

Consumer Acceptance of Autonomous Vehicles and Digital Adoption

Problem Statement

Why is there a variation in consumer acceptance of autonomous vehicle (AV) technology across different countries?

Introduction

Autonomous vehicle technology has been improving rapidly. Recently policy, legislation, and infrastructure have begun to catch up, addressing the possibility of mass-scale AV deployment. Consumer acceptance of AVs depends on many factors that rely on larger forces such as policies that decide AV regulation, spatial planning, infrastructure investment (KPMG 2020), private and public investment in innovation and technology (IMF 2017 UNESCO 2017, Heritage Foundation 2019). Moreover, there are psychological factors such as comfort with AV, openness to new technologies, and tech literacy.

My assumption is that given that consumer acceptance in any technology generally depends on the factors mentioned above, similar factors must have affected the acceptance of digital technologies; factors like – internet and mobile network penetration, construction of towers for coverage, policies, and regulations for cloud services and data security.

In general, there is a linear relationship between adoption and acceptance for any technology, sometimes bordering on a tautology. I want to understand if regular users or people ready to adopt digital technologies are equally willing to embrace autonomous vehicles. Specifically, I am looking for a positive linear relationship between digital technology adoption and consumer acceptance of Autonomous Vehicles (AV). Suppose there is a strong linear relationship between digital adoption and consumer acceptance of AVs, then I can use this knowledge to forecast a similar trend for consumer adoption of AVs. If there is a weak linear relationship or no relationship, there must be something else affecting consumer acceptance, maybe psychological/societal factors. Of course, to arrive at this conclusion, we must first adjust for factors such as policy, innovation, and infrastructure.

Rationale and Alternative Explanations

When I propose a linear regression between digital adoption and AV acceptance, I am suggesting ‘Openness to New Technologies’ as the hidden factor behind both variables. Yet, we could observe this linear relationship without the above hidden aspect, e.g., digital adoption has a positive linear relationship with tech literacy ([Lazar, Panisoara, and Panisoara 2020](#)). This means tech-literate users tend to adopt digital technologies and be more accepting of AVs simply because they are more tech literate. Instead of checking for a positive linear relationship between tech literacy and consumer acceptance of AVs, I decided to investigate if there is a positive linear relationship between digital tech adoption and consumer acceptance of AVs. I would posit that one does not have to be tech literate to be open to new technologies.

The possibility of a solid linear relationship seems unlikely, given that many factors are affecting AV acceptance. Something that makes even early adopters concerned is the intersection of this particular technology with an activity that might suddenly become fatal. For this reason, I must concede that consumer acceptance of AVs also depends on factors such as vehicle security (73%), system security (72%), and self-driving vehicles being confused by the unexpected situations (71%), as the top 3 problems reported ([“Main Barriers Preventing Consumers Worldwide from Adopting Self-Driving Cars”, 2019](#)). Nevertheless, we must also keep in mind that device security, system security, and confusion by unexpected situations are three problems that digital users face that may change their response to these problems in general.

Literature Review

Prior work has been done in [“Exploring Trust in Self-Driving Vehicles Through Text Analysis”](#) (Lee and Kolodge 2020). Here the authors explore the role of trust in qualitative data analyzed quantitatively using structural topic modelling. Their data is sourced from associated open-ended comments by 16,464 drivers. Though the data and methods employed are pretty good, it would be more fruitful to use them in tandem with indirect methods to figure out the role of such qualitative experiences as trust or openness by using different data sources.

Most literature on consumer acceptance of AVs comes from surveys. E.g., “Readiness to Ride in an Autonomous Car” (Statista, 2020) gets its results from asking respondents when they would be ready to ride in an autonomous vehicle. Though this kind of survey is crucial to determine what people may want, our intent to learn about consumer acceptance cannot

solely depend on people's opinions of their acceptance levels. "What people say, what people do, and what people say they do can be totally different things" -- Margaret Mead. We must be wary of hidden variables that might be influencing what people are reporting about themselves. Other reports, such as the [2021 Global Automotive Consumer Study](#) by Deloitte ("2021 Global Automotive Consumer Study" 2021), show us concerns such as cost, safety, and logistic issues. Nevertheless, we do not fully know to what extent are these concerns the primary reasons for consumer acceptance scores.

