How China will shape the future of autonomous vehicles

QVARTZ

AUTHORS:

Nikolaj Christian Herskind
nikolaj.herskind@qvartz.com
+65 9338 8586

Chee-Kiang Lim
chee-kiang.lim@qvartz.com
+65 9834 5513

Sophia Holst
sophia.holst@qvartz.com
+47 915 88 594

CONTENTS

Executive summary

China is going to be a dominating force in the industry for autonomous vehicles (AVs) and Chinese AV companies will offer their services in Western markets as serious competitors to local firms. To some, this might be an obvious statement while to others, it is a bold prediction. AVs are a hot topic all around the world, but so far, most of the public attention has been on the efforts of American and European companies to develop AV technology. In the past 2-3 years, however, an entire ecosystem of Chinese companies has emerged, which is developing AV technology on the back of the Chinese government's plan to make China the world leader in artificial intelligence (AI) and autonomous vehicles by 2025.

We believe that China will become a leading force in AV technology for a number of reasons:

(i) Chinese AV companies are catching up to its Western peers technologically and will take a leading position as they have an exceptionally high innovation rate. For one, China has an existential problem of traffic gridlock and pollution in its large cities. Getting AVs on the roads as soon as possible will be a crucial part of the solution. Furthermore, Chinese companies have much larger quantities of available data to train self-driving software compared to the West and there is a relentless competition between Chinese AV players, which is pushing them to innovate at an incredible speed. Finally, Chinese tech firms are already world leaders in building online ecosystems and mobility services. This will be the main value-generating segment of the industry, shifting the power balance to these firms.

(ii) Second, the Chinese government has made no secret of its desire for China to become the world leader in electric and autonomous vehicles as part of the "Made in China 2025" masterplan. This national policy is backed up by a strategy to invest hundreds of billions of dollars in "smart cars" and train thousands of AI experts in the coming years. The announcement also has the effect of rallying the whole ecosystem and galvanizing the automotive and technology industries to work together towards a common cause. Given China's proven historical record of achieving its ambitious goals, the pursuit becomes highly credible.

(iii) Third, China will be first to roll out the next generation of mobile infrastructure. Similar to AVs, China aims to be a leader in 5G technology by 2020. China is already rolling out its 5G network faster than Western countries, thus enabling the communication between vehicles and their surroundings, which is a crucial precursor for the commercial use of AV mobility concepts in the 2020s. As the three largest mobile operators in China are all state-owned, motivating and funding the rollout of 5G will not be a problem.

(iv) Fourth, Chinese consumers are more willing adopters of new technologies than people in the West. Recent surveys show that three quarters of Chinese consumers would be willing to ride in an autonomous car today while only about half or less of respondents in Western countries give the same answer. Consumer sentiment in China is likely to accelerate the dawn of the epoch of commercial AV services, whereas in Europe and the U.S., lacking willingness to adopt AVs might delay their market entry due to e.g. safety concerns.

In ascending the world stage in autonomous vehicles, Chinese AV firms will not confine themselves to their domestic boundaries. We expect Chinese companies to target Western markets with mobility solutions such as ride-hailing services in urban areas as soon as they have proven the concepts in China, for a number of reasons. First, Chinese companies will want to enter new markets in their search for additional growth. Autonomous mobility will likely expand city by city. After they have grown to their limits within China's top tier cities, local AV players may likely turn to foreign cities for growth before looking at lower tier cities in China. Second, fierce competition among Chinese AV companies will quickly drive down prices and margins, which will lead some firms to search for growth elsewhere. Third, given the speed with which the Chinese AV industry is developing, there will be an opportunity for Chinese companies to move into white spots in Western markets where domestic companies are less mature. Fourth, the Chinese government's quest for world leadership as expressed by the Made in China 2025 plan puts external pressure on companies to move into foreign markets.

This push by the Chinese AV industry has wide-reaching implications for European and American governments and

companies and represents a significant risk of them being outcompeted in their home markets. In any case, Western regulators and businesses will not be passive bystanders to this development and they will make use of a range of options to protect their home markets and to take advantage of the opportunities the Chinese market presents to them.

Western governments are already setting up barriers to entry by developing regulations that curb foreign takeovers in certain sensitive industries, in an effort to protect themselves from foreign appropriation of intellectual property and technology. An example is the German government's consideration to ban Huawei from rolling out 5G in Germany. Furthermore, strict rules on public and passenger safety will likely require Chinese mobility providers to adapt their products to Western markets (though most regulation concerning AVs is yet to be defined). This will require additional time and effort but probably not be a showstopper as it would be worthwhile for Chinese firms to make this investment to upgrade their offering.

In addition to setting up regulatory barriers to entry with their governments, Western AV companies are also trying to protect their home markets in the business arena. Similar to what Chinese AV companies do, Western businesses could enter into alliances with each other to develop AV solutions, which many of the leading AV companies are already doing.

Smaller companies in the software, hardware and automotive supplier industries should try to do the same and join existing alliances or establish specialized partnerships of their own. Alternatively, if there are no obvious Western companies to partner with, these smaller companies should consider to work with Chinese firms to become suppliers or business partners that help them succeed in the West, in order to appropriate some part of the AV value chain and not be outcompeted. Furthermore, Western AV firms should work to swing public opinion in their favor, prove to the public that AVs are a safe mode of transport in general, and then focus on passenger and public safety as a central part of their value proposition.

