first order conditions for the problem as:

$$MUC_t = \beta E_t \left[MUC_{t+1} \left(1 + \alpha \theta_{t+1} k_{t+1}^{\alpha-1} - \delta \right) \right] \tag{3a}$$

$$\theta_t k_t^{\alpha} = D_t + k_{t+1} - k_t (1 - \delta) \tag{3b}$$

$$\ln \theta_{t+1} = \left(1 - \rho^{\theta} \right) \theta + \rho^{\theta} \ln \theta_t + \varepsilon_{t+1}^{\theta} \tag{3c}$$

in which $MUC_t \equiv D_t^{-\sigma}$ in equations (3a) is the marginal utility of consumption at time t.

The solution to the model is a sequence $\{k_{t+1}, D_t\}$ that satisfies the optimality conditions (3) given the productivity shocks $\{\theta_t\}$ and initial conditions. By using the rational expectation model package in Miranda and Fackler (2002), we can easily obtain the numerical simulation results for dividend policy, investment policy and capital stock transition paths by applying the simple parameter values the same as in package to the model. Figure 1 presents the flat accumulation process of capital stock that leads to the growth of economy. The expected investment policy in figure 2 goes up rapidly and then drops slowly to the optimum. The result suggests the increasingly smooth trend in dividend policy in a three dimensional vision from figure 3.

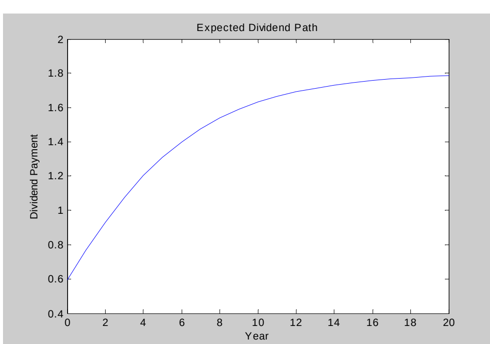

Figure 1: Expected Capital Stock Path

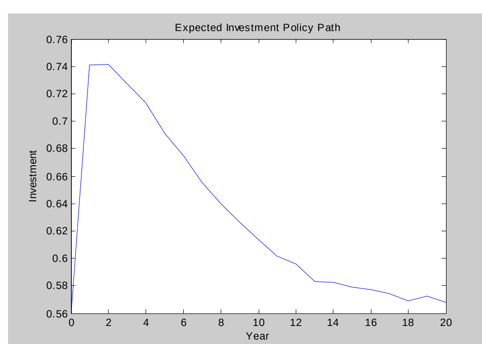

Figure 2: Expected Investment Policy

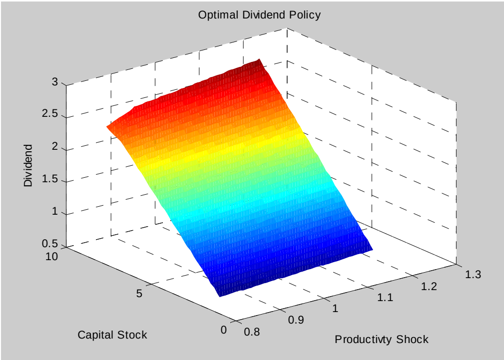

Figure 3: Dividend Policy

Benchmark Model with Financial Borrowing

In this subsection we will extend the previous model to the firm level and make it more realistic and flexible by allowing for the financial borrowing. The deviation from the Miller-Modigliani dividend irrelevance theorem due to the extensive presence of incomplete capital market, we argue that financial borrowing and its corresponding leverage ratio might play a certain role in dividend and investment decision. The foregoing model is appropriately modified as:

$$\max_{\{D_t, i_t, b_{t+1}\}_{t=0}^{\infty}} \left[E_0 \sum_{t=0}^{\infty} \beta^t \frac{D_t^{1-\sigma}}{1-\sigma} \right] \tag{4}$$

$$\theta_t k_t^{\alpha} + b_{t+1} - b_t \geq D_t + i_t + r_t b_t \tag{5a}$$

$$i_t = k_{t+1} - (1-\delta) k_t \tag{5b}$$

$$\theta_{t+1} = \bar{\theta} + \rho(\theta_t - \bar{\theta}) + \varepsilon_{t+1} \tag{5c}$$

