

Will Baidu's "All in AI" Strategy Bring It Back to the High-Speed Growth Train?

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We examine whether Baidu's "All in AI" strategy will return the company back to high growth. Baidu has suffered a slowdown in recent years, mainly due to the decline of search ads and revenue in a mobile era where Baidu is lagging its competitors, such as Alibaba, Tencent, or ByteDance. To make up, Baidu has been actively pursuing other revenue sources and decided on the "All in AI" strategy after some exploration. Baidu is aggressively investing in artificial intelligence (AI) technologies and striving to be a leader in AI. We examine five pillars under Baidu's AI endeavors: the AI-driven mobile ecosystem, AI cloud, intelligent and autonomous driving, digital voice assistants, and AI chips. Although many of the AI initiatives, such as autonomous driving, are still in early stages with insignificant contribution to revenue, they are expected to become the growth engines for the future. In conclusion, our analysis shows Baidu's AI efforts is promising yet the company will face many technological, financial, and political challenges in the next few years.

Keywords: Baidu, AI, artificial intelligence, AI chip, AI Cloud, robotaxi, autonomous vehicle

INTRODUCTION

Baidu had been one of the most successful Internet companies in China, also known as the Google of China, and the B in the so called BAT (which stood for Baidu, Alibaba, and Tencent—the most powerful Internet companies in China). However, in recent years, Baidu's market value has lagged significantly behind its peers, compared to Google in the US and Alibaba and Tencent in China in its market value. Table 1 compares Baidu's market value with its peers, both in China and US as of April 19, 2021, and Sept. 19, 2014. Compared to its peers whose market value has increased many times over, Baidu's market value has remained mostly stagnant.

**TABLE 1
BAIDU'S MARKET VALUE COMPARED TO ITS PEERS**

Company	Market value Sept. 19, 2014	Market value Apr. 19, 2021
Baidu	\$ 62 billion	\$ 73 billion
Google	\$ 595 billion	\$ 1548 billion
Amazon	\$ 153 billion	\$ 1700 billion
Alibaba	\$ 231 billion	\$ 637 billion
Tencent	\$ 150 billion	\$ 764 billion

Source: Bloomberg Database (Bloomberg L. P., 2021a).

Baidu's management thought Baidu was undervalued and was making steady share buybacks, with a 2020 buyback program totaling around US\$4.5 billion until 2022. However, when we examine Baidu's growth over the last ten years, Baidu's lagging market value is not a surprise. Table 2 shows Baidu's revenue growth rates for the last 10 years compared to its peers. From these, it was clear that Baidu's revenue growth rate had slowed significantly in recent years. In the last five years, from 2016 to 2020, Baidu's total revenues grew at a compound annual growth rate of 11% (Baidu, 2020e). This slowdown in growth has been the biggest reason behind Baidu's stagnant market value.

**TABLE 2
BAIDU'S REVENUE GROWTH RATE COMPARED TO ITS PEERS**

Revenue growth rate (YoY)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Baidu	83%	54%	43%	54%	35%	6%	20%	21%	5%	-0.3%
Google	29%	22%	21%	19%	14%	20%	23%	23%	18%	13%
Amazon	41%	27%	22%	20%	20%	27%	31%	31%	21%	38%
Alibaba	79%	68%	72%	52%	45%	33%	57%	58%	51%	35%
Tencent	45%	54%	38%	31%	30%	48%	57%	32%	21%	28%

Source: Bloomberg Database (Bloomberg L. P., 2021b).

Furthermore, Baidu's return on invested capital (ROIC) has also been on the decline over the last ten years. ROIC is a critical measure of the viability of a business and efficiency of capital deployed, and normally it needs to be higher than the weighted average cost of capital (WACC). Baidu's ROIC/WACC has stayed below 1 since 2016, which shows Baidu is earning a return on capital. This is lower than the cost of capital—not a good sign. In comparison, Google's ROIC was 1.75 while Facebook's was 2.32 at the moment, and both companies had this ratio above 1 for most years. However, a low ROIC vs WACC ratio might also be due to aggressive capital investment in new business areas, just like in the case of Amazon, which has had this ratio less than 1 for many years.

