Harvest Cost and Value of Citrus Operations with Alternative Technology: Real Options Approach

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Abstract

The prospect of immigration policy reform has renewed growers' concerns of serious labor shortages and cost increases. These concerns are more serious for specialty crop agriculture, not only because it is highly labor intensive, but also it requires labor in a very short period, particularly at harvest time. Two representative approaches of the investment valuation have been applied to the case of harvesting mechanization for the model citrus grower in Florida. Specifically, we applied the NPV approach and the real options approach (ROA) to processed-market Hamlin orange operations in Southwest Florida.

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Introduction

The prospect of immigration policy reform has renewed growers' concerns of serious labor shortages and cost increases because a large portion of the workforce in agriculture is unauthorized for U.S. employment. According to the National Agricultural Workers Survey (NAWS) data, at least 53% of agricultural workers were unauthorized for U.S. employment for the years 2001-02 (Office of Assistant Secretary for Policy 2005). Clearly, this concern of labor cost increase is more serious for specialty crop agriculture, not only because it is highly labor intensive, but also it requires labor in a very short period, particularly at harvest time. On this matter Sarig, et al. (2000) report that "…at least 20-25% of the U.S. vegetable acreage and 40-45% of the U.S. fruit acreage is totally dependent on hand harvesting." Given that immigration policy reform may lead to much higher ratio of legal workers, the concern over harvest cost increases is legitimate since existing literature suggests that a significant wage gap exists between legal and illegal workers in U.S. agriculture (Taylor 1992; Ise and Perloff 1995).

Agricultural employers may address the increased harvest cost in various ways, but likely options include (a) adoption of a technology which uses less labor and (b) termination of current crop production if an alternative technology is not available (Emerson 2007). Mechanical harvesting is a typical example of the former, whereas the latter may involve changes to the cropping mix such that less labor is required. If we focus on adoption of mechanical harvesting, the most imminent effect of immigration policy reform might be on crops mainly used for processing for which labor-intensive technology is currently employed, but an alternative, less labor-intensive technology is already developed. Florida citrus is a current example of a major specialty crop with these characteristics.

The Florida citrus industry is facing many difficulties in addition to labor availability for harvest, from recent hurricanes to new diseases (citrus canker and citrus greening) to increased international competition. As a result of all these factors the Florida citrus industry has been pursuing mechanical harvesting with an increased intensity over the past few years. The estimated cost of mechanical harvesting of Florida oranges for juice processing ranges between 10 and 30 cents per 90-lb box less than hand harvesting (Roka). This is a significant cost difference because harvest cost savings translate to an increase in grower net returns by as much as a $150 per acre. While an economic advantage appears to be present, the adoption of mechanical harvesting systems remains relatively low at about 7.5% of the Florida orange acreage in 2006-07 (UF). The hesitation by growers to adopt the new technology is not uncharacteristic of the experience in other commodities such as cotton, tomatoes, and sugarcane where mechanization has taken place in the past. The important point is that the value of each operational mode cannot be measured by the cost advantage for a single year. To overcome this problem we use two approaches often used for analysis of dynamic decision-making: net present value (NPV) and real options approach (ROA) with special attention on the latter.

The NPV approach simply assumes that the producer must invest if the NPV from adopting the new technology is greater than that from the current operation. In the case of Florida citrus operation, the farmer must switch to the mechanical harvesting if the discounted cash flow less the investment cost for mechanical operation is greater than the discounted cash flow from the current operation. The real options approach (ROA), which applies financial option theory for investment in real assets, assumes that the producer has the option to invest or wait, called "investment flexibility". However, once the producer makes an irreversible investment,[1] he/she exercises, or "kills" its option to invest. Hence the producer does not invest until the discounted cash flow of the mechanical harvesting operation less investment cost is greater than the discounted cash flow of hand cut operation by the margin of the option value of investment flexibility (Dixit and Pindyck 1994, Trigeorgis 1996). The consideration for flexibility and irreversibility of investment in the ROA often yields a much higher trigger value of the cash flow from mechanized harvesting operation than that calculated from the NPV approach, implying the investment decision should be delayed until a higher cash flow is more likely. Since citrus farmers have the ability to postpone their decision on investment, and, in general, investment in agriculture is at least partially irreversible (Napasintuwong and Emerson 2004), the consideration for these aspects of investment is important.