$$(b_0, k_0) \text{ Given} \tag{5d}$$

From the perspective of individual firm and its stockholders, equation (4) the same as the last one indicates that the equity value is the sum of the expected discounted stream of dividends D. All of the utilities of stockholders are derived from the dividends rather than the capital gains in the long run. The only difference between above two models is the inclusion of one period expiration short-term debt in equation (5a) that requires that the last period debt much be paid out in the current period. This short-term borrowing allows the firm to resort to the external finance in the case of expansion in good state and negative cash flow in bad state. The firm size indexed by the capital stock is likely to grow rapidly to arrive at the steady sate of firm production without restriction or price penalty on the leverage ratio in the sense that the firm can borrow as much as what they want. Even though the underlying assumption seems implausible, we do witness the coincidence for this type of growth in ethanol production industry. Some ethanol-producing firms, like Hawkeye Company in Iowa Falls, expand very fast to achieve their mature size in a very high leverage ratio. More and more external investors and financial institutions will be involved in ethanol industry due to its prosperous future particularly accelerated by the government policy.

The optimality conditions derived from the first order conditions consist of four equations in (6) that are sufficient for us to obtain the numerical results for four unknown equilibrium sequences $\{\theta_t, k_{t+1}, b_{t+1}, D_t\}$:

$$MUC_t = \beta E_t\left[MUC_{t+1}\left(1+\alpha\theta_{t+1}k_{t+1}^{\alpha-1}-\delta\right)\right] \tag{6a}$$

$$MUC_t = \beta E_t\left[MUC_{t+1}\left(1+r_t\right)\right] \tag{6b}$$

$$\theta_t k_t^{\alpha} + b_{t+1} - b_t = D_t + k_{t+1} - k_t\left(1-\delta\right) + r_t b_t \tag{6c}$$

$$\theta_{t+1} = \left(1-\rho^{\theta}\right)\theta + \rho^{\theta}\theta_t + \varepsilon_{t+1}^{\theta} \tag{6d}$$

One more control variable financial borrowing $\{b_{t+1}\}$ is added in this model and all else are held the same as the previous model. Adopting the same parameter values and the fixed short-time interest rate 6%, we are able to compute the numerical results again for the modified system. Since financial borrowing can be used either in compensating investment or in distributing dividends when the firm is in short of internal funds, we would expect the sharp increase in financial borrowing to the optimum value thus the firm depends largely on external borrowing for the expansion. Three policy transitions for borrowing, investment and dividend are shown in figure 4, 5 and 6.

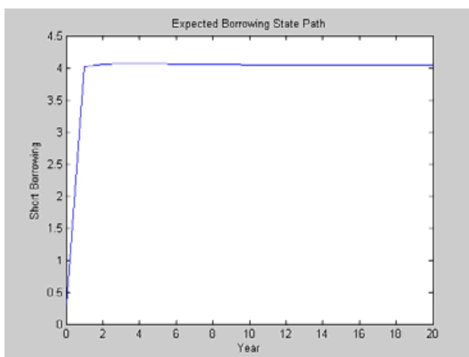

Figure 4: Expected Borrowing State Path

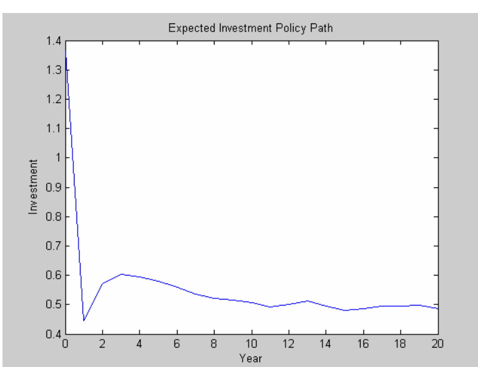

Figure 5: Expected Investment Policy

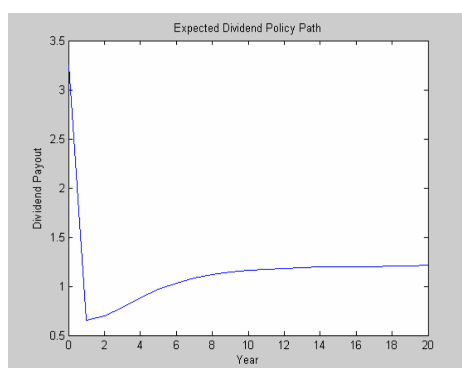

Figure 6: Expected Dividend Policy

Dynamic Model Applied in Ethanol Production

Given the sharp growth of short borrowing in first period or the argument that the firm largely depend on the external financial source to finance the capital, it is more common to impose the non-price or quantity restriction on short borrowing so as to bring us more realistic smooth growth path for capital, borrowing, investment and dividend. Even though we are not able to derive the closed form solution for the theoretical model, it is still possible to compute the numerical results and simulate the dividend and investment transition paths. The basic setting of the model is exactly the same as the preceding model except one more constraint on the short-term borrowing:

