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MEASURING THE PROFITABILITY AND LIQUIDITY OF VITICULTURE AND WINE PRODUCTION DURING THE ROMAN EMPIRE

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ABSTRACT

The production of agricultural goods and services within the Roman economy was necessary in acquiring political and economic wealth. Only few primary writers, however, discuss the exact financial gain behind such investments. In particular, viticulture, or the cultivation of harvesting grapes into wine, was known to drive high levels of returns on capital for wealthy Roman landowners. This thesis will serve to better understand Roman viticulture as a whole, including the functions of business operations in relation to its investable return. More specifically, this thesis concludes relative return on capital, or measures of profitability and liquidity, based upon the development of a multi-year period financial model of a Roman vineyard.

Subsequently, by reviewing both primary and secondary sources, the financial model further serves to justify financial gain and long-term success, as well as its importance to the Roman economy. Although modern scholars have discussed the profitability of Roman vineyards, none have carefully examined levels of liquidity, including solvency and cash flow-related metrics. Using a more dynamic approach, different assumptions can be made on the relative return on capital of Roman viticulture as it relates to geographical location and political rulership under the empire. Ultimately, given the high degree of variability in viticulture, this research and analysis will offer keener insights into the finances behind Roman vineyards as businesses.

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Introduction

From secondary source perspectives and research, viticulture and wine production is one of the best attested economic activities from the ancient world, with abundant information about yields and profitability. Most discussion concentrates on viticulture within Italy, given the necessary climate, arable land, and soil for large-scale production. Other Roman provinces, such as Spain, would qualify under these circumstances, but in general, these territories would not generate the same profitability or liquidity as vineyards within Italy. Most primary writers, nonetheless, write based upon this assumption. In the research and development of this multi-period financial model, there is a specific concentration on a vineyard's core business functions, with the goal of isolating as many external factors as possible, such as a vineyard's location. In a more realistic scenario, a vineyard's finances would fluctuate year-over-year based on these factors, but modern research of Roman viticulture does not have sufficient data for these considerations. Thus, the calculations of revenues and expenses are averaged across an assumed eight-year cycle on the vineyard. In the development of a multi-period financial model, a series of sensitivity tests on the different business functions would offer analysis into understanding of the most optimally situated and sound vineyard within the Roman economy.

Specifically, this thesis engages in a debate with one primary source writer, Columella, and one modern writer, Richard Duncan-Jones. Through their findings and expertise of Roman viticulture, the multi-period financial model makes adjustments and revisions to their work as well as including new assumptions. Firstly, this thesis covers Columella's *De Re Rustica*, which describes levels of viticulture profitability within Rome. His insights give broader understanding into the operations and management of a vineyard, as well as the value of general costs and revenues. The third book of his text covers a vineyard's finances with revenues and expenses

assumed all in the same period. Using his analysis, Duncan-Jones reviews and critiques Columella's testimony. Duncan-Jones references the work of other Roman writers, including Varro, Cato, Graecinus, and Pliny the Elder to disprove and restructure Columella's calculation of revenues and expenses. He also includes his own research on new revenue and expense assumptions, arriving at his results for a vineyard's profitability. His concepts and analysis utilize reoccurring expenses and establish multi-period understandings over an eight-year period but do not cover measures of liquidity. After discussion of his writings, critical analysis and examination of both authors is offered. With these recalculations and further research, both liquidity and profitability measures are produced in the financial model. Using sensitivity analysis, the financial model is then tested against different assumptions, displaying broader context of Roman viticulture and its market economy.

In sum, the goal of this thesis is to understand Roman viticulture profitability and liquidity. Given the limited amount of surviving information from primary writers, there is not a one-size fits all scenario for these calculations. These measurements rely on numerous known and unknown variables, which modern scholars can only hope proves justification of analysis. From a general Roman economic standpoint, this research strives to understand wine demand and the business decision-making behind vineyards as it relates to finance.

Chapter 1
Viticulture and Roman Agriculture

The Roman economy operated extensively as an agricultural oriented market with differing levels of productivity depending on goods and services. Many consider its "farming, viticulture, arboriculture, and market gardening, comparable, and often superior, in its productivity and agronomic expertise to the best agricultural practice of England … France, and Northern Italy in the mid-nineteenth century" (Kron, 2012, pg. 156). In particular, Roman viticulture was often viewed as a primary generator of high yields and returns for the economy given its degree of specialization, customization, and expertise. Profitability varied based upon a multitude of different factors including location, land quality, preparation, and ownership. One author, Lucius Junius Moderatus Columella, describes the processes in viticulture, the costs associated, and the potential profitability. The viticulture profitability model developed in this thesis draws on Columella's testimony, refined where necessary through the criticism of modern scholars, coming to a best estimate of the yields in an isolated scenario of a model-sized vineyard.

Columella was born and raised in Gades (Cadiz), a Roman province in Spain. Based on his academic background and education, he was likely born to wealthy land owners. Much of his youth is unknown but he often admired the work of his uncle, Marcus Columella, who was an excellent farmer from the Baetic province. At some point, he moved to Italy, using his wealth to acquire and own multiple farms and vineyards across local regions. His writings and research were completed later in life, after owning farms in the neighborhoods of Rome, including the towns of Carseoh, Ardea, Albanum, and in Latium.[1]

[1] Ash, 1940: pg. ix.

Columella's extensive research and analysis across four books covers everything from the situation and quality of land to the methods of planting vineyards, describing a sophisticated set of practices from the 1st century A.D. Specifically, his third book focuses on the management of a vines and operations of the vineyard, explaining it to be the most important part of rural husbandry.[2] Columella discusses different districts, regions, and areas of land and their "customary yield," each having certain distinguishable reputations.[3] His analysis, however, primarily focuses on viticulture within Italy, rather than other economies across the empire. Throughout, he references other writers' work at the time including Marcus Varro, Cornelius Celsus, Trebellius, Graecinus, Julius Atticus, Volusius, and Gallo, intervening in a literary review of viticulture and its profitability.[4]

The practicality of owning, managing, and supporting a vineyard has long been debated among Roman writers. Viticulture, in itself, encompasses many costs and risks which hurt long-term growth. Columella seeks prove that 'his' ideal vineyard is indeed profitable, even resounding with success. In his review, he first reveals the importance of proper management of the business's operations as well as past writers' profitability measures, culminating with the appraisal of wealthy land owners Cato and Terentius Varro.[5] He states (Colum. 3.3.2):

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[2] Colum. 3.1.1: English translation of Columella's Latin are provided by Ash (1940), unless otherwise noted.

[3] Colum. 3.3.2: Columella describes the importance of land and location of vineyard, discussing whether it is preferable to own meadows and pastures in certain locations. He mentions Sasena being unfavorable to the land and Tremelius approving of it. The ground needs to near trees to cut for supports of the rows of vines.

[4] Ash, 1940: pp. ix-xi. Taken from Introduction Section on Harrison Boyd Ash's Lucius Junius Moderatus Columella on Agriculture. Columella quoted Lucius Annaeus Seneca and Pliny the Elder, revealing a similar age to the writers and the completion of his book to be in his elder years.

[5] Colum. 3.3.2: States Terentius Varro speaks on grain yields in parts of Italy, Etruria, Syria, and Africa a century prior in his book *Res Rusticae.* This also quotes Cato's *Origines.*

> Interim studiosi agricolationis hoc primum docendi sunt, ubernmum esse reditum vinearum,
>
> Meanwhile those devoted to the study of agriculture must be informed of one thing first of all that the return from vineyards is a very rich one,

divulging not only its reputation to investors but also the emphasis on fiscal return. Throughout, Columella carefully weighs the risks involved with viticulture investment, inferring profitability in his ideal scenario of a vineyard.

Columella discusses a vineyard's many costs and expenditures, understanding the extensive maintenance required throughout its entire lifespan. For his analysis, he isolates a small-sized model vineyard in Ceretanum, the size of seven *iugera*, which he uses to approximate his calculations of expenses and profits.[6] Specifically, he covers both long-term capital expenditures as well as reoccurring expenses.[7] In this model scenario, he assumes at least two years of vine preparation and planting, meaning the business does not realize profitable returns until at least the third year. Losses accrue over the first couple years of the business, which becomes costly for the ownership. The investment's break-even between its profit and initial costs would take even longer than just the returns experienced after the third year. Given these periods of unprofitability, Columella likely suspects proprietors of the wealthy class to undergo an investment in a vineyard. He approximates a cost of 1,000 *sesterces* per *iugerum* in this scenario, totaling a land price of 7,000 *sesterces*.[8] Other capital expenditures include a one-time expense for a worker, known as a vinedresser, who specializes in preparation and harvesting of the vineyards, worth between 6,000 and 8,000 *sesterces*. Vinedressers typically lived on the

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[6] Ash, 1940: pg. 267. Each *iugerum* measures to 240 x 120 feet, totaling 33,600 square feet, roughly a bit less than one acre.

[7] Colum. 3.3.8: Columella assumes seven *iugerum*, likely to set the maximum amount of land covered by a single vinedresser.

[8] Colum. 3.3.8.

vineyard and were skilled in viticulture-related labor. After the initial purchase, additional expenses would likely consist of the slave's basic needs such as food and shelter. Yet, Columella does not include these reoccurring costs in his analysis. Further, Columella estimates 2,000 *sesterces* of maintenance required for each *iugerum* of land. Maintenance included the preparation of uncultivated land, performing tasks such as planting stakes, determining vine placement, and other ancillary work. An additional interest expense of six percent of the total initial purchase, occurring over the first two years, is also included in his calculations. Also, depending borrowing base of the investment and the owner's relationship with lender, there may be additional interest expenses. Columella assumes a perpetual annuity of 1,950 *sesterces* every year following the two-year period for this expense. Costs and expenses total 30,480 *sesterces*, not including the perpetual interest expense.[9] These expenses are assumed in totality in one period, rather than spanning over the course of multiple years.

Roman viticulture profits are generated through the sale of *cullei* or *urnae* of wine, which vary widely based on quality, duration of the harvest, and location of the market. Given the complexities of wine production and variation within each plant, it is difficult to estimate the revenue generated from single vines or rows within a vineyard. Instead, Columella discusses in great detail the relationship between a single *iugerum* and wine yields, approximating there to be anywhere from 800-to-1000 grafted stocks in each *iugerum.* In this case, Columella bases his wine output in *cullei*, giving an average equivalency of its value to each *iugerum*. He states (Columella 3.3.3):

[9] Colum. 3.3.9.

> His certe temporibus Nomentana regio celeberrima fama est inlustris, et praecipua quam possidet Seneca, vir excellents ingenu atque doctrinae, Cuius in praedus vinearum iguera singula culleos octonos reddidisse plerumque.
>
> The neighborhood of Nomentum is illumined by a most distinguished reputation, and especially that part owned by Seneca, a man of outstanding genius and erudition on whose estates it is learned that every *iugerum* of vineyard has yielded commonly eight *cullei.*

Given this sentiment and appraisal, eight *cullei* to the *iugerum* would appear to be on the upper-bound of vineyard yields – what land-owners might strive for. For his small model scenario, Columella suggests seven *cullei* to the *iugerum* is appropriate, slightly lower than the outstanding yields on Seneca's vineyard.[10] It is Columella and his colleague's opinion that vineyards yielding less than three *cullei* to each *iugerum* should be cut down or removed as a sunk cost to avoid future loss. He also uses another metric, volumes of *amphorae*, to judge the reasonable amount of wine yielded from a vineyard, following Graecinus's lowest estimate of twenty *amphorae* from every *iugerum*.[11]

Prices for wine can widely vary based on a multitude of factors. Columella assumes that each *culleus* can generally be sold at least for 300 *sesterces* as "the lowest market price".[12] If one *iugerum* equals seven *cullei*, then there are approximately 49 *cullei* within the seven *iugerum* plot of land. 49 *cullei* equates to 14,700 sesterces of revenue generated each year from Columella's vineyard, starting in the third year.

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[10] Colum. 3.3.3.

[11] Ash, 1940: pg. 255. Ash equates 1 *amphora* to be roughly 6.84 (5.70 Brit) gallons.

[12] Ash, 1940: pg. 255. Ash states that 1 *sesterces* equals about 4 cents.

Revenue Generated *(in Sesterces)*	
Land Size (iugerum)	7.00
Wine Volume (culleus)	49.00
Wine Sales (yearly in sesterces)	14,700
Ratio (sesterces / culleus)	300

Figure 1. Columella's Revenue Output

Columella also looks at additional sources of revenue on the vineyard, including the sale of nursery plants. He plants between the rows in the vineyard some 20,000 nursery plants to each *iugerum* to be sold at profit after harvesting. This figure of 20,000 is the maximum estimate, as Columella compares himself to Julius Atticus, who plants four-thousand fewer plants to the *iugerum.* Based on Columella's assumptions on the growth of the vineyard, the nursery plants would first become purchasable after eight years from initial planting. Approximating about a third of these plants die to environmental factors, contract-vineyardists purchase the sum of the plants from each *iugerum* for anywhere from 2,000 to 3,000 sesterces according to Columella. He believes these earnings of the nursery plants can be sold to cover the costs associated with the maintenance.[13]

Including the interest expense on Columella's model, total costs and expenditures are 32,480 sesterces.[14] Revenue generated is assumed on an eight-year cycle, given the purchase of nursery plants. Although these one-time costs likely last longer than eight years, the average return or profitability is 9.67%. Profitability increases over a longer duration of time, given less of a need for additional costs such as labor, land, and maintenance as well as the continuous yearly wine sales.

[13] Colum. 3.3.13.

[14] See pg. 9. Figure 2 shows costs and expenditures

Columella's Model *(in Sesterces)*	
Purchase of Land	7,000
Purchase of Vinitor	8,000
Maintenance Costs	14,000
Interest Expense	3,480
Total Costs	32,480
Wine Sales (over 8-year period)	88,200
Nursery Plant Sales (over 8-year period)	55,320
Years until Profitability (in years)	4.50
Average Return or Net Margin (over 8-year period)	9.67%

Figure 2. Columella's Calculation of Viticulture Profitability

The break-even period or time period until profitability matches the original costs is four-and-half years. In many cases, Columella assumes the best-case scenarios for pricing and conversions, not accounting for the multitude of extraneous risks involved. He does not include multi-year expense calculations and the possible variations in revenue growth year-over-year. As a reader, we are supposed to assume the averages for each situation, including returns and costs, making only for approximations of the returns of this model vineyard Columella proposes. Depending on location, the price and sale of goods changes drastically, affecting wine revenue. Moreover, nursery-planting was only practiced heavily in Italian regions, in areas of rich and moist soil, where it may be possible for this market to exist. In another location, without these profits, what might happen to the vineyard's returns? If we hold constant all of Columella's assumptions, removing nursery plants, his vineyard's average net margin drops to 7.90% and his break-even period increases to a drastic 7.70 years.[15]

[15] Average net margin refers to average net income as a percent of average sales throughout the duration of the eight-year cycle. Net income is the theoretical monetary value that is returned to the equity holders or investors of the vineyard.