**TABLE 3
BAIDU'S RETURN ON INVESTMENT CAPITAL (ROIC) COMPARED TO ITS PEERS**

ROIC	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Baidu	47%	33%	19%	13%	7%	6%	8%	6%	1%	5%
Google	16%	16%	15%	13%	14%	14%	8%	14%	15%	15%
Amazon	7%	-0.1%	3%	-0.2%	3%	7%	6%	13%	10%	12%
Alibaba	n/a	n/a	23%	34%	11%	9%	9%	13%	13%	16%
Tencent	28%	25%	21%	24%	20%	17%	20%	16%	15%	18%

Source: Bloomberg Database (Bloomberg L. P., 2021b).

WHY HAS BAIDU LOST ITS SHINE?

Baidu's lackluster business performance in recent years shows that Baidu has slowed down considerably in its growth as opposed to the other Internet giants who have been able to keep growing at a fast pace. So, what has caused Baidu's slowdown in growth? To answer this question, it is important to study Baidu's business fundamentals—the story behind that was driving these numbers. This includes the industry, the company, the regulation, and the firm's management and strategy.

Baidu's business consisted mainly of two segments: Baidu Core for search and AI related products and iQIYI, the online video platform. Baidu generated almost all revenue from China. In fiscal year 2020, Baidu has a total revenue of US\$15.5 billion. Baidu Core contributed around 73% to total revenue, while iQIYI contributed around 27%. Within Baidu Core, online advertising makes up around 85% of the Baidu Core revenue while non-advertising businesses such as cloud, smart devices, and others makes up around 15%.

Baidu had been a laggard in catching up to new digital trends in the mobile era and only tried to focus on mobile much later than its rivals. Compared to Google, who was able to maintain a strong foothold in the mobile world through an 85% market share in smartphone OS (operating systems), 66% market share in browsers in addition to 92% market share in search, Baidu still relies on search for the majority of its revenue and has much less presence in other areas than Google. Baidu still has a dominant market share in Internet search, it handled 76% of search queries as of March 2021 (Statistica, 2021). However, there had been a big shift in how Internet users spent their time and thus how advertisers allocate their online ad budgets. With the rising dominance of mobile usage, search engines' online ad revenue share in China fell from 33% in 2014 to only 12% in 4Q 2019, losing share to ecommerce, social, and news platforms. In the first half of 2019, Alibaba accounted for 33% of the Internet advertising market, ByteDance 23% from its short video platform Douyin and newsfeed app Toutiao while Baidu and Tencent had 17% and 14% market share, respectively.

So, why have online search ads been on the decline, and who has eaten Baidu's cake? There has been a significant shift in user behavior with the increasing dominance of mobile Internet. With people spending more time on their mobile devices, the use of the traditional search engine has been on the decline. Users are more likely to use the built-in search functions within apps such as Alibaba or just consume news feeds or other content recommended by apps such as Toutiao and Douyin, plus the user experience with apps is usually better than searching via a browser on the mobile device.

Baidu had long been criticized on ethical grounds and was regarded as putting commercial interests ahead of consumer welfare, a contrast to Google's ethos of Don't Be Evil (Huang, 2016). The most prominent incident came in a huge scandal in 2016, during which a young man Wei Zexi died after being misled by Baidu's highly ranked search results to advertisements of false cancer therapy from shady for-profit hospitals (Huang, 2016). After that, the government tightened regulation, including distinguishing advertising from search results, and imposed limits on the healthcare ads, which had caused Baidu to lose its most lucrative revenue source.

BAIDU'S EFFORTS TO REINVENT ITSELF

Baidu realized it needed to reinvent itself to avoid reliance on the maturing search market and gain more growth. In 2014-2015, it invested in a number of O2O (online to offline) services such as ride hailing, food delivery, group buying, and so on. However, since 2017, it has divested most of its O2O ventures due to the fierce competition and Baidu's lack of competitive advantage in these markets. In the meantime, Baidu has come up with various initiatives, including rolling out its news feed function, launching Baijiahao—its own content platform, and acquiring YY Live for live streaming in November 2020. Among these initiatives, YY Live was expected to contribute around 10% to Baidu's revenue and profit in 2021.

