ENGR 110 Project

Fall 2021

M1 Pro & Intel MacBook Pro Comparison for Video Editors

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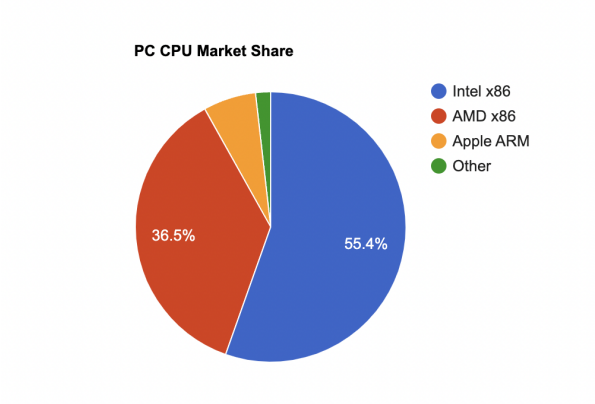
Microeconomics

In 1965 Gordon Moore, the co-founder of Intel, posited that the number of transistors in integrated circuits would double roughly every two years. Moore's Law would largely prove true and cement itself in popular culture as a reminder of the fast-paced nature of the tech industry.

Half a century later, Gordon Moore's company and its flagship x86 architecture dominate the PC CPU market. However, this architecture has garnered criticism for its complexity when compared to ARM, a comparatively simpler architecture which had seen tremendous success in the phone and tablet market for its performance and energy efficiency.

A year ago one of the biggest players in the mobile/tablet space, Apple, made their attempt to push the ARM architecture past the PC barrier with their M1 chip, first introduced in their 2020 MacBook Air line up. ARM has since taken 8% of PC CPU market share (source 2), with Apple is on track to capture 79% of this segment by year's end according to a market analysis (source 1). However, the remaining 92% of the market is solely dominated by Intel and AMD's x86 CPUs, controlling 60.2% and 39.7% of the x86 CPU market respectively (source 2).



2020 PC CPU market share, extrapolated from sources 1 and 2.

The approximately 92% share of the PC CPU market controlled by Intel and AMD makes the market an oligopoly, more specifically a duopoly. In this oligopolistic environment, Apple is making several large moves to capture market share and take out competitors:

- Apple is flexing their cash reserves to fund research and development. Although the exact investment into R&D isn't public, Apple has disclosed that the M1 is the culmination of a decade of the firm's silicon work (source 3).
- Apple is pushing prices down through economies of scale by introducing the M1 to 8.6 million M1 Macs in 2020 alone, with an estimated average variable cost of $40-50 when compared to Intel's core i5 dual and quad-core offerings in the range $175-250 in previous 13-inch Macbook Airs according to an IBM executive (source 4). With lower marginal costs on its Macbooks, Apple is able to offer lower prices and maintain profitability in higher quantities, evidenced by a 94% year over year increase in laptop production following the introduction of Apple silicon (source 6). This increased output and downward pressure on price has allowed Apple to capture this market share.
- Since PC's aren't homogenous products, Apple has leaned heavily into performance metrics to differentiate their product from the competition in their advertising (source 5). With this product

differentiation, Apple Silicon has since garnered a cult following among digital creatives, who swear by its superiority over x86 processors.

Is Intel too big to fail, or is the field that birthed Moore's Law too fast-paced for x86 to maintain market dominance?

This paper will compare the economic factors behind choosing between an Intel x86 MacBook Pro and an Apple M1 Pro (ARM) MacBook Pro through the perspective of a full-time video editor, a user-base known for demanding performance from their PCs. We will also assume that the lifespan of a computer is 4 years. To avoid compounding factors, we will isolate for the CPU in two MacBooks with similar specs (16GB RAM, 512GB SSD):

- 16-inch M1 Pro MacBook Pro ($2399 Amazon)
- 16-inch Intel Core i7 MacBook Pro ($1899 BestBuy)

Since we will be taking the time value of money into account, we need to figure out a suitable Minimum Attractive Rate of Return (MARR). Since individuals aren't entities that can issue stocks, bonds or equity, Weighted Average Cost of Capital (WACC) will be excluded as a factor. Assuming a historically stable 10% nominal rate of return from S&P 500 as opportunity cost and a median US credit score of 723 that can achieve a 13.32% rate for personal finance loans (source 7, 8), we will take the maximum of the two and set a MARR at 13.32%. Taking into account current inflation rates of 6% with the Fisher formula, our MARR in real terms is **6.9%**.