On the other hand, what would be the effect of changing the level of wine output on vineyard's profitability? If we assume Columella's worst-case scenario, three *cullei* to the *iugerum*, where the vines "should be uprooted," average net margin dips to 8.14% yearly, and the break-even period increases to roughly five-and-half years. Like these two changes, there is many different values that change Columella's findings. If wine is in high-demand within the region of sale, prices may be drastically affected. Or, for example, more or less nursery plants may be tarnished before sale, changing numerous factors in overall return. Compounding effects of multiple negative changes to the model's inputs, say in a worst-case scenario, may deem the business to even unprofitable, causing foreclosure or bankruptcy to the vineyard. Nonetheless, Columella's assumptions may not truly be exact, but his findings tell a greater story about business owners and their financing decisions.

Chapter 2
Columella's 'ideal' Vineyard in Review

Columella's analysis of a vineyard's costs and expenditures are rather simplistic given variations in business operations year-over-year. He assumes all of the expenses, even those that would seem to reoccur, happen within the initial investment. Realistically, these operational costs should extend over the long-term lifespan of the vineyard. Given Columella's limited knowledge of modernized profitability metrics and accounting policies, his vineyard's operations do not offer a precise understanding of multi-year finances.

Providing context to his research, Columella focuses on investment return as a core metric of business success. However, this model will also address his vineyard's cash positions and solvency, based on the business's operating profit, Earnings before Interest, Taxes, Depreciation, and Amortization (EBITDA), and free cash flow levels. This analyzes the vineyard's operations in different scenarios, including situations of unprofitability or insolvency. Both revenues and expenses will be projected out over an eight-year period, rather than relying on inputs from one year. Further, Columella's inputs and variables are fixed on one scenario or assumption. This model's research will show a broad array of scenarios, not just best or worst cases. If these data inputs are more flexible, a sensitivity analysis would also show a more exact approximation of the average vineyard, not just Columella's model-sized vineyard. Lastly, does Columella account for every expense within his viticulture business? Surely, there are expenses and costs he forgets or foregoes that should be included in the model's estimates. This will include depreciation and amortization expenses, other related operational costs, and tax implications. Other writers, including modern scholars have even expanded on Columella's work, critiquing anything from the valuation of his expenses to the pricing and output related to

profitability. Using both primary and secondary sources, these findings will give a more finalized consensus of Roman viticulture.

Duncan-Jones's Criticism of Costs and Expenditures

In particular, one modern historian, Richard Duncan-Jones, expresses his viewpoints on Columella's analysis of Roman agriculture. Duncan-Jones believes that Columella's findings largely overstate viticulture profitability, by not including certain expenses and overestimating key revenue figures. He uses primary comparisons to Columella's work, including manuscripts from other notable writers at the time. Also, he draws similarities between Columella's yields to those in pre-industrial Europe, offering a more accurate picture of wine yields. Duncan-Jones begins his critique of Columella's method of discussion, starting with his analysis on a seven *iugera* model vineyard, stating, "it will be argued that the main set of figures (from Columella) is palpably inaccurate" (Duncan-Jones, 1974, pp. 33). Throughout, he gives a critical examination of Columella while providing inferences for his assumptions of levels of viticulture profit.

Duncan-Jones recalculates Columella's expenses by reworking the types of expenses into two different categories, capital outlay and overhead expenses. Beginning with capital expenses, he includes ancillary woodland and additional slave labor, which Columella overlooks in his model. Furthermore, Duncan-Jones assumes the land to be uncultivated, meaning owners would first have to properly prepare and fertilize the farm land to grow grain for the workers. Duncan-Jones lays out his capital expenses, shown below.

Capital Outlay *(in Sesterces)*	
Purchase of Land	7,000
Purchase of Vinitor	8,000
Maintenance Costs	14,000
(Farm Buildings and Equipment)	19,600
(Grain Land)	1,700
(Ancillary Woodland)	1,670
(Ancillary Slave Labor)	400
Total Capital Outlay	52,370

Figure 3. Duncan-Jones's Additional Business Expenditures, designated by (…)

Duncan-Jones only briefly speaks about additional farm buildings and equipment, which draws a large portion of his additional expenses, totaling 19,600 sesterces. He states that the calculations are based upon Cato's work, which details different types of farm equipment and their respective prices. He also agrees with Columella's assumption for duplicates of agricultural tools on the vineyard.[16] Duncan-Jones includes an expense covering ancillary woodland, which describes the wood used to supply the vineyard's stakes and ties. Duncan-Jones accepts figures from Julius Atticus, who states that three and half *iugera* of groves to 25 *iugura* of vines are needed. Based on this ratio, 0.98 *iugera* of woodland should support Columella's vineyard, costing a total 1,670 *sesterces.*[17] Duncan-Jones takes a different approach in his calculation of ancillary grain and labor for the vineyard. In addition to the seven *iugera* of land, the landowner would need approximately 50 *modii* of grain to support the laborers with bread. This additional land required to grow the grain would cost approximately 1,700 *sesterces*, which Duncan-Jones describes as a

[16] Duncan-Jones, 1974: pg. 41. In the footnotes, Duncan-Jones states that Columella advises the landlords to keep duplicates of the equipment necessary for farming
[17] Duncan-Jones, 1974: pg. 42.

"rough capitalization".[18] He accepts Columella's assumption that a farm of 200 *iugera* needs 8 men, a fourth of that devoted to grain land. Four total men are needed to work the uncultivated land into grain, meaning one *iugerum* would be one-twelfth of the maintenance cost of slave. Through Duncan-Jones calculation, additional slave labor to manage the grain land would cost 400 *sesterces*.[19]

Duncan-Jones also includes additional, "overhead expenses," used to portray the reoccurring costs associated with the long-term function of the vineyard, a key aspect missing in Columella's model. Duncan-Jones primarily focuses on depreciation and amortization-related expenses, as well as a new calculation of the interest expense owed within the first two years of the business. Duncan-Jones assumes the average vineyard has a lifespan of 30 years, and slaves live an average of 20 years. After accounting for the thirty years, the land would be deemed uncultivatable and wine production would cease. On the other hand, slave laborers may live longer than twenty years, but their salvage or market value would be reduced to zero. Duncan-Jones seeks to display all parts of the business, even the intangible assets that are less quantifiable. Shown below are Duncan-Jones's selective overhead expenses.

Overhead Expenses *(in Sesterces)*	
(Interest Expense) (6% bi-yearly)	785
(Maintenance Spent on Laborers)	170
(Amortization of Vines)	467
(Amortization of Farm Buildings and Equipment)	653
(Amortization of Vinitor and Slaves)	518
Total Overhead Expenses	2,593

Figure 4. Duncan-Jones's Overhead Expenses, designated by (…)

[18] Duncan-Jones, 1974: pg. 42.
[19] Duncan-Jones, 1974: pg. 42.

Firstly, Duncan-Jones reassesses his interest expenses on the vineyard, given his newly projected capital outlay. Total capital outlay equaled approximately 52,370 *sesterces,* and six-percent of this total loss is worth 3142.2 *sesterces.* Assuming Duncan-Jones's six-year cycle of profitability and an additional two years of planting, the total lifespan of vineyard is eight years.[20] Assuming the total interest expense of 3142.2 *sesterces* during the eight-year cycle, an interest expense on a bi-yearly period equals approximately 785 *sesterces*.[21] Duncan-Jones accepts Columella's word on both the six-percent interest rate, and the recognition of this six-percent occurring in the first two years of losses.

The other overhead expenses in Duncan-Jones's assumptions includes an expense of 170 *sesterces* spent on additional maintenance of workers. Firstly, this would likely support laborer costs such as food, shelter, clothing, which Duncan-Jones calculates as 140 *sesterces*. The remaining 30 *sesterces* is allocated to labor costs associated with the tending trees and cereals.[22] Lastly, Duncan-Jones includes expenses which he categorizes as amortization costs. Essentially, the vineyard's assets, including buildings, equipment, and slave labor, will lose value over time during its lifespan. In this case of physical assets, such as the buildings and equipment and vines, Duncan-Jones assumes original capital outlay cost and divides it by its lifespan, assuming no salvage value. For buildings and equipment, the initial capital outlay cost is 19,600 *sesterces* and its life span is 30 years, meaning the yearly amortization costs equals approximately 653 *sesterces*. If this process is repeated for the amortization of vines themselves, the calculated costs

[20] Duncan-Jones, 1974: pg. 41. Duncan-Jones discusses the vineyard's profitability on a six-year cycle (post the two-year planting period) based upon the sale of nursery-plants, which would first become available after eight years after the expenditures on land and vine-planting. All of Duncan-Jones's average annual returns are based around this six-year cycle.

[21] Duncan-Jones, 1974: pg. 43. Duncan-Jones's calculation of the bi-yearly interest expense rounds down from its exact value of 785.55 *sesterces.* The yearly interest expense would be 392.78 *sesterces.*

[22] Duncan-Jones, 1974: pg. 42. Duncan-Jones says that there is little information on payments to slaves, and believes it would uneconomic to employ them unless there was greater exploitation.

equals approximately 467 *sesterces.*[23] By definition, Duncan-Jones assumes that both the owner's buildings and equipment and its vines have no "market-value" after 30-years. This simply means that the owner of the vineyard would not be able to sell leftover equipment, buildings, and vines for any return or value at the end of the lifespan. If assets have no value, then there is simply no fundamental use. Although this may not necessarily be true in every scenario, Duncan-Jones argues that "on-average," this would be the case scenario. Thus, he reiterates that the vineyard's assets should be viewed in his assumption of their lifespans.

In addition to the vineyard's physical assets, Duncan-Jones also includes amortization of other assets including the laborers and slaves themselves. The amortization cost of the slave labor is worth a total of 518 *sesterces*, given their 20-year lifespan.[24] Since the laborers are not employed by the vineyard, but instead purchased at the initial purchase period, they incur value as an asset for the vineyard. Simply put, these laborers can be sold for a profit or loss for the owner at theoretically anytime, which changes the overall dynamic of the vineyard's long-term value.

DUNCAN-JONES'S REVISION OF REVENUE AND PROFITABILITY

Duncan-Jones critiques Columella's findings through a discussion of two separate comparisons to his wine yield assumptions. Firstly, he accepts lower yields from other primary sources, assuming wine yields per each *iugerum.* Similarly, he compares Columella's minimum

[23] Duncan-Jones, 1974: pg. 41. The exact value of the amortization costs of buildings and equipment is 653.33 *sesterces*, where Duncan-Jones rounds down in value. Similarly, the exact value of the amortization of vines is 466.67 *sesterces.*

[24] Duncan-Jones, 1974: pg. 41.

yield of three *cullei* per *iugerum* to those in Italian vineyards in the early twentieth century, stating Columella's assumptions to be three-times the average. According to Duncan-Jones, the average in Italy from 1909 to 1913 was 1.16 *cullei* per *iugerum*, with the average only increasing slightly to 1.17 *cullei* per *iugerum* from 1909 to 1936. He even compares this to regions that yield lower returns such as Calabria, which returned 0.60 *cullei* per *iugerum* from 1931 to 1934.[25] Duncan-Jones believes that there is almost no way to "conjecture some radical difference between the yield of ancient and modern methods of cultivation and vinification" (Duncan-Jones, 1974, pg. 45). Further, comparing Columella's findings with Graecinus, another Roman writer, Duncan-Jones accepts three *cullei* per *iugerum* was not the lowest representative of wine yields in vineyards. Plus, Cato's large-scale vineyard of 100 *iugerum* only managed 160 *cullei*, which equates to 1.6 *cullei* per *iugerum*.[26]

Another approach Duncan-Jones considers is Columella's selling price. He believes Columella's minimum wine price of 300 *sesterces* per *culleus* is too high. Specifically, he references primary sources that cover market inscriptions from various cities Herculaneum, Pompeii, Samnium, and others across the empire. Although Duncan-Jones supplies reasonable information for Columella's overestimation, it is quite possible that the sale of a bulk of goods or products would have a standardized price, which Columella suggests. Even more so, from what Duncan-Jones reveals, the price discrepancy could be based on location, with Rome having the highest prices. From Columella's background, modern-scholars suggest many of his farms were in rural areas, but still surrounding the great city.[27]

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[25] Duncan-Jones, 1974: pg. 45.
[26] Duncan-Jones, 1974: pg. 45.
[27] Ash, 1940: pg. ix.

Chapter 3
Relevant Business Model Considerations

Shown by the analysis of both authors, a model Roman vineyard can be subject to many different assumptions and changes that can affect profitability and liquidity. Duncan-Jones expands on Columella's simplistic model, using financial and accounting concepts that support a multi-period understanding of profitability. But there are additional considerations that are necessary. On top of some of Duncan-Jones broad assumptions for his new expenses and recalculation of pre-existing revenues and expenditures, he also limits his model to a set time period. He uses a simplistic approach in categorizing his expenses, only separating them into "Capital outlay" and "Overhead expenses". Furthermore, Duncan-Jones ignores some of the long-term aspects of Roman viticulture, which goes hand-in-hand with understanding a business's solvency. In order to gain a more insightful picture into a vineyard's liquidity, additional business model considerations and reorganization of expenses are needed.

In many ways, Columella simplifies the ownership of a vineyard, isolating core foundations for easier understanding of business concepts, which Duncan-Jones criticizes. In Columella's other manuscripts, he explains the more in-depth processes and functions of a vineyard, such as the inclusion of other crops. Yet, he does not include these in his quantitative analysis in his third book. Duncan-Jones states, "None of the agricultural writers specifically advocates complete monoculture, Columella's synopsis of the ideal farm includes all the main crops as well as stock breeding", criticizing him for isolating his model farm to only viticulture-related expenses. (Duncan-Jones, 1974, pg. 37). These concepts are crucial for understanding both writers' perspectives, which will be explored in this section.

THE COST OF PLANTING AND PREPARATION

In Columella's model vineyard, he calculates 2,000 *sesterces* as a maintenance expense used in the preparation of the vineyard. Although Duncan-Jones does include this in his capital outlay expense build, he analyzes the legitimacy of this large cost, explaining it "to be another case where Columella has chosen a convenient round figure without considering its plausibility in detail" (Duncan-Jones, 1974, pg. 54). Duncan-Jones describes the process in preparing the vineyard, discussing the steps of reaching the best planting density, the trenching of soil, and the labor costs associated. He estimates the cost of equipping the vineyard at 328 *sesterces* per *iugerum* and the maximum cost of extra labor to be approximately 240 *sesterces.* Duncan-Jones assumes a planting density of 706 vines per *iugerum* and an average price of nursery-plants at 0.465 *sesterces*, equaling the costs of initial preparation of 328 *sesterces* per *iugerum*. Second, he calculates a rough estimate of additional labor by assuming 160 man-days per *iugerum* multiplied by the labor costs of 1.5 *sesterces* per day, equaling 240 *sesterces* per *iugerum.*[28] He includes a few other expenses including the work-rates for cutting and shaping wood as well as the props and stakes required for the *iugerum* of vines. In total, Duncan-Jones comes to less than 1,000 *sesterces* in costs associated with preparation, believing Columella's assumptions to be wrong.[29] Although Duncan-Jones has a persuasive reason for these adjustments, he overlooks Columella's simplification of these expenses.

Certainly, Duncan-Jones is right that Columella has a "convenient round figure" but that may be completely purposeful. Columella gives a broad definition of what the 2,000 *sesterces*

[28] Duncan-Jones, 1974: pg. 54.

