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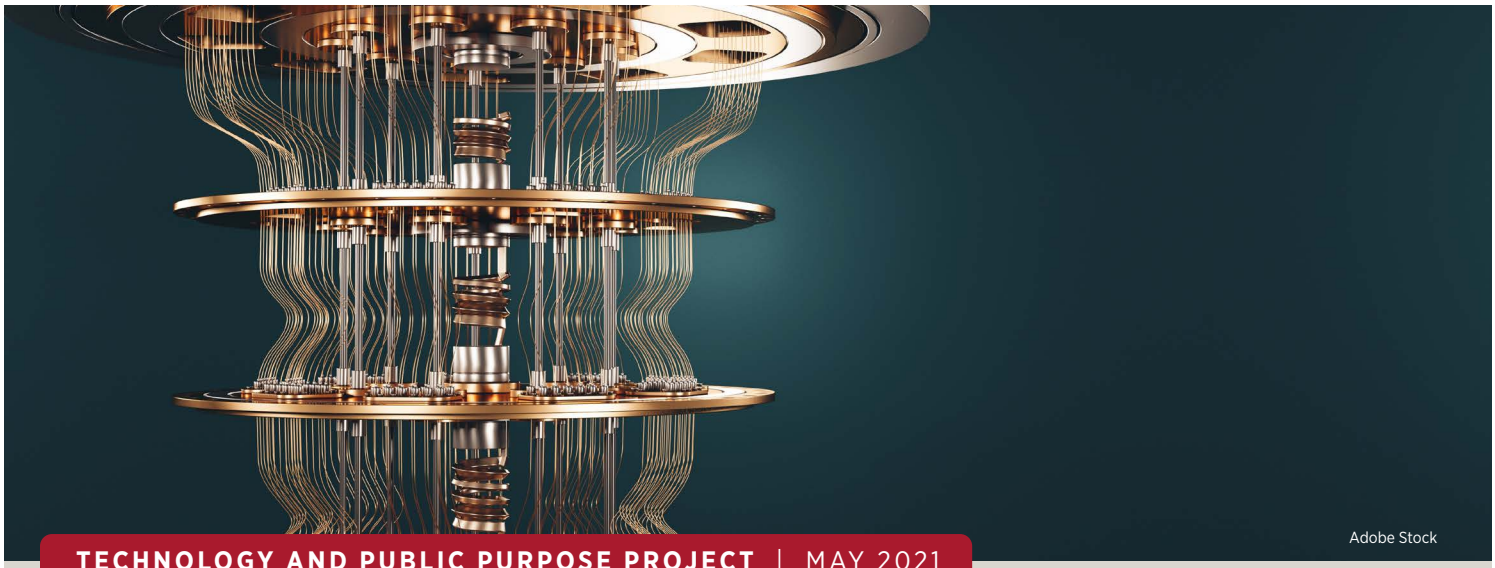

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Using Advance Market Commitments for Public Purpose Technology Development

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Introduction

Over the last year, there has been a renewed focus on improving American competitiveness in key fields of science and technology. Numerous bills and executive initiatives have been implemented or proposed to dramatically increase investment into science and technology. Recent examples, including the Endless Frontiers and the Clean Futures Act, use a wide variety of policy tools to advance research and development (R&D) along multiple axis. Here we consider the free market portion of these tools, in which the private sector plays a key role in determining topic and direction, while the public sector supports these activities through high-level directives, conditional

contracts, and other mechanisms. While other approaches such as public purpose consortia and R&D tax credits have been considered elsewhere, here we focus on Advance Market Commitments.

Advance Market Commitments (AMCs) are a powerful policy tool that can be used to ensure that America can retain leadership in technology fields such as climate change, computing, and medicine. In an AMC, a U.S. agency commits to buying some specified new technology before that technology exists. This provides a price, specification, and framework for evaluation that can streamline decision making and funding approaches in the private sector and accelerate progress towards well defined technical outcomes without being directed about the underlying solution and steps along the path. As such, AMCs represent a powerful option for ground-up technological building where private investment replaces the role of more traditional, blue sky government funding, and the larger market for the resulting product is jump-started by an initial government market.

We find that

- AMCs represent a powerful option for mid- to long-term technology acceleration, particularly for fields with an existing base of R&D that enables effective specification of desired products and roadmapping for 5-7 year outcomes.
- Nascent markets can be efficiently jump-started by AMCs by combining the fiscal benefits of a prize-like structure with a regular, repeat customer base represented by the agency or department issuing the AMC.
- As the private sector has substantial freedom in both financing and implementing AMCs, they represent a powerful means of leveraging the free market economy, while ensuring connection of the resulting outputs to a broader public purpose.
- Specific opportunities for AMCs today include climate change technology, computing and autonomous vehicles, which we detail through short case studies below.