Finally, the Chinese market presents exciting opportunities for Western AV companies. Western companies should place part of their R&D in China to work on solutions for Chinese mobility problems directly, rather than adapt solutions they have developed at home to a vastly different market. This approach should make economic sense, as China is already by far the largest market for the automotive industry, and will only become bigger. Furthermore, Western companies should collaborate with Chinese firms and cities to co-develop solutions. For the first time, Western firms want the knowledge that Chinese companies have, and not the other way around. Such East-West alliances could prove fruitful for all parties, as long as they remain protective of their intellectual property. Establishing tight bonds with Chinese companies and regulators as well as the development of AV solutions for the local market are crucial prerequisites for Western AV firms to succeed in China, or anywhere in the world for that matter, since China represents such a large part of the world's mobility markets. Or as Daimler-CEO Dieter Zetsche puts it: "When we want to go autonomous, we have to make sure it works in China."

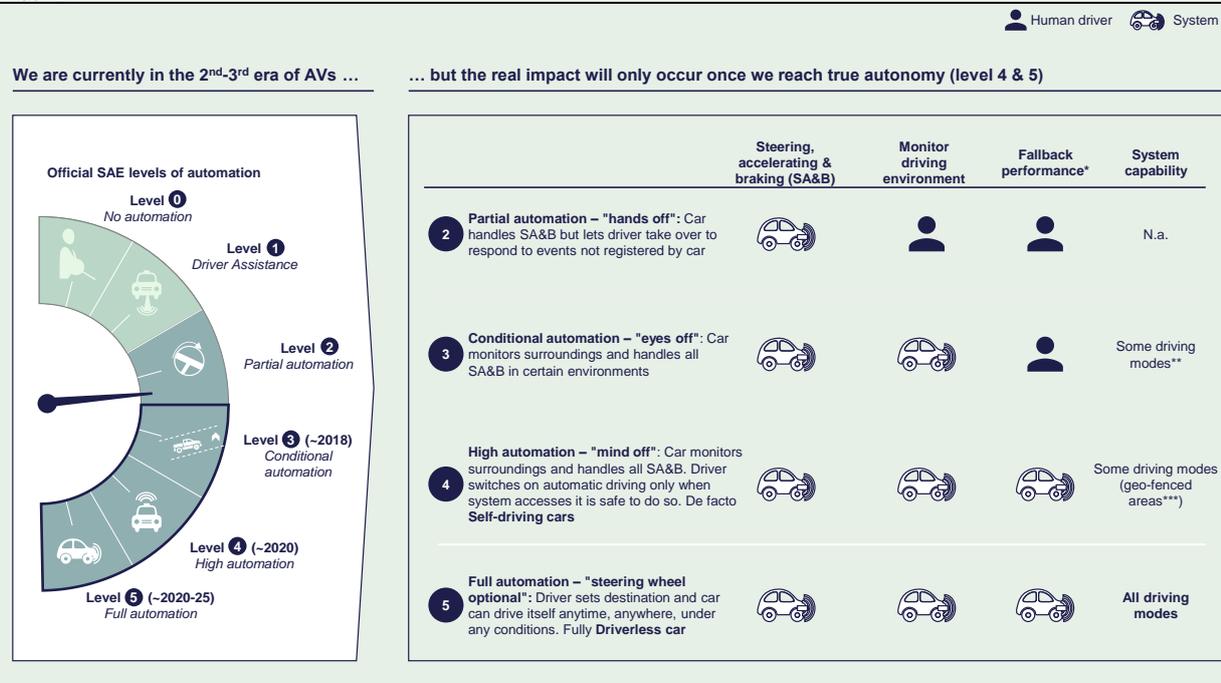# 1. A helicopter view of the current state of the AV industry

Truly autonomous vehicles do not yet exist. There are five levels of autonomy with level 5 being fully autonomous (i.e. driverless) driving in all situations, including all geographic locations, and under any conditions (see figure 1). The most modern cars today reach level 2-3, with the new Audi A8 and Tesla's models S, X and 3 being some of the first level 3 cars available in the market. Level 2 and 3 autonomy already have a significant impact on safety through advanced driver assistance systems (ADAS) such as adaptive cruise control and lane keeping/lane departure warning.

Most car manufacturers predict that they will deploy level 4 autonomy in personal vehicles around 2020-21. On the way to autonomous driving, different companies choose different paths. The traditional car manufacturers are developing autonomy incrementally to fit into their existing offering, while tech companies are planning to jump straight to level 4 autonomy. We will likely not see the first cars with level 5 autonomy on the streets before the mid-2020s. When level 5 autonomy does arrive, it will redefine how we use cars, by e.g. freeing up the driver for more productive tasks and reducing the need for parking spaces.

Currently, all companies developing AV technology, including traditional car manufacturers and technology companies, are still testing their vehicles and collecting data to ensure consistent vehicle performance in different situations and reduced software errors. Testing on public roads has been possible for some years in the U.S. and Europe and, since 2018, in China as well.

FIGURE 1

We are currently in the 2nd-3rd era of AVs …

… but the real impact will only occur once we reach true autonomy (level 4 & 5)

Official SAE levels of automation

Level 0 — No automation
Level 1 — Driver Assistance
Level 2 — Partial automation
Level 3 (~2018) — Conditional automation
Level 4 (~2020) — High automation
Level 5 (~2020-25) — Full automation

|		Steering, accelerating & braking (SA&B)	Monitor driving environment	Fallback performance*	System capability
2	**Partial automation – "hands off":** Car handles SA&B but lets driver take over to respond to events not registered by car				N.a.
3	**Conditional automation – "eyes off":** Car monitors surroundings and handles all SA&B in certain environments				Some driving modes**
4	**High automation – "mind off":** Car monitors surroundings and handles all SA&B. Driver switches on automatic driving only when system accesses it is safe to do so. De facto **Self-driving cars**				Some driving modes (geo-fenced areas***)
5	**Full automation – "steering wheel optional":** Driver sets destination and car can drive itself anytime, anywhere, under any conditions. Fully **Driverless car**				**All driving modes**

*: Responsible for interfering when unexpected situations arise   **: E.g. on freeways   ***: Potentially excluding severe weather
Note: Autonomy levels based on SAE International definitions
Source: SAE International; QVARTZ analysis

The first commercially viable level 4 and 5 AVs will most likely be introduced in big cities as ride-hailing, car sharing, on-demand buses and delivery services. To begin with, the technology will only work reliably in geo-fenced areas where high definition maps and high-speed V2X communication networks exist. Furthermore, the regulatory framework is still in its early stages and will need to evolve in tandem with the maturing technology and use cases. Fleet operators will be the first to get approval to operate AVs commercially as they will monitor their fleets continuously and will initially require human engineers to ride alongside the AVs to monitor the systems at all times for the passengers' safety.