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Project Evaluation

Salvage Value

History

Apple had three transitions for its personal computers' instruction set architectures. The second transition, which was from PowerPC to Intel processors, was the transition before the shift to Apple Silicon. The transition was announced at the 2005 Worldwide Developers Conference and it proceeded very quickly. On June 23, 2011, with the support for Mac OS 10.5 Leopard coming to an end, it marked the ending of Apple's support of PowerPC-based software.

On June 22, 2020, Apple announced the Mac transition to Apple silicon, and we've seen a rapid shift in current Mac models. Though Apple stated that it will continue to support and release new versions of MacOS for Intel-based Macs for years to come, we would like to estimate the support coming to an end in five years similar to the transition from PowerPC to Intel Processors.

Useful Lifetime

For video producers, useful lifetimes for their laptops vary based on personal habits and other external factors. However, it is expected that the lifetime for MacBook Pro will be 4-7 years. For calculating the cash flows and taking the history of PowerPC-to-Intel transition into consideration, we will assume the useful lifetime for both models to be 4 years. That is, we will sell or trade in our device in 2025.

Trade-In & Second-Hand

In order to estimate the salvage values for both intel-based MacBook Pro and M1 MacBook Pro, we researched both the trade-in values and prices for second-hand models on the market. Since intel-based MacBook Pro was first released in the market in 2019 and the M1 Pro MacBook Pro was introduced this year and great changes have been made to these two models, there is a significant price difference between these two models.

To estimate the future prices, we used the price histories of other MacBook models. In addition, from the research of other MacBook models, we noticed there is a smaller price depreciation for trade-in models than second-hand models. We would like to take this into consideration when estimating the prices in the future. We also assume the support for Intel-based models would end in 2025 and factor that into calculating the estimates for 2025. The average result of second-hand and trade-in value in 2025 will be used in the cash flow.

Current 2021 Trade-In & Second-Hand Prices

	Intel MBP	**M1 Pro MBP**
Trade-In	$650	Not Available
Second-Hand	$1,300 - $1,500	$2,000 - $2,400

Estimated Trade-In & Second-Hand Prices in 2025

	Intel MBP	**M1 Pro MBP**

Trade-In	$250	$700
Second-Hand	$600	$1,500
Average	**$425**	**$1,100**

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Opportunity Cost of Time

The performance level for an average editor varies from app by app. However, we are looking at the industry-standard Adobe Premiere Pro and Photoshop for the comparison; the two models have been hands-on tested using two types of projects on the software and getting the average time in seconds to see the performance levels. To show the benefits of which model has an economical benefit, we will utilize the average cost of an editor salary, and assume they spend 2 hours per day on heavy-workload tasks (such as video exporting), as shown in Table 1:

Editors Hourly wage	Cost		Time
Low Range (Inexperince)	$	75.00	
High Range (Professional)	$	150.00	
Average	$	112.50	1 hour
		$225.00	2hours

Table 1

We want to demonstrate the loss that will be incurred by the performance difference between the two models. Table 2 compares the performance of both models on the same series of six heavy tasks performed by a typical video editor. The saving of time on the M1 Pro model is significant, with a calculated average time saving of 57.7% compared to the Intel model.

Given that the opportunity cost of 2 hours per day is $225 per day, the expected extra savings per year by choosing the M1 Pro model will be $225 x 57.7% x 365 days = **$47410.17 per year**.