AMCs for developing and scaling challenging technologies provide a viable path for America to expand its leadership in technology. AMCs leverage private industry, and significantly de-risks the execution of government technology agenda. Lastly, accomplishment of these technological challenges will inspire humanity for generations to come.

What is an Advance Market Commitment and why do they work ?

An Advance Market Commitment is a binding contract, typically offered by a government or other financial entity, used to guarantee a viable initial market for a product once it is successfully developed. Generally AMCs are used in circumstances where the cost of developing a new product is too high to be worthwhile for the private sector without a guarantee of a certain quantity of purchases in advance. The key to AMC's success is that private markets take on the R&D cost to develop a product, while the government provides an assurance of a sufficient initial market to enable a potential return on investment even before an organic market develops.

COMPARISON OF ADVANCE MARKET COMMITMENTS TO OTHER INCENTIVE MECHANISMS

- Grants - governments give research grants in the scenario that the technology is not commercializable by itself. If a grant is being given to an organization, there are usually stipulations on how the IP generated from the grant is used.
- Corporate Tax Credits - governments can give corporate tax credits to companies that perform basic research. In this scenario, the government has little or no say of how the research dollars are spent.
- Rebates - in the case that a new technology has not yet achieved scale of market adoption needed to be competitive with existing technology, rebates may be a good way to grow the market to the point that the scale is no longer an issue. The best example of this giving rebates for hybrid vehicles. This is better for relatively mature technologies
- Taxes and tariffs - governments may implement higher taxes in order to dissuade buyers from an inferior technology in favor of a new technology, to account for the societal harm that using a piece of technology, or to encourage specific approaches for building the technology that ensure domestic growth. A good example of this is carbon taxes.
- Government Backed Loans - this is where the government provides guaranteed loans to technology companies usually to scale manufacturing. This is very unpopular with voters because the government takes on all the risk.

A recent example of an Advance Market Commitment is NASA's COTS and Commercial Resupply Services program. In the early 2000s, the United States had lost the ability to build and launch cost effective rockets to space, and was forced to buy its rockets from an increasingly adversarial Russia. Not only was this a challenge for the NASA space program, but it became a national security threat because there were no more US built rockets needed for sending military satellites to space for the purposes of intelligence gathering. The final cost of the program was $5B over 10 years - or 0.0024% of GDP which is 1000x cheaper than the Apollo space program. Furthermore, it helped launch companies like SpaceX (worth $100B), and has likely added on the order of 0.5B in stock market capitalization in the form of smaller space companies.

Advance Market Commitments work when free markets fail to price in societal cost. One example are vaccines. Vaccines are only effective if they are distributed to a large percentage of the population at the same time regardless of purchasing power or income level. Therefore traditional consumer pull and pricing strategies do not work when it comes to vaccines. Or, in the case of rocket procurement, the cost of having the only economical supply of rocket parts coming from a potential US adversary was also not reflected in the market price of rockets.

AMCs work best when the government has a clear understanding of the technological milestones and challenges, as well as reasonable knowledge regarding potential market failures that have prevented the desired technology from emerging. One of the first AMCs for vaccines was five countries (Canada, Italy, Norway, Russia, the United Kingdom), and the Bill & Melinda Gates Foundation committed US$1.5 billion to launch the first Advance Market Commitment (AMC) to help speed the development and availability of a new vaccine. The Gates Foundation members credited the success of the program to "doing their homework", namely the staff at the foundation had intimate knowledge of where the costs in the supply chain lay.

AMCs are particularly good at helping to accelerate nascent markets, where the basic research has already been performed, technology milestones are well understood, and there are enough competitors so that there are multiple paths to success. The risk structure of an AMC is closer to that of a prize (made famous by the Ansari X-prize) competition, except that AMCs catalyze a longer-term commitment for purchase by the government, provide actual users of the product and thus help improve the technology, and jump start the market ecosystem around the technology. Furthermore, they do not have some of the political risk associated with loans, tax credits, and grants, all of which provide money to performers before results are available.

Economic advantages of AMCs

The most important economic advantage of AMCs is that it leverages the private market to take on the risk of developing new technologies, which not only allows tapping of private market capital but also allows a diversity in companies and the technologies dedicated to pursuit of the specific technological goal. In the case of the NASA COTS program, multiple companies had raised significant venture capital to pursue a space launch program, which eventually yielded several winners, including SpaceX. Or in the case of vaccines, multiple, different vaccines for COVID-19 were developed in parallel, reducing the risk of failure for society and providing resiliency to potential supply chain or side effect challenges.