In the first years after commercial introduction, the sticker price of AVs will be significantly higher than for conventional cars, but they will be cheaper to run. This is less of a problem for fleet operators whose highly-utilized AVs can generate revenue around the clock compared to private owners who typically use their car less than 5% of the day.

FIGURE 2

AV industry overview

Source: QVARTZ analysis
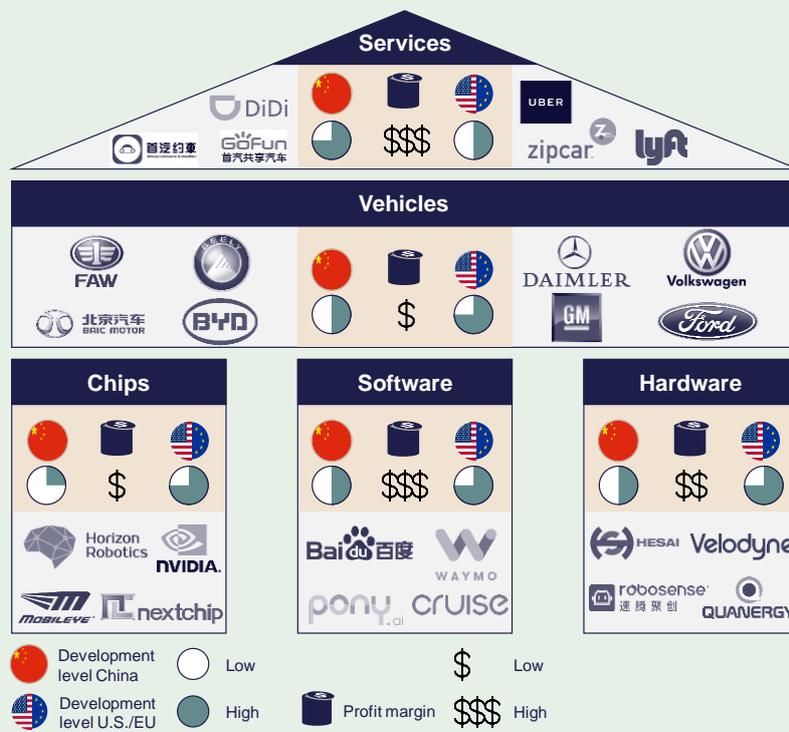
If we take a helicopter view of the AV industry of today, it essentially consists of several adjacent industries that together make up the full AV ecosystem. Each industry can be referred to as a layer in the AV "house". The largest and boldest companies and alliances, such as Waymo, GM-Cruise and Daimler-Bosch, are aiming to take ownership over the full house. However, most companies in the industry specialize in one specific layer.

Above, we have illustrated the AV industry as three pillars and two additional layers that together comprise the AV industry. The three pillars are the components that make up the self-driving technology in a car. These are installed in a vehicle that is then brought to market via a service or business model, which in the beginning of the AV age most often will be ride-hailing taxi and bus services.

Pillar 1 is the AI chip, which forms the AV's nerve center that controls all software and hardware. American firms dominate this part of the AV industry and Chinese AV firms are in many cases dependent on American chips. Chips are therefore the area of the AV industry where China has the largest gap to Western competitors. However, in order to reduce its dependence on American chips, the Chinese government has poured in huge amounts of resources to grow the domestic chip industry. Alibaba and Baidu have simultaneously joined the U.S. tech giants like Nvidia, Intel and Google to create chips purposely designed for AI.

Pillar 2 is the AI software. This area garners the most attention in the media as the software is what makes vehicles autonomous. Prominent companies such as Waymo, Cruise Automation and nuTonomy from the U.S. and Baidu, Pony, WeRide.ai and Momenta from China focus their efforts in this space.

Pillar 3 in the AV industry consists of the sensor hardware. Examples of this are the radar, lidar, cameras and other sensors that are installed in test cars to enable them to navigate their surroundings. Companies in this area of AV are important suppliers and partners to the industry leaders but do not take a leading role themselves.

The vehicle manufacturers build the cars in which the self-driving technology of pillars 1 to 3 is installed. Traditional car manufacturers entered the AV race shortly after the

tech companies did and have formed alliances with suppliers and tech startups in order to develop self-driving software and thereby secure their position in the market. Car companies that stick to pure manufacturing of vehicles risk becoming commodity suppliers to the upcoming AV leaders from the software part of the industry.

China is today still somewhat lagging behind the West in technology development of software, hardware and vehicles but is rapidly catching up. Baidu is, for instance, already producing level 4 autonomous buses in the hundreds and is planning to deploy them in cities like Beijing, Xiongan, Shenzhen and Tokyo. Another area to watch Chinese AV development is software development. Here, Chinese companies have an advantage over their Western counterparts as they have access to much larger quantities of data to improve the self-driving algorithms.