The global digital readiness index ("[Global-Digital-Readiness-Index](#)" 2020) shows us that technology innovation, infrastructure, and digital readiness go hand in hand. Within this technology, adoption plays a key role. The readiness index is meant to be a predictor of how digitally prepared a country is and to what extent digitalization can occur in a given country. This question is similar to the one I am pursuing in the current report for AVs. The AV readiness indexes for countries tell us how prepared the entire country is for accepting autonomous vehicles. However, I will still have to control variables such as infrastructure, policy, legislation, etc., when trying to understand these AV acceptance scores.

Methodology

I decided to extract the data for digital adoption and consumer AV acceptance from two separate sources to eliminate the possibility of finding correlated data handpicked by a single report, i.e., If the figures from two individual data collections correlate, then the chances are that the correlation is genuine and not forced.

I intend to run a multiple regression on the indexes, with one control variable.

IV - Digital Technology Adoption

DV - Consumer Acceptance of Autonomous Vehicles

Control – AV Technology Implementation Readiness Index

Data Collection:

Two indexes from separate sources:

1. Autonomous Vehicles Consumer Acceptance Index 2018

- KPMG's Autonomous Vehicles Readiness Index (KPMG 2018) – a cross-sectional study
- The report assesses 20 countries' openness and preparedness for autonomous vehicles.
- We look at the Index Results → Consumer Acceptance Score (scale: 0-10).
This score calculates four equally weighted factors: population living in AV test areas, consumer survey data on AV acceptance, KPMG's Change Readiness Index on people and civil society technology use, Technology Readiness from World Economic Forum.
- Survey Data for China, France, Germany, India, Japan, Netherlands, Singapore, UAE, UK, and the US came from a 2015 survey.
- Data for Canada, Russia, and Brazil came from a 2013 research study.
- All data had randomized probability sampling.
- KPMG also has a 2020 report, but this report does not contain consumer survey data on AV acceptance. Instead, it extrapolates a consumer acceptance index of AVs from the ICT adoption index and digital skills index.

- One control variable - I also intend to use a combined variable called Technology Implementation Readiness index that is a summation (additive scale) of the “Policy & Legislation”, “Technology & Innovation” and “Infrastructure” columns. Since consumer acceptance in any technology is influenced by how well placed the policy and legislation regarding the Tech is, how fast the technology evolves and how equipped the state is to handle this evolving technology, we need to control for a combination of these factors. Luckily, we can combine three AV-relevant indexes from the same report on AV into an additive scale.

2. Digital Technology Adoption Index 2019

- Source: [Global-Digital-Readiness-Index](#) 2019.
- Assesses a country’s capability to deploy digital technologies and how big is its digital footprint.
- This index is separate from ICT indexes which include more basic Internet-based Communication Technologies. The intent of using a digital readiness index is to measure not just digital literacy but also users’ level of sophistication and practice.
- We look at Appendix A. Country digital readiness scores and stages → Tech Adoption.
- Tech Adoption defines demand for digital products and services. The measures are a mean of Mobile Cellular Penetration, Internet Usage, Cloud Services Spending, and IT Forecast Data.
- The data was collected originally by ITU (2017) and Gartner (2018). All data had randomized probability sampling.

Hypothesis –

H0: There is no positive linear relationship between digital tech adoption index and consumer AV acceptance index.

H1: There is a positive linear relationship between digital tech adoption and consumer AV acceptance index.

Since we have a ratio variable by ratio variable relationship, I will use multiple regression with a control that is also a ratio variable. As these are country-wide data points, we know they must be normally distributed. I will first calculate the p-value to check for statistical significance. Our critical alpha will be 0.05 for a 95% confidence interval. Our slope coefficient (β) will give us the strength and direction of the relationship between IV and DV.

We will also calculate the standard error, model significance, and model strength.

Since there are 20 countries, our degrees of freedom = $20 - 1 = 19$.

Our p value has to be < 0.05 and $\beta > 0$ for H0 to be rejected.