Adobe Photoshop	Seconds
Focus Stack (Aligning and Mergering)	
MacBook Pro (intel)	147.2
MacBook Pro (m1)	69.5
Time difference	77.7
50 Raw images to jpeg	
MacBook Pro (intel)	227
MacBook Pro (m1)	83
time difference	144
MacBook Pro (Intel) averages	187.1
MacBook Pro (m1) averages	76.25
Time difference	66.3
Adobe Premier Pro	Seconds
Exporting 10 min HD Video	
MacBook Pro (intel)	385
MacBook Pro (m1)	204
Time difference	181
importing 4k Clip 1minute	
MacBook Pro (intel)	770
MacBook Pro (m1)	160
Time difference	610
MacBook Pro (Intel) averages	577.5
MacBook Pro (m1) averages	182
Time difference	395.5

Table 2

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Power efficiency

The power consumption of a computer depends on its current load level. Higher load level usually means greater power consumption. For greater precision, we will split the loads into 5 different levels, sleep, idle, light, medium and high, each corresponding to a different power rating. To mimic real-life usage, we also assume a load mixture for a typical video editor. Based on the load mixture and power ratings, we will be able to calculate the annual electricity consumption. Given the average electricity price in the US ($0.1419 per kWh) we can estimate the annual electricity costs for both models.

Intel Model

Load	Hours per Day	Power (W)	Daily Consumption (Wh)	Annual Consumption (kWh)	Annual Cost ($)
Sleep	14	0.60	8.40	3.07	0.44
Idle	1	5.44	5.44	1.99	0.28
Light	1	9.94	9.94	3.63	0.52
Medium	6	40.33	241.98	88.32	12.53
Heavy	2	90.00	180.00	65.70	9.32
Total	24	/	/	162.71	**23.09**

M1 Pro Model

Load	Hours per Day	Power (W)	Daily Consumption (Wh)	Annual Consumption (kWh)	Annual Cost ($)
Sleep	14	0.47	6.58	2.40	0.34
Idle	1	7.12	7.12	2.60	0.37
Light	1	8.10	8.10	2.96	0.42
Medium	6	12.10	72.60	26.50	3.76
Heavy	2	27.00	54.00	19.71	2.80
Total	24	/	/	54.17	**7.69**

The annual electricity cost of the Intel model is $23.09, where the annual electricity cost of the M1 Pro model is just $7.69. Thus, we can conclude that a typical professional video editor can save **$15.40 per year** on electricity if he or she chooses to purchase the M1 Pro model over the Intel model. The saving is noticeable, though by means substantial enough to influence the purchasing decision alone.

Assumptions

- Most calculation steps are omitted for simplicity.
- Power estimates on sleep and idle levels are provided by Apple's Product Environmental Report, assuming operating voltage of 115V.
- Power estimates on light load are provided by GeekerWan who performs a test on a M1 (not Pro) model. Assume similar power ratings on a Pro model.
- Power estimates on heavy load are provided by Max Tech who performs a test running Cinebench R23 benchmark. Assume similar power ratings during video exports.
- Power estimates on medium level are not publicly available. Assume the M1 Pro model consumes 5x more power than the light level. Assume the M1 Pro model consumes 70% less than the Intel model as suggested by Apple.

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Cost of Incompatibility and Failures

There were some M1 MacBook users reporting excessive usage of M1 MacBook built-in SSD, which may greatly decrease the lifespan of this component[1,2]. Some users on social media and forums, such as Twitter and Linus Tech Tips, reported that their M1 chip MacBooks' SSD had unusually high drive writes over a short period of time. The most extreme case reported has consumed about 10%-13% of the maximum TBW (Terabytes written) value of the SSD. One Twitter user Hector Martin, who is a Linux developer, shared the SSD health info. of his MacBook Pro that has 2TB SSD and 16GB memory. The picture below shows that the consumption of the SSD is 3%, and he claims that the MacBook is only 2 months old.