The final segment of the AV industry is mobility services. These services are the delivery system that companies will use to bring AVs on the road as a commercial offering. The most established digital business model in the automotive industry today is ride-hailing, exemplified by Uber and Didi Chuxing who compete with traditional taxi companies and plan to introduce AVs on a large scale. AV-enabled services will take many forms and shapes that do not yet exist. Thus, this part of the AV industry offers a large potential for innovation from start-ups in the future in areas such as social networking, media and marketing. Other than Waymo's AV taxi service launched in Arizona in December 2018, we assess players from China to be leading the innovation race towards AV-enabled mobility services as the leading Chinese AV companies have vast experience in building ecosystems around their applications and business models such as WeChat, a Chinese online messaging service.

The future winners in the AV industry must control the critical and most value-adding areas of the value chain, the software and services and to a smaller degree car manufacturing. However, no individual company excels in all these areas. This makes it necessary for players to enter into alliances to become full service providers and extract maximum value from the technology.

This is why Baidu is currently developing its own software while using Velodyne's lidar and partnering with Nvidia to

develop AI chips. Baidu is furthermore collaborating with BAIC to develop the actual vehicles and with state-backed ride-hailing service Shouqi for its ride-hailing service. Similarly, GM acquired Cruise Automation to own the AV software and purchased a minority stake in Lyft to use its mobility service, while GM itself has its core competence in car manufacturing. The "alliance leaders" such as Baidu and GM face a large potential upside and perhaps even a winner-takes-all market if they can dominate certain geographical or industry areas, or be first to market with a commercially viable solution. However, they also face a large potential downside if they are late to market. The first movers will be able to offer significantly reduced prices for ride-hailing due to the removal of the driver, leaving competitors with the option to adapt prices at a loss or allow the first mover to appropriate a large share of the market. The alliance leaders therefore need deep pockets and must be able to afford to lose large sums of money in order to make the necessary investments.

Most companies in the AV industry focus on their core competences and enter into alliances as top tier suppliers rather than the leading entity. These companies will have a viable business model no matter who "wins" the AV race, but they also face a limited upside as the competition to be part of the strongest alliances is fierce and suppliers usually get squeezed on margins as their technology matures.

2. China's path to world leadership in the AV industry – drivers and rationales

In short: Yes, we believe that China will eventually lead the AV industry. Chinese companies will take the leading position especially within software and services and we believe that Chinese companies will catch up to Western firms within chips and hardware as well. There are several underlying drivers to our optimism, which we will dissect in the following paragraphs along with supporting arguments.

Innovation rate: China is developing AV technology extremely fast to help solve its congestion and pollution problems. Large amounts of available data for algorithm training, intense competition and vast experience in building online ecosystems and mobility services are further driving the innovation rate.

Government support: China's government aspires to become the world leader in AI and AVs. The government supports this aspiration with enormous sums of investment capital earmarked to AV technology development and the education of AI and AV specialists. Furthermore, China's less stringent regulation on personal data enables firms to more easily collect the required data to train their machine learning models.

Infrastructure: China will be ahead of most Western countries when rolling out comprehensive improved road and data infrastructure.
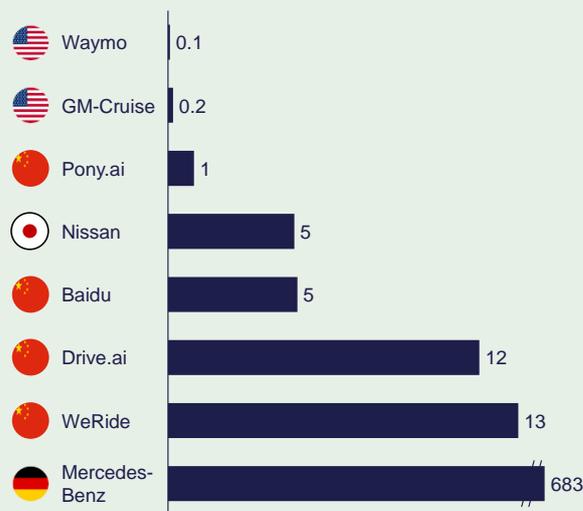
Consumer adoption: Finally, Chinese consumers are much more willing to adopt AVs than people in the U.S. and Europe, which makes the first commercial rollout of e.g. AV ride-hailing services more likely to take place in China.

China has an exceptionally high innovation rate

China is a currently a few years behind the U.S. and Europe on AV technology (chips, software and hardware) as the Chinese AV industry had a later start. Chinese companies have only tested AVs for a relatively short time and their cars are not yet performing as reliably as those of their American competitors in particular. Drivers of Chinese firms' AV test vehicles in California had to intervene more
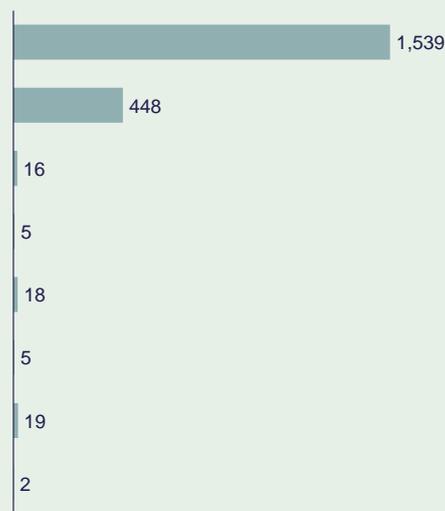
FIGURE 3

Number of disengagements of self-driving mode per 1,000 miles, 2018

🇺🇸	Waymo	0.1
🇺🇸	GM-Cruise	0.2
🇨🇳	Pony.ai	1
🇯🇵	Nissan	5
🇨🇳	Baidu	5
🇨🇳	Drive.ai	12
🇨🇳	WeRide	13
🇩🇪	Mercedes-Benz	683

Distance driven on public roads in California
Thousands of miles in autonomous mode, 2018

	1,539
	448
	16
	5
	18
	5
	19
	2

Source: California DMV; QVARTZ analysis

often than Waymo and GM-Cruise's test vehicles in 2018, while also driving significantly fewer total miles (see figure 3). Driver interference statistics are one of the few quantitative measures of AV technology development available today, but they are still very crude and should be interpreted with care.