[29] Duncan-Jones, 1974: pg. 54. The total cost of preparation includes 328 *sesterces* of equipping costs, 240 *sesterces* of additional labor, not more than a few hundred *sesterces*, and work rate of cutting stakes at 100 *sesterces*, which accounts for anywhere from 900 to 1,000 *sesterces* of expenses per *iugerum*.

would be used for, and that being preparation of the vineyard. In including all of Duncan-Jones's additional expenses, such as ancillary slave labor, ancillary woodland, and grain land, it is very possible that the 2,000 *sesterces* might be a "catch-all" for those additional expenses. Taking the total of Duncan-Jones's additional expenses is however greater than the 2,000 *sesterces* Columella proposes, but it is reasonable to assume Columella is not as inaccurate as Duncan-Jones believes. Duncan-Jones tends to modernize his calculations of expenses to fit his narrative, rather than consider the situation and audience Columella writes to.

EXPENSE RECOGNITION AND ACCOUNTING POLICIES

With additional costs to a vineyard's business model at a time during the Roman Empire, it is crucial to faithfully represent the value of these considerations as it relates to modern profitability and liquidity metrics. Simply, there is not an apples-to-apples comparison for the financial reporting seen during the Roman Empire versus the modern day, meaning adjustment is needed. Nowadays, U.S. businesses follow strict rules of accounting known as Generally Accepted Accounting Principles (GAAP). International businesses follow a similar set of accounting principles, using the International Financial Reporting Standards. Even the foundations and framework for these principles date back to a system developed in 1494 by Luca Pacioli, an Italian monk and mathematician.[30] The rules and accounting principles set forth in GAAP and IFRS ensure that "companies produce financial information that is useful to …

[30] Phillips, Libby, and Libby, 2010: pg. 17., Kestenbaum, 2012: *The Accountant Who Changed The World*. Pacioli was known as the father of accounting, innovating a dynamic double-entry bookkeeping model where transactions were entered twice into a business's financial records. Merchants were able to "neatly" understand their bookkeeping as well as the effect of time on recording transactions.

potential investors, lenders, and other creditors in making decisions in their capacity as a capital provider" (Phillips, et al., 2010, pg. 18). This includes proper representation of a business's assets, liabilities, revenues, and expenses, as well as following core principles such as revenue recognition, matching and full disclosure.[31] Revenue recognition policies are extremely important in accurately portraying a business, especially when it relates to accrual basis accounting, which is required under GAAP. Adding a dynamic expense build and multi-year periods to the vineyard's financial model would require following GAAP. The Roman economy, and therefore Columella, are not known to have employed these standards of practices for their businesses.

Classifying Duncan-Jones's costs and expenses, he employs accrual basis accounting techniques with the addition of his amortization expenses. Accrual-based accounting records revenue, expenses, and other financial decisions at the occurrence of the transaction. This means revenues are recognized when they are earned, meaning the business has performed its service to the customer.[32] An example would be a customer using a credit-card at a store to purchase goods, and the company would immediately record that service as revenue, even though the business has not received cash in its bank account. As opposed to Duncan-Jones, Columella uses a strict cash-in, cash-out to record expenses. Cash-based accounting recognizes transactions when the payment is exchanged. Taking the same situation in the prior example, the business would not record the service as revenue until receiving the cash in its bank account. Depending on the transaction, there might be a significant lag in time before the revenue is recognized, which

[31] Phillips, Libby, and Libby, 2010: pg. 100, 102, and 626. Revenue recognition accounts for when a business reports its revenue. In accrual accounting, revenues are recognized when they are earned and expenses when they are incurred. Matching is a requirement under accrual basis accounting, which records expenses in the same period as revenues they generate, not necessarily the period in which cash is paid for them. Full disclosure policy means businesses must present all information in their financial reports.

[32] Phillips, Libby, and Libby, 2010: pg. 100.

shows that cash-based accounting does not account for the value of money, where it relates to time. Furthermore, expenses such as depreciation and amortization only occur in accrual-based accounting, and are aimed to better-value assets over its complete lifespan. Duncan-Jones attempts to build in expenses over the lifespan of the vineyard by categorizing between capital outlay and overhead expenses, creating a more dynamic build to profitability. Although his metrics of profitability may stay intact based on his assumptions, judging the vineyard's long-term value and solvency requires more analysis given his addition of depreciation and amortization expenses.

Firstly, Duncan-Jones categorizes his additional overhead expenses as amortization. Amortization relates to intangible assets, which are assets without physical value. All of Duncan-Jones's assets are technically physical assets, even the slave-labor, meaning there is a physical value placed on its worth. This means that Duncan-Jones is truly measuring the depreciation of his assets, not amortization. Both depreciation and amortization are considered non-cash expenses, which are costs that cannot be converted to cash. Based on Columella's model vineyard, it is apparent the Roman Empire and its respective businesses did not operate using the accrual-based accounting methods. Roman businesses would not consider the cash benefits through depreciation of employing slave-labor from an accounting standpoint, because the Roman economy was already centered around the practice. Columella's right to consider a cash-in, cash-out business, simply because Roman's did not have the extensive bookkeeping and accounting policies that future modern civilizations now use. If this model uses Duncan-Jones's depreciation costs and expenses, the levels of the vineyard's cash flow will be artificially higher than what is expected in a cash-based accounting society. And, if Duncan-Jones's additional expenses cause higher levels of cash for the vineyard, then the owner should be able to invest the

cash back into the business, purchasing more land, equipment, and labor to drive further growth and profitability.

Another aspect of including accrual-based accounting in a cash-based society is the market value of goods and products can change. Accrual-based accounting is more exact in its valuation of market goods, but not if the initial buying value of the goods might be different. If a vinedresser costs 6,000 to 8,000 *sesterces* using cash-based accounting, a potential buyer might not be valuing the prices correctly. If the transaction is not recognized until the payment is exchanged, then there is a possibility this price is different from one under the accrual-based accounting measures, which Duncan-Jones suggests. Accrual-based accounting does give a more complete picture of a firm's finances, but it also comes with extensive rules of reporting, which Duncan-Jones may not consider.

Lastly, focusing on Duncan-Jones's depreciation of assets, he assumes certain time periods for assets and the same yearly depreciation expense. For example, he calculates a 30-year life span for the farm buildings and equipment and a 20-year life span for the slave labor. Duncan-Jones calculates these expenses by using the original market value divided by the time period. However, he does not consider the market value of these goods after their lifespan and if there's salvage value.[33] In the case of the slave labor, it is more difficult to understand the salvage value, and Duncan-Jones implores a simplification of the expense by taking the average lifespan of a Roman slave. On the other hand, with buildings and equipment, what is to say that these assets do not have value after the 30-year period. Many of the vineyard's tools would certainly be reused or possibly sold after the 30-year period. Obviously, these prices would come a severe discount but there would be value in the materials of goods. Additionally, buildings,

[33] Phillips, Libby, and Libby, 2010: pg. 410. Duncan-Jones uses the straight-line method of depreciation, which is the (initial cost – salvage value) / useful life. Duncan-Jones assumes there is no salvage value on any of the assets.

which were likely made of stone or another rock-material, would certainly be reused or repurposed for centuries after the end of the vineyard's lifespan. Given the lack of data and information, it is difficult to include these assumptions within the model, but it's worth noting the effect on the depreciation expenses.

Duncan-Jones is by no means wrong in his assumptions of profitability, but his model certainly raises the question about the best way to compare this model across multiple periods during the Roman Empire, possibly even against different civilizations where wages are treated differently. Simply put, if one of the only ways Roman viticulture was deemed profitable was from the benefits of slave labor and other accounting policies, then its long-term success should be called into question. This model seeks to fix these notions through a couple of changes. Rather than treating labor as an expenditure with a depreciation expense, the laborers including the vinedressers will be treated as a yearly wage worth the 518 *sesterces* for their 20-year lifespan. Although this reduces the cost of the initial expenditures, the wages more-than cover the cost of the original investment as an operating expense. Also, Duncan-Jones even agrees that the 8,000 *sesterces* for the vinedressers is rather high, describing it as an "overestimate of the average cost of obtaining slave labor of the necessary quality for a vineyard of economic size" (Duncan-Jones, 1974, pg. 53). Similarly, the amortization of vines will be treated as maintenance of vines, categorized as a sales, general, and administrative yearly expense, rather than depreciation. Surely, if vines of grapes are dying, they will be replaced by the vinedresser, costing an expense. Lastly, the 14,000 *sesterces* of capital outlay expenses used in the maintenance, purchase, and planting of vines will be adjusted to 7,000 *sesterces* of expenses based upon Duncan-Jones's assumptions. The expense, however, will be recognized as two 3,500 *sesterces* worth of expenses, occurring in year one and year two, given Columella's

explanation of their occurrence in the first two years before realizing wine sales.[34] These 3,500 *sesterces* worth of expenses will be repeated after the six-year cycle of profitability that both Columella and Duncan-Jones assume. The associated amortization costs of 467 *sesterces* on the vines will be treated as reoccurring maintenance expenses. Since the expenses in the first two years were treated as non-depreciating expenses, amortization related costs would not exist. However, given the likely need for additional maintenance and preparation on the pre-existing vineyard, the amortization cost will be added as another yearly expense. This helps maintain Duncan-Jones's assumptions while maintaining the authenticity of this profitability model. Moreover, these structural changes to the vineyard's recorded expenses help more accurately portray the functionality of Roman viticulture.

TAX IMPLICATIONS ON RELATIVE RETURN

Under accrual-based accounting practices and recognition policies, there are various implications on tax practices. This model will have a broad simplification of the accounting policies given the limitations of the Roman financial system, but will still be consistent with the primary objectives of financial reporting. Nowadays, companies employ many different types of depreciation and amortization, which allow for tax benefits and higher net margins.[35] Regardless of the complexities and simplifications of the tax implications employed, it is necessary to include in Columella's model. Both Columella and Duncan-Jones do not mention the possibility

[34] Colum. 3.3.8.

[35] Phillips, Libby, and Libby, 2010: pg. 414. Duncan-Jones uses the straight-line method of depreciation, which has the same yearly depreciation expense for the useful life of the asset. Other depreciation types include the double-declining-balance formula, which causes the depreciation expense to decline over time, and the units-of-production method, which varies based upon the asset's production. Both of these allow businesses to optimize profits based upon type of asset and its useful life.

of government taxes on practicing viticulture. Especially, in the case of the modern scholar Duncan-Jones, who is extremely critical of Columella's work, calling it "palpably inaccurate," even he does not discuss taxation, instead choosing to nitpick on amortization costs such as slave labor.[36]

Any economy with ownership of property and a centralized government dictating trade, such as in the case of the Romans, enforces tax practices or receives some sort of monetary value from its citizens. The amount given towards the treasury depended on a multitude of factors including economy output, government spending, and military necessities. With the Roman treasury, there were demanding expenditures to meet, including any related military expenses, civil infrastructure and construction, and government funding, all at the discretion of the ruling class. Military campaigns themselves had enormous costs, driving a large portion of economy output. Army salaries alone contribute more than 600 million sesterces, and that is not even considering other non-salary costs.[37] Nonetheless, to fund these expensive expenditures required extensive fiscal support from the Roman people, meaning taxes would come at a high price.

During periods of military dominance and expansion, the Roman government would exploit its provinces and colonies', tapping its resources and money. At those times, Roman land-owners would benefit from the treasury's surplus, where local taxes were not as necessary. Further, in agricultural dominated regions, it was common practice that the government would tax in the form of tributes, seizing goods and products. Roman land-owners, such as Columella, were typically not required to pay tribute, but those in conquered territories certainly did. The government may also store these goods to control trade supply or for in case of food shortages

[36] Duncan-Jones, 1974: pg. 33.
[37] Scheidel, 2015: pg. 156.

seen from famines or diseases. From a profitability standpoint, returns to businesses drastically changed based on these factors, including location as well as the tax practices. If a tax comes in the form of a tribute, a sale of goods and products never occurs, hurting revenue output. However, if businesses are simply taxed from a profitability perspective, only a percent of net income drops. Direct taxes in various provinces and Roman territories were easy to implement and reported levels of one-seventh to as high as one-fifth of farm output.[38] Regardless of the level of taxes in discussion, Roman land-owners would still have to pay, something Duncan-Jones's adjusted assumptions do not include.

Based on Columella's references of Lucius Annaeus Seneca (circa 4 B.C. to A.D. 65) and Pliny the Elder (23 B.C. to A.D. 79), he was writing during the first half of the 1st century, A.D, under the imperial tax system in the High Empire or Imperial Rome.[39] Specifically, during this period, the empire employed a few main elements to the imperial tax system.[40] The main elements included: direct taxes on privately owned land, direct capitation taxes on trades and crafts, rents on various categories of public land, indirect taxes on inheritances or sales, military requisitions, and revenue in kind performed by public service.[41] Modern scholars have long debated the complexities of the tax system and the approximate amounts seized from the imperial government. However, for Columella's model vineyard, taxes may have come in a few different forms. It is unlikely that a tribute was necessary, but a tax percentage could have been decided based upon output or overall profitability.

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[38] Scheidel, 2015: pg. 157.

[39] Ash, 1940: pp. ix.

[40] Bowman, 2018: pg. 32. Bowman suggests the High Empire existed up until early 4th century, believing changes occurred in 'consisted budgeting' for the imperial tax system around A.D. 300.

[41] Bowman, 2018: pg. 32. Bowman explicitly states most taxes were paid to the imperial government during this period. Changes were introduced during the period of Diocletian with a greater presence of municipal taxation.

Firstly, focusing on tax percentage as a total output, during a period in the empire, an annual tax of one-percent of the total business was reported in Syria and Cilicia. Assuming profits of five-to-six percent, the tax rate would be anywhere from 16% to 20%, which seems reasonable given tribute levels. Depending on the type of agriculture, different taxes would be applied. In Egypt, tax totaled one-eight or one-tenth of output on private grain land and even as high as 30% to 40% for public land. Status as well as location also played a crucial role in the deciding of taxes.[42] Assuming a one-fifth of farm output direct tax on the revisions to Columella and Duncan-Jones's models in years after planting, net profit drops from 26,659 to 20,779 *sesterces*, which marks an approximate 22.1% decrease caused by the tax. On the other hand, with a direct tax of one-seventh of output, net profit drops approximately 15.8%.[43] If Columella's vineyard is instead taxed at 16% of its profit, net profit drops from 26,659 to 22,394 *sesterces*. Taxed at 20%, net profit drops to 21,327 *sesterces*, slightly higher than the direct tax. Given Columella's primary location of Rome for his vineyard, he's certainly on the lower bound of these tax implications. In his scenario of profitability, it would be optimal to prefer the one-seventh direct output tax, rather than the lowest tax bracket of 16%. A rough estimate for the vineyard's taxes would be likely be anywhere from 15% to 20%. This estimate would vary considerably based upon location, economic status, and the installed government.

Although Duncan-Jones covers direct tax rates in some of his other works, he does not include his assumptions in determining the vineyard's profitability. His calculations, as well as another scholar's, Bagnall, suggest all-in tax rates as high as 30% to 40%, stemming from Egyptian tax data. Both scholars combine average revenues from private and public land,

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[42] Scheidel, 2015: pg. 159.