The Baijiahao initiative was a major effort to make up the huge loss of revenue from healthcare ads after the 2016 WeiZeXi scandal. However, it was skewing search results towards its own content platform, thereby affecting the search quality. In fact, a casual search on the Internet revealed many criticisms on Baidu, revealing the fact that Baidu had not fundamentally changed its ethical compass. However, Baidu

still was still holding a dominant market share, not because of its search quality but due to the lack of strong competitors since Google had retreated long ago due to the censorship.

Since 2012, Baidu has obtained a controlling interest in iQIYI. Similar to Netflix, iQIYI provides a broad spectrum of professionally produced and other mostly entertainment-oriented videos. iQIYI makes up around 27% of Baidu's total revenue, yet it has a negative 27% drag on Baidu's net income in 2020. Due to the need for aggressive investments in a highly competitive market, iQIYI is still incurring heavy losses. iQIYI's competitors include heavyweights such as Tencent Video, Youku, and many others. In order to differentiate itself with premium content, content cost has been high, and in 2020, it accounts for about 75% of iQIYI's cost of revenue. iQIYI generates revenue mainly through membership, online advertising, and others. Although there has been a steady increase of iQIYI revenue, it is still uncertain when it can turn a profit due to the high cost and fierce competition.

Baidu expanded into live streaming by completing its acquisition of YY Live—a domestic video-based entertainment live streaming business in early 2021. Live streaming became an extremely popular phenomenon recently in China's ecommerce scene, currently makes up about 5% of China's ecommerce market, and is growing rapidly. This deal is expected to allow Baidu to gain more revenue sources beyond advertising, such as ecommerce and subscription. However, there is no assurance that live streaming will be here to stay, or Baidu can gain a substantive advantage in this sizzling hot market where all the Internet giants are competing.

BAIDU'S "ALL IN AI STRATEGY" AND ITS AI ENDEAVORS

In recent years, Baidu has put a greater focus on AI and launched an "All in AI" strategy (Cheng, 2021). In fact, Baidu has changed its position from "a leading search engine, knowledge and information centered Internet platform and AI company" to "a leading AI company with strong Internet foundation" (Baidu, 2020c; Baidu, 2021b). Without a doubt, Baidu is a leading AI company in China and has been investing heavily in AI for over a decade. Of the major Internet companies, Baidu is considered the strongest in technology, and it holds the largest portfolio of AI patents and AI patent applications in China as of October 30, 2020. It is also one of the few companies that offers a full AI stack, including core AI capabilities such as deep learning framework, natural language processing, computer vision, and an open AI platform (Baidu, 2021). Baidu's major AI initiatives include its intelligent driving system Apollo, Xiaodu smart devices powered by DuerOS smart assistant, Baidu Cloud, and AI chip development.

AI-Driven Baidu App & Mobile Ecosystem

Baidu has been greatly shocked by the rise of ByteDance, which made Baidu realize the declining role of search in the mobile dominated era. ByteDance's AI-driven apps, such as its news app Toutiao and short video app Douyin directly push content to consumers without the need to search. Within a short number of years, these apps have become extremely popular and made ByteDance rise from nowhere to become a top Internet company in China and the world. ByteDance now commands a higher share in Internet advertising than Baidu and has become the biggest competitor and threat to Baidu.

To play catch up in the mobile space, Baidu has since then released its own revamped Baidu App, which combines search and feed, and recommends feed content based on AI. The look and functions of Baidu App closely follows ByteDance's Toutiao app. Baidu App has accumulated a monthly active user (MAU) base of 544 million users as of December 2020. In addition to Baidu App, Baidu has built a mobile ecosystem which includes over a dozen apps, such as Haokan and Baidu Post, which revolve around providing a platform for people to discover and consume information through search and feed. These apps use an open-platform model, aggregating content and services from third-party apps and websites and leveraging Baidu's network partners of Baijiahao accounts, etc. The revenue generated from these apps is mainly through the online marketing services, leveraging Baidu's AI technology to match customers with advertisers.