This means that about 60GB of the storage was consumed, which takes about 12% of a 512GB SSD. Thus, the SSD would wear out in about 2 years in the worst scenario. Hector claims that his assumption is that the problem may be caused by memory swap, which means the system constantly uses the SSD as a virtual RAM. There are not many reports about this issue, so it may not be a widely experienced issue. According to the recent report, Apple resolved this issue in the recent system updates[3]. Note that this issue was originally reported on M1 (not Pro) models, and it is unknown whether or not the issue still exists on the M1 Pro model. However, if there is indeed an SSD failure, the cost of repair will be around $500 since Apple will replace the entire logic board. Assuming the probability of such failure is 10%, the expected cost of such failure on the M1 Pro model will be **$50**, due end of 2nd year.

```
SMART/Health Information (NVMe Log 0x02)
Critical Warning:                   0x00
Temperature:                        42 Celsius
Available Spare:                    100%
Available Spare Threshold:          99%
Percentage Used:                    3%
Data Units Read:                    311,440,203 [159 TB]
Data Units Written:                 294,649,919 [150 TB]
Host Read Commands:                 1,244,600,021
Host Write Commands:                762,843,255
Controller Busy Time:               0
Power Cycles:                       144
Power On Hours:                     432
Unsafe Shutdowns:                   16
Media and Data Integrity Errors:    0
Error Information Log Entries:      0
```

Another report says that M1 chip has a flaw that creates a convert channel, allowing two or more processes to secretly send data to each other[5,6]. This bug allows data to be exchanged in an undetected manner without taking advantage of special tools. By taking advantage of this bug, malware in the computer can communicate with each other without being noticed. This bug was also found by Hector Martin, and it was named as M1RACLES[7]. Hector claims that this bug is not as scary as it sounds, but he does express his concern that advertising companies may use this bug for cross-app tracking.

Compatibility is another issue that M1 MacBook users may run into. Apple introduced Apple Silicon Mac in 2020 and announced that it would transit to ARM chips in the next few years. So, ARM-based laptops are still pretty new in the market. Apple had been using Intel x86 architecture processors for more than 10 years before it switched to ARM. Therefore, there are still many software products that do not natively support the brand-new processor. To help both customers and Mac product lines transit smoothly, Apple developed a translation process called Rosetta 2, which allows a Mac with Apple Silicon to run apps that were built for Intel processors. The translated apps usually have a small percentage of loss in performance compared to apps with native Apple Silicon support. Meanwhile, there are still some apps and plugins, such as Autodesk Flame, that do not even support Rosetta 2[8]. For video editors who rely on these apps and plugins that are not compatible with Apple Silicon, buying the M1 Pro Mac could bring unavoidable and unnecessary costs. If video editors who currently are Intel MacBook Pro and Autodesk Flame users plan to purchase an M1 Pro MacBook Pro, they will have to switch to other video editing software, such as Adobe After Effects which costs $239.88 per year. Assuming the probability that new software needs to be purchased is 20%, the expected extra cost of using the M1 Pro model is **$47.98 per year**.

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Cash Flow

Intel Model:

Item	Value ($)	Due	EUAW
Purchase	-1,899	Year 0 (2021)	-559.37
Salvage Value	+425	Year 4 (2025)	+95.86
Total	/	/	**-463.51**

M1 Pro Model:

Item	Value ($)	Due	EUAW ($)
Purchase	-2,399	Year 0 (2021)	-706.65
Salvage Value	+1,100	Year 4 (2025)	+248.12
Time Saving	+47,410.17	Per Year	+47,410.17
Electricity Saving	+15.40	Per Year	+15.40
SSD Failure	-50	Year 2 (2023)	-12.89
Software Purchase	-47.98	Per Year	-47.98
Total	/	/	**+46906.17**

Notes

- MARR of 6.9%, obtained from the Microeconomics part, is used in the calculation of EUAW.
- EUAW of a single item is calculated from bringing the value to time Year 0 and then uniformly distributing it over 4 years, the lifespan of the computer.
- We only consider the difference of EUAW of the two models in order to make the comparison. One should not consider the EUAW of a single model alone as a meaningful number.