If we look some years into the future, however, the picture will be different. Compared to 2017, when Baidu was the only Chinese representative to drive significant miles in autonomous mode in California, four Chinese AV companies did so in 2018. In fact, their vehicles performed as well or better than e.g. Nissan and Mercedes-Benz who already conducted tests in previous years. This indicates China's ability to catch up and take the lead in AV development within the next 3-5 years. Looking at figure 3, we expect Chinese AV firms to close the gap to their American competitors on disengagements and miles driven in the next years, especially when taking testing in China into account. Baidu has today already produced and dispatched several hundred autonomous buses in China.

AV technology development relies heavily on data to train the software, and China generates much more data than any other country ("There is no data like more data", Fred Jelinek). For instance, Uber processes around 15 million rides a day globally while Didi Chuxing services 25 million requests daily in China alone. Furthermore, driving conditions in China are arguably more challenging than in the U.S. and Europe, so Chinese AV test cars encounter more situations they can learn from than if tests only took place in the U.S. (and especially in places like Arizona with broad roads and relatively light traffic). On the other hand, Europe might even fall behind as the new GDPR rules take effect and further limit companies' ability to collect data.

Second, the congestion problems of Chinese cities are much larger than in almost any Western city (10 of the 25 most congested cities in the world are in China according to TomTom's congestion index). This causes both the government, cities and private companies to work intensely to find a solution. Exacerbating the problem is the fact that the car ownership rate in China is still ~5 times lower than in the U.S., but it is fast increasing so Chinese cities risk suffocating from their congestion if they do not find a solution soon. AVs can be a part of the solution as they can coordinate with other AVs around them and consequently, traffic will flow more smoothly. Furthermore, AVs will help reduce the total number of vehicles and free up parking space as one AV can be used by many more people than normal cars under personal ownership.

Third, intense competition among Chinese companies will help accelerate technological progress. In the U.S. and Europe, there are already clear market leaders whereas in China, the competitive picture is more balanced with Baidu gaining a head start and other tech companies not being far behind. What is more, the "other companies" is a large group and several of them are founded by ex-Baidu key employees with extensive AV experience. The vast Chinese market and huge amount of available funding encourages

them to enter the market, thus driving up the number of companies competing for market dominance.

Fourth, China is already an innovation leader in online mobility services (the top layer of the AV industry). Mobility service companies control the customer interface and own customers' data on usage patterns of AV services. As AVs will be connected to the Internet at all times, this data will become highly valuable and with its ownership comes a shift in the power balance from traditional car manufacturers towards the tech companies. China is one of the most advanced markets in the world in developing new online business models and ecosystems, such as the application landscape around WeChat, and we assess China to be ahead of Europe and the U.S. in mobility services already. This gap will likely widen even more in the future and thus enable Chinese companies to assume a leadership position in the global AV industry.

Chinese government support for AVs is unrivalled in the world

As mentioned throughout this paper, China's goal is to become the world leader in AI and AVs as part of its Made in China 2025 plan. To achieve this goal, the Chinese government has set a target that 10% of all cars sold in China should be fully autonomous by 2030, equal to around 3-4 million cars. This has helped jumpstart the AV industry in China, from almost nothing 2-3 years ago to an exponential growth of companies developing AVs today.

This top-down approach is fundamentally different to how the West approaches such issues. Both the U.S. and Europe are taking a bottom-up approach for AVs, where for example the U.S. government invites tech company executives to a conference to hear their views on AI and AVs, and asks how the government can support them.

China's approach is ultimately a key reason why Chinese AV technology will catch up and advance on the West because it rallies the whole technology ecosystem to work towards a common goal. Furthermore, the government has a strong history of attaining its ambitious goals, e.g. by building the world's largest high-speed rail network in less than a decade. In the process, China has sometimes missed the deadlines it has set itself but ultimately always achieved its targets.

The Chinese government plans to help the industry achieve its goals in a number of ways. Financially, it is planning to invest USD 120 billion (~0.5% of GDP) in what it calls "smart cars" between 2018 and 2021, particularly through "Government Guidance Funds" that provide seed capital to funds investing in industries that are strategically important to the country. Compare this to the EUR 450 million (USD ~510 million, or 0.003% of GDP) that the EU is planning to spend on roads and telecoms infrastructure, and the scale of China's commitment to this cause becomes clear.

To accelerate the local AV development further, China plans to educate at least 500 teachers and 5,000 students in AI over the next 5 years. According to investment bank Goldman Sachs, in 2018, China accounted for over half of the new AI projects in the world but merely had 5% of the global AI talent pool, which means Chinese companies rely heavily on foreigners as well as returning Chinese AI experts that were trained abroad. The government's focus and investment in this sector means that the brightest Chinese graduates are now moving into AI and AV development, which will dramatically increase the size of the talent pool and the industry's output in the coming years.

In terms of regulations, the Chinese government laid out national AV road-testing guidelines in April 2018, giving cities and regions greater discretion to hand out road-testing licenses, which they have since done increasingly. In contrast, the U.S. Department of Transport has issued guidelines rather than regulations or laws for automated vehicles. In the meantime, American states and cities are taking the lead on drawing up legislation concerning testing and use of autonomous vehicles. This movement helps bring AVs to certain areas in the short term but leads to fragmented legislation that has to be rolled back when federal regulation eventually arrives. In the EU, road safety legislation still stipulates that the driver has to be in control of the vehicle at all times. Regulations regarding AVs are slowly being developed, but the EU is significantly behind China and the U.S. in this area.