However, Baidu is facing heavy headwinds and fierce competition in the fight for online advertising dollars. Since 2018, Baidu's revenue from online marketing services has been showing a decreasing trend.

From news and content apps, such as ByteDance's TouTiao and Tencent News, to social media apps, such as Tencent's WeChat, to eCommerce apps with built-in search from Alibaba, or the increasingly popular short video apps, more and more apps are grabbing users' attention, and many of these apps are much more enticing and stickier than Baidu as users get addicted and tend to spend a lot more time.

Baidu AI Cloud

As the name suggests, Baidu AI Cloud concentrates on providing advanced and stable cloud computing services including big data, computing and storage, network and content delivery network, database, and security. Currently, Baidu boasts to have the most AI patent applications in China, over 5,700 of them, and second most globally (Baidu Cloud, n.d.). In July 2020, Baidu topped China's AI public cloud services, surpassing Alibaba Cloud, Tencent, Amazon Web Services, and Microsoft Azure (Vena, 2020). This capability enables developers to build customized AI solutions by leveraging Baidu's full suite of cloud-based and modularized solutions that span across its algorithms, pre-training modules, and data sets in areas such as speech recognition, computer vision, natural language processing (NLP), optical character recognition (OCR), and analysis of video data and structured data.

Perhaps more importantly, Baidu is integrating the various components of AI. For example, Baidu won a RMB460 million or 70 million USD project to help the city of Guangzhou, China to improve its traffic safety and efficiency by adopting the Vehicle-to-Everything (V2X), which is a part of the Apollo system (Baidu, 2020e, p. 72). This project applies the Apollo ACE transportation engine, which in essence is a transportation cloud solution that processes traffic information in real time in the cloud from Apollo MaaS and V2X. For vehicles with DuerOS and Baidu Maps, this level of automation and real-time communication provides traffic agencies with improved traffic management capabilities and transportation services, not to mention superior autonomous driving experiences for the vehicle riders. The Guangzhou project is an illustration of the power of this full-stack integration across Baidu's AI ecosystem (Baidu, 2020e, p. 72). According to Baidu's annual report, as of December 31, 2020, Baidu has won projects in over one dozen cities, including metropolises such as Beijing and Shanghai.

To date, the revenue generated from Baidu Core's cloud service is still relatively meager at RMB 9.2 billion or 1.4 billion USD) in 2020 or 8.6% of the company's revenue, but this represents a 44% increase from the previous year and with an accelerating growth in the fourth quarter which earned RMB3.3 billion (0.5 billion USD) alone (Baidu, 2020e, p. 73). In the competitive Chinese cloud computing market, Baidu was ranked as the fourth position behind Alibaba, Tencent, and Huawei, at the end of 2020. For the AI cloud services, the Chinese market was valued at 166 billion USD in 2019 with Baidu being the dominant player, and it is forecasted to grow annually by 94% between 2018 and 2024 (Baidu, 2020). According to the IDC report that was presented in this press release, in addition to leading in market share and innovations, Baidu Cloud offers the most robust AI products and capabilities such as natural language processing (NLP), voice recognition, facial and body recognition, conversational AI, and machine learning (Baidu, 2020, July 15).

The competitive advantage of Baidu AI Cloud is significant, and this includes one of the most comprehensive suites of cloud services and solutions in the market with extensive integration across its AI landscape. Furthermore, Baidu has been investing steadily and heavily in this arena. Two plans illustrate their ambition: 1) train 5 million AI experts over the next five years, and 2) plan to deploy 5 million intelligent cloud servers by 2020 (Vena, 2020). Baidu's AI also benefits from being in one of the largest markets and populations in the world—China. This enables the company to learn quickly with a consumer base of 1.3 billion people. Perhaps just as important, the company seeks to partner with various verticals, such as a partnering with Intel in 2018 on AI collaboration (Business Wire, 2018) and collaborating with China Huaneng Group, one of five largest state-owned electricity generation enterprises in China, to create an intelligent energy future including information technology, digitalization, automation, big data analysis, and intelligent services (AIT NewsDesk, 2021).