$$\max_{\{D_t, i_t, b_{t+1}\}_{t=0}^{\infty}} \left[E_0 \sum_{t=0}^{\infty} \beta^t \frac{D_t^{1-\sigma}}{1-\sigma} \right] \tag{7}$$

$$\theta_t k_t^{\alpha} + b_{t+1} - b_t \geq D_t + i_t + rb_t \tag{8a}$$

$$b_{t+1} \leq \Gamma \cdot k_{t+1} \tag{8b}$$

$$i_t = k_{t+1} - (1-\delta)k_t \tag{8c}$$

$$\theta_{t+1} = \bar{\theta} + \rho(\theta_t - \bar{\theta}) + \varepsilon_{t+1} \tag{8d}$$

$$(\theta_0, b_0, k_0) \text{ Given} \tag{8e}$$

In contrast with the preceding benchmark models, we are proposing two significant distinctions that make our model more applicable to ethanol production firms. First, the extra constraint (8b) imposes an upper bound to the leverage rate in order to effectively limit the sharp growth in debt. As a result, the numerical results will generate more smooth transition paths for dividends and investment. Second, the productivity shock will be treated and simulated as margin shock in the analysis. The price uncertainty happens more frequently and crucially in the ethanol agricultural business rather than the productivity income shocks since the production technology is quite stable and fixed in dry mill ethanol plants. However, productivity shocks were studied widely in the macro real business cycle models. Therefore, the margin shock highlighted in this model comes from randomness of the difference between output price and input price given the fixed technology. Specifically studying ethanol industry, we investigate the ethanol price, distillers dried grains with solubles (DDGS) price, corn price and natural gas price as the major issues contributing to the margins.

The equilibrium conditions for the new modification is quite the same as the forgoing model, but the programming codes are changed in order to take the leverage upper bound (8c) into account. Furthermore, the parameter values suited for ethanol production need to be calibrated very carefully.

The numerical method requires parameter values for $\{\beta, \sigma, \delta, r, \Gamma, \alpha, \rho, \bar{\theta}, \tau\}$. Following most dynamic investment studies since Kydland and Prescott (1982), we set the discount rate β as 0.9 and the depreciation rate δ to 0.1. The fixed short-term interest rate r is equal to $\left(\frac{1}{\beta} - 1\right)$, i.e., 11 percent for each period. The intertemporal elasticity coefficient σ is set to 0.4 to be consistent with the forgoing two models. To be conservative, the leverage upper bound Γ for the ethanol plants is given the value 60 percent.

How to calibrate the reasonable capital share in production function is critical to our dynamic analysis. Gallangher, Brubaker and Shapouri (2005) estimated the plant size and capital cost relationships in the dry mill ethanol industry from the survey data. The simple log-linearization: estimates were obtained using least squares:

$$\ln(K) = 0.85 + 0.84\ln(Y)$$

The corresponding production function can be retrieved as:

$$Y = 0.364 \cdot K^{1.19}$$

However, this result did not provide us the plausible numerical result that can be applied to the model. Since the power for capital in production function is greater than 1, it indicates the ethanol industry is experiencing increasing returns to scale and lower capital cost associated with one unit increase in output. This result is completely opposite to our presumption about the production function that has to be decreasing returns to scale to obtain the convex constraint set. Otherwise our dynamic system will not be convergent in that the further expansion in plant size always results in greater dividends and utilities. Another output-unit capital cost estimates were obtained in the same context:

$$K/Q = 1.97 - 0.034 + 0.000264Q^2$$

The quadratic estimate of minimum unit costs suggests a range of decreasing costs followed by increasing cost. Since most of the plant sizes involved in the survey are strictly less than the optimal capacity that results in minimum unit cost, the overall characteristics of power production function turns out to be increasing returns to scale. We need to be aware that some of current plant sizes are rapidly expanded beyond the range of minimum unit cost in the sense that they are more likely to undergo the increasing cost stage given the adoption of constant technology. In addition, we argue that assembly costs associated with corn might increase with scale and overwhelm decreasing economies of production. With more and more ethanol plants constructed within the same corn production region, they have to compete with each other and go further to gather corn in case of plant expansion. If we take both factors into account, we would expect the desirable production function with power less than 1.

The following strategy is used to compute the capital coefficient: we use the Monte-Carlo simulation tool to generate the second stage capacity and cost data from the previous quadratic function and estimate the log-linerization production function again. Based on 5000 simulations we obtain the histogram of the capital share estimate (Figure 7) and the mean of capital share is equal to 0.391337. Therefore, the magnitude of α is set to 0.4. Moyen (1999) estimates the sensitivity parameter α as 0.45 from annual COMPUSTAT data.