Our preliminary result using the enterprise (entity) DCF approach, the most widely used NPV approach, shows that the NPV of the current operation is slightly lower than the NPV (before deducting investment cost) of the mechanical harvesting operation with the standard scenario. However, the NPV difference is less than 1% (Iwai et al. 2009). A similar approach has been applied to Florida sugarcane harvest

[1] Note also that investment can be modeled partially reversible in the ROA. In our case this means that citrus farmer can turn back to hand cut harvesting with some cost.

mechanization. The ROA study applied for Florida sugarcane mechanization in the early 1970s shows that, since the sugarcane farmers were exposed to a highly volatile free cash flow, the value of keeping the flexibility option alive was very high, enough to overturn the NPV conclusion (Iwai and Emerson 2008). Our primary interest in the current study is how the consideration for the value of the flexibility option would affect the investment decision for the citrus farmers in Florida. By contrast with the sugarcane study where mechanization had already taken place, the current application to the citrus industry is prospective since mechanization remains largely experimental at the present time.

Data

The most important source of data is the archive of "Budgeting Costs and Returns for Southwest Florida Citrus Production" which is available from 1993-4 season to 2004-5 season.[2] In the report costs and returns of growing processed-market Hamlin orange and fresh-market seedless grapefruit in the Southwest area of Florida (Charlotte, Collier, Glades, Hendry and Lee counties) are presented for the twelve consecutive years. The southwest area of Florida has become a major citrus production area representing 169,386 acres, over 22.6% of total Florida citrus acreage in 2004 (Muraro et al. 2005). Furthermore, more than 90% of the mechanically harvested acreage is in southwest Florida. The budget cost items in the report have been revised to reflect the most current grove practices (e.g., chemical mowing, different spray materials and rates of

[2] Although the archive includes data from 1986-7 season to 1992-3 season, the important information such as harvesting and assessment cost, interest payments, property tax and water management district tax has been omitted. So we focus on the data from 1993-4 season to 2004-5 season.

fertilization, microsprinkler irrigation, more reset trees, etc.) being used by growers for the respective seasons (Muraro et al. 2005).

As illustration, the estimated annual per acre cost for a mature, Hamlin grove in southwest Florida producing oranges for juice processing is shown in Table 1 from 2001-2 season to 2004-5 season. The average mature Hamlin orange grove is composed of 3% of 3 year old, 3% of 4 year old, 33% of 5-15 year old, 49% of over 15 year old trees, and 3% of trees producing 50% of expected yield.[3] In the budget below, beyond average management and cultural practices, the following specifics are assumed:

1. A mature (10+ years old), low volume irrigated grove;
2. Annual tree loss is 4.4% per acre;
3. Trees are pulled and replaced when production falls below 50% of expected yields;
4. Tree density is 145 trees per acre.

[3] This adds up to 91 percent as 9 percent of the trees were non-bearing (pulled and reset, or 1 and 2 year old trees).

Table 1. Cost for growing and harvesting Hamlin orange for a model farm ($ per acre).

Season	2001-2	2002-3	2003-4	2004-5
Production/Cultural Cost				
Weed control	184.79	183.13	165.52	172.96
Spray program	136.43	137.18	131.69	141.19
Fertilizer	114.00	124.05	135.33	159.39
Dolomite	10.66	12.04	12.01	14.56
Pruning	40.97	28.03	27.51	28.38
Tree replacement and care	280.48	286.60	296.15	316.55
Total Production/Cultural Cost	**767.33**	**771.03**	**768.21**	**833.03**
Management	48.00	48.00	48.00	48.00
Interest on operating cost	38.37	38.55	38.41	41.65
Property tax and water management district tax	61.00	61.00	61.00	61.00
Canker decontamination cost	27.72	4.54	4.54	4.54
Capital expenditure	367.85	378.50	321.22	321.22
Total Grower Cost	**1,310.27**	**1,301.62**	**1,241.38**	**1,309.44**
Pick/spot pick, roadside and haul	1,088.64	1,120.39	1,143.97	1,187.93
DOC assessment	83.16	83.16	77.40	83.16
Total delivered-in cost	**2,482.07**	**2,505.17**	**2,462.75**	**2,580.52**

Source: Muraro et al. (2002, 2003, 2004, 2005).

Next, we combine cost items above with revenue to calculate free cash flow (FCF) which is equal to the after-tax operating earnings of the farm, plus non-cash charges, less investments in operating working capital, property, and other assets (Copeland and Antikarov 2003). Unlike "cash flow from operations" reported in financial statement, FCF is independent of financing and nonoperating items. It can be thought of as the after-tax cash flow as if the company held only core operating assets and financed the business entirely with equity.[4] This is the correct cash flow for the enterprise DCF model since it reflects the cash flow that is generated by a farm's operation and available to all capital providers, both debt and equity (Koller et al. 2005). Instead of showing the procedure to calculate the FCF, we refer readers to Iwai et al.

[4] Instead, FCF is discounted by the risk-adjusted cost of capital (WACC) which reflects the capital structure of the company. We explain the calculation of the WACC later.

(2009) which elaborate all the necessary steps. In Table 2, we show the calculation result for the FCF per acre for the model Hamlin orange grower from 2001-2 season to 2004-5 season.