An additional factor helping Chinese AV companies are China's lax rules for the protection of personal data. In China, data privacy is not a priority and focus is on technological progress. The product will be better with more data, so companies are not restricted in using all of the customer data and other data they can possibly mine. If problems should turn up along the way, the guiding principle is to try and fix them, but the government rarely uses policy to limit progress. This is a stark contrast to Europe, where the protection of individuals' data is more important than companies' interests, as seen with the recent GDPR legislation. Without going into the moral aspects of this issue, GDPR will lead to the accumulation of less data, which will slow technological advance on AVs relative to China.

China will be first to roll out a comprehensive data infrastructure

Road and data infrastructure are crucial (and often overlooked) enablers for the commercialization of AVs. Road infrastructure comprises special road markings and road signs along which AVs can orient themselves. Road markings need to be upgraded in order for AVs to be able to drive safely in and outside of cities, especially in the early phases of level 4 and 5 AV commercialization. Unclear lane markings in an area with construction work caused a Tesla driving in autopilot mode to frontally hit a concrete highway divider in March 2018, killing its driver. In China, several cities such as Jiading have already introduced new types of lane markings in test zones and are planning to expand the markings to the rest of the city in the coming years. In Europe and the U.S., companies and research institutions conduct tests to create "smart roads" with sensors in the roads and road signs that communicate with AVs to keep them on track. However, implementing a smart road infrastructure will likely be very costly and no city or state in Europe or the U.S. has so far begun this implementation.

Creating a data infrastructure that allows AVs to communicate with each other as well as with their surroundings is another challenge. The first major step towards achieving this V2V (vehicle-to-vehicle) and V2I (vehicle-to-infrastructure) communication is to establish a broad 5G (fifth-generation wireless) data network (and potentially even beyond 5G). 5G is expected to accelerate data transfer to speeds of up to 10 times higher than 4G, enabling fast and reliable data transfer among AVs and between AVs and operators, GPS, and so on.

Same as with AVs, China aims to be a leader in 5G technology by 2020, and we expect China to roll out its 5G network faster than Western countries, thus enabling AVs to be used commercially in the early 2020s. The Chinese government is requiring telecom operators to cover all regions

of China with 5G. As the three largest mobile operators in China (China Mobile, China Unicom and China Telecom) are all state-owned, motivating and funding the rollout of 5G will not be a problem. China Mobile has conducted full-scale trials in 2018 in Hangzhou, Shanghai, Guangzhou, Suzhou and Wuhan. The three mobile operators have furthermore tested 5G in more than 20 cities across China during 2018, and 5G is scheduled to be available in all of China in 2020. In the U.S., Verizon and AT&T launched initial 5G services in cities like Houston, Indianapolis, Los Angeles and Sacramento in 2018, and will expand their service to approximately 20 cities in 2019. Europe is lagging further behind China and the U.S., and expectations of a broad rollout of 5G technology stretch as far as 2025. The main reasons for this lag are regulatory inertia, insufficient investments due to poor coordination of countries' auction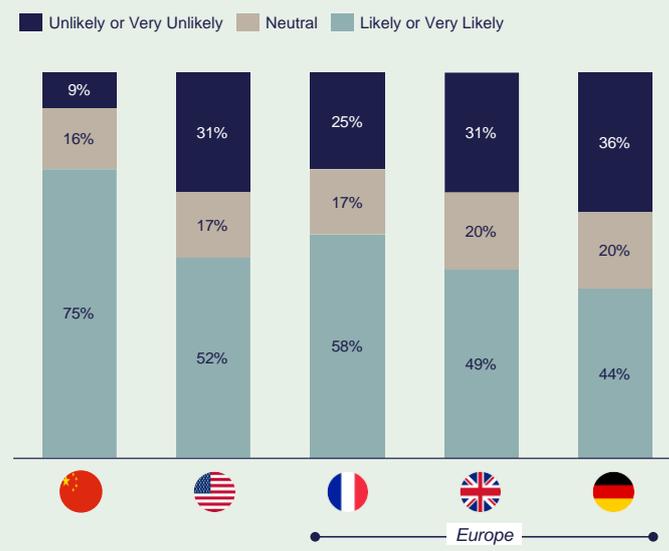s of radio spectrum as well as the comparatively smaller and more fragmented European markets, making for a weaker business case than in China and the U.S.

Chinese consumers are early adopters of new technologies

In the near term, the success of AVs depends on people's willingness to get into a car without a driver and let it take them to their (pre-programmed) destination. Consumer sentiment in China is likely to accelerate the launch of the epoch of commercial AV services, whereas in Europe and the U.S., lacking willingness to adopt AVs might delay their market entry due to e.g. safety concerns. In a recent survey, 75% of Chinese consumers said they were likely or very likely to try an AV, whereas only 44% of German consumers said the same (see figure 4).