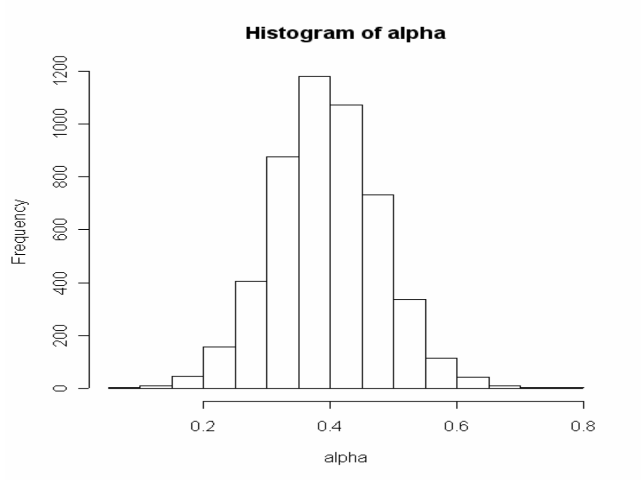

Figure 7: Histogram of Capital Share Coefficient.

According to the Iowa Value Added Resource Manual (Bryan, Inc. 2000), dry mill ethanol process converts corn into ethanol according to the following input-output relationship: 1.0 bushel (bu) of corn and 0.165 million British thermal units (mmBtu) of natural gas can produce 2.7 gallon of ethanol and 17 pounds of distillers dried grains with solubles (DDGS). Projected commodity price levels and the fixed proportions of technology determine the guaranteed level of gross margin according to the following formula (Paulson, 2004):

$$MarGuar = \frac{1}{12}\left(2.7 * \sum_{t=1}^{12} ETHP_t + 0.0085 * \sum_{t=1}^{12} DDGP_t - \sum_{t=1}^{12} CORNP_t - 0.165 * \sum_{t=1}^{12} NGP_t\right)$$

If we normalize the ethanol output into one unit, we can derive the following total margins:

$$Mar = \frac{1}{12}\left(\sum_{t=1}^{12} ETHP_t + 0.0032 * \sum_{t=1}^{12} DDGP_t - 0.37 * \sum_{t=1}^{12} CORNP_t - 0.061 * \sum_{t=1}^{12} NGP_t\right)$$

It is easy to obtain monthly price data for ethanol, corn and DDG. But the monthly data for natural gas is quite restricted in old years. The net margins are reported from 1982 to 2004 in Figure 8. According to the margin shock process of equation (8d), we obtain the least squared estimators for persistence ρ, steady state mean $\bar{\theta}$ and volatility τ based on our 22 periods yearly data:

$$\theta_{t+1} = 0.80 + 0.45(\theta_t - 0.80)$$

Hence, we set persistence ρ to 0.45, steady state mean $\bar{\theta}$ to 0.80 and volatility τ to 0.17. The normality of residuals can also be visualized in Figure 9. The straight line suggests the normal distribution assumption is well satisfied.