Expected Findings

I expect to find a statistically significant positive linear relationship between the Digital Adoption Index (IV) and the Consumer AV Acceptance Index (DV). I expect that this result sustains even when controlling for the Technology Implementation Readiness Index (IV 2). This readiness could independently impact consumer acceptance of AVs. By summing the three indexes regarding autonomous vehicles: “Policy & Legislation,” “Technology & Innovation” and “Infrastructure”, I will create a tech implementation readiness index

(additive scale). Combining these three, I represent the country's total readiness to deploy the necessary resources for autonomous vehicles. Our dataset is just 20 countries, and the law of large numbers tells us that the chance of a type 2 error is high. i.e., I might fail to reject the null and believe that there is no relationship between AV acceptance and Digital Adoption when indeed there is one. Further studies should consider a larger sample, though the number of countries participating will always be limited. Since my analysis begins with preliminary findings to guide the later phase of my research, I am content with using a sample of 20 countries.

At first glance, the Tech Implementation Readiness index seems correlated to the consumer AV acceptance index. This correlation makes sense since AV tech implementation is a directly responsible factor in how accepting people can be about AVs. If there are no roads, laws, and innovations regarding AVs in a country, it is absurd to expect its consumer population to accept AVs. For this reason, I am not just looking at consumer survey acceptance scores of AV but rather a consumer AV acceptance index which is an aggregate of “percentage of the population living in AV test areas”, “consumer survey data on AV acceptance”, “KPMG change readiness of people and civil society technology use” and the “Global competitive technology readiness index”.

Actual Findings:

Summary statistics

	Digital Tech Adoption	Consumer AV Acceptance	Tech Implementation Readiness
Mean	1.562	4.2885	14.187
Median	1.65	4.465	16.085
Mode	1.69	█ #N/A	█ #N/A
Variation Ratio	0.85	1	1
Range	1.56	4.72	17.56
Q3	1.7675	5.415	18.2675
Q1	1.4125	3.1	11.59
IQR	0.355	2.315	6.6775
SS	2.81392	39.416255	606.83302
Variance	0.148101053	2.07453974	31.93858
Std Deviation	0.384838996	1.44032626	5.65142283

Q1 and Q3 show us the range of numbers between which 50% of our data falls. The mean, mode, and median are similar for each group, suggesting that the data could be normally distributed.

AV Digital Model 1

Let us first look at a simple linear regression model referred to as “AV Digital Model 1” between the Digital Adoption index and Consumer AV Acceptance index:

Preliminary Findings

Statistic	Value	Critical alpha	Result
P-value	0.000172	<0.05	Model Significance
Degrees of freedom	18		
Adjusted R-squared	0.5279		Model Strength

This finding tells us that the model is statistically significant, and we can trust the linear relationship values it generates. Since the p-value is lesser than the critical alpha, we know that model is statistically significant. Model Strength tells us that 52.79% of the variation in our data can be explained by the AV Digital Model 1. Now let us look at the slope –

AV Digital Model 1

Residuals:

Min	1Q	Median	3Q	Max
-1.6347	-0.5938	-0.0425	0.6129	1.901

Coefficients:

	Estimate	Std. Error	t value	p-value
Intercept	-0.05795	0.94769	-0.061	0.951917
Digital Tech Adoption	2.78262	0.58995	4.717	0.000172

Residual standard error:	0.9896 on 18 degrees of freedom		
Multiple R-squared:	0.5528	Adjusted R-squared:	0.5279
F-statistic:	22.25 on 1 and 18 DF	p-value:	0.000172

+2.78 gives us the strength and the direction of this relationship, i.e., a positive slope tells us that there is a positive linear relationship between Digital Tech Adoption and AV Acceptance in consumers. Every unit increase in Digital Tech adoption represents a +2.78 increase in Autonomous Vehicle Acceptance in consumers. Since $0.000172 < 0.05$ critical alpha, this linear relationship and its slope are statistically significant.