In addition to this primary benefit, there are additional advantages. For example, as suggested in Taylor's prior work on tax credits, there are substantial changes in the cash and investment elements of technological focused companies in the private sector that make AMCs more useful than in past decades. Today's interest rates are so low that traditional economic metrics such as Profit / Earning ratios are no longer the driver of stock value. In some sectors, the key driver of valuation (stock price) is having a technology oriented narrative. No company has managed the narrative better Elon Musk. On Sept 22, 2020 during the annual meeting of stockholders he focused on his future plans to build the batteries of the future. As a reward for such boldness, Tesla's stock has gone up 8x in just one year with a market capitalization of nearing $1 trillion dollars. AMCs has the potential to launch multiple unicorn companies (companies valued over $1B USD), and increase the US stock market by trillions of dollars.

Finally, there are substantial benefits for AMCs in jump-starting a broader marketplace and doing so in a manner that reduces regulatory burden. For technologies that are 'born in captivity'—those which exist in an already regulated space such as drones and autonomous vehicles—technology development and deployment must happen in the context of the existing regulators. When U.S. agencies support technology outcomes with AMCs, they also can provide the necessary regulatory relief and oversight to enable early deployment and pilot programs, while ensuring a path to appropriate regulation. The world has witnessed the effectiveness of reducing regulatory burden through the development of vaccines for COVID. Innovation in America, especially in infrastructure, has been significantly hampered by bureaucracy in the name of public safety. For example, achieving fully autonomous driving can be massively accelerated if the US transportation department aggressively reduces the regulatory burden of experimentation of self-driving cars, which will in turn save lives in the long term. The combination of AMCs with effective government deregulation can create brand new markets that never existed in America before.

The societal advantages of AMCs

Having the public and their representatives back AMCs is critical for their success and implementation. The economic advantages of AMCs over others such as corporate tax credits or government backed loans make it easier to sell AMCs to the American public. But there are several other advantages that make them effective means of ensuring public purpose is integrated with the resulting technology.

One example of this type of societal advantage of AMCs is how they reduce the challenges associated with industrial policy, in which the government picks winners or losers. Any type of government-subsidized technology funding (including AMCs) faces the challenge of historical failings of governments subsidies to technology companies. The best example of such failure is Solyndra. In 2009, the USG lent $500M to Solyndra via a government backed loan, which Solyndra eventually defaulted on.

In many respects, the culprit of the Solydnra's failure was the flooding of the market by Chinese companies of cheap solar panels. The Chinese companies were able to operate at a significant loss because China offered more than $30B in government loans to Chinese backed solar companies, enabling Chinese manufacturers to operate at a loss until the market had scaled up enough so that they could operate at a profit.

Advance Market Commitments could have mitigated the failure of Solyndra in several ways. The US government would not have to provide a loan to individual companies. Solyndra would have to borrow money from the private markets to build out its factories. If Solyndra had failed to deliver products meeting the requirements set by the AMC, there would be other US companies that can leverage the AMC. This prevents the USG having to pick winners or losers.

Furthermore, AMCs are usually negotiated to provide a guaranteed market for a number of years for US technology providers. Instead of providing a loan, an AMC would have been able to protect the US solar industry (including Solyndra) from Chinese competitors at least for a period of time, which would have given Solyndra more runway to scale its operations and lower its prices. AMCs can further be negotiated to have a "Fair Profit Margin" component - namely putting a cap on the profitability of business that receive money from the government, hence reducing the optics of crony capitalism (see GAVI Vaccine AMC criticism)

Another societal advantage of America using AMC funded technologies is that they enable America to be the "first to accomplish a certain technology milestone". When JFK had proposed that

"America become the first to land on the moon before the end of the decade", the accomplishment that all Americans relate to for generations to come. In similar fashion, in the case of the NASA COTS program, the AMC cost requirement necessitated American companies to become the first at creating reusable launch vehicles. The technological marvel of seeing rockets return to earth is very popular with the American public.

Finally, AMCs provide key signalling and prioritization which make it easy for the public to understand their purpose and intent. This helps, for example, in the ability for politicians to point to recent successes - most notably Operation Warpspeed - US's COVID vaccine program. Operation Warpspeed is particularly successful with the US public because it combined several key ingredients:

- The government only paid pharma companies only if they had passed clinical trials. Therefore the USG was not picking winners or losers.
- The government actively participated in deregulating vaccine trials by enabling parallelization of trial activities, hence drastically accelerating the time to market for these products.
- There was an immediate effect on the American public - namely regaining lost freedom - hence creating a very positive association of AMCs with the day-to-day lives of all Americans

Case Study: Quantum Computing

Today, quantum systems are small, and their use has been limited to small ('toy') problems. However, already there are known and projected use cases for quantum computers that will likely upend established industries and security practices. It is also a technology that US has a technological lead. Thus there is a joint benefit between the government and industry in accelerating the early use of quantum computers—it provides a nascent market, which helps build a better business model for quantum computing and better quantum computing technologies—but it also provides potential long-term users the ability to explore and develop potential applications before such computing transforms their field, leading to a quantum-ready public sector. The challenge is that from a development standpoint, a conservative estimate for developing 1 type technology (e.g. ion traps or superconducting qubits) will likely require on the order of $2-5 billion dollars. Therefore, to maximize the chances of the United States becoming the first to build useful quantum computers, it will require an ecosystem of industrial players to simultaneously pursue multiple paths towards realizing useful quantum computers.