Table 2. Historical FCF for growing and harvesting Hamlin orange for a model farm ($ per acre).

Season	2001-2	2002-3	2003-4	2004-5
Revenue	2,577.96	2,539.15	2,310.13	2,259.91
Production/Cultural Cost	767.33	771.03	768.21	833.03
Management	48.00	48.00	48.00	48.00
Overhead taxes and regulatory cost	88.72	65.54	65.54	65.54
Harvesting and assessment cost	1,171.80	1,203.55	1,221.37	1,271.09
Operating cash flow	502.11	451.03	207.01	42.25
Depreciation	367.85	378.50	321.22	321.22
EBIT	134.26	72.53	-114.21	-278.97
Tax on EBIT (29% if positive)	38.94	21.03	0.00	0.00
Capital expenditure	367.85	378.50	321.22	321.22
FCF	95.32	51.50	-114.21	-278.97

Source: Authors calculated from Muraro et al. (2002, 2003, 2004, 2005).

<u>**FCF Forecast**</u>

Next task is forecasting the future FCF for growing and harvesting processed-market Hamlin orange, which is usually done in the following steps. First we model and estimate the stochastic factors in the operation (citrus yield, price, production cost, and harvesting cost) using data from the archive of “Budgeting Costs and Returns for Southwest Florida Citrus Production” available from 1993-4 season to 2004-5 season. Second, using the Monte Carlo simulation applied for the estimation results, we generate 100,000 samples of 10-year future path for the four stochastic factors, from which sample paths for future FCF are generated. Simply taking average of the 100,000 samples of FCF will yield the expected future FCF for each year. Again, instead of showing all these steps, we refer readers to Iwai et al. (2009). The expected FCF for the next ten years is shown as Table 3.

Table 3. Expected FCF for growing and harvesting Hamlin orange for a model farm ($ per acre)

Season	2007-8	2008-9	2009-2010	2010-2011	2011-2012
FCF	906.43	880.15	848.62	823.36	796.63
Season	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
FCF	760.40	738.35	702.41	660.78	630.19

From Table 3, we can calculate the expected FCF growth rate of –3.96 percent for a model Hamlin orange grower.

Estimation of Weighted Average Cost of Capital

Now that we have estimated future free cash flow, the next step is to discount the FCF by the appropriate discount rate. The discount rate we use is the weighted average cost of capital (WACC) which is the time value of money used to convert the expected FCF into a present value for all investors. Since enterprise cash flows are available for payment to both sources of capital, debt and equity, the discount rate must comprise a weighted average of the marginal costs of both sources of capital. In our application WACC is given by

$$WACC = k_d(1-T)\frac{D}{D+E} + k_e\frac{E}{D+E}, \tag{1}$$

where k_d is the pretax market expected yield to maturity on debt, for which we take k_d=7.69% from Florida Department of Citrus (2005),[5] T is the operational tax rate for the enterprise, which is 29% in our application, and k_e is the market-determined opportunity cost of equity capital. D is the market value of interest-bearing debt, and E is the market value of equity, but the important point is that we need to use the long term target level of debt equity ratio (Koller et al., 2005). For this we use the average

[5] Florida Department of Citrus (2005) indicates that the typical interest rate for citrus operation is 1.50% over prime rate. We take the average majority prime rate of 6.19% for 2005 from Federal Reserve Statistical Release (http://www.federalreserve.gov/releases/h15/data/Annual/H15_PRIME_NA.txt).

debt equity ratio of 18.67% for 1994-2003 for all Florida farms including citrus farms (Economic Research Service). Many farms were actually farming multiple crops, but financing is done for the farm unit basis not for individual crop basis. In this case the cost of capital should reflect the risk structure of the farm unit rather than that of the specific crop. Since D/E=18.67%, so that $D/(D+E)$=0.1573.

Finally we estimate k_e, the market-determined opportunity cost of equity capital. Here we use the most widely used estimation method: capital asset pricing model (CAPM). The equation for the cost of equity from the CAPM is given as

$$k_e = r_f + [E(r_m) - r_f]\beta_e, \tag{2}$$

where r_f is the risk-free rate of return, $E(r_m)$ is the expected rate of return on the overall market portfolio, so that $[E(r_m)-r_f]$ is the market risk premium. β_e is the systematic risk of the equity (levered equity beta) which is defined as $COV(r_j, r_m)/VAR(r_m)$ where r_j is the rate of return from the equity to be evaluated. After many calculations, we have k_e = 0.0943 which is substituted into equation (1). From equation (1) we have WACC of 8.81%.[6]

Present Value Calculation

Present value for year t, which is state dependent, is defined as

$$PV_t(\boldsymbol{X}_t) = \sum_{\tau=t+1}^{2016} \frac{E[FCF_\tau(\boldsymbol{X}_\tau)|\boldsymbol{X}_t]}{(1+WACC)^{\tau-t}} + \frac{(1+g)E[FCF_{2016}(\boldsymbol{X}_{2016})|\boldsymbol{X}_t]}{(1+WACC)^{2016-t}(WACC-g)} \quad \text{for} \quad t<2016.$$ [7]

$PV_{2016}(\boldsymbol{X}_{2016}) = \frac{(1+g)FCF_{2016}(\boldsymbol{X}_{2016})}{(WACC-g)}$. The latter is continuing value after the explicit

[6] See Iwai et al. (2009) for the detail of the calculations.