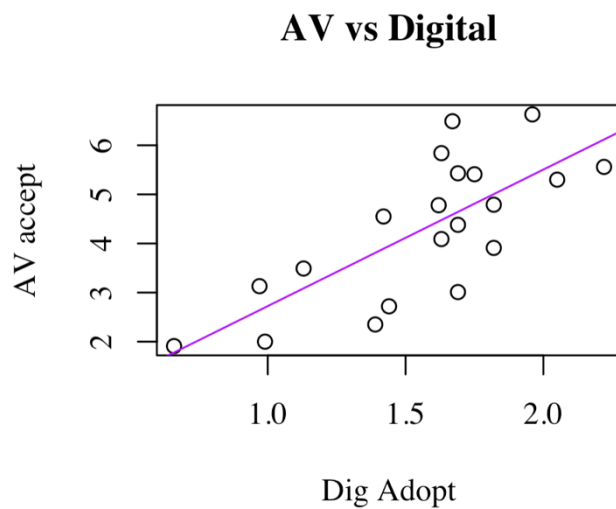
To check if the data in our AV Digital Model 1 is normally distributed, I ran a Shapiro-Wilk normality test. Below are the results:

W = 0.96064	p-value = 0.5566
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Since p-value $0.56 > 0.05$ critical alpha, I can reject the null hypothesis that the data is not normally distributed. i.e., the data is normally distributed in our model. To be safe, I also ran a test for homoscedasticity using a Breusch-Pagan test.

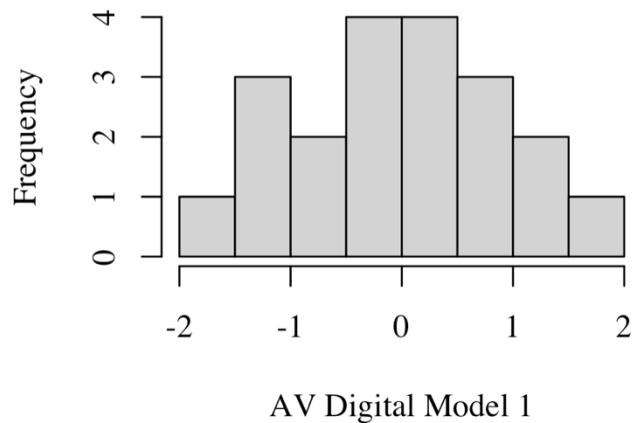
BP = 0.43762	df = 1	p-value = 0.5083
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Since p-value $0.5083 > 0.05$, I know that our AV Digital Model 1 has homoscedasticity. i.e., the random disturbance in the relationship between Digital Adoption and AV acceptance is the same across all values of Digital Adoption.



- The data looks uniformly distributed around the slope.
- It shows the increase in AV acceptance as we move from Digital adoption 1.0 to 2.0.

AV Digital Model 1 Residuals



A Shapiro-Wilkins test on the residuals tells us that the p-value is $= 0.9475 > 0.05$ critical alpha meaning, the variances in our model are also normally distributed.

AV Digital Model 2

Now let us see if this relationship sustains when we control for AV Technology

Implementation Readiness. As mentioned before, I want to control this variable to test our hypothesis that Digital Adoption does indeed share a positive linear relationship with Consumer AV Acceptance due to an openness to new and updating technology playing a pivotal role. I want to eliminate any function that a country's technology orientation, wealth, infrastructure, and civic readiness play in the linear relationship we just saw. I shall conduct a multiple regression and call this AV Digital Model 2. Let us check the model significance and strength first –

**Linear Regression between
(Digital Tech Adoption & Tech
Implementaton) vs Autonomous
Vehicle Acceptance**

**Preliminary Findings for
AV Digital Model 2**

Statistic	Value	Critical alpha	Result
P-value	0.00005	<0.05	Model Significance
Degrees of freedom	17		
Adjusted R-squared	0.6499		Model Strength

P-value < 0.05 explains that AV Digital Model 2 is statistically significant and its strength of 0.6499 tells us that the model can explain 64.99% of the variation in our data.

AV Digital Model 2

Residuals:

Min	1Q	Median	3Q	Max
-1.88607	-0.28365	-0.01839	0.49286	1.26865

Coefficients:

	Estimate	Std. Error	t value	p-value
Intercept	0.6976	0.8629	0.808	0.43
Digital Tech Adoption	0.8172	0.8885	0.92	0.3706
Tech Implementation Readiness	0.1631	0.0605	2.697	0.0153

Residual standard error:	0.9896 on 18 degrees of freedom	Adjusted R-squared:	0.5279
Multiple R-squared:	0.5528	p-value:	0.000172
F-statistic:	22.25 on 1 and 18 DF		