[43] See pp. 24 for adjustments to Duncan-Jones's expenses. This assumes yields of seven *cullei* per *iugerum*, sold at a price of 300 *sesterces*. Direct tax of one-seventh to the total output results in a net profit of 22,459 *sesterces*.

creating a combined tax and wheat equivalent for the price.[44] It is reasonable to assume that Columella's model is not dealing with public land, which would show the variation in the rate, given that public land has a higher tax rate. Additionally, it is very possible tax rates in Egypt were higher given its vast resources, agricultural fertility, and production. Other scholars, such as Hopkins and Lo Cascio, assume taxes as low as 10% or less.[45] Both Hopkins and Lo Cascio are largely criticized for not including military impositions and requisitions, as well as public service.[46] Depending on the level of overhead expenses on trade, indirect taxes may vary significantly for a model vineyard. External import and export costs could be charged at a high rate of 25%.[47] In Duncan-Jones's profitability assumptions, he largely assumes Columella is selling the vineyard's produce in Roman regions, which nonetheless would require less transport. Hence, these assumptions support a tax rate of anywhere from 15% to 20% for this vineyard's profitability model.[48]

INTEREST EXPENSE RECALCULATION

Columella suggests a six-percent interest expense occurring in the first two years of losses, which Duncan-Jones follows. In his case, the interest rate of six-percent would cover the first two years of losses on his total expenditures calculation of 52,370 *sesterces*. This result

[44] Bowman, 2018: pg. 34. See pg. 28 for higher taxes on public land. Cites Roger S. Bagnall's *Egypt in Late Antiquity* (1993).
[45] Bowman, 2018: pg. 35. Cites Keith Hopkins's *Rents, Taxes, Trade and the City of Rome* (2000), as well as Elio Lo Cascio's *Mercati Permanenti e mercati periodici nel mondo Romano* (1997).
[46] Bowman, 2018: pg. 36.
[47] Bowman, 2018: pg. 38.
[48] Duncan-Jones, 1974: pg. 46. Duncan-Jones references numerous Italian inscriptions of wine prices from locations in Italy, including a colloquial graffito from Pompeii and a bar-tariff from Herculaneum.

would be divided by eight years, equaling 785 total *sesterces* for the calculation of the expense over the two-year period.[49] Though, Columella does briefly speak about a potential other interest expense, which describes the relationship between the vineyard's owner and creditor. Columella explains, (Columella 3.3.9):

> *Quod quasi nomen si ut faenerator cum debitore ita rusticus cum vineis suis fecerit, euis summae ut in perpetuum praedictam usuram semissium dominus constituat, percipere debet in annos singulos mille nongentos quinquaginta sestertius nummos*
>
> And if the husbandman would enter this amount as debt against his vineyards just as a moneylender does with a debtor, so that the owner may realize the aforementioned six per cent interest on that total as perpetual annuity, he should take in 1950 *sesterces* every year.

Based on this passage, it is difficult to understand Columella's exact argument for the interest expense. The 'husbandman' must refer to the owner, and the assumed debt will be placed against his vineyard. However, the quote also explains that the 'husbandman' would 'realize' the six-percent interest expense. It is unknown if the 'husbandman' is truly paying six-percent to the moneylender. Columella also explains that if the six-percent interest is treated as a perpetual annuity instead, it will be worth 1950 *sesterces* every year. If the 'husbandman' is indeed paying the moneylender, he would be foolish to not bear the six-percent for the two-period over the perpetual expense as it is significantly cheaper considering the overall lifespan of the vineyard. Is it possible the perpetual interest expense deals with the amount of collateral on the loan? For example, if the owner decides to back the loan with the assets on the vineyard, based upon a lender agreement, then the owner receives the cheaper option of the two? Regardless, the owner's wealth and relationship with a money-lender seems to be crucial in determining Columella's interest expense calculation, which Duncan-Jones also surmises.

[49] Duncan-Jones, 1974: pg. 43.

In an early section of Duncan-Jones's criticisms of Columella, he discusses the interest expense rather as a possible reference point for potential investments. He believes that Columella, and his audience, are certainly too wealthy for the need of money-lending. Thus, there must be another reason for including the six-percent interest expense. Duncan-Jones suggests that Columella wants to ensure his readers that at least six-percent return can be achieved for any investment. Throughout, Columella demonstrates a profitability of more than a return of six-and a half-percent for his vineyard. And if his audience is not satisfied, Duncan-Jones believes that Columella is suggesting an investment in another's vineyard as a money-lender, guaranteeing at least six-percent.[50] This investment would probably be against less wealthy land owners or new and unexperienced vineyard owners, who'd need more fiscal support. Ultimately, Duncan-Jones does not believe Columella includes any interest expense after the first two years in his model vineyard.

Duncan-Jones does reference the work of other writers, who interpret Columella's quote in various meanings. One account suggests a perpetual six-percent interest rate on capital even after the first two years of losses, which would imply some sort of relationship with a money-lender. For broader functionality and use of the model, this profitability function will include a perpetual interest expense continued from the first two years of realized losses. Similar to Columella's and Duncan-Jones's calculations, the interest expense will be a percent of the total amount of capital outlay divided by eight-year period. Given that the revised capital outlay of 29,970 *sesterces* is less than both Columella and Duncan-Jones's initial costs, the interest expense will be slightly less. However, given the model's addition of converted capital outlay to

[50] Duncan-Jones, 1974: pg. 39.

overhead expenses, the changes are accounted for. This equals a total yearly interest expense of approximately 450 *sesterces*.

REPRESENTATION OF PRICING AND YIELDS

Duncan-Jones calls into question Columella's revenue assumptions, referencing 20th century modern yields in Italy, as well as historic selling prices for *cullei* of wine. He criticizes Columella's minimum wine yield of three *cullei* to the *iugerum*, believing it to be considerably too high of an assumption. Throughout, Duncan-Jones seeks to disprove Columella based upon pure metrics and representation of comparable examples. Though, he does not consider both the quantity and of quality of wine that Columella's vineyard produces, failing to portray a complete picture of the wine-making production process.

As Duncan-Jones focuses on Columella's profitability assumptions, many other modern researchers have discussed Columella's other manuscripts, which analyze day-to-day operations on a vineyard. Given Columella's expertise, many suggest that his vineyard would focus not only on overall yield, but even more so, quality. In particular, one modern scholar in viticulture, T.J. Santon, even states (Santon, 1996, pg. 59):

> "Columella was more concerned with the quality of wines than many of the growers at the time, but that at the same time, he was aware that vineyards must remain competitive, and that for many the best way to ensure this was to produce the largest possible quantities of wine."[51]

Columella's yields for his vineyard begins with the planting of vines, followed by the harvesting of wine grapes. He dedicates his three other books to reveal the best planting, processing, and harvesting methods to his readers. Wine yields, and thus the total amount of *cullei* generated, are

[51] Santon, 1996: pg. 59. *Columella's Attitude Towards Wine Production*, Journal of Wine Research.

solely determined by the number of wine grapes from any given vineyard, less any lost to adverse weather conditions or other external forces. Columella's expertise in agriculture suggests that he'd seek to plant the maximum number of vines within his plot of land, while maintaining overall quality. Duncan-Jones's discussion on modern yields in the early 20th century do not explain the complexities behind Roman vineyards and Columella's assumptions. Duncan-Jones references averages seen during the early 20th century, stating wine yields as low as 0.60 *cullei* to the *iugerum*. This amounts to an enormous decrease of approximately 90% in wine yield, given Columella's expectation of seven *cullei* to the *iugerum*, which seems almost insurmountable.[52] Even Columella's minimum yield of three *cullei* per the *iugerum* represents a decrease of 80% in total wine yield to Duncan-Jones's minimum suggestion. Duncan-Jones surmises that "it is very difficult to accept that this could lead to a three-fold difference in the size of yield" (Duncan-Jones, 1974, pg. 45). Certainly, there must be a reason for this discrepancy other than Columella's inaccuracies.

Considering the situation of Italian viticulture during the early 20th century, there are a multitude of different factors that may have affected overall wine output within the regions. Roughly 50-years prior, Phylloxera, a type of insect, was introduced to European vineyards. The insect, indigenous to America, and first arriving off the southern coast of France, infects grape vines, attacking its roots, causing dry leaves and lower yields. Over the next decades, the pest would ravage wine production throughout Europe, with France baring the worst results.[53] Italy would feel less of an effect of the disease given its slow transmission, but yields were still

[52] Shown in Figure 9 and Figure 10. Assuming a ratio of one *cullei* per *iugerum* sold at a price of 300 *sesterces*, average return drastically drops in the revised model, with net margins of less than 1.5%. Additionally, Internal Rate of Return (IRR) drops to approximately -9.00%, which gives an owner little to no reason to even undertake the vineyard as an investment project.

[53] Banerjee, Duflo, Postel-Vinay, and Watts, 2010: pg. 716.

certainly affected. By the turn of the century, Phylloxera, had struck twenty-six provinces in Italy, accounting for destruction of 285,845 acres of vineyard land, with roughly another 200,000 acres on the way. What is even more alarming, the small island of Sicily estimated another 240,000 acres lost to the disease, devastating its wine economy and accounting for $40 million in losses.[54] By 1912, approximately 10% of the country's vines were infected by the pests.[55] Duncan-Jones's analysis uses averages in Italy from 1909 to 1913, which would coincide with an especially low period of wine yields and output. Further, as the costs of living in Italy increased in years approaching the First World War, so did the price of wine. Consumption of wine, dropping by as much as 30%, was soon purged from everyday life for Italian families because of money-needs and budgeting. As a result, yields would remain low for at the least the next decade until the fascist-led government came to power in the 1920s. Further, around that time, prohibition efforts in countries such as the United States, Finland, Norway, and the Soviet Union were in effect, with many other countries experiencing all sorts of regulation and impacts on the sale of alcohol.[56] But, through many marketing efforts and pro-wine campaigns, wine production in Italy grew significantly during the 1930s, eventually reaching a level of national identity for its citizens. By those years, vineyard specialization began to grow, with wine yields and outputs varying heavily on the quality of wine grapes.[57] In Duncan-Jones's second claim of evidence, he coincidentally uses data of wine yield averages that reach until 1936, but not any further.

Likewise, Duncan-Jones chooses not to consider the relationship between the quality of wine and price of wine. As the quality of wine improves with the respect to its market, so should

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[54] *The New York Times*, Nov. 8th, 1895: pg. 5. *Phylloxera Ravages Italy – Sicily Has Suffered Greatly, and the Infection is Spreading*.
[55] Ordish, 1987: pg. 172.
[56] Hayler, 1923. *The New Europe and Prohibition*.
[57] Griffith, 2020: pg. 396.

its price. Duncan-Jones does not assume this relationship with analysis of modern yields. During the years Duncan-Jones suggests as comparisons, variation of quality was less existent and therefore less representative of viticulture-centered economy as seen during the Roman Empire. Duncan-Jones could have, instead, analyzed wine yields at periods once a market economy for wine grew in Italy. Or even, an analysis of output across Europe during the mid-19th century prior to the loss of vineyard production caused by Phylloxera insects would prove useful for understanding this relationship. In the Roman world, it is less of a surprise that Columella's selling price of 300 *sesterces* is higher than prices seen from colloquial graffito in Pompeii and a bar-tariff from Herculaneum, given its higher quality.[58] Thus, Columella may be providing rough estimates or "best-case scenarios" for his wine output and selling price, but that does not necessarily mean he is as inaccurate as Duncan-Jones suggests.

Modern-yields range on a multitude of different factors in the wine economy, which are discussed in the previous section. Nowadays, a rough estimate of wine output equals around four tons of grapes per acre.[59] Columella's vineyard suggests a total land size of seven *iugerum*, which equals approximately four-and-a-half acres.[60] Assuming this ratio, and a rough estimate of 700 to 800 bottles of wine harvested from each ton of grapes, anywhere from 350 to 450 Gallons of wine are produced per year on one *iugerum* of Columella's vineyard.[61] From Ash's analysis

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[58] Duncan-Jones, 1974: pg. 46.

[59] Interview with Dr. Centinari, Ph.D. Associate Professor of Viticulture, Department of Plant Science, Pennsylvania State University. Nowadays, roughly an average of four tons of grapes are harvested on an acre of land. This number can vary based upon vineyard customization and quality. The number of grapes harvested are not expected to reach its maximum amount until approximately the third or fourth year into the vineyard's life. Both Columella and Duncan-Jones suggest vineyard require re-planting after eight years but modern vineyards now operate on twenty-year cycles.

[60] Ash, 1940: pg. 267. Each *iugerum* measures 240 x 120 feet, which equals 28,800 square feet. Assuming an acre size of 43,560 square feet, each *iugerum* equates to approximately 66% of a total acre. Seven *iugerum* is approximately 4.63 acres in size. Duncan-Jones calculates the seven *iugerum* equal to approximately 62% of a total acre.

[61] Interview with Dr. Centinari, Ph.D. Associate Professor of Viticulture, Department of Plant Science, Pennsylvania State University. 800 bottles per a single ton multiplied by four tons equals 3200 bottles per acre.

on Columella, this model vineyard should yield around three to four *cullei* per *iugerum*.[62] This calculated wine yield gives an estimate of a possible output for Columella's model vineyard given modern utilization of outputs. It is difficult to account for the differences in wine processing as well as the technological advancement of viticulture over the last two-thousand years. Weather conditions and other external factors and conditions certainly adversely affected Roman viticulture more than nowadays. Further, harvesting techniques and preservatives have likely improved significantly over this time period, which suggests the yields a bit lower than those implied. With additional conversions and approximations for Columella's *iugerum*, a large degree of variation in output would occur. Assuming better-than average years for Columella's vineyard, this model portrays four *cullei* per *iugerum* in its analysis.

Given 750 milliliters, which is the per bottle rate, equals approximately 0.198 U.S. gallons, an acre yields ~ 635 U.S. Gallons of wine per year. Assuming a single *iugerum* is two-thirds of an acre, each *iugerum* yields ~ 420 U.S. Gallons.

[62] Ash, 1940: pg. 254. One *culleus* equals about 137 U.S. Gallons. 420 U.S. Gallons equals 3.1 *cullei* per *iugerum*

Chapter 4
The Profitability and Liquidity Financial Model

Following the previous section's critique of both author's analysis, this thesis aims to create a multi-year period financial model displaying measures of profitability and liquidity for a model Roman vineyard. With additional business factors to consider including expense recalculations, reorganization of costs, tax implications, business relationships, and overall vineyard output, this financial model offers both a modernized income statement and a complete calculation of levered free cash flows for Columella's assumed model vineyard size.