[7] Generally, PV is expressed as $PV_t(\mathcal{F}_t)$ where the information $\mathcal{F}_t$ is composed of past and present values of $\boldsymbol{X}$ (Pliska 1997). However, the Samuelson theorem, which will be explained in the ROA section, guarantees the Markov property of PV, so that $PV_t(\mathcal{F}_t)= PV_t(\mathbf{X}_t)$.

forecast period estimated using growing FCF perpetuity formula in which g is the expected growth rate in FCF in perpetuity (−3.96% for hand cut harvesting operation).[8] Simply adding FCF to PV yields NPV for each year: $NPV_t(\boldsymbol{X}_t) = FCT_t(\boldsymbol{X}_t) + PV_t(\boldsymbol{X}_t)$ ($-I_t$ if the investment is made in that year).

Substituting *WACC, g*, and 100,000 samples of FCF in the above formula yields PV and NPV for each season for each operational mode. In Table 4 we show sample mean of these figures for seasons after 2007-8 season. Note, however, that those for 2007-8 season in Table 4 are the actual values, since the state is already known for that season.

Table 4. Mean of PV and NPV from growing and harvesting Hamlin orange for a model farm ($ per acre)

Season	2007-8	2008-9	2009-2010	2010-2011	2011-2012
PV	**7,407.52**	7,179.97	6,963.91	6,754.07	6,552.47
NPV	8,313.95	8,060.12	7,812.53	7,577.43	7,349.10
Season	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
PV	6,369.34	6,192.13	6,035.25	5,906.18	5,796.32
NPV	7,129.74	6,930.48	6,737.66	6,566.96	6,426.51

Next, we repeat the same procedures for mechanical harvesting operation. According to Roka the adoption of mechanical harvesting technology typically has the following impacts on citrus operation in subsequent seasons:

1. Harvest recovery rate becomes 98%.
2. Harvest cost decreases by $0.25 per box. That is, harvesting cost reduction of $0.25 for 98% of fruit, zero harvesting cost for 2% of fruit.
3. There is cost increase of $10/acre for skirting.

[8] The continuing value is set zero if it is negative. It is not assumed that an agent continues to hold an asset with negative value in perpetuity.

In addition to these annual impacts, the grower incurs the following costs in the initial season:

1. Cost increases by \$20/acre for skirting, \$40/acre for pruning and \$40/acre for irrigation.
2. Yield reduces by 2% due to skirting.

In summary, this typical scenario will lead to 4% decrease in fruit harvest but \$0.25 harvesting cost decrease for 96% of fruit, and zero harvesting cost for 4% of fruit in the initial season. In subsequent seasons, fruit harvest decreases by 2%, but harvesting cost decreases by \$0.25 for 98% of fruit, and harvesting cost becomes zero for 2% of fruit. Other effects include \$10/acre cost for each season, and \$100/acre cost for the initial season. In Table 5 we show sample mean of FCF, PV and NPV from the generated 100,000 samples with the mechanical harvesting operation. Note, again, that values for 2007-8 season in Table 5 are the actual values, since the state is already known for that season.

Table 5. Mean of FCF, PV and NPV from growing and harvesting Hamlin orange with mechanical harvesting (\$ per acre)

Season	2007-8	2008-9	2009-2010	2010-2011	2011-2012
FCF	811.93	900.90	870.06	845.23	818.86
PV	**7,531.60**	7,294.24	7,066.81	6,844.16	6,628.26
NPV	8,343.54	8,195.14	7,936.86	7,689.39	7,447.13
Season	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
FCF	783.07	761.21	725.64	684.49	654.22
PV	6,429.15	6,234.35	6,057.95	5,907.16	5,773.37
NPV	7,212.21	6,995.56	6,783.59	6,591.65	6,427.58

In an alternative mechanical-harvesting scenario (lower recovery, higher cost reduction case) also introduced by Roka, the harvest recovery rate becomes 90% from 98%, and per box harvest cost reduction becomes \$0.51 from \$0.25. Compared to the manual harvesting case, this alternative scenario will lead to 12% decrease in fruit harvest, but $0.51 harvesting cost decrease for 88% of fruit, and zero harvesting cost for 12% of fruit in the initial season. In subsequent seasons, fruit harvest decreases by 10%, but harvesting cost decreases by $0.51 for 90% of fruit, and harvesting cost becomes zero for 10% of fruit. Other effects include $10/acre cost for each season, and $100/acre cost for the initial season. In Table 6 we show sample mean of FCF, PV and NPV from the generated 100,000 samples with the mechanical harvesting operation with lower fruit recovery and higher cost reduction scenario. Note, again, that values for 2007-8 season in Table 6 are the actual values, since the state is already known for that season.