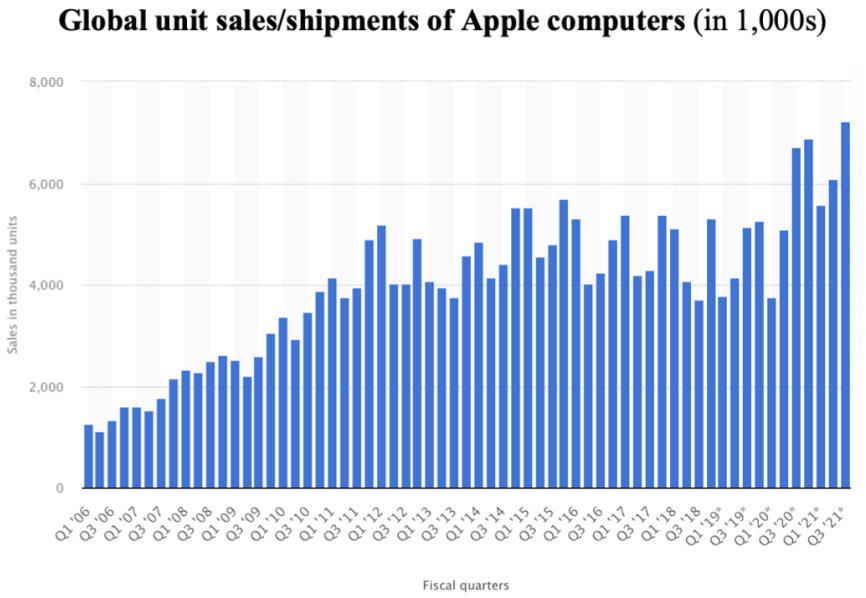
Conclusion

Compared to the Intel model, the M1 Pro model brings an extra EUAW of 46906.17-(-463.51) = **$47369.68**. The biggest saving comes from the opportunity cost of time brought by the extraordinary performance improvement in heavy video editing tasks. Other benefits of the M1 Pro model such as electricity saving are observable but trivial. Even though the M1 Pro model has a few drawbacks like higher initial cost and potential hardware failure, their costs are negligible considering the magnitude of the benefits. Thus, for a video editor, it is highly recommended to choose the M1 Pro model over the Intel model at this moment.

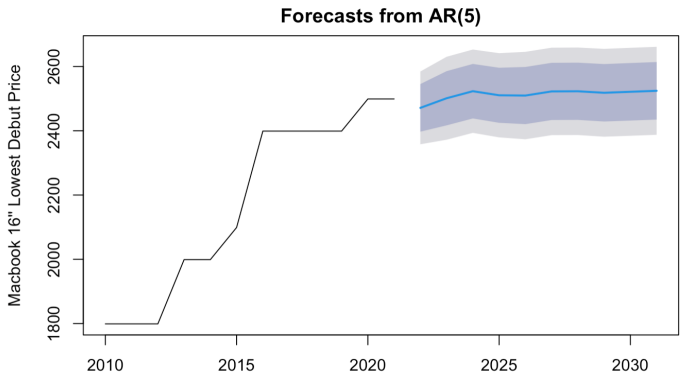
Macroeconomics

Laptop sale trend of Apple

The global demand for Apple has been steadily increasing in the period of 2006-2012 and in recent two years despite the stagnation in 2015-2019. Possibly because of the global pandemic, firms may have to purchase a large amount of laptops or computers to support their employees working from home and keep the company running.



Collecting the lowest debut price of Macbook 16”/15” since 2010, we create an AR model that predicts the future price trend. By comparing the Akaike information criterion level of candidate models, we keep AR(5), which takes the price levels of past 5 years as predictors, as the final model. The 10-step-ahead forecast below infers a potential mild increase in macbook prices within 10 years in the future.



Chip Shortage as the Macroeconomic Trend

The global chip shortage will potentially lead to an even higher price of electrical devices in the future given its indispensability in the production process. In the meantime, the demand for MacBooks and other electrical devices is unlikely to decrease in the near future given the heavy use of them in current workspaces of various industries. The resulting soaring price may hurt the current electronic device market by making the devices inaccessible/unaffordable for certain groups of people. However, the imbalance between supply and demand may inspire some revolutionary designs of technical appliances using new materials and resources that are not yet exploited.

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