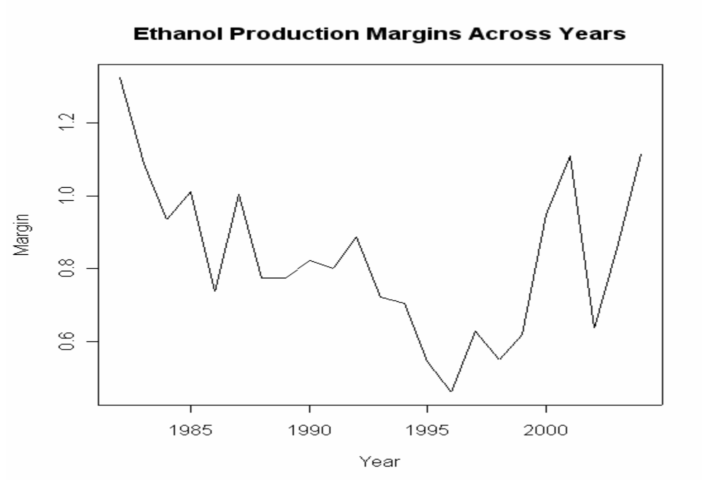

Figure 8: Ethanol Margins Series

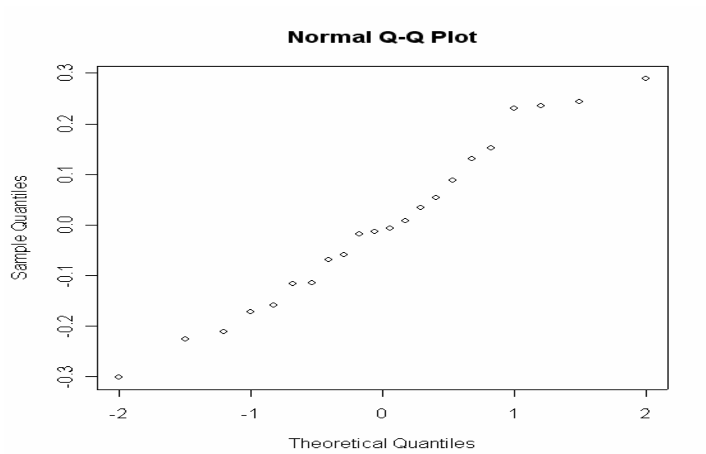

Figure 9: Normal Plot of Residuals

The numerical results using the tool kit (Miranda and Fackeler, 2002) are compatible with the expectation of behavior of investment and dividend in ethanol plants. The result presents the common features of the capital accumulation, dividend payment policy like those in the first benchmark model and short-term debt variations associated with different stochastic realizations of margins.

The transition path of dividends in Figure 10 obtained from the average of 1000 simulations of random process strongly supports the trend of smoothing procedure of dividends throughout the life of ethanol plants, which is consistent with Lintner's survey (1956). Lintner revealed the smoothing procedure of dividends as a stylized fact extensively true from managers' perspective so that managers would be quite reluctant to deduct the dividend payment unless the particularly well-known market information enforced them to do. The optimal growth model proposed in our framework successfully guarantees the smoothing procedure of dividends that plays the same role as consumption in the general macroeconomic context.

Furthermore, we find that the average optimal dividend is following plant's life cycle. According to life cycle propositions, firm's successful expansion usually undergoes four sequential phases: start-up, growth, maturity and exit. It is recognized that the dividend policy tends to be adjusted properly to track the life cycle since it should reflect firm's investment opportunities and access to both internal and external funds. Early in the life cycle, when investment opportunities are plentiful and funding limited, firms tend to pay out very few dividends. Later on, as cash flows from internal investments increasing and new investment opportunities dropping off, the capacity to pay dividends increases gradually. Our dynamic model does accommodate the life cycle pattern by implicitly imposing the simultaneous interaction between smoothing dividend and optimal investment under the growing background. At start-up stage starting from initial period 0 to period 2, firms do not generate large cash flow yet, so they pay small fraction of dividends. The growth stage roughly runs from period 3 to period 6 in which they generate a certain cash flows and dividend payment is continuous increasing. But over the mature growth stage from 8 shown on the Figure, ethanol plants have larger cash flows and fewer available projects so that they are apt to pay a high proportion of earnings to members.

From the simulated transition paths for capital stock, dividend and financial borrowing, we find that the acceleration role played by financial borrowing is fairly reduced and the upper bound of leverage ratio provides us smooth growth in capital stock and dividend. Since the leverage ratio cannot exceed 60 percent in each period, the ethanol plant has to gradually accumulate its external debt and arrive at steady state borrowing amount finally.

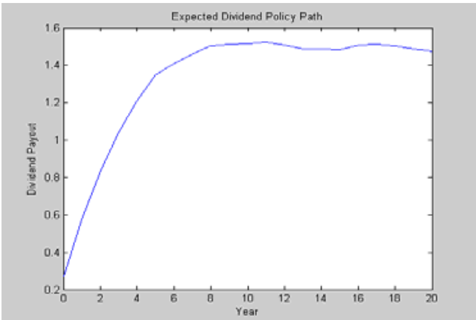

Figure 10: Expected Dividend Policy

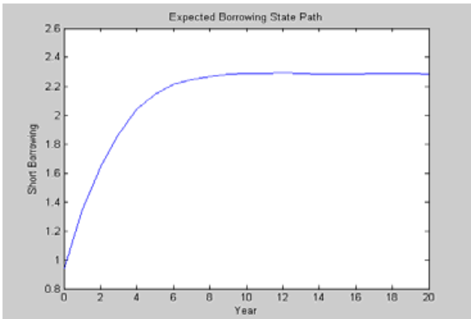

Figure 11: Expected Borrowing Path

Post-Optimality Analysis

After the ethanol plants achieve their steady state, we would further examine the treatment effects on borrowing, dividend and investment decisions given the exogenous margin and interest rate shocks. In this section we are trying to numerically compute how much degree of variability the dividend payment, investment amount and other key variables will present respectively over the mature period.