Table 6. Mean of FCF, PV and NPV from growing and harvesting Hamlin orange with mechanical harvesting (lower fruit recovery, higher cost reduction scenario) ($ per acre)

Season	2007-8	2008-9	2009-2010	2010-2011	2011-2012
FCF	717.76	808.75	779.03	755.15	729.98
PV	**6,789.43**	6,578.82	6,379.38	6,186.26	6,001.29
NPV	7,507.19	7,387.57	7,158.41	6,941.40	6,731.27
Season	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
FCF	696.17	675.34	641.85	603.29	574.80
PV	5,833.83	5,672.45	5,530.35	5,414.28	5,316.48
NPV	6,530.00	6,347.79	6,172.19	6,017.57	5,891.28

The next issue is the investment cost for the mechanical harvester. Since the current study assumes that the operation is integrated up to harvesting under the grower, he/she makes the payment for the mechanical harvester. It is estimated that, in 2008, approximately 30,000 acres of citrus were mechanically harvested by the self-propelled canopy shakers which cost about $1.2 million. Given that 13 units were operating across the southern Florida region, each set was harvesting roughly 2,300 acres annually. Considering these figures, we assume that the model orange grower has 2,300 acres of citrus operation for which he/she has the option of mechanizing the harvesting. Therefore, the estimate for the investment cost is \$520 per acre (≈\$1.2 million/2,300 acres).

The actual amount of payment the grower makes, including the interest payment, could be much greater than this price of mechanical harvester. However, the present value of the total payment discounted with the appropriate discount rate, which reflect the riskiness of the payment, must be equal to the market price of the harvesting machine.[9] In Table 7 we pick up the PV and investment cost, as of 2007-8 season to show the decision of the model farmer as to mechanizing harvesting at that time using the traditional NPV approach.

Table 7. PV and investment cost for each operation for 2007-8 season (\$ per acre)

	PV	Investment Cost	PV – Inv. Cost
Hand cut harvesting	7,407.52		7,407.52
Mechanical harvesting (standard scenario)	7,531.60	520.00	7,011.60
Mechanical harvesting (lower fruit recovery scenario)	6,789.43	520.00	6,269.43

Comparing the PV less investment cost as of 2007-8 season in Table 7, we find that the manual harvesting operation has the highest NPV of \$7,407.52 per acre, followed by the mechanical harvesting with standard scenario with NPV of \$7,011.60. The alternative mechanical harvesting scenario (the lower fruit recovery, higher cost reduction scenario) has the lowest NPV of \$6,269.43 per acre. However, the NPV difference between the first two scenarios is very small (only 5.65%), while NPV from the alternative mechanical harvesting scenario is lower than the hand cut operation by

[9] Also, note that interest payment, which is non-operating item, does not change PV of the current operation, unless the debt from investment dramatically changes the capital structure. The significant change in capital structure should be reflected in estimation of WACC.

15.36%. In conclusion, the enterprise DCF approach using the current data available for the Hamlin orange operation in Southwest Florida shows that, as of 2007-8 season, the NPV of the manual harvesting operation is slightly higher than those of mechanical harvesting operations.

Real Options Approach

The traditional NPV approach simply assumes that the citrus grower must switch to the mechanical harvesting if the PV less the investment cost for mechanization is higher than the PV from the current operation. The analysis in the previous section suggests that, based on the NPV approach, the model citrus grower should not switch to the mechanical harvesting in 2007-8 season. This conclusion from the NPV approach cannot be changed qualitatively using the real options approach. However, consideration for the option value of investment might have a significant impact on the relative value of mechanical operation, implying further delay of the mechanization investment.

The real options approach (ROA), which applies financial option theory for investment in real assets, assumes that the producer has the option to invest or wait, called "investment flexibility". However, once the producer makes an irreversible investment, he exercises the option to invest and gives up the option value of investment flexibility. Hence the producer does not invest until the PV less investment cost for mechanization is greater than the PV for the current operation by the margin of the option value of investment. Therefore calculating the option value is the most important part of the ROA.