Intelligent and Autonomous Driving Initiatives

According to the Society of Automotive Engineers (SAE), there are six levels of automations (Shuttleworth, 2019) as shown in Table 4.

TABLE 4
LEVELS OF AUTOMATION

Level	Name	Description
0	Manual	Human performs all driving tasks; there is no automation.
1	Driver Assistance	Assistance with singular task such as lane centering OR adaptive cruise control
2	Advanced Driver Assistance	Assistance with compound tasks such as lane centering AND adaptive cruise control
3	Conditional Automation	Environmental detection enables autonomous driving in limited settings; human still remains alert, and override is REQUIRED .
4	Advanced Automation	More advanced environmental scanning enables automation in all tasks when conditions are met. Human override is OPTIONAL . Robotaxi starts at this level.
5	Full Automation	Vehicle can automatically function in all controls. Human override is not required. Currently, Level 5 is in the early development cycle.

Source: Adapted from the Society of Automotive Engineers J3016 (Shuttleworth, 2019)

Baidu's Apollo is the leading autonomous driving platform in China and is supported by the Chinese government. Since 2013, Baidu has been developing its Apollo autonomous driving platform, and with a consortium of 40 firms, there has been much progress. As of December 31, 2020, Baidu autonomous driving has earned 4.3 million accumulated test miles and 199 autonomous driving licenses across China (Baidu, 2021). This compares favorably with the closest competitor in China with only 20 licenses, making Baidu Apollo a clear leader of autonomous vehicles in China.

Baidu's Apollo self-driving services (ASD) provide automakers with self-driving technology and is a well-recognized brand among automakers. Apollo self-driving services include Baidu high-definition maps, automated valet parking (AVP), and most recently Apollo autonomous navigation pilot (ANP). These services are now mostly at the L3 level or below and are expected to continuously upgrade to achieve the L4 level at some time in the future. Baidu expects ASD to be gradually accepted by automakers and has signed at least ten strategic arrangements with 10 leading automakers that agreed to use Apollo self-driving services to power their smart vehicles. Baidu is exploring revenue sharing or fee-based models with automakers in this area. However, right now ASD is still in the early stage of monetization with a small and insignificant contribution to revenue (Baidu, 2021).

In the longer term, Baidu management has seen robotaxi (L4 autonomous driving mode) as the most promising future revenue source with over 1 trillion RMB market size in 2030. There are now three Apollo robotaxi pilot programs underway in China, in Beijing, Cangzhou, and Changsha (Dai, 2020; Zhang, 2020; Pan, 2021). However, large-scale adoption of robotaxi may still take a long time given the significant challenges since L4 full autonomous driving requires a 99.99999% success rate, and right now there are insufficient real operation use cases to improve that success rate. In addition, it also needs to achieve a lower cost compared to vehicles driven by human beings to drive large-scale adoption.

Capitalizing on the recent boom in electric vehicles, in January 2021, Baidu and Geely announced an electric vehicle joint venture, with Baidu as the majority owner. This venture is expected to mass produce smart electric vehicles in three years (Baldwin, 2021). Baidu will focus on the software and technology side while Geely will be responsible for manufacturing. China's electric vehicle market is taking off rapidly and has become the world's largest market for EVs, aided by generous government subsidies and strong infrastructure support. Global and local electric vehicle makers such as Tesla, Nio, Li Auto, and Xpeng

Motors all compete fiercely in this hot market. Baidu is hoping to get in on some of the action with next generation intelligent electric vehicles.