An income statement, one out of three main financials statements used under GAAP, reports the financial performance of the business over a specific accounting period.[63] Duncan-Jones does employ the rudimentary concepts of an income statement, with revenues, expenses, and net income levels in specific case scenarios, but nothing extensive enough to have a multi-purpose use. The other two main financial statements covered under GAAP, known as a company's balance sheet and cash flow statement, are less used throughout the thesis. However, using line-items and identifications from the completed income statement, primary cash flow metrics, such as levered free cash flow can be calculated. Further, the modern scholar, Duncan-Jones, does use concepts typically seen on the balance sheet by including valuations of the vineyard's assets, but fails to speak on the vineyard's cash flow levels.[64] By including the initial purchase of assets such as the land and vineyard's buildings and equipment, this model also includes the initial foundations in creating a balance sheet. However, given the complexities and relationships between all three accounting statements, a complete cash flow statement can only

[63] Phillips, Libby, and Libby, 2010: pg. 16.
[64] Phillips, Libby, and Libby, 2010: pg. 12. The balance sheet reports a business's current financial position, assessing assets, liabilities, and the owner's equity.

be created by both a finalized income statement and balance sheet. Thus, the vineyards liquidity will be judged using a financial proxy for valuing the vineyard's cash levels, using levered free cash flows.[65]

The following section separates the income statement and levered free cash flow build in step-by-step basis for understanding of each line-item. Additionally, only the first, third, and eighth year after the initial purchase of the model vineyard, are shown for the sake simplicity. The expected revenues and costs at the end of the year one and two are the same based upon assumptions made in the model. The same relationship applies to the third year and its next following four years, which portrays the same revenues and expenses. The last year, which is the expected eighth year of the vineyard, include nursery plant sales as well as other expenses given new calculations, completing the eight-year cycle that both writers assume.[66] Although each year independently would experience variations in its revenues and expenses based on a multitude of external factors including market forces, weather conditions, or simply yield fluctuations, these three expected years are highlighted due to changes to the vineyard's primary operations.

REVENUE, COSTS OF GOODS SOLD, AND GROSS PROFIT

Businesses drive revenue by converting their supplies into products, which are then sold at a certain price on the market. Revenue is calculated by the quantity of product sold multiplied

[65] Koller, Goedhart, and Wessels, 2020: pg. 178. *Valuation: Measuring and Managing the Value of Companies*. Levered free cash flows are the cash flows attributable to only equity holders in one single year. This is different from unlevered free cash flows, which are the cash flows available to equity holders and debt holders in a single year. A business's ending cash flow balance is the current amount of cash held, not what they are generated each year. The changes in levered free cash flows year-over-over represent a proxy for the ending cash flow levels. Insert something about difference between cash flows and levered free cash flows.

[66] See Appendix A for reference of the complete financial model.

by the price of the products. The supplies that are converted into the final goods and products are known as inventory. Companies begin with raw materials inventory, which enter the work in process inventory before being completed as finished goods inventory.[67] For each product, there is a cost associated with the preparation of inventory into a finalized product. In the case of viticulture, the preparation and continued maintenance of vines within the vineyard would be these costs associated with producing the final output of wine. Other costs that would also be included would be the harvesting of grapes, processing of wine, and bottling. These costs are typically known as cost of goods sold. Both revenue and cost of goods make up the basic functionality of any business, and how its products operate. The more intensive processing required means a higher cost of goods sold. The result of these two-line items is known as gross profit, which is the firm's revenue minus cost of goods sold. Gross profit as a percent of total revenue calculates gross margin, which analyzes the intensity of the firm's manufacturing process.

Provided the assumptions in the previous chapters, from Columella, Duncan-Jones, and research findings, the model's revenue, cost of goods sold, and gross profit in the first, third and eighth year is shown below in Figure 5.

Income Statement (in Sesterces)	**Year 1E**	**Year 3E**	**Year 8E**
Total Revenue	**-**	**8,400**	**42,000**
Wine	-	8,400	8,400
Nursery Plants	-	-	33,600
Cost of Goods Sold	**(3,967)**	**(467)**	**(13,067)**
Maintenance/Planting of Vines	(3,967)	(467)	(467)
Nursery Plant Failures	-	-	(12,600)
Gross Profit	**(3,967)**	**7,933**	**28,933**

Figure 5. Total Revenue, Cost of Goods Sold (COGS), and Gross Profit

[67] Phillips, Libby, and Libby, 2010: pg. 310.

The total revenue produced by the vineyard was based upon revisions made to viticulture yield and sale price. This assumes a wine yield output of four *cullei* to the *iugerum*, at a sale of price of 300 *sesterces* per *culleus*.[68] In the first two years of the vineyard, the vineyard does not generate any revenue, either from wine or nursery plants. Assuming no growth or declines in productivity, revenue remains steady until the eighth-year, where the nursery plants are sold for a total of 33,600 *sesterces*. Cost of goods sold includes the costs associated with maintenance and preparation of vines, as discussed in Chapter 3.[69] In the first couple of years, the vineyard's cost of goods sold are greater due to more intensive preparation from the vinedressers, totaling 3,967 *sesterces*. Although no revenue is generated, there are costs associated with the preparation and planting of the vineyard. Further, in the eighth-year, nursery plant failures total 12,600 *sesterces*, accounting for the destruction or perishing of the nursery plants planned to be sold. In both of the years shown, gross profit hits the peak of the vineyard's planting cycle, valued at 14,233 *sesterces*. In the first two years of the business, gross profit remains at zero and in the eighth-year, gross profit jumps significantly to 35,233 *sesterces*. This depicts the vineyard's model at three different years along its cycle of profitability, helping portray the different stages of the business.

OPERATING PROFIT (EBIT)

Operating profit, also known as Earnings before Interest and Taxes (EBIT), describes the core functions of any business. If operating profit or EBIT is greater than zero, this means

[68] See pg. 33. Detailed analysis on the model's representation of wine sales.
[69] See pg. 26. Findings of the model's value of cost of goods sold.

business generate more money than spent on the selling of goods and services. By taking gross profit, less any operating expenses, operating profit is calculated. Operating expenses include any expenses related to sales, general, and administrative, depreciation and amortization, or research and development. Sales, general, and administrative expenses typically include any wages paid out by the business. On the other hand, depreciation and amortization are non-cash expenses that describe the loss of value of a business's assets over time.[70] Research and development closely relate to any new projects or experiments a business undertake that relate to the product or good being sold. In the case of Columella's vineyard, it is possible there might be some costs associated with research and experimentation on new variations of wine grapes. However, given the lack of information and verification of these processes, this thesis will not include these types of expenses.

Operating profit or EBIT is used heavily as a ratio in valuing businesses. This allows for seamless comparison of businesses in different locations or economic situations. Assuming two vineyards during the Roman Empire, holding true wine yields and selling prices, in two different locations, how might they be compared? If the first vineyard is situated near Rome, and the other in a province, there would likely be a huge discrepancy between both vineyards' taxes and interest expense. Both vineyards' operating profits would be used for an easier comparison between the two. Further, to account for the possible difference in vineyard size and scale, Operating profit could be taken as a percent of total revenue and compared to its peers.

[70] See pg. 23. This covers the value and calculation of depreciation and amortization expenses as non-cash expenses.

Income Statement (in Sesterces)	Year 1E	Year 3E	Year 8E
Gross Profit	**(3,967)**	**7,933**	**28,933**
Additional Related Operating Costs	(170)	(170)	(170)
Wages on Vinedresser and Slave Labor	(518)	(518)	(518)
Depreciation of Farm Building and Equipment	(653)	(653)	(653)
Operating Profit (EBIT)	**(5,308)**	**6,592**	**27,592**

Figure 6. Operating Profit (EBIT)

Under Columella's model vineyard, "Additional Relating Operating Costs", which Duncan-Jones loosely defines as the maintenance of *vinitor* and other slaves, describes the costs associated with the well-being of the vineyard's laborers.[71] This would include any food, housing, and clothing-related costs associated with the laborers. This type of expense would be closely categorized under a sales, general, and administrative expense. Second, "Wages on Vinedresser and Slave Labor" displays the recalculation and reorganization of the initial slave labor. Instead of treating the expense of 518 *sesterces* as purely amortization, which would provide a net-benefit to cash flows, the expense is instead treated as wages under sales, general, and administrative.[72] Lastly, the "Depreciation of Farm Building and Equipment", as Duncan-Jones discusses, is also included as an operating expense of 653 *sesterces*. These expenses are flat-lined at the same level for the duration of the vineyard's profitability cycle.

Subtracting these expenses, operating profit is negative in the first two years of the vineyard's business, given the lack of revenue generated and greater maintenance costs associated with preparation and planting. Over time, operating profit increases with gross profit, reaching its highest output in the final year of the vineyard. As a percent of revenue, however, operating margin is largest in years three to seven, at 78%.[73] In the final year, operating margin

[71] Duncan-Jones, 1974: pg. 43.
[72] See pg. 15. Referred to as "Maintenance spent on laborers" by author Duncan-Jones.
[73] Koller, Goedhart, and Wessels, 2020: pg. 243. Operating margin is operating profit as a percent of total revenue.

falls to 66% primarily due to increase of goods of sold-related expenses.[74] As wine yields and total revenue change depending on market conditions and the vineyard's success, costs remain fixed, which drastically changes both operating profit, but also operating margin.

PRE-TAX PROFIT AND NET INCOME

After calculation of operating profit, interest expense and income tax expense are subtracted resulting in the vineyard's profitability value, also known as net income or net profit. Net income describes the value or amount remaining for shareholders of the business.[75] In theory, the owner of the vineyard should receive this value as return if it is taken from the business. The owner would be paid out in the form of a dividend, which is the value of cash given to the shareholders. However, if the owner chooses, he instead can use the profit to drive future growth for the business. In turn, the ending value of the vineyard, if it is sold or liquidated, may be worth more than it would be if yearly dividends did not exist. Any owner understands the risks realized by undertaking an investment or project over a multi-year horizon, which may also lead to greater return. This model analyzes net income from the perspective that the returns generated could be taken by the owner on a yearly basis, but through a few revisions.[76] Using modern accounting practices, returns are first converted to yearly free cash flows, which measures the amount of total cash the business receives. This helps display not only an owner's commitment to pay back debts, but also the costs associated with the initial purchase of equipment, buildings, and land. Therefore, dividends do not exist in the model. Yet, it is very

[74] See pg. 43. Costs of goods are higher due to the assumption of nursery plant failures or deaths.
[75] Phillips, Libby, and Libby, 2010: pg. 521.
[76] See pg. 49. Discussion of revisions related to levered free cash flows.

likely some sort of portion of returns were taken yearly by the owner. It is unknown if those returns would be used for improving the business or for personal gain.

Income Statement (in Sesterces)	Year 1E	Year 3E	Year 8E
Gross Profit	**(3,967)**	**7,933**	**28,933**
Additional Related Operating Costs	(170)	(170)	(170)
Wages on Vinedresser and Slave Labor	(518)	(518)	(518)
Depreciation of Farm Building and Equipment	(653)	(653)	(653)
Operating Profit (EBIT)	**(5,308)**	**6,592**	**27,592**
Net Interest Expense	(450)	(450)	(450)
Pre-Tax Profit	**(5,757)**	**6,432**	**27,143**
Income Tax Expense	-	(1,075)	(4,750)
Net Income	**(5,757)**	**5,068**	**22,393**

Figure 7. Pre-Tax Profit and Net Income

The line-item shown, prior to net income, is known as pre-tax profit, which shows the vineyard's interest expense subtracted from operating profit. Interest expense and income tax expense would vary based upon the owner's situation. As Duncan-Jones surmises, an interest expense would not seem necessary because the owner would likely not be taking on any debts, given the wealthy status of Roman vineyard owners.[77] Further, both author's do not include a tax expense in their financial assumptions. Including these expenses, the financial model displays the levels of profitability of the vineyard over the eight-year cycle. Similar to operating profit, gross profit, and total revenue, profitability is highest in the final year, reaching a value of 22,393 *sesterces* and a net margin of 53%.[78] Over the eight-year cycle period, though, the average return or average net margin, is only approximately 5.39%.[79]

[77] Duncan-Jones, 1974: pg. 39.
[78] Phillips, Libby, and Libby, 2010: pg. 226. Net margin is a business's net income as a percent of total revenue.
[79] The vineyard's net margin is calculated by taking the summation of the business's yearly net income as a percent of the total revenue over the eight-year period. This value is divided by eight, resulting in the average net margin.

Duncan-Jones's analysis of viticulture and Columella's model suggest returns anywhere from approximately -1.50% to 12.00%, given a varying degree of changes in expense structure. On the other hand, Columella's returns average around 9 to 10%, reaching as high as approximately 15% under the perfect conditions.[80] An average net margin of 5.39% would seem reasonable given the work of both authors, suggesting Columella's work is not as wrong as Duncan-Jones's originally believes. Duncan-Jones even does conclude that it is possible but unlikely that profits might reach 7% to 10%, given the right conditions.[81] Though, assuming Duncan-Jones's interpretation of Columella's interest expense calculation is right, this model's average return would be right around the 6% mark of investable return.[82] Regardless, the financial model's profitability is subject to numerous assumptions and inputs with varying degree of results. Average net margins may fluctuate on a multitude of different considerations especially with yearly changes, and may fall anywhere between 2% and 8% in total.[83] It is difficult to assume how profitability changes based upon the market conditions and location of the vineyard. Nonetheless, these figures relay the importance of viticulture as a primary generator of high yields in returns in agriculture, with an existence of a crucial market economy for investments and projects.

[80] Duncan-Jones, 1974: pg. 58.
[81] Duncan-Jones, 1974: pg. 59.
[82] See pg. 31.
[83] See pg. 55.

ADJUSTED EBITDA & LEVERED FREE CASH FLOW

In terms of long-term success, this financial model relays the importance of sustainable growth as it relates to Roman viticulture. Roman land-owners would have to employ practices in properly managing business financials by maintaining a consistent revenue base, an effective cost structure, and a lean capital structure. Despite its relative high profitability as compared to other agriculture products, viticulture in itself experiences significantly more volatility and yearly changes than other agriculture goods and services. Although Columella writes in a period of flourishing success and economic expansion, overall consumption would be extremely sensitive to price fluctuations as well as changes to wine output. On a regular daily basis, wine was used for a multitude of different purposes and provided an enormous source of calorie-intake and nutrition for the Romans.[84] However, higher quality wine, such as in the case of Columella, may have been treated more as delicacy and a more discretionary type of product. In periods of economic uncertainty, Romans would save money, hurting overall discretionary spending. Hence, there would be a greater propensity for variations in returns based on these risks discussed, especially as compared to other agriculture products such as wheat, grain, fruits, and vegetables.[85] With these considerations, viticulture also dealt with numerous uncontrollable external factors. Years of profit could be wiped out by simple change in weather pattern or the emergence of disease and famine.

From the perspective of vineyard owners, business decisions would have greater importance because of the degree of variation in viticulture. If a vineyard achieves profitability and success in one year and decides to increase expenditures as a result, profitability may not be

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[84] Allen, 2009: pg. 333. Allen discusses the daily calorie intake of Romans during the 4th century, under the price Edict of Diocletian.
[85] Parkin, and Pomeroy, 2007: pg. 244.

greatly affected in the next year.[86] However, greater expenditures or capital outlay comes with a greater loss in cash during the purchase period. If there is too much investment in the initial period or throughout the lifespan of the vineyard, an owner may experience a liquidity crisis, leading to business insolvency. There is a key difference between profitability and liquidity. Profitability does not consider that general expenses, as well as new investments, have to be paid full in cash. Or in the case of the Romans, coin. There would an exchange of monetary value based on that purchase. Liquidity also portrays the difference between cash and non-cash expenses, and their effect against the financial stability of a business. If a model vineyard experiences losses in a specific year, the effects may compound into experiencing greater losses in liquidity in the future. If there is an agreed upon yearly expense throughout the eight-year cycle of the vineyard, such as in the case of interest expense, the business may run out of necessary funds, leading to business failure or bankruptcy. If wealthy land-owners can cover the losses, it becomes less of an issue for the vineyard. But mismanagement and poor decision-making on part of the owner could lead to its demise, something that yearly profitability does not convey. Overall, liquidity and the company's cash levels provide a more contextual understanding of business decisions, and the timing and rationale of new projects as well as expenses.