One problem with applying the ROA in our case study is that there are four stochastic factors: citrus yield, price, labor cost and other operating cost. Option valuation with early exercise features with multiple stochastic factors has so called "dimensionality problem". As a rule of thumb, standard numerical methods such as lattice solvers and finite difference methods become impractical for applications with more than three stochastic factors (Brandimarte 2006, Tavella 2002). The most common approach for the case of many stochastic factors is the consolidated approach suggested by Copeland and Antikarov (2003). In the consolidated approach, stochastic factors are integrated into the single risk factor. The risk factor is reflected in the value process which follows the geometric Brownian motion. The approach is based on the following theorem attributable to Samuelson (1965): regardless of the pattern of cash flows expected in the future, the changes in the present value will follow a random process so that return is iid process, as long as investors have rational expectations about the cash flow. The assumption made for this theorem is quite general: all the information about the expected future cash flows is already backed into the current PV in such a way that, if expectations are met, investors will earn exactly their expected cost of capital. We assume that this assumption is met for our case study.[10]

Another question is how far forward to extend the horizon for our application. Copeland and Antikarov (2003) note that "*the present value of their expected cash flows that are reasonably far out in time, is discounted by a present value factor that rapidly diminishes toward zero.*" and conclude *"A rule of thumb worth considering is to ignore options beyond about 15 years out."* (p. 239). Considering the changing

[10] See Copeland et al. (2003) for empirical evidence supporting Samuelson's theorem.

business environment including the technology of harvesting, we assume that the current option is available for the grower for 10 years.

Methodology to Calculate the Option Value

Here we show the formula to calculate the option value of investment flexibility for the citrus grower. After harvesting in year $t \in [0,\mathrm{T}]$ the grower has two alternatives in the action set: $a_t = \{0, 1\}$ where 0 if he does not invest, 1 if he invests. The feasible control set is that the grower can exercise the investment option one time in $t \in [0,T]$. Given the action in this year and the state in next year ($\boldsymbol{X}_{t+1}$), the cash flow function for the next year is given as,

$$f_{t+1}(a_t, \boldsymbol{X}_{t+1}) = \begin{cases} FCF_{t+1}(\boldsymbol{X}_{t+1}) & \text{if } a_t = 0, \\ NPV^m_{t+1}(\boldsymbol{X}_{t+1}) & \text{if } a_t = 1, \end{cases}$$

where $NPV^m_{t+1}(\boldsymbol{X}_{t+1})$ is net present value for mechanized operation in t+1. After exercising the investment option, the cash flow becomes zero.[11] The grower's objective function is given as $V_0^C(\boldsymbol{X}_0) = \sum_{t=0}^{T} \frac{\widetilde{E}[f_{t+1}(a_t, \boldsymbol{X}_{t+1}) | \boldsymbol{X}_t]}{(1+r_f)^{t+1}}$ where $\widetilde{E}$ is the expectation operator with the risk neutral probability under which the asset value is measured by cash flow discounted by r_f. (Kijima 1994). The farmer chooses the control among the feasible control set to maximize the objective function. The optimization problem can be expressed as the Bellman equations as

$$V_T(\boldsymbol{X}_T) = \max[P\mathrm{V}_T(\boldsymbol{X}_T), P\mathrm{V}^m_T(\boldsymbol{X}_T) - I_T], \quad (3)$$

for t=T,

[11] Actually there is cash flow from mechanized operation, but they are included in $NPV^m_{t+1}(\boldsymbol{X}_{t+1})$. This is made just for calculation convenience, but the result is the same.

$$V_t(\boldsymbol{X}_t) = \max\left[\widetilde{E}(\frac{V_{t+1}(\boldsymbol{X}_{t+1})}{1+r_f}|\boldsymbol{X}_t),\ \widetilde{E}(\frac{NP\mathrm{V}^m_{t+1}(\boldsymbol{X}_{t+1})}{1+r_f}|\boldsymbol{X}_t)\right]. \qquad (4)$$

for $t<T$. Note that, in the above equation, the first term is the continuation value, and the second term is value from switching to the mechanized operation. Also, since investment cost has the present value of I_t, we have $\widetilde{E}(\frac{NP\mathrm{V}^m_{t+1}(\boldsymbol{X}_{t+1})}{1+r_f}|\boldsymbol{X}_t) = P\mathrm{V}^m_t(\boldsymbol{X}_t) - I_t$. Solving the above equations iteratively results in $V_0(\boldsymbol{X}_0)$, which is the value of the objective function resulting from the optimum control. Further, the option value of investment flexibility is given as: $V_t^O(\boldsymbol{X}_t) = V_t(\boldsymbol{X}_t) - PV_t(\boldsymbol{X}_t)$ for each t. In the following sections, we follow the above method and analyze the citrus mechanization decision.