In addition, Baidu has also been piloting with city governments to provide smart transportation solutions. These include smart traffic signals to optimize the time of traffic light dynamically based on traffic flows to reduce traffic congestion, which has been implemented in Baoding and has successfully reduced traffic waiting time by 20-30% in rush hours. In addition, Apollo V2X (vehicle to everything) is an intelligent vehicle infrastructure cooperation system, which can sense all the moving objects within the range of the crossroad, conduct precise analysis, and share the real-time traffic information to all vehicles around the crossroad to eliminate possibilities of traffic accidents (Baidu Apollo, n.d.). The future outlook of Baidu's smart transportation solution is worth watching, but it has to invest a lot in the first place, and a profitable business model is not clear at this early stage.

A significant advantage for Baidu Apollo may be in its open platform strategy. The development center for Apollo.auto has eight open and free lessons on its website to train software developers. In addition, there are over 100 global members in the Apollo partnership program. For example, there are 34 OEM partners, including globally recognized companies such as BMW, Daimler, Ford, Honda, Toyota, and Volkswagen. Under hardware, there are 74 members with well-known companies such as Pioneer, Nvidia, and Texas Instruments. Major companies such as Microsoft and LG are software members. Part of this ecosystem is striving toward profitability.

Baidu is facing tough competition, both in electric vehicles and the autonomous driving platform market. Tesla is a strong competitor, both in the electric vehicle and also in the software. However, Tesla has only achieved Level 2 automation so far while Baidu is at Level 4. In autonomous driving, Baidu is ranked as second position in the world only behind Waymo in terms of test miles driven: Baidu has accumulated 4.3 million test miles while Waymo has over 20 million test miles driven. Of course, the great speculation in this arena is whether Apple is making an autonomous vehicle. As the most valuable company with over \$2 trillion on the stock market, its entry into this field would automatically generate attention and interest (Bomey, 2021). Despite the excitement all over the world with autonomous vehicles and electric vehicles, the most likely place Baidu will mainly compete is in the Chinese market. In China, there is already a lot of competition in electric vehicles, with domestic players such as Nio, Li Auto, and Xpeng Motor in addition to Tesla. In April 2021, the formidable telecom giant Huawei launched vehicles powered by its autonomous driving system. In its product launch, Huawei announced it will mass produce vehicles with its autonomous driving system by the end of 2021. Given its wolf culture and aggressive competitive spirit, Huawei's entry into autonomous vehicles no doubt constitutes a significant new threat to Baidu's Apollo platform.

Despite the excitement with Baidu's autonomous driving, it is still in the early stage of development and it is not clear when it would become a significant revenue source for Baidu. Baidu has been bleeding cash for the past few years as it attempted to monetize its self-driving technologies. While there has been promising progress, such as fee-for-service of its robotaxi, the revenue is pittance compared with costs. For Baidu, there are several formidable advantages. It has an early start in the most populous nation, China. This enables the company to attain 4.3 million miles of experience. With over 100 global members in its network of partners, Baidu is also building an entire ecosystem of integrated products and services that can present formidable competitive advantages. Its open-source approach provides a higher degree of assurance to parties who would otherwise think twice about partnering with a Chinese firm, which on the global stage has some reputational issues with governance and transparency. Perhaps most importantly, Baidu received T4 licenses, the highest level of autonomous driving test license issued by the working group led by Beijing Municipal Commission of Transport. Its fleet of 500 robotaxis have been operating in cities like Beijing, one of the most populated cities in the world. In an article written by Baidu and published in MIT Technology Review, Baidu explained at length how the company is using 5G and artificial intelligence to build trust and engender adoption of autonomous vehicles (Baidu, 2020d). In addition, Baidu is already working on the next generation, Level 5, with the release of its fifth-generation autonomous driving kit in September 2020 (Baidu, 2020b). Perhaps the most formidable near-term advantage is that Baidu mainly operates in China with a favorable economy for autonomous cars and backed by strong governmental

support. This enables Baidu to improve its system quickly by collecting vast amounts of data in record time, enhance its software and complementary technologies, and yet be shielded, at least somewhat, from heavy external scrutiny. The future of Baidu Apollo is likely to be bright, yet still needs much patience with many twists and turns along the way.