In terms of the modernized financial model, a business's cash levels fluctuate yearly but maintain a balance, which is created by both an income statement and a balance sheet. Without a proper understanding of all of the balance sheet items within the vineyard, it is difficult to portray the exact levels of ending cash flows each year. Instead, using both the income statement analysis and the inclusion of the vineyard's additional investments, this financial model

[86] See pg. 13. Figure 3 displays examples of the capital expenditures Duncan-Jones suggests.

calculates the amount of yearly cash flows generated. In the model, one of these commonly used metrics is calculated, known as Levered Free Cash Flow. The firm's levered free cash flows are measured in the model by Adjusted Earnings, before Interest, Taxes, Depreciation, and Amortization (EBITDA), less Income Tax Expense, the Change in Net Working Capital (NWC), Capital Expenditures, and Net Interest Expense.[87] EBITDA, similar to operating profit, is commonly used in comparing businesses. However, EBITDA removes the depreciation and amortization expenses, due to them non-cash expense nature. Comparing businesses using EBITDA isolates both businesses on a more general level, because firms tend to have varying levels of depreciation and amortization from various purchases. With higher depreciation and amortization, businesses have higher cash levels, because of its "add-back" nature on cash flow statements. The Adjusted portion of EBITDA is to account for any one-time or unusual expenses that are not a core function to the business. As such, after calculation, Adjusted EBITDA is known to be a good "proxy" for free cash flows.[88] The following expenses subtracted from EBITDA are paid out in the form of cash. Specifically, the Change in Net Working Capital in the model describes the difference between the change in current assets and current liabilities.[89] This tracks items seen on the balance sheet, which given our lack of knowledge of Roman bookkeeping and expense recognition, are difficult to predict. In this case, the financial model maintains a flat-line rate of zero for its yearly cost in cash. The initial purchases, shown under Capital Expenditures, are also included in calculating the vineyard's Levered Free Cash Flow, displaying the importance of investment.

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[87] Koller, Goedhart, and Wessels, 2020: pg. 800. Derivation of levered free cash flow formula.
[88] Koller, Goedhart, and Wessels, 2020: pg. 820. EBITA/EBITDA used as a coverage formula in judging leverage for a business's free cash flows.
[89] Phillips, Libby, and Libby, 2010: pg. 569.

Income Statement (in Sesterces)	Initial Purchase	Year 1E	Year 3E	Year 8E
Net Income	**-**	**(5,757)**	**5,068**	**22,393**
Income Tax Expense	-	-	1,075	4,750
Net Interest Expense	-	450	450	450
Adjusted EBIT	**-**	**(5,308)**	**6,592**	**27,592**
Depreciation of Farm Building and Equipment	-	653	653	653
Adjusted EBITDA	**-**	**(4,655)**	**7,245**	**28,245**
Levered Free Cash Flow				
Adj. EBITDA	-	(4,655)	7,245	28,245
-- Income Tax Expense	-	-	(1,075)	(4,750)
-- Change in Net Working Capital	-	-	-	-
-- Capital Expenditures	(29,970)	-	-	-
-- Net Interest Expense	-	(450)	(450)	(450)
Levered Free Cash Flow	**(29,970)**	**(5,104)**	**5,721**	**23,046**

Figure 8. Adjusted EBITDA and Levered Free Cash Flow

Similar to the levels of profitability, the vineyard's liquidity improves throughout the eight-year business cycle assumed. However, with the inclusion of the initial capital outlay, the years reached until the investment is fully paid off, is significantly longer. Based on the model's free cash flow levels, returns to the business would not be generated until the end of the eighth year. After that time, the vineyard now has a surplus of cash to spend on a multitude of functions, including improving the business, used on new and greater investments, or simply to return cash to the owner. Specifically, covering the levels of liquidity in the model, 5,721 *sesterces* of levered free cash flows is generated in periods following preparation and planting. This level continues until the eighth year, where the vineyard drives 23,046 *sesterces* of levered free cash flow. Throughout, there are no unusual expenses during the life-cycle, meaning EBITDA and Adj. EBITDA are the same value. The vineyard's levered free cash flows follow a similar value to net income, but with select adjustments, the values become more representative of the business's longevity and long-term success.

Calculating the return of free cash flows varies from profitability and net income returns. In determining a business's profitability, an average of net margin gives the yearly levels of return assumed. However, with liquidity, including the initial purchase, the rate of return needs to account for the time value of money and the investment's net present value. Time value of money describes the relationship of money in the near term being worth more than in the future, due to earnings potential. Using this concept, another idea is considered, known as net present value, which calculates the current value or present value of the investment project based upon the future cash flows receives, determining if the investment is worth undertaking or not.[90] If the investment's net present value is greater than zero, then the business should invest in the project. In this case, this would be a Roman land-owner deciding to build a vineyard.

Due to the time value of money, each cash flow has to be discounted back to present value, using a discount rate (*r*). The discount rate (*r*), determines the rate at which money loses value year-over-year to account for the time value of money.[91] Using the vineyard's financial model, the business's levered free cash flows are discounted by the respective discount rate and year of its occurrence.

$$-\frac{29{,}970}{(1+r)^0} + \frac{-5{,}104}{(1+r)^1} + \ldots + \frac{5{,}721}{(1+r)^3} + \ldots + \frac{23{,}046}{(1+r)^8} = 0$$

Figure 9. Net Present Value and Internal Rate of Return

Assuming positive or negative levered free cash flows remain in the vineyard until the eighth-year, the investment should only be undertaken if the net present value is greater than zero, as described above. At this point, there's not conception of a discount rate. In modern-

[90] Phillips, Libby, and Libby, 2010: Appendix C.1.
[91] Koller, Goedhart, and Wessels, 2020: pg. 697.

practices, the discount rate is commonly the risk-free rate, or in a business sense, the cost of equity.[92] This would be considered the value missed out on if the investment is not undertaken. In the Roman economy, these systems simply did not exist, so there is no concept of a discount rate. However, assuming net present value equals zero, a discount rate can be calculated, which would show the minimum yearly amount of return lost if there is no investment in the project. Solving for this discount rate, gives a value of (r), which is known as the Internal Rate of Return (IRR).[93] This essentially judges the returns in cash flows to the business and its operations, using the values of levered free cash flow.

For Columella's model-sized vineyard, the internal rate of return equals approximately 4.35%.[94] Given that this is a positive return, an investment in the vineyard should be undertaken. If, in the case that the internal rate of return was negative, then the owner should not invest in the project. Essentially, the internal rate of return of 4.35% shows the percent return an individual would be foregoing in favor of holding onto their monetary value. Simply, this reasoning does not seem sensible from an owner's perspective, as their monetary value would lose value over time. On other hand, if the internal rate of return is below zero, it shows that the owner's monetary value would surprisingly appreciate if they were not to invest in the project. From these assumptions and the understanding of time value of money, there would certainly be a market for viticulture within the Roman economy given positive net present value.

[92] Koller, Goedhart, and Wessels, 2020: pg. 692.
[93] Koller, Goedhart, and Wessels, 2020: pg. 483.
[94] See pg. 60. Appendix A shows the Internal Rate of Return.

Sensitivity Analysis of Profitability and Liquidity

Analysis from the financial model determines profitability and liquidity levels based upon pre-ordained assumptions for revenues and expenses. In the previous section, profitability and liquidity was judged based upon yields of four *cullei* to the *iugerum* and a selling price of 300 *sesterces* per *iugerum*. Additionally, certain expenses, such as the vineyard's tax implications, as well as the interest expense recalculation, were assumed on a set notion from this thesis's research and analysis. However, what would be the case if these variables were to change? How might Roman viticulture, its profitability and liquidity, shift based upon different assumptions? Using the multi-period financial model, sensitivity tests are performed by factoring in the change in the value of inputs, creating an extensive data set of different scenarios. Both authors, Columella and Duncan-Jones, view Roman vineyards in a simplistic sense, that there is only one correct answer to levels of profitability. Though, given the wide-ranging market dynamics and importance of viticulture to the Roman empire, this certainly cannot be the case. Further, with the addition of liquidity and cash flows returned to a Roman vineyard, there's even more valuable insight into the business operations and an owner's decision-making.

The financial model has many inputs and variables given the changes in revenue and different types of expenses. These tests must hold a few key assumptions when using the financial model to measure the sensitivity of profitability and liquidity. Firstly, only two variables within the model can be tested at one single time. Second, certain variables, especially many of the vineyard's expenses, which are not set to certain ratios or percentages of other of the model's aspects, are difficult to include in the sensitivity analysis. Lastly, these sensitivity tests are unable to judge profitability and liquidity as it relates to economies of scale. Both revenues and expenses are presumed on seven *iugera* of land scale, which makes results indeterminant at a

larger or smaller land-size. Together, the assumed variables suggest a wide-array of different levels of input across column and row, which create a multitude of outputs based upon the relationship between the two inputs.

Total Revenue Output

Revenue Analysis (*in Sesterces*)		***Cullei per Iugerum***										
		7.00	6.50	6.00	5.50	5.00	4.50	4.00	3.50	3.00	2.50	2.00
Sesterces per Culleus	425	20,825	19,338	17,850	16,363	14,875	13,388	11,900	10,413	8,925	7,438	5,950
	400	19,600	18,200	16,800	15,400	14,000	12,600	11,200	9,800	8,400	7,000	5,600
	375	18,375	17,063	15,750	14,438	13,125	11,813	10,500	9,188	7,875	6,563	5,250
	350	17,150	15,925	14,700	13,475	12,250	11,025	9,800	8,575	7,350	6,125	4,900
	325	15,925	14,788	13,650	12,513	11,375	10,238	9,100	7,963	6,825	5,688	4,550
	300	14,700	13,650	12,600	11,550	10,500	9,450	8,400	7,350	6,300	5,250	4,200
	275	13,475	12,513	11,550	10,588	9,625	8,663	7,700	6,738	5,775	4,813	3,850
	250	12,250	11,375	10,500	9,625	8,750	7,875	7,000	6,125	5,250	4,375	3,500
	225	11,025	10,238	9,450	8,663	7,875	7,088	6,300	5,513	4,725	3,938	3,150
	200	9,800	9,100	8,400	7,700	7,000	6,300	5,600	4,900	4,200	3,500	2,800
	175	8,575	7,963	7,350	6,738	6,125	5,513	4,900	4,288	3,675	3,063	2,450

Figure 10. Revenue Sensitivity Analysis

Using the inputs provided in the financial model, total revenue is tested against two changing variables, *cullei* per *iugerum* and *sesterces* per *culleus*. As wine yields or outputs, shown by *cullei* per *iugerum*, increase, total revenue output does as well. Given higher selling prices, shown by *sesterces* per *culleus*, total revenue output increases. The sensitivity analysis assumes ranges for wine yields of two to seven *cullei* per *iugerum* and a range for prices of 175 to 425 *sesterces* per *culleus*. Given the two variables and their respective ranges, the lowest amount of revenue generated is 2,450 *sesterces*, and the highest is 20,825 *sesterces.*

Typically, based on contextual research, wine yields and selling prices are inversely correlated. If quality tends to be higher, than less wine grapes are harvested in the viticulture process. This would lead to lower wine yields or output. At the same, however, higher quality means greater demand for the product, resulting in higher prices for the wine. If owners are able to manage this dilemma while increasing total revenue output, it would be most ideal.

Profitability

Average Return (%)		***Cullei per Iugerum***										
		7.00	6.50	6.00	5.50	5.00	4.50	4.00	3.50	3.00	2.50	2.00
Sesterces per Culleus	425	7.7%	7.5%	7.4%	7.2%	6.9%	6.7%	6.4%	6.0%	5.6%	5.0%	4.3%
	400	7.6%	7.4%	7.2%	7.0%	6.8%	6.5%	6.2%	5.8%	5.4%	4.8%	4.2%
	375	7.4%	7.3%	7.1%	6.9%	6.6%	6.4%	6.0%	5.7%	5.2%	4.6%	4.0%
	350	7.3%	7.1%	6.9%	6.7%	6.5%	6.2%	5.8%	5.4%	5.0%	4.4%	3.7%
	325	7.1%	6.9%	6.7%	6.5%	6.3%	6.0%	5.6%	5.2%	4.8%	4.2%	3.5%
	300	6.9%	6.7%	6.5%	6.3%	6.0%	5.7%	5.4%	5.0%	4.5%	4.0%	3.3%
	275	6.7%	6.5%	6.3%	6.1%	5.8%	5.5%	5.1%	4.7%	4.3%	3.7%	3.0%
	250	6.5%	6.3%	6.0%	5.8%	5.5%	5.2%	4.8%	4.4%	4.0%	3.4%	2.7%
	225	6.2%	6.0%	5.7%	5.5%	5.2%	4.9%	4.5%	4.1%	3.6%	3.1%	2.4%
	200	5.8%	5.6%	5.4%	5.1%	4.8%	4.5%	4.2%	3.7%	3.3%	2.7%	2.1%
	175	5.4%	5.2%	5.0%	4.7%	4.4%	4.1%	3.7%	3.3%	2.9%	2.4%	1.8%

Figure 11. Average Net Margin Sensitivity Analysis

In this case scenario, the profitability of the vineyard is tested against *cullei* per *iugerum* and *sesterces* per *culleus*. Profitability is best determined by the average return or average net margin on the vineyard. Assuming all expenses remain constant, how does average return change based upon a change in revenue output. Given the range for wine yields of two to seven *cullei* per *iugerum* and a range for prices of 175 to 425 *sesterces* per *culleus*, the lowest return is approximately 1.8% and the highest is nearly eight-percent. Even at significantly depressed prices and wine yields, average return still maintains positivity, showing the sheer profitability of the Roman viticulture market.

Modern scholar, Duncan-Jones does discuss *cullei* per *iugerum* ratios being as low as 0.60 or one *cullei* per *iugerum*, which would certainly impact profitability. Under those assumptions, his model shows negative profitability, which would be in-line with this financial model's assumptions. On the other hand, this profitability is not as high as Columella's suggested values.