Volatility Estimate

In this section, we estimate the volatility of the current operation. The historical volatility is defined as standard deviation of the annual rate of return: $r_t = \ln(FCF_t + PV_t) - \ln(PV_{t-1})$. However, the annual rate of return is not directly observable for non-listed firms for which present value (or even stock price) is not available. Alternative method often used is logarithm cash-flow return approach suggested by Mun (2003). In the approach, volatility is measured as the standard deviation of logarithm of relative FCF returns: $\widetilde{r}_t = \ln(FCF_t) - \ln(FCF_{t-1})$. This approach is quite useful when FCF is positive for all sample periods. Since we have negative FCF for 2003-4 and 2004-5 season as shown in Table 2, we need to use another variable for the calculation. The suggestion from Mun (2003) for the negative FCF case is to move the DCF model from FCF to EBIT, to operating CF, even to revenue, where all the values are positive. We use the standard deviation of logarithm of relative operating CF returns: $\tilde{r}_t = \ln(OCF_t) - \ln(OCF_{t-1})$. This is an appropriate statistic to measure the volatility of the current operation, since items such as depreciation and CAPEX, that are adjusted in FCF but not adjusted in operating CF, are quite stable over the sample periods as shown in Table 2. We calculate the standard deviation of these returns using operating CF from 1993-4 to 2004-5 season, so that volatility for the current operation is 65.56%.

The theory of ROA generally predicts that higher volatility results in a high value of keeping the option alive which gives the investor an incentive to further delay the investment, since the volatility raises the value of waiting to see what is going to happen in the future (Dixit and Pindyck 1994). This high volatility of returns and resulting high value of the option might suggest further delay of the mechanization investment which is already concluded using NPV approach.[12]

Option Value Computation

Following Copeland and Antikarov (2003), we build the binomial tree which approximates the value process by geometric Brownian motion. In the binomial tree shown as the figure below, PV in this year evolves to NPV in next year as $NPV_{t+1}(\boldsymbol{X}_{t+1}) = e^{\sigma} PV_t(\boldsymbol{X}_t)$ with the risk neutral probability $q = \dfrac{1 + r_f - e^{-\sigma}}{e^{\sigma} - e^{-\sigma}}$, and to $NPV_{t+1}(\boldsymbol{X}_{t+1}) = e^{-\sigma} PV_t(\boldsymbol{X}_t)$ with probability $1-q$. Note that σ is the annual volatility for the current operation, which is estimated 0.6556. After deducting free cash flow

[12] The current study evaluates the NPV and the option value on a per acre basis. Valuation of the NPV and option value at the operation level is an issue for future research.

$FCF_{t+1}(\mathbf{X}_{t+1})=F_{t+1}*NPV_{t+1}(\mathbf{X}_{t+1})$ where F_{t+1} is FCF/NPV ratio for t+1 calculated using Table 3 and 4, the same calculation is repeated for subsequent periods until the expiration of the option.

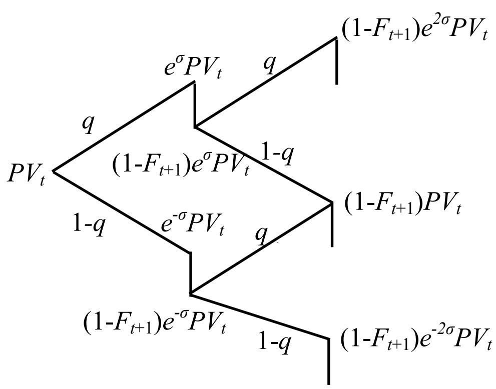

Figure 1. Binomial tree

Using the completed binomial tree, computation of value function is started from the expiration year. First, we calculate equation (3) for each node in year T. Then the value function is revised by adding back $FCF_T(\mathbf{X}_T)$ for each node. Using the risk neutral probability shown above, the value function, given as equation (4), in each node for $t<T$ is given as:

$$V_t(\boldsymbol{X}_t) = \max\left[\frac{qV_{t+1}^u + (1-q)V_{t+1}^d}{1+r_f},\ PV_t^m(\boldsymbol{X}_t) - I_t\right], \tag{5}$$

where V_{t+1}^u is the value in t+1 in the up state in the binomial tree, while V_{t+1}^d is in the down state. After adding back $FCF_t(\mathbf{X}_t)$, the same calculation is repeated back to the 2007-8 season. Finally, deducing PV_{2007} from the value function yields the option value of investment flexibility of \$3,648.34 per acre for 2007-8 season. The result is summarized as Table 8.

Table 8. PV, option value, and initial investment cost for 2007-8 season ($/acre)

	PV	Option Value	Investment Cost	PV +Option Value −Inv Cost
Hand cut harvesting	7,407.52	3,648.34		11,055.86
Mechanical harvesting (standard scenario)	7,531.60		520.00	7,011.60

We repeat the same calculations using the lower fruit recovery and higher cost reduction scenario for the mechanical harvesting operation. Resulting PV, option value and investment cost are shown as Table 9.