DuerOS - Digital Voice Assistant

Another major component of Baidu's AI strategy is DuerOS, the AI behind Baidu's many smart devices under the Xiaodu umbrella, such as the voice assistant Xiaodu smart speaker and Xiaodu smart display. DuerOS is a conversational AI platform that can embed intelligent natural language support in a wide range of Internet of Things (IoT) products such as smart thermostats, home appliances, mobile phones, wearable devices, and smart vehicles with full integration with the Apollo systems. Baidu has an advantage in this area due to its access to large volumes of language data from its search experience operating in a market with over 1.3 billion people in China. In addition, by partnering with more than 130 DuerOS partners, the voice assistance is embedded in more than 100 brands of appliances such as refrigerators, TVs, and speakers (Marr, 2020). DuerOS's key differentiation is its multi-round conversation AI capabilities that offers over 4,400 skills across wide-ranging genres such as education, video, gaming, and live streaming (Baidu, 2020e).

According to Statista, there were estimated 4.2 billion digital voice assistant devices in the world. This number is forecasted to jump to double by 2024, a number that is higher than the world's population. Baidu DuerOS is well positioned to play a leadership role in this arena. According to an analysis by Citic Private Equity, Baidu Capital (Baidu's investment arm), and IDG Capital, the Smart Living Group, a business division responsible for the development of DuerOS, is valued at \$2.9 billion (Kharpal, 2020).

When Baidu entered the smart speaker market in 2017, they were virtually nonexistent. By Q2 of 2018, Baidu reported less than 1% of the market; yet over the next twelve months, Baidu's market share rose sharply to become the second largest vendor of smart speakers in the world with a market share of 17.3%, surpassing Google in 2019, and only ranking behind Amazon with a 25.4% market share (Sentance, 2020). Xiaodu smart display was ranked number 1 in shipment globally for 2019 (Baidu, 2021, p. S-8). Baidu's strategy to gain market share is by lowering the price to successfully engage in a price war with its competitors. But in December 2019, when Baidu introduced the Xiaodu Zaijia X8 model, it launched the product at a full price (Sentance, 2020). Today, with a formidable install base of over 400 million devices with over 3.6 billion queries, DuerOS is on the march to potentially overtake Amazon with its formidable partnership and open platform.

For Baidu, their ambition is for "everyone on this planet" to use its conversational AI DuerOS. At the inception of this venture, Baidu acquired Kittai, the creator of bots used in chat apps like Facebook Messenger and Alexa in June 2017. It is working with leading companies like Huawei, Vivo, and Qualcomm to improve the capability, user friendliness, and integration of its system while reducing cost at the same time. However, DuerOS is available in Chinese, and it is not clear how much progress the system has made beyond Chinese. Its future as an independent product is questionable beyond China, but as a part of Baidu's AI ecosystem, especially with native integration in smart transportation system Apollo, one should not underestimate the potential of DuerOS.

AI Chip

As a core part of its AI strategy, Baidu also strived to make inroads on hardware with two sets of chips: Kunlun for high powered industry-grade performance and Honghu mainly for consumer devices such as smart speakers based on DuerOS. Baidu first announced the launch of Kunlun, China's first cloud-to-edge AI chip in 2018 designed to power search and AI cloud services including deep learning. The chip is designed to be both powerful and cost-efficient. Baidu partnered with Samsung, and by December 2019, they announced the completion of the Kunlun 1st generation chip and prepared for mass production. Within a year, Baidu has produced more than 20,000 Kunlun 1 pieces and deployed the AI chip across Baidu's search engine and Baidu intelligent cloud ecological partners (China Money AI, 2021). Kunlun 1 can realize the INT8 processing capacity of 256 TOPS (or trillions of operations per second); as a point of comparison,

the new Apple 12 contains Apple’s A14 bionic chip with brings 11 TOPS, and Nvidia’s V100S chip has a computer power of 130 TOPS (China Money AI, 2021; Horwitz, 2020). Accelerating the development, Kunlun 2, with three times the performance of the first-generation chip, will also soon start mass production in 2021. In March 2021, Kunlun completed a new round of funding, valuing this business at \$2 billion (Yang & Munroe, 2021).