FIGURE 4

Consumers' openness to try autonomous driving
Percent of respondents

Legend: Unlikely or Very Unlikely | Neutral | Likely or Very Likely

China: 9% / 16% / 75%
U.S.: 31% / 17% / 52%
France: 25% / 17% / 58%
UK: 31% / 20% / 49%
Germany: 36% / 20% / 44%

Europe

*: Survey of 1,500 U.S. drivers
Source: Jefferies; expert interviews; QVARTZ analysis

Chinese consumers are in general much more tech-savvy than Westerners are, and have made digital technology an integral part of their lives. While people in Europe and the U.S. slowly made the transition from an analogue to a digital world via desktop computers, the Chinese jumped straight to mobile devices and today use their phones much more frequently than consumers do in the Western world. China also leads technology adoption in areas such as mobile payments. For example, Chinese consumers pay approximately 15 times more often with their phones than Americans do, and order 3 times more meals online. This development has been made possible in large part by the deep integration of services such as WeChat (the Chinese version of Facebook's messenger) in people's everyday lives, allowing them to book cinema tickets, rides on Didi Chuxing and so on from one app. Consequently, consumer adoption will not be a barrier to the spread of AVs in China, whereas consumers in the U.S. and Europe might take more convincing, slowing down the AV commercialization process.

3. Implications for European and American businesses

We have thus far argued why we believe that Chinese AV firms will catch up with their Western competitors and eventually take a leading position in the AV industry within critical sectors such as software and services. As long as Chinese companies stay in their local market, their strength will have little effect on Western AV companies and markets. However, we believe that Chinese AV firms will attempt to enter European and American markets. This poses a competitive threat to Western firms in their home markets but can also present an opportunity to move into China if the firms know how to act in the Chinese AV market.

Chinese AV firms could choose to stay in their domestic market and turn huge profits without worrying about expanding abroad. After all, the Chinese car market is the single largest market in the world, and its 30% share of global car sales is expected to grow to almost 40% by 2025. However, we expect Chinese AV companies to move into foreign markets for several reasons.

For one, Chinese companies will need to enter new markets in their search for additional growth. The expansion of autonomous mobility will likely happen city by city. After setting up mobility services in Chinese tier one and two cities, the next cities with similar potential may well lie outside of China. Many successful Chinese startups experience exponential growth within China early on in their lives, which means their valuations become very high very quickly. However, after the initial growth spurt, the valuations often stagnate because there are no options for further expansion within China.

Second, competition among startups in China is often much more fierce than in the West. If one company is successful with a good idea, a myriad of similar businesses from all over the country will quickly sprout to compete for the same customers. Even though the Chinese market seems huge, expansion in many industries happens city by city, so all startups end up competing for the same tier one and tier two cities and thus quickly drive down prices and profitability. This has recently happened in the Chinese bike-sharing market, for example, where the main competitors Mobike and Ofo both went from close to zero to 40 million monthly users and correspondingly high valuations within a year, after which their numbers stagnated and even declined. Driven by the desire to command increasing

valuations, Chinese tech startups have to look outside China for additional growth opportunities. Especially companies planning IPOs in the future will need to find new geographies to grow.

Third, given the speed with which the Chinese AV industry is developing, there will be white spots in Western markets where domestic companies are less mature. Chinese companies that are able to leave their home market and comply with Western regulations will have a competitive advantage in these markets and will actively seize this opportunity. These white spots will likely be in markets without dominant local automotive and software industries, such as Eastern Europe.

Fourth, some companies will move into foreign markets due to external pressure, either to fulfill the Chinese government's quest for world leadership (especially state-owned enterprises). Since China released its Made in China 2025 plan in 2015, Chinese companies have already more than doubled their foreign direct investment (FDI) in European firms, especially in high-tech manufacturing, communications technology and infrastructure industries.

Two significant factors further support the business case for Chinese AV and mobility services' foreign ventures. Salaries for taxi drivers are significantly higher in the West, which makes it more attractive for consumers to use AVs instead of taxis with human drivers, enlarging the potential market and profit margins. Furthermore, the Chinese are the single largest group of tourists from any country. Chinese mobility services would be able to enter into markets like London or Paris by only serving Chinese tourists, and then later expand their services to local customers. The Chinese payment service Alipay is an example of a company that has used such a strategy to enter the Western hemisphere in the U.S., Canada and Norway in 2017-2018.

Western AV companies will try to protect their home markets

However, European and American governments and companies are not watching the Chinese push for market domination passively. Regulators and the private sector have several options to protect their home markets (and are already doing so), and to take advantage of the opportunities the Chinese market presents to them.

The West will try to safeguard itself against foreign competition through regulations, which will pose a significant challenge to Chinese firms wanting to enter Western markets. The industries underpinning autonomous vehicles such as telecommunications infrastructure, AI software and automobiles are all strategic industries for Europe and the U.S. Western countries are already setting up barriers to entry by developing regulations that curb foreign takeovers in certain sensitive industries, in an effort to protect themselves from foreign appropriation of intellectual property and technology. The German government has for a while considered banning Huawei from providing 5G equipment in its cities due to security concerns. Chinese FDI in the U.S. between mid-2017 and mid-2018 decreased by 92% as a result of policy changes in China, stricter investment screening in the U.S. and the ongoing trade war between the two countries. The recent episode surrounding the American Justice Department's charges of Huawei, China's largest smartphone maker, regarding bank fraud, theft of trade secrets and circumvention of U.S. trade sanctions, further illustrates how concerned Western countries are with foreign interference in strategic industries. The case is driving the two countries away from each other politically and economically, and shows how protectionist actions hinder global collaboration and competition. Regulation regarding foreign ownership of Western businesses and technology is likely to delay the entry of Chinese AV companies to Western markets but may on the other hand also be a barrier to entry for Western firms into China.

Furthermore, in the same way that Western firms struggle to navigate the Chinese market and its idiosyncratic regulations, Chinese entrants to Europe and the U.S. will likely face a substantial set of distinctive Western rules and guidelines they need to comply with. Western governments will in some cases develop these rules together with local industry players who will lobby to make regulations that favor Western businesses. For example, Europe and the U.S. will probably install regulations regarding public safety that are stricter than China's, and European countries might furthermore develop rules trying to limit the job loss associated with AVs. This means that mobility service providers and AV developers will need to invest a lot of time, money and effort to shape and comply with these regulations. Chinese tech companies will be at a disadvantage as they lack experience in navigating this unknown environment, and might be kept out of the market while they work on complying with public safety standards. On the flipside, Chinese firms that do manage to comply with Western safety standards can credibly claim to offer a premium product domestically and will be able to charge a higher price to their customers, so it will make sense for them to make these investments.