Table 9. PV, option value, and initial investment cost for 2007-8 season with lower fruit recovery scenario ($acre)

	PV	Option Value	Investment Cost	PV +Option Value −Inv Cost
Hand cut harvesting	7,407.52	3,179.40		10,586.92
Mechanical harvesting (lower fruit recovery scenario)	6,789.43		520.00	6,269.43

Since making investment for this particular season means exercising the option to invest, the citrus grower loses the option value of investment flexibility at the same time. Therefore, the farmer would not make an investment until PV less investment cost for the mechanization is larger than PV for hand cut operation by the margin of option value. The decision rule applied to the result in Table 8 is given as: $PV_{2007}^{m} - I_{2007} = \$7011.60 < \$11,055.86 = PV_{2007} + V_{2007}^{O}$, which suggests that the citrus grower should not invest in the mechanization in 2007-8 season. In the current case, due to the high volatility of returns (0.6556), option value of investment opportunity is relatively high ($3,648.34), reinforcing the conclusion from the NPV approach. We have a similar conclusion for the alternative mechanization scenario. The decision rule applied to the result in Table 9 is given as: $PV^m_{2007} - I_{2007}$ = \$6,269.43 < \$10,586.92= $PV_{2007} + V^O_{2007}$, which again suggests no invest in 2007-8 season.

The results in Table 8 and 9 seem to show that the current operation has the value advantage over mechanical operation by a substantial margin. For the immediate mechanization in 2007-8 season with the standard scenario (Table 8), PV difference ($PV^m_{2007} - PV_{2007}$) has to increase by \$4,044.26 per acre, either from PV^m_{2007} increase or PV_{2007} decrease. That is, fixing other variables, the threshold level of PV^m_{2007}, which should initiate the immediate mechanization, is \$11,575.86 per acre. Again, this figure seems to show the large gap existing between the threshold PV and the current PV for mechanical operation, but it is not exactly true. Using the growing FCF perpetuity formula introduced in the NPV calculation section, we can show rough estimates for FCF level or growth rate necessary to reach the threshold level of PV for the mechanical operation.

Appling the growing FCF perpetuity formula with the current growth rate of FCF and WACC, \$4,044.26 PV increase for the mechanical operation could be achieved either through an increase in its current FCF by \$463.18 without changing its transition in subsequent seasons, or through an increase in the FCF growth rate by 4.05 percentage points without changing the current FCF. Labor cost increase, operational efficiency gain of the harvester, investment cost reduction are among many factors that would lead to improvement of relative position of mechanical operation.

Concluding Remarks

Two representative approaches of the investment valuation have been applied to the case of harvesting mechanization for the model citrus grower in Florida. Specifically, we applied the NPV approach and the real options approach (ROA) to processed-market Hamlin orange operations in Southwest Florida. The present paper evaluates the NPV and option value on a per acre basis. Evaluation at the enterprise level is an issue for future research.

The standard scenario of the mechanical harvesting operation assumes that mechanization decreases harvesting cost by 25 cents per 90-lb box less than hand harvesting, but the fruit recovery rate also decreases by 2%. The alternative (lower recovery, higher cost reduction) scenario of the mechanical harvesting operation assumes that mechanization decreases harvesting cost by 51 cents per 90-lb box less than hand harvesting, but the fruit recovery rate decreases by 10%.

Present value (PV) less investment cost calculated using the representative NPV approach (enterprise DCF approach) is $7,011.60 per acre for the standard mechanization scenario, which is slighter lower than the PV of $7,407.52 per acre for the hand harvesting operation. However, the NPV difference is only 5.65%. On the other hand, PV less investment cost for the alternative mechanization scenario (lower recovery, higher cost reduction) is $6,269.43 per acre, which is substantially lower than the other two operations. This result suggests that, based on the NPV approach, the model citrus grower should not switch to the mechanical harvesting in 2007-8 season.

We also calculated the option value of investment flexibility using the standard real options approach (consolidated approach) which is often used for the case of many stochastic factors. In the current study, due to the high volatility of returns (0.6556), option value of investment flexibility is relatively high ($3,648.34) for the standard mechanization scenario, reinforcing the conclusion from the NPV approach. The decision rule from the ROA applied to the standard mechanization scenario is given as: $PV_{2007}^{m} - I_{2007} = \$7011.60 < \$11,055.86 = PV_{2007} + V_{2007}^{O}$, which again suggests that the citrus grower should not invest in the mechanization in 2007-8 season.

The threshold level of PV for the mechanized operation, which should initiate the immediate mechanization, is $11,575.86 per acre, indicating $4044.26 increase from the current level. This figure seems to show the large gap existing between the threshold PV and the current PV for mechanical operation, but application of the growing FCF perpetuity formula indicates that current FCF increase by $463.18 per acre or increase in the FCF growth rate by 4.05 percentage points is enough to reach the threshold level of PV for the mechanized operation.

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