Model Setup

Given the properties in ethanol businesses, we use the rational expectation framework again to study the dynamic moment features capturing the dividend, investment decisions and other interesting flow variables around the mature stage. Except for the margin shocks like in previous model, we are able to add the additional interest rate shocks in our model setting. The impulse responses functions associated with 1 percent change in margin shocks or interest rate shocks help us better understand the essence of internally dynamic decisions from the other perspective. By making use of the Toolbox package from Oviedo (2005), we are able to simulate many different sample shocks to analyze the effects the key variables are experiencing. Since all of the analysis and results are based on the bottom of the fact that we could exactly identify the steady states of linear rational expectation model, we call our work in this time interval as the post-optimality analysis. We will follow Oviedo's approach to compute impulse response functions and moment properties for key interested variables that are associated with margin shocks and interest rate shocks around the steady state.

The ethanol firms maximize the equity value subject to random variations of margin and short-term interest rate by choosing the dividend, investment and debt policies:

$$\max_{\{D_t, k_{t+1}, b_{t+1}\}_{t=0}^{\infty}} \left[E_0 \sum_{t=0}^{\infty} \beta^t \frac{D_t^{1-\sigma}}{1-\sigma} \right] \tag{9}$$

The objective function (9) is subject to the following constraints in each period:

$$\theta_t k_t^{\alpha} - \Psi(i_t, k_t) + b_{t+1} - b_t \geq D_t + i_t + r_t b_t \tag{10a}$$

$$r_t - r_t^* = \omega(b - b_t) \tag{10b}$$

$$i_t = k_{t+1} - (1-\delta)k_t \tag{10c}$$

$$\theta_{t+1} = (1-\rho^{\theta})\theta + \rho^{\theta}\theta_t + \varepsilon_{t+1}^{\theta} \tag{10d}$$

$$r_{t+1}^* = (1-\rho^r)r + \rho^r r_t^* + \varepsilon_{t+1}^r \tag{10e}$$

$$(b_0, k_0) \text{ Given} \tag{10f}$$

The capital adjustment cost is taken into account because its inclusion reduces the variability of the capital stock particularly in the presence of unrestricted financial borrowing. It is a function of net investment in which ϕ is the cost parameter and $(1-\gamma)$ is the depreciation rate of capital:

$$\Psi(i_t, k_t) = \frac{\phi}{2}(i_t - (1-\gamma)\cdot k_t)^2 = \frac{\phi}{2}(k_{t+1} - k_t)^2 \tag{11}$$

After substituting i_t and r_t from equations (10c) and (10b) into equation (10a) respectively, the first order conditions of the problem are:

$$\left(1+\phi\left(k_{t+1}-k_{t}\right)\right)MUC_{t}=\beta E_{t}\left[MUC_{t+1}\left(1+\alpha\theta_{t+1}k_{t+1}^{\alpha-1}+\phi\left(k_{t+2}-k_{t+1}\right)-\delta\right)\right] \quad (12a)$$

$$MUC_{t}=\beta E_{t}\left[MUC_{t+1}\left(1+r_{t+1}^{*}-\omega\left(b_{t+1}-b\right)\right)\right] \quad (12b)$$

$$A\theta_{t}k_{t}^{\alpha}-\Psi\left(i_{t},k_{t}\right)+b_{t+1}-b_{t}=D_{t}+k_{t+1}-k_{t}\left(1-\delta\right)+\left[r_{t}^{*}-\omega\left(b_{t}-b\right)\right]b_{t} \quad (12c)$$

$$\theta_{t+1}=\left(1-\rho^{\theta}\right)\theta+\rho^{\theta}\theta_{t}+\varepsilon_{t+1}^{\theta} \quad (12d)$$

$$r_{t+1}^{*}=\left(1-\rho^{r}\right)r^{*}+\rho^{r}r_{t}^{*}+\varepsilon_{t+1}^{r} \quad (12e)$$

in which $MUC_{t}\equiv D_{t}^{-\sigma}$ in equations (12a) and (12b) is the marginal utility of consumption at time t.