Liquidity

Internal Rate of Return (IRR) (%)		***Cullei per Iugerum***										
		7.00	6.50	6.00	5.50	5.00	4.50	4.00	3.50	3.00	2.50	2.00
Sesterces per Culleus	425	22.0%	20.2%	18.4%	16.5%	14.4%	12.3%	10.1%	7.8%	5.3%	2.6%	-0.3%
	400	20.5%	18.8%	17.0%	15.2%	13.2%	11.2%	9.0%	6.8%	4.4%	1.8%	-1.0%
	375	19.0%	17.4%	15.6%	13.8%	12.0%	10.0%	7.9%	5.7%	3.4%	0.9%	-1.7%
	350	17.5%	15.9%	14.2%	12.5%	10.7%	8.8%	6.8%	4.7%	2.4%	0.1%	-2.4%
	325	15.9%	14.3%	12.7%	11.1%	9.3%	7.5%	5.6%	3.6%	1.4%	-0.8%	-3.2%
	300	14.2%	12.7%	11.2%	9.6%	7.9%	6.2%	4.4%	2.4%	0.4%	-1.7%	-3.9%
	275	12.5%	11.1%	9.6%	8.1%	6.5%	4.8%	3.1%	1.3%	-0.6%	-2.6%	-4.7%
	250	10.7%	9.3%	7.9%	6.5%	5.0%	3.4%	1.8%	0.1%	-1.7%	-3.6%	-5.5%
	225	8.8%	7.5%	6.2%	4.8%	3.4%	1.9%	0.4%	-1.2%	-2.8%	-4.5%	-6.3%
	200	6.8%	5.6%	4.4%	3.1%	1.8%	0.4%	-1.0%	-2.4%	-3.9%	-5.5%	-7.2%
	175	4.7%	3.6%	2.4%	1.3%	0.1%	-1.2%	-2.4%	-3.7%	-5.1%	-6.5%	-8.0%

Figure 12. Internal Rate of Return Sensitivity Analysis

Measuring a vineyard's liquidity as a factor of changing *cullei* per *iugerum* and *sesterces* per *culleus*, internal rate of return varies significantly as compared to its net margin counterparts. Assuming the same range for each variable, internal rate of return reaches as low as negative eight-percent and as high as 22%. Specifically, if wine yields are both lower than approximately three *cullei* per *iugerum* and 300 *sesterces* per *culleus*, internal rate of return is negative. Even under other certain cases, where variables are extremely polarized, internal rate return is also negative. At these assumptions, this suggests an owner should not undertake the vineyard as an investment, because it will not produce a positive net present value.

Despite showing positive net margins on the profitability, the liquidity measurements display a more dire situation if the vineyard's revenue drops. Owners certainly would have to prioritize smoothing of pricing and yield output, meeting demand in the market.

Profitability

Average Return (%)		***Interest Rate***										
		0.0%	1.5%	3.0%	4.5%	6.0%	7.5%	9.0%	10.5%	12.0%	13.5%	15.0%
Tax Rate	0.0%	7.4%	7.3%	7.2%	7.0%	6.9%	6.8%	6.6%	6.5%	6.3%	6.2%	6.1%
	2.5%	7.2%	7.1%	6.9%	6.8%	6.7%	6.5%	6.4%	6.3%	6.1%	6.0%	5.9%
	5.0%	7.0%	6.9%	6.7%	6.6%	6.5%	6.3%	6.2%	6.1%	5.9%	5.8%	5.7%
	7.5%	6.8%	6.6%	6.5%	6.4%	6.3%	6.1%	6.0%	5.9%	5.7%	5.6%	5.5%
	10.0%	6.5%	6.4%	6.3%	6.2%	6.0%	5.9%	5.8%	5.7%	5.5%	5.4%	5.3%
	12.5%	6.3%	6.2%	6.1%	5.9%	5.8%	5.7%	5.6%	5.5%	5.3%	5.2%	5.1%
	15.0%	6.1%	6.0%	5.9%	5.7%	5.6%	5.5%	5.4%	5.3%	5.1%	5.0%	4.9%
	17.5%	5.9%	5.8%	5.6%	5.5%	5.4%	5.3%	5.2%	5.0%	4.9%	4.8%	4.7%
	20.0%	5.6%	5.5%	5.4%	5.3%	5.2%	5.1%	5.0%	4.8%	4.7%	4.6%	4.5%
	22.5%	5.4%	5.3%	5.2%	5.1%	5.0%	4.9%	4.7%	4.6%	4.5%	4.4%	4.3%
	25.0%	5.2%	5.1%	5.0%	4.9%	4.8%	4.7%	4.5%	4.4%	4.3%	4.2%	4.1%
	27.5%	5.0%	4.9%	4.8%	4.7%	4.5%	4.4%	4.3%	4.2%	4.1%	4.0%	3.9%
	30.0%	4.8%	4.7%	4.5%	4.4%	4.3%	4.2%	4.1%	4.0%	3.9%	3.8%	3.7%
	32.5%	4.5%	4.4%	4.3%	4.2%	4.1%	4.0%	3.9%	3.8%	3.7%	3.6%	3.5%
	35.0%	4.3%	4.2%	4.1%	4.0%	3.9%	3.8%	3.7%	3.6%	3.5%	3.4%	3.3%
	37.5%	4.1%	4.0%	3.9%	3.8%	3.7%	3.6%	3.5%	3.4%	3.3%	3.2%	3.1%
	40.0%	3.9%	3.8%	3.7%	3.6%	3.5%	3.4%	3.3%	3.2%	3.1%	3.0%	2.9%

Figure 13. Profitability Analysis on Interest and Taxes

Maintaining a vineyard with yields of three *cullei* per *iugerum* at a selling price of 300 *sesterces* per *culleus*, as seen in the financial model, different tax brackets as well as interest rates are assumed in the calculation of average return. Under the best conditions, zero interest rate and zero tax conditions, average returns are as high as 7.4%. On the other hand, at the lowest, with taxes as high as 40% and interest rates at 15%, returns drop significantly to 2.9%.

Duncan-Jones's assumptions in his model do not include either interest expense or a tax expense, which would show the return on the highest end of the sensitivity table. Both of these expenses play a crucial role in determining average return, shown by the discrepancy between Duncan-Jones's case of no expenses and the calculated average return of approximately 5.4%.

Liquidity

Internal Rate of Return (IRR) (%)		***Interest Rate***										
		0.0%	1.5%	3.0%	4.5%	6.0%	7.5%	9.0%	10.5%	12.0%	13.5%	15.0%
Tax Rate	0.0%	8.9%	8.6%	8.2%	7.9%	7.6%	7.3%	7.0%	6.7%	6.4%	6.0%	5.7%
	2.5%	8.4%	8.1%	7.8%	7.5%	7.2%	6.9%	6.6%	6.2%	5.9%	5.6%	5.3%
	5.0%	8.0%	7.7%	7.3%	7.0%	6.7%	6.4%	6.1%	5.8%	5.5%	5.2%	4.9%
	7.5%	7.5%	7.2%	6.9%	6.6%	6.3%	6.0%	5.7%	5.4%	5.0%	4.7%	4.4%
	10.0%	7.0%	6.7%	6.4%	6.1%	5.8%	5.5%	5.2%	4.9%	4.6%	4.3%	4.0%
	12.5%	6.5%	6.2%	5.9%	5.6%	5.3%	5.0%	4.7%	4.4%	4.1%	3.8%	3.5%
	15.0%	6.0%	5.7%	5.4%	5.1%	4.8%	4.5%	4.2%	4.0%	3.7%	3.4%	3.1%
	17.5%	5.5%	5.2%	4.9%	4.6%	4.4%	4.1%	3.8%	3.5%	3.2%	2.9%	2.6%
	20.0%	5.0%	4.7%	4.4%	4.1%	3.8%	3.6%	3.3%	3.0%	2.7%	2.4%	2.1%
	22.5%	4.5%	4.2%	3.9%	3.6%	3.3%	3.0%	2.8%	2.5%	2.2%	1.9%	1.6%
	25.0%	3.9%	3.7%	3.4%	3.1%	2.8%	2.5%	2.2%	1.9%	1.7%	1.4%	1.1%
	27.5%	3.4%	3.1%	2.8%	2.5%	2.3%	2.0%	1.7%	1.4%	1.1%	0.8%	0.6%
	30.0%	2.8%	2.5%	2.3%	2.0%	1.7%	1.4%	1.1%	0.9%	0.6%	0.3%	0.0%
	32.5%	2.2%	2.0%	1.7%	1.4%	1.1%	0.9%	0.6%	0.3%	0.0%	-0.2%	-0.5%
	35.0%	1.7%	1.4%	1.1%	0.8%	0.6%	0.3%	0.0%	-0.3%	-0.5%	-0.8%	-1.1%
	37.5%	1.0%	0.8%	0.5%	0.2%	0.0%	-0.3%	-0.6%	-0.9%	-1.1%	-1.4%	-1.7%
	40.0%	0.4%	0.1%	-0.1%	-0.4%	-0.7%	-0.9%	-1.2%	-1.5%	-1.7%	-2.0%	-2.3%

Figure 14. Liquidity Analysis on Interest and Taxes

In terms of liquidity, internal rate of return drops significantly with higher interest rates and tax expense, suggesting that the investment of the vineyard would not take place, based upon net present value. For example, at a tax rate of 37.5% and an interest rate of six-percent, internal rate of return is exactly zero, meaning the owner would be undecided on undertaking the project. Similar to the changes in revenue output, tax and interest rate implications would play a crucial role in determining the return towards the vineyard, as a business. Both of these factors directly affect the vineyard's levered free cash flows, which indirectly determines internal rate of return. Given the relationship between the two variables, at many different points on the sensitivity table, the investment would simply not happen.

Conclusion

Through this research, a multi-period financial model was created to best judge profitability and liquidity measures in Roman viticulture. Utilizing both primary and secondary sources, the model gives a notion of the variability in wine production and the business structure of vineyards. After the restructuring and reorganizing of scholarly work, with the addition of new concepts and business functions, this model portrays Roman viticulture in the modern-sense. Due to the complex nature of modern practices with a business's finances, reassumption of Roman ideas creates a more applicable framework for measuring profitability and liquidity. Upon completion of the financial model based upon key assumptions set forth by primary writer, Columella, and modern scholar, Richard Duncan-Jones, sensitivity tests were performed on multiple variables considered in the vineyard's operations.

What is shown in these sensitivity tests is not necessarily that either one author or another is completely wrong or right, but instead, that Roman viticulture experiences a high propensity for variation in profitability and liquidity. Obviously, from a supply and demand perspective, an owner would be selling higher quality wine at higher price levels, likely showing overall lower yields. In Columella's perspective, which seems most ideal, managing both high prices and higher quality is important in driving strong relative return. This financial model also portrays a similar perspective. Specifically, judging the vineyard's liquidity aspects, prioritizing optimal supply and demand through the smoothing of price levels and yields, internal rate of return is maximized. Further, this financial model elaborates on the concepts of Roman consumption and spending. If a vineyard's selling price is high based on its quality, then the owner is appealing to certain market of Romans, those being the wealthy. Similarly, if a certain type of wine is very cheap, it is targeting another completely different consumer market. Now, however, if quality is

maintained but prices are not as steep, there is an appeal from both markets. During times, where consumer or discretionary spending was low, there'd always be a market for this type of wine, which is directly where Columella presumes to operate. Columella, and nowadays, modern scholars, such as Duncan-Jones, prioritize profitability as the most ideal metric of understanding. This research shows that liquidity is just as important, if not more, in understanding the value of investment.

Roman viticulture profitability barely changes even with drastic changes to revenue output. This tells readers and an audience that Roman viticulture is a generator of high yields and returns. What is not shown is the huge variation of returns, and its effect on the net present value of an investment's relative return. These averages of net margin do not display the significant amount of risk associated and uncertainty of wine yields and returns. Liquidity analysis, instead, will portray many of these risks, seen through the massive swings in internal rate of return. Thus, Roman viticulture certainly had its success in the market, but there were certainly cases of business failure and bankruptcy, which researchers often overlook.

Appendix A
Financial Model – Case 1

Income Statement (in Sesterces)	Initial Purchase	Year 1E	Year 2E	Year 3E	Year 4E	Year 5E	Year 6E	Year 7E	Year 8E
Total Revenue	-	-	-	**8,400**	**8,400**	**8,400**	**8,400**	**8,400**	**42,000**
Wine	-	-	-	8,400	8,400	8,400	8,400	8,400	8,400
Nursery Plants	-	-	-	-	-	-	-	-	33,600
Cost of Goods Sold	-	**(3,967)**	**(3,967)**	**(467)**	**(467)**	**(467)**	**(467)**	**(467)**	**(13,067)**
Maintenance/Planting of Vines	-	(3,967)	(3,967)	(467)	(467)	(467)	(467)	(467)	(467)
Nursery Plant Failures	-	-	-	-	-	-	-	-	(12,600)
Gross Profit	-	**(3,967)**	**(3,967)**	**7,933**	**7,933**	**7,933**	**7,933**	**7,933**	**28,933**
Additional Related Operating Costs	-	(170)	(170)	(170)	(170)	(170)	(170)	(170)	(170)
Wages on Vinedresser and Slave Labor	-	(518)	(518)	(518)	(518)	(518)	(518)	(518)	(518)
Depreciation of Farm Building and Equipment	-	(653)	(653)	(653)	(653)	(653)	(653)	(653)	(653)
Operating Profit (EBIT)	-	**(5,308)**	**(5,308)**	**6,592**	**6,592**	**6,592**	**6,592**	**6,592**	**27,592**
Net Interest Expense	-	(450)	(450)	(450)	(450)	(450)	(450)	(450)	(450)
Pre-Tax Profit	-	**(5,758)**	**(5,758)**	**6,142**	**6,142**	**6,142**	**6,142**	**6,142**	**27,142**
Income Tax Expense	-	-	-	(1,075)	(1,075)	(1,075)	(1,075)	(1,075)	(4,750)
Net Income	-	**(5,758)**	**(5,758)**	**5,068**	**5,068**	**5,068**	**5,068**	**5,068**	**22,393**
Income Tax Expense	-	-	-	1,075	1,075	1,075	1,075	1,075	4,750
Net Interest Expense	-	450	450	450	450	450	450	450	450
Adjusted EBIT	-	**(5,308)**	**(5,308)**	**6,592**	**6,592**	**6,592**	**6,592**	**6,592**	**27,592**
Depreciation of Farm Building and Equipment	-	653	653	653	653	653	653	653	653
Adjusted EBITDA	-	**(4,655)**	**(4,655)**	**7,245**	**7,245**	**7,245**	**7,245**	**7,245**	**28,245**
Levered Free Cash Flow									
Adj. EBITDA	-	(4,655)	(4,655)	7,245	7,245	7,245	7,245	7,245	28,245
-- Income Tax Expense	-	-	-	(1,075)	(1,075)	(1,075)	(1,075)	(1,075)	(4,750)
-- Change in Net Working Capital	-	-	-	-	-	-	-	-	-
-- Capital Expenditures	(29,970)	-	-	-	-	-	-	-	-
-- Net Interest Expense	-	(450)	(450)	(450)	(450)	(450)	(450)	(450)	(450)
Levered Free Cash Flow	**(29,970)**	**(5,105)**	**(5,105)**	**5,721**	**5,721**	**5,721**	**5,721**	**5,721**	**23,046**

Profit Margins	Initial Purchase	Year 1E	Year 2E	Year 3E	Year 4E	Year 5E	Year 6E	Year 7E	Year 8E
Gross Margin	-	-	-	94%	94%	94%	94%	94%	69%
Operating/EBIT Margin	-	-	-	78%	78%	78%	78%	78%	66%
EBITDA Margin	-	-	-	86%	86%	86%	86%	86%	67%
Net Margin	-	-	-	60%	60%	60%	60%	60%	53%