Looking at the p-values, we see that tech implementation has a statistically significant relationship ($0.015 < 0.05$ critical alpha) with Consumer AV acceptance which is not the case with Digital Tech Adoption ($0.37 > 0.05$ critical alpha). We see that the slope for Digital Tech Adoption has also dropped significantly compared to our simple linear regression in AV Digital Model 1. Our Tech Implementation slope tells us that every unit increase in the Tech Implementation Readiness index gives us a 0.16 increase in the consumer AV Acceptance

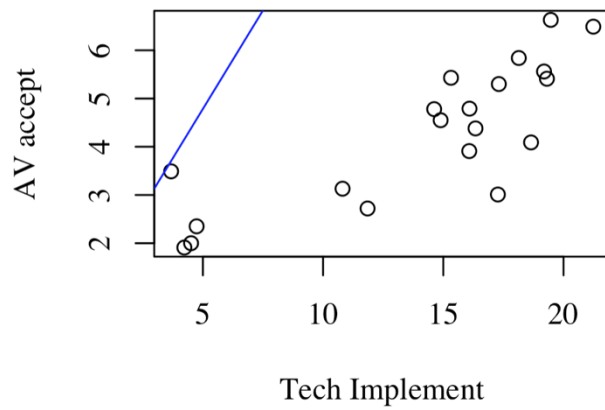
index value. Our statistically insignificant slope of Digital Adoption tells us that every unit change in the Digital Adoption index gives us a 0.82 increase in the value of the AV acceptance index.

BP = 0.45605	df = 2	p-value = 0.7961
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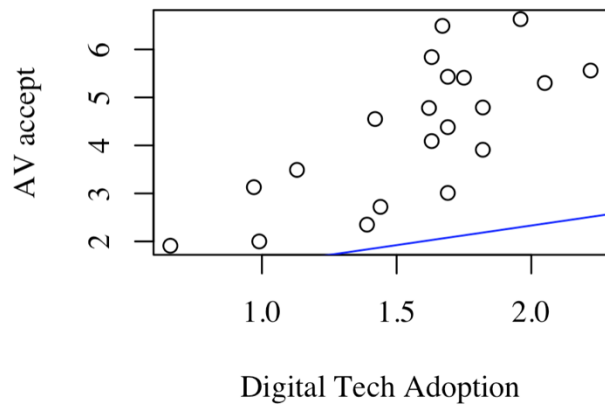
Since $p\text{-value } 0.796 > 0.05$, I know that our AV Digital Model 2 has homoscedasticity.

Nevertheless, we lose our linear relationship between Digital Adoption and AV acceptance. We have evidence from only one cross-sectional study that there is a linear relationship between Tech Implementation Readiness and Consumer AV acceptance (KPMG 2018). Our findings tell us that this is the case even when we control for the Tech Implementation readiness index for the same countries.

AV vs Digital



AV vs Digital



The VIF or Variance Inflation Factor is –

Digital Tech Adoption	Technology Implementation Readiness
3.058272	3.058272

Since $5 > 3.06 > 1$, the two independent variables are moderately correlated.

Conclusion

Evidence does not support our hypothesis that Digital Tech Adoption has a strong positive linear relationship with consumer AV acceptance. i.e. (though $\beta > 0$, the p-value > 0.05 and so H_0 cannot be rejected). Yet, our univariate analysis is indicative that a positive linear relationship might exist in our multivariate analysis if we provide a different intervention. At the same time, we must not forget that our multivariate analysis confirmed our suspicion that the simple positive linear relationship was dubious. There are numerous repercussions on the hypothesis. First, we must understand why openness to technology could not affect this linear relationship strong enough to sustain statistical significance once we controlled our Tech Implementation variable. Second, we can question whether the consumer AV acceptance score calculated from 4 equally weighted factors covers all dimensions of true consumer acceptance. Thinking about the other three weighted factors added on top of the consumer survey acceptance score: what if a better survey can capture tech change readiness, openness, and what the consumer ‘thinks’ of civil preparedness to deploy AVs? Can a different survey capture richer data relevant to “openness to AV tech” and include it in a singular consumer AV acceptance index instead of aggregating four weighted indexes (One that may not need to include change readiness and other indexes to generate a weighted index)? This paper would recommend extending the current study through a survey design that explicitly searches for this “openness to AV tech” within digital adopters.

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