Since we attempt to investigate the interrelation between investment decision and internal financial decisions, such as internal liquidity, debt leverage and dividends payments, we show interest in the following flow variables:

Internal Funds: $$if_{t}=A\theta_{t}k_{t}^{\alpha}-\frac{\phi}{2}\left(k_{t+1}-k_{t}\right)^{2} \quad (13a)$$

Investment: $$i_{t}=k_{t+1}-k_{t}\left(1-\delta\right) \quad (13b)$$

Interest Payment $$ip_{t}=rb_{t} \quad (13c)$$

Savings: $$s_{t}=if_{t}-D_{t} \quad (13d)$$

Calibration

To calibrate the model straightforwardly, we rely on the non-stochastic steady states. The calibration of the model to the value added ethanol business needs the following parameter default values: $\alpha=0.40$; $\delta=0.10$; $\phi=0.018$; $r^{*}=0.06$; $D/y=0.70$; $\sigma=1.5$; we normalize the calibration setting $k=4.5$ and obtain the system of equations characterizing the steady state:

$$1=\beta\left(1+\alpha\frac{y}{k}-\delta\right) \quad (14a)$$

$$1=\beta\left(1+r^{*}\right) \quad (14b)$$

$$y=D+\delta k+r^{*}b \quad (14c)$$

$$y=\theta k^{\alpha} \quad (14d)$$

We obtain that $\beta=0.943$; $D=1.26$ $y=1.8$; $b=1.5$; and $\theta=0.986$ from the above four equalities. Since the parameters ω, ρ^{θ} and ρ^{r} are not involved in the system of equations. (14a)-(14d), we are able to define their values exogenously. We set $\omega=0.0025$, $\rho^{\theta}=0.92$ and $\rho^{r}=0.87$. Furthermore, as there are no mathematical constraints on the statistical properties of the innovations to interest-rate and productivity shocks these properties can be freely selected. Notwithstanding this, the critical assumption here is that the innovations to the exogenous predetermined variables are zero-mean Gaussian processes.

Result Implications

Population and sample moments for dividends, investment and other interested variables are reported in the Table 1 and 2. Both of them provide us the insight into examining the variability of response variables in ethanol plants given the external margin and interest shocks. The numerical result from population moments is analogous to that from sample moments. Among response variables that we are interested in, we find that interest payment is most stable and investment appears most vulnerable to outside changes. Since the financial borrowing is subject to the interest rate shock and internal funds demand, the overall interest payment as a cash outflow turns out to be fairly constant in each period. The dividend payment less variable than investment decision suggests the smoothing strategy employed again by ethanol plants. The investment amount is adjusted in a wide range to balance the overall internal funds in ethanol firms. The evidence from cross correlations with internal funds indicates that dividend decision is highly associated with cash flows available in ethanol plants, whereas the investment is less restricted to cash flows. This result determined implicitly by the rational expectation model also provides the support for the free cash flow hypotheses.

The impulse response functions are also illustrated in Figure 12, 13 and 14 for steady state value of internal funds, dividends and investment with respect to 1% innovation to both margin and interest rate shocks. Since two innovations are jointly taken into account in computing the impulse response functions, the results turn out to be hard to predict and largely depends on which innovation dominates in the simulation process. Generally speaking, the margin shock generates the positive response for both dividends payment and investment amount while the greater impact on investment would be expected. However, 1 percent innovation in interest rate shock would negatively influence the internal cash flow in ethanol plants and lead to bigger interest payment. The overall result indicates that investment has a relatively large response in contrast to dividend and internal funds.