Average Return: 5.39%

Internal Rate of Return: 4.35%

Assumptions: Four *cullei* per *iugerum*, nursery plant sales, interest expense (6% of capital outlay), and income tax expense (17.5%)

Revenue Calculations

Revenue Yearly per Vineyard (*In Sesterces*)	
Iugerum	7
Culleus	28
Sesterces	8,400
Sesterces / Culleus Ratio	300

Nursery Plant Sales (*In Sesterces*)	
Nursery Plant sale	33,600
Loss of Nursery Plant Life (%)	37.5%
Loss of Nursery Plant Life	(12,600)

Expense Calculations

Expense Build (*In Sesterces*)	**Initial Cost**	**Lifespan**	**D&A**	**OpEx**	**COGS**
Vinitor	(8,000)	20	-	(518)	-
Ancillary Slave Labor	(400)	20	-	(170)	-
Maintenance	(7,000)	30	-	-	(467)
Purchase of Land	(7,000)	inf.	-	-	-
Purchase of Farm Buildings and Equipment	(19,600)	30	(653)	-	-
Grain Land	(1,700)	inf.	-	-	-
Ancillary Woodland	(1,670)	inf.	-	-	-

Unit Conversions

Ratio (1 equals x amount equivalency)						
	Iugerum	***Culleus***	***Amphorae***	***Urns***	***Vines***	***U.S. Gallons***
Iugerum	1.000	0.250	-	0.002	-	-
Culleus	4.000	1.000	0.050	-	0.009	0.007
Amphorae	100.000	20.000	1.000	0.500	-	0.146
Urns	600.000	-	2.000	1.000	-	0.292
Vines	-	114.286	-	-	1.000	-
U.S. Gallons	-	137.000	6.850	3.420	-	1.000

Financial Model – Case 2

Income Statement (in Sesterces)	Initial Purchase	Year 1E	Year 2E	Year 3E	Year 4E	Year 5E	Year 6E	Year 7E	Year 8E
Total Revenue	-	-	-	**8,400**	**8,400**	**8,400**	**8,400**	**8,400**	**42,000**
Wine	-	-	-	8,400	8,400	8,400	8,400	8,400	8,400
Nursery Plants	-	-	-	-	-	-	-	-	33,600
Cost of Goods Sold	-	**(3,967)**	**(3,967)**	**(467)**	**(467)**	**(467)**	**(467)**	**(467)**	**(13,067)**
Maintenance/Planting of Vines	-	(3,967)	(3,967)	(467)	(467)	(467)	(467)	(467)	(467)
Nursery Plant Failures	-	-	-	-	-	-	-	-	(12,600)
Gross Profit	-	**(3,967)**	**(3,967)**	**7,933**	**7,933**	**7,933**	**7,933**	**7,933**	**28,933**
Additional Related Operating Costs	-	(170)	(170)	(170)	(170)	(170)	(170)	(170)	(170)
Wages on Vinedresser and Slave Labor	-	(518)	(518)	(518)	(518)	(518)	(518)	(518)	(518)
Depreciation of Farm Building and Equipment	-	(653)	(653)	(653)	(653)	(653)	(653)	(653)	(653)
Operating Profit (EBIT)	-	**(5,308)**	**(5,308)**	**6,592**	**6,592**	**6,592**	**6,592**	**6,592**	**27,592**
Net Interest Expense	-	-	-	-	-	-	-	-	-
Pre-Tax Profit	-	**(5,308)**	**(5,308)**	**6,592**	**6,592**	**6,592**	**6,592**	**6,592**	**27,592**
Income Tax Expense	-	-	-	-	-	-	-	-	-
Net Income	-	**(5,308)**	**(5,308)**	**6,592**	**6,592**	**6,592**	**6,592**	**6,592**	**27,592**
Income Tax Expense	-	-	-	-	-	-	-	-	-
Net Interest Expense	-	-	-	-	-	-	-	-	-
Adjusted EBIT	-	**(5,308)**	**(5,308)**	**6,592**	**6,592**	**6,592**	**6,592**	**6,592**	**27,592**
Depreciation of Farm Building and Equipment	-	653	653	653	653	653	653	653	653
Adjusted EBITDA	-	**(4,655)**	**(4,655)**	**7,245**	**7,245**	**7,245**	**7,245**	**7,245**	**28,245**
Levered Free Cash Flow									
Adj. EBITDA	-	(4,655)	(4,655)	7,245	7,245	7,245	7,245	7,245	28,245
-- Income Tax Expense	-	-	-	-	-	-	-	-	-
-- Change in Net Working Capital	-	-	-	-	-	-	-	-	-
-- Capital Expenditures	(29,970)	-	-	-	-	-	-	-	-
-- Net Interest Expense	-	-	-	-	-	-	-	-	-
Levered Free Cash Flow	**(29,970)**	**(4,655)**	**(4,655)**	**7,245**	**7,245**	**7,245**	**7,245**	**7,245**	**28,245**

Profit Margins	Initial Purchase	Year 1E	Year 2E	Year 3E	Year 4E	Year 5E	Year 6E	Year 7E	Year 8E
Gross Margin	-	-	-	94%	94%	94%	94%	94%	69%
Operating/EBIT Margin	-	-	-	78%	78%	78%	78%	78%	66%
EBITDA Margin	-	-	-	86%	86%	86%	86%	86%	67%
Net Margin	-	-	-	78%	78%	78%	78%	78%	66%

Average Return: **7.43%**

Internal Rate of Return: **8.87%**

Assumptions: Four *cullei* per *iugerum*, nursery plant sales, no interest expense or tax expenses

Financial Model – Case 3

Income Statement (in Sesterces)	Initial Purchase	Year 1E	Year 2E	Year 3E	Year 4E	Year 5E	Year 6E	Year 7E	Year 8E
Total Revenue	-	-	-	**8,400**	**8,400**	**8,400**	**8,400**	**8,400**	**8,400**
Wine	-	-	-	8,400	8,400	8,400	8,400	8,400	8,400
Nursery Plants	-	-	-	-	-	-	-	-	-
Cost of Goods Sold	-	**(3,967)**	**(3,967)**	**(467)**	**(467)**	**(467)**	**(467)**	**(467)**	**(467)**
Maintenance/Planting of Vines	-	(3,967)	(3,967)	(467)	(467)	(467)	(467)	(467)	(467)
Nursery Plant Failures	-	-	-	-	-	-	-	-	-
Gross Profit	-	**(3,967)**	**(3,967)**	**7,933**	**7,933**	**7,933**	**7,933**	**7,933**	**7,933**
Additional Related Operating Costs	-	(170)	(170)	(170)	(170)	(170)	(170)	(170)	(170)
Wages on Vinedresser and Slave Labor	-	(518)	(518)	(518)	(518)	(518)	(518)	(518)	(518)
Depreciation of Farm Building and Equipment	-	(653)	(653)	(653)	(653)	(653)	(653)	(653)	(653)
Operating Profit (EBIT)	-	**(5,308)**	**(5,308)**	**6,592**	**6,592**	**6,592**	**6,592**	**6,592**	**6,592**
Net Interest Expense	-	(450)	(450)	(450)	(450)	(450)	(450)	(450)	(450)
Pre-Tax Profit	-	**(5,758)**	**(5,758)**	**6,142**	**6,142**	**6,142**	**6,142**	**6,142**	**6,142**
Income Tax Expense	-	-	-	(1,075)	(1,075)	(1,075)	(1,075)	(1,075)	(1,075)
Net Income	-	**(5,758)**	**(5,758)**	**5,068**	**5,068**	**5,068**	**5,068**	**5,068**	**5,068**
Income Tax Expense	-	-	-	1,075	1,075	1,075	1,075	1,075	1,075
Net Interest Expense	-	450	450	450	450	450	450	450	450
Adjusted EBIT	-	**(5,308)**	**(5,308)**	**6,592**	**6,592**	**6,592**	**6,592**	**6,592**	**6,592**
Depreciation of Farm Building and Equipment	-	653	653	653	653	653	653	653	653
Adjusted EBITDA	-	**(4,655)**	**(4,655)**	**7,245**	**7,245**	**7,245**	**7,245**	**7,245**	**7,245**
Levered Free Cash Flow									
Adj. EBITDA	-	(4,655)	(4,655)	7,245	7,245	7,245	7,245	7,245	7,245
-- Income Tax Expense	-	-	-	(1,075)	(1,075)	(1,075)	(1,075)	(1,075)	(1,075)
-- Change in Net Working Capital	-	-	-	-	-	-	-	-	-
-- Capital Expenditures	(29,970)	-	-	-	-	-	-	-	-
-- Net Interest Expense	-	(450)	(450)	(450)	(450)	(450)	(450)	(450)	(450)
Levered Free Cash Flow	**(29,970)**	**(5,105)**	**(5,105)**	**5,721**	**5,721**	**5,721**	**5,721**	**5,721**	**5,721**

Profit Margins	Initial Purchase	Year 1E	Year 2E	Year 3E	Year 4E	Year 5E	Year 6E	Year 7E	Year 8E
Gross Margin	-	-	-	94%	94%	94%	94%	94%	94%
Operating/EBIT Margin	-	-	-	78%	78%	78%	78%	78%	78%
EBITDA Margin	-	-	-	86%	86%	86%	86%	86%	86%
Net Margin	-	-	-	60%	60%	60%	60%	60%	60%

Average Return: 4.69%

Internal Rate of Return: 3.01%

Assumptions: Four *cullei* per *iugerum*, no nursery plant sales, interest expense (6% of capital outlay), and income tax expense (17.5%)

Appendix B
Primary and Secondary Sources

Columella's Calculations

Columella's Model *(in Sesterces)*	
Purchase of Land	7,000
Purchase of Vinitor	8,000
Maintenance Costs	14,000
Interest Expense	3,480
Total Costs	32,480
Wine Sales (over 8-year period)	88,200
Nursery Plant Sales (over 8-year period)	55,320
Years until Profitability (in years)	4.50
Average Return or Net Margin (over 8-year period)	9.67%

Duncan-Jones's Expenditures

Capital Outlay *(in Sesterces)*	
Purchase of Land	7,000
Purchase of Vinitor	8,000
Maintenance Costs	14,000
(Farm Buildings and Equipment)	19,600
(Grain Land)	1,700
(Ancillary Woodland)	1,670
(Ancillary Slave Labor)	400
Total Capital Outlay	52,370

Duncan-Jones's Yearly Expenses

Overhead Expenses *(in Sesterces)*	
(Interest Expense) (6% bi-yearly)	785
(Maintenance Spent on Laborers)	170
(Amortization of Vines)	467
(Amortization of Farm Buildings and Equipment)	653
(Amortization of Vinitor and Slaves)	518
Total Overhead Expenses	2,593

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ACADEMIC VITA

EDUCATION

The Pennsylvania State University | Schreyer Honors College & Paterno Fellows Program **University Park, PA**
Smeal College of Business | Bachelor of Science in Finance *Class of May 2023*
College of the Liberal Arts | Bachelor of Science in Economics

- Completed Interdisciplinary Honors Thesis in the Departments of Finance & Classics and Ancient Mediterranean Studies

RELEVANT EXPERIENCE

BofA Securities, Inc. **New York, NY**
Investment Banking Summer Analyst | Leveraged Finance (received full-time offer) *Jun 2022 – Aug 2022*

- Analyzed prospective leveraged loan and high yield bond deals by performing credit analysis, evaluating credit agreements, examining capital structures, building financial models, and conducting ratio analysis
- Performed Leveraged Buyout Analysis (LBO) on a deal involving a leading manufacturer of snowplow equipment, by assessing financial performance through model analysis and the creation of a private equity investment thesis
- Completed weekly healthcare reports distributed to hundreds of clients covering recent sector events, levered loan and high yield commentary, BofA-led leveraged loan and high yield deals, and retail fund flows expectations

The Riverside Company **Cleveland, OH**
Private Equity Summer Analyst | Riverside Capital Appreciation Fund (RCAF) *Jun 2021 – Aug 2021*

- Evaluated a potential $300M acquisition of a Healthcare Technology Services firm with senior Riverside team, by interviewing industry experts to understand competitive dynamics and conducting industry research on the firm's services
- Assessed three add-on acquisitions for a heating, ventilation, and air conditioning (HVAC) solutions portfolio company, reviewing the competitive landscape in target markets, and presenting results to the RCAF Investment Committee
- Participated in Riverside's training program, learning the fundamentals of LBO modeling, market sizing, and data analysis techniques, and attended Riverside's weekly networking sessions led by the firm's senior team and experts in the field

Resolvit, LLC **Cincinnati, OH**
Integrated Talent Sourcing Analyst *Jun 2020 – Aug 2020*

- Sourced and evaluated hundreds of experienced IT professional candidates' resumes and credentials to fill permanent and contract-to-hire consultant positions for clients at Fortune 50 companies including Kroger, General Electric, and P&G
- Worked closely with the recruiting team, HR department, and account sales managers, advising the talent acquisition process and conducting screening interviews with potential candidates
- Attended an Amazon Web Services one-week training program to develop foundational skills and broad understanding in cloud computing processes used for sales and recruiting purposes

INVOLVEMENT

Leveraged Lion Capital **University Park, PA**
Vice President, Director of Recruiting, Lead Analyst & Associate Analyst | Smeal College of Business *2020 – 2022*

- Selected to Executive Leadership Team of the nation's first student-run paper leveraged loan and high yield bond portfolio, partnered with Bank of America Merrill Lynch, the Loan Syndications and Trading Association, and S&P Global
- Co-managed a $25 million fund in the Industrials sector (19% of the portfolio) – holdings included TPC's Sr. Unsecured Bond, CVGI's TLB, and DCO's TLB, returning 31.58%, 7.39%, and 17.65%, respectively, over one-and-a-half-year tenure
- Led recruiting efforts and taught weekly workshops for the organization's feeder program, the Penn State Fixed Income Association, which provides the basic understandings of the credit markets, valuation techniques, and financial accounting

Academic Peer Mentorship Program (APMP) **University Park, PA**
Student Mentor | Division of Undergraduate Studies *2021 – 2022*

- Provide mentorship and supervision to students in academic warning, seeking to address emerging issues and concerns through relevant offered academic resources, utilizing a mentor/mentee pairing
- Completed Mentoring Practicum, which provided advanced training for mentors in the Academic Peer Mentoring Program, practicing motivational interviewing skills, active listening, time management techniques, and professional documentation of weekly meeting notes and conversations

Wall Street Boot Camp I **University Park, PA**
Graduate | Smeal College of Business *Aug 2020 – Dec 2020*

- Among the top 50 Smeal College of Business students selected out of 400+ applicants for intensive 15-week training program taught by current and former Wall Street professionals covering finance related career paths
- Expanded knowledge of Wall Street operations and opportunities through weekly educational seminars and interviews

OTHER ACHIEVEMENTS

- **Honors/Activities:** Dean's List (7/7); Schreyer Honors College Academic Excellence Scholarship, Deloitte National Undergraduate Case Competition, PwC Challenge Case Competition, Penn State Intramural Hockey League
- **Interests:** Christopher Nolan movies; Sci-fi; fantasy football; hockey; skiing; Cleveland sports; *Star Wars*