In addition to setting up regulatory barriers to entry with their local governments, Western AV companies are also trying to protect their home markets in the business arena. Similar to what Chinese AV companies do, Western businesses should enter into alliances with each other. The aim of such alliances would be to develop full-scale, market-ready AV solutions at maximum speed, in order to take significant market share in Western countries before Chinese firms arrive there, and thus pre-empt their home markets from take-over over by foreign competitors. Many large companies are already doing so: Typically, the slower but affluent car manufacturers partner up with fast-moving technology firms in order to go live in their home markets before Chinese firms exploit the opportunity. Examples include General Motor's collaboration with its subsidiary Cruise Automation and BMW's joint venture with Daimler, Fiat Chrysler Automobiles and Intel-owned Mobileye. A similar logic may apply to smaller companies in the software, hardware and automotive supplier industries who should try to join existing alliances or establish specialized partnerships of their own. Alternatively, if there are no obvious Western companies to partner with, these companies should consider entering into discussions with Chinese firms to become suppliers or business partners that help them succeed in the West, in order to appropriate some part of the AV value chain and not be outcompeted. Companies that are not bound by an alliance have the luxury of playing on several potential winners and diversify their risk in this way.

Furthermore, Western AV players should work to swing public opinion in their favor. Since people in the West are currently less inclined to support autonomous vehicles, mainly due to safety concerns, American and European companies should prove to the public that AVs are a safe mode of transport for the public. In their own branding, Western car companies should build on their heritage, and put safety at the heart of their value proposition, which brands like Renault and Volvo have done for many years. This positioning would likely help to build consumer loyalty

to local car brands and in people's perception position them on a different safety level than Chinese AV firms, though Chinese players may of course achieve the same safety levels as their Western counterparts.

China offers opportunities for Western AV companies

Looking outside their home turf, the Chinese market presents an enormous potential for Western businesses as well. Being the largest automotive market in the world, it is crucial for all significant Western firms in the AV ecosystem to build a presence in China. In the past few years, China has relaxed its requirements for joint ventures somewhat as the government sees the need to bring in foreign knowledge to reach its Made in China 2025 targets. An example of looser JV regulation is in electric vehicle production where the Chinese government is rolling back on a long-standing requirement that manufacturing operations in China have to be at least 50% Chinese-owned. If, however, Western countries continue to tighten their restrictions on foreign ownership and America's trade war with China becomes more intense, we see a risk that China too will close itself off more towards foreign investments.

Currently, car manufacturers are spearheading the Western movement into the Chinese market but, assuming no change in current JV regulations, we would expect a second wave of software and hardware companies to enter China as potential suppliers to the local alliance leaders in the near future. Western firms have several options to establish a presence in China. One option is to set up R&D facilities in the country, which several of the biggest companies in the automotive industry have already done. For example, VW is researching e-mobility, connectivity and autonomous driving in China to develop solutions directly for the Chinese market.

Some Western companies have also entered into alliances with local OEMs, AV tech companies, research institutes and city governments in order to develop their AV solutions directly in China and get early access to the local market. These alliances are in some cases formed based on requirements by the Chinese state but nonetheless present a good opportunity for Western firms to exchange knowledge with their Chinese partners. For example, Audi, Daimler and BMW have recently gained licenses to conduct road tests in China and are working with Chinese data

and mapping providers instead of their usual Western service partners in order to get these licenses. Of course, the threat of losing intellectual property to Chinese competitors is still relevant in this situation, so it is important that Western companies are aware of the risks when entering the Chinese market in this way. However, tight bonds with Chinese companies and regulators as well as local development of AV solutions for the local market are a crucial prerequisite for Western AV firms to succeed in China, or anywhere in the world for that matter, since China represents such a large part of the world's mobility markets. Or as Daimler-CEO Dieter Zetsche puts it: "When we want to go autonomous, we have to make sure it works in China."

Conclusion

This paper argues that Chinese AV companies will become world leaders in self-driving cars within the next few years. These companies will mainly take leadership within AV software and mobility services, but they will soon get close to the technology level in the West in both AV chips and hardware, as a consequence of their innovation rate, government support, infrastructure and consumer adoption. In the race towards global AV leadership, Chinese companies will expand their operations to the Western hemisphere and become a strong competitor to European and American firms, especially in countries where there are no local firms to establish the infrastructure and mobility services for AVs.

The Chinese AV industry poses both a threat and an opportunity to Western AV companies and adjacent industries. European and American governments are responding by increasing the barriers to foreign investment in strategically critical industries. Western companies in the automotive supplier, AV software and hardware sectors should enter into similar alliances as those between the largest car manufacturers and their tier one suppliers. In some cases, Western firms that might risk being outcompeted by Chinese competitors should instead try to enter into alliances with Chinese companies to move into Western markets as partners rather than competitors.

On the other hand, Western companies have the opportunity to enter the Chinese market, which will probably be ready for commercial AVs before the West. The window of opportunity is getting smaller, however, as Chinese AV firms are closing the technological gap to their Western competitors. Western firms should seek alliances with Chinese AV companies to enter the Chinese market and, if possible, set up R&D and testing facilities in China to develop local solutions directly for the Chinese market. The largest car manufacturers are already doing this and all other companies that are interested in taking a share of the Chinese AV market should move now, or they will have missed their chance.