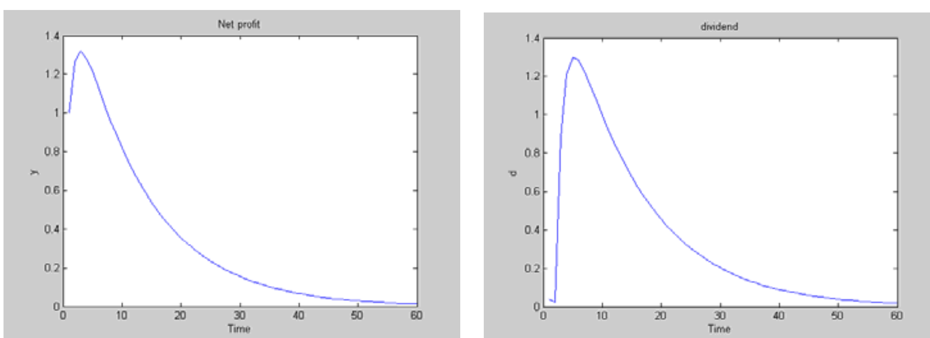

Figure 12 and 13: Impulse Response Functions for Internal Funds and Dividends

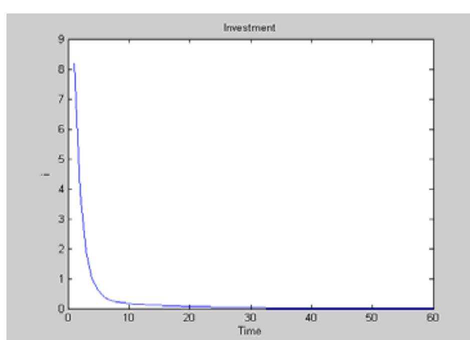

Figure 14: Impulse Response Functions for Investment

Conclusions

This paper develops a rational expectation model to analyze the dynamic dividend and investment decisions in ethanol production throughout its growth and post steady state stages. By adding the particular role played by the financial borrowing, the proposed model examines the simultaneous interaction among smoothing dividends, optimal investment and external financial borrowing in ethanol plants. The dividend payment policy resulting from the simulation work is consistent with the smoothing trend first revealed by Lintner (1956) and follows the life cycle of firm. The investment decision is an optimal result implicitly implied by maximizing median representative member's utility function. We also find that the investment decision largely depending on the variations of earnings follows a more volatile style.

By allowing the interest rage shock, we further make post-optimality analysis on the critical response variables. The impulse response functions for dividend, investment and internal funds around the steady state associated with 1 percent change in margin shocks or interest rate shocks are numerically computed. The result suggests that investment amount is adjusted in wide range and dividend decision is highly associated with cash flows available in ethanol plants.

In addition to providing theoretic insights into dividend policy, the proposed model helps to work out a practical dividend policy tool and an optimal investment arrangement for ethanol plants. The simulation process is flexible to be adjusted for different flavors of members and managers. Those agents might be ready to apply appropriate parameters and characteristic functions to their ethanol businesses and then attain the results as guidance for their dividend and other financial decisions.

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Table 1: Population Moments in Ethanol Production Models

Variable	Standard Deviation (percent)	Relative Stand. devi.	Autoco-rrelation	Cross Correlations with internal funds: Inter. Funds at t t+1 t+2 t+3 t+4	Inter. Funds at t t-1 t-2 t-3 t-4
Int.Funds	3.984	1.000	0.964	0.96 0.91 0.84 0.78	0.96 0.91 0.84 0.78
Dividends	5.268	1.322	0.713	0.66 0.60 0.55 0.50	0.86 0.87 0.84 0.79
Investment	9.348	2.346	0.482	0.58 0.58 0.55 0.51	0.28 0.17 0.11 0.09
Capital	3.647	0.915	0.969	0.90 0.84 0.78 0.71	1.00 0.97 0.92 0.86
Debt	4.348	1.091	0.870	-0.00 -0.00 -0.0 -0.0	-0.00 -0.00 -0.0 -0.0
Savings	4.841	1.215	0.351	0.50 0.50 0.48 0.45	0.24 0.15 0.10 0.07
Inte. Payment	0.288	0.072	0.935	-0.00 -0.00 -0.0 -0.0	-0.00 -0.00 -0.0 -0.0
Margin shock	2.547	0.639	0.920	0.97 0.91 0.85 0.79	0.91 0.84 0.77 0.71
Inte. Shock	2.231	0.560	0.870	-0.00 -0.00 -0.0 -0.0	-0.00 -0.00 -0.0 -0.0

Table 2: Sample Moments in Ethanol Production Models

Variable	Standard Deviation (percent)	Relative Stand. devi.	Autoco-rrelation	Cross Correlations with internal funds: Inter. Funds at t t+1 t+2 t+3 t+4	Inter. Funds at t t-1 t-2 t-3 t-4
Int.Funds	3.861	1.000	0.966	0.96 0.91 0.84 0.78	0.96 0.91 0.84 0.78
Dividends	5.212	1.350	0.706	0.65 0.61 0.56 0.52	0.84 0.86 0.83 0.79
Investment	7.836	2.289	0.483	0.58 0.58 0.55 0.52	0.30 0.19 0.14 0.11
Capital	3.535	0.916	0.971	0.91 0.85 0.79 0.74	1.00 0.97 0.92 0.87
Debt	4.704	1.218	0.882	-0.04 -0.04 -0.04 -0.04	-0.05 -0.05 -0.03 -0.01
Savings	4.850	1.256	0.349	0.48 0.47 0.45 0.42	0.24 0.14 0.10 0.07
Inte. Payment	0.313	0.081	0.937	-0.04 -0.04 -0.04 -0.04	-0.05 -0.04 -0.02 -0.01
Margin shock	2.463	0.638	0.924	0.97 0.92 0.86 0.80	0.91 0.84 0.78 0.72
Inte. Shock	2.414	0.625	0.882	-0.04 -0.04 -0.04 -0.04	-0.05 -0.03 -0.02 -0.01