The Honghu made its debut at the Baidu AI Developer Conference in July 2019 with a focus on low-energy consumption in consumer devices. For example, the Honghu chip’s standby power consumption is merely 100 milliwatts, making it an ideal chip for energy-saving appliances. In addition, the Honghu chips are built with vehicle regulations in their core design, making them attractive for smart cars. Not surprisingly, this chip is used in Apollo Smart Car Link. Currently, the most popular use is in the Baidu’s Xiaodu smart speakers, which in 2020 alone, there were 8.6 million units shipped (China Money AI, 2021).

Baidu plans to continue the expansion of its AI chip ecosystem. One notable initiative is Baidu’s PaddlePaddle, a deep learning platform with more than 2.65 million developers. This group has created more than 340,000 models to cover many verticals such as communication, electricity, urban management, agriculture, public welfare, and others. Collectively, these products and services have become the core of Baidu Brain, a new type of AI infrastructure that impacts all everyone in all walks of life.

Baidu is becoming a dominant player in China in the AI platform, but it will meet significant headwinds as it expands globally and confronts well-established players such as IBM, Microsoft, Google, and Amazon. To better commercialize its technology, Baidu is looking to spinoff the chip division as a standalone company, with Baidu as a majority owner (Lenexweb, 2021). Perhaps the newly raised funds would help the company with this goal.

CONCLUSIONS

Baidu has been incurring heavy capital expenditures due to its heavy investments in the AI related areas. Baidu’s R&D expenses have been steadily on the rise from 9% in 2011 to 18% in 2020. On the other hand, Baidu’s operating profit margin has been steadily decreasing from 52% in 2011 to 13% in 2020. Table 5 below shows the trend of Baidu’s profit margin and R&D expenditure as percentage of revenue for the last ten years. As pointed out by Baidu itself (Baidu, 2020e), the expansion into new areas including AI cloud, intelligent driving, voice assistant, and smart device may put downward pressure on Baidu’s operating margin since all of them have margins much lower than online marketing.

**TABLE 5
BAIDU’S PROFIT MARGINS AND R&D EXPENDITURES 2011-2020**

Baidu’s key ratios	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Operating margin	52%	50%	35%	23%	13%	14%	19%	15%	6%	13%
R&D expenses/Revenue	9%	9%	10%	14%	15%	14%	15%	15%	17%	18%

Source: Bloomberg Database (Bloomberg L. P., 2021b).

There are also political and regulatory issues. The Chinese government has raised some antitrust issues on big Internet companies and were seen to take an increasingly tougher stance against Alibaba, Tencent, etc. Since November 2020, it has suspended the much anticipated IPO of Ant Financial and then ordered an overhaul of the group due to the risk it is considered to pose to the financial system. In March 2021, China’s antitrust regulators fined some of China’s largest Internet companies, including Tencent and Baidu for failing to report acquisitions, huge market opportunities in the long term. In April 2021, the Chinese government fined the internet giant Alibaba a record \$2.8 billion for anticompetitive practices. In addition, the tension in US-China relationships had also raised some risks for Baidu, including the delisting risk of Baidu from the US, which prompted Baidu to seek an upcoming secondary listing in Hong Kong Stock Exchange of around US\$3.5 billion. In addition, Baidu could potentially face a sanction on chip purchases from the US if any connection is discovered between Baidu and the Chinese government or military.

After examining Baidu's endeavors in the AI areas, we come back to our question: Will AI put Baidu back on the high-speed growth train? In conclusion, we think Baidu has a lot of promising AI initiatives in the making with huge and exciting market opportunities for the long term. However, except the cloud services, whose revenues have been growing at a fast pace, Baidu's other AI related initiatives remain at early stage commercialization with insignificant contribution to revenue in the short term. This gives the concern that, although Baidu's future is likely to be bright, the next few years may still likely be challenging with many twists and turns before many of these AI growth engines take off.

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