Multiple companies have demonstrated roadmaps indicating a 1000 logical qubit quantum computer is both useful and achievable in 10 years. With this maturity, multiple competitors and practitioners are able to help create appropriate use cases and specifications for an AMC. The computing companies, systems companies, supply-chain companies, and business-to-business or business-to-government companies all need to grow in concert with demand and capability improvements. AMCs provide a public sector-driven baseline market that catalyzes the underlying ecosystem. The resulting 'product'—the government-subsidized use of advanced quantum computing systems by researchers in academia and national labs to explore, understand, and enable the use of quantum computers in mission-relevant operations—provides secondary benefits to the U.S. government's ability to make best use of this revolutionary technology.

How can this be realized? We suggest that the AMC be focused on the use of quantum computers by researchers, with capabilities (and thus pricing) determined on a year-by-year basis, where the commitment is a total dollar amount that agencies are intending to spend. Specifically:

- AMCs will need to motivate each industrial player to invest on the order of several billion dollars for their particular technology. Accordingly, the estimated total market must grow to a sufficient size, with the government portion (represented by AMCs announced in the present time) an appropriate fraction of this estimated total market. Thus the scope of a quantum computing AMC must be large, and the time line long.
- Specifications for quantum computing system use remain nascent; thus AMCs should be responsive to changes in the specifications using existing bodies such as the Quantum Economic Development Consortium to create initial specifications and to revise specifications as technology advances. In essence, an industry-wide body with government interaction can help set yearly market rates for the use of quantum systems of various scopes.
- As a precursor to an AMC, a smaller government initiative—QUEST—was created to enable researchers to explore the usefulness of quantum computers while simultaneously building up the necessary workforce to make use of quantum computers. This QUEST program, if initiated, could establish performance goals and milestones for AMCs by other end-user U.S. departments and agencies.

Case Study: Carbon capture and long-term storage

The Biden administration has made it a public goal to cut emissions 50% of CO_2 emissions by 2030, and become a net-zero carbon country by 2050. Although this is a very worthy goal to help mitigate climate change, the goal has serious challenges, the biggest of which is technical. Specifically, the technology is not mature enough to meet these goals without seriously impairing the US economy. Billions of dollars of risky R&D is necessary across multiple sectors - energy, manufacturing, transportation, etc is necessary to get to net-zero carbon.

Climate change, similar to vaccines, is an ideal area for the USG to use AMCs, namely because the true cost of climate change is not reflected in today's market prices for such products. Furthermore, by selling these AMCs as "First for America to achieve X before the end of the decade", these are much more relatable technology goals for the American public.

To solve both problems at the same time, the US can embark on launching multiple AMCs around climate change. As described in a prior whitepaper, one area of particular interest is carbon capture from the atmosphere and its long-term storage (DAC-LTS). The existing space of DAC-LTS already assumes an eventual government market. However, AMCs represent a simple way to jump-start this marketplace while other policy actions, including potential carbon credits, carbon taxes, and other mechanisms, are developed and deployed.

To execute these climate change AMCs, we propose that the US government form an industry consortium with government agency participation to construct and implement a joint technology development program that will deliver transformational climate change technologies before 2030.

- Much like as in quantum computing, the changing technological and policy landscape for DAC-LTS is changing rapidly, and so any AMC should be in the form of a dollar commitment that translates into a specific amount of carbon stored which can vary from year to year.
- In addition, the year-over-year approach can be leveraged to ensure that carbon, once captured, stays captured if, for example, the government leases stored carbon rather than outright buying it.
- The consortium plays a key role in both developing and regulating the marketplace, as well as ensuring the technical specifications for each year are well defined and appropriately set to prevent 'capture' of the regulator by the industry.
- While the focus of this piece is on DAC-LTS, a variety of other climate-related technologies can benefit from a similar structure. For example, AMCs and associated consortia can

support the development of new base-load electric power technologies, the creation and use of energy storage, and early deployment of greenhouse gas-reducing technologies.

Case Study: Infrastructure that enables self-driving cars

True level 5 self-driving vehicles will drastically improve transportation while accelerating the replacement of gas vehicles, which represent 29% greenhouse gases. Not depending on humans to control a car during operation on roads has the added benefit of improving safety. The added convenience of not having to drive will help boost car sales, hence increase American motor industry jobs. Achievement of such goal will help drastically improve America's ranking of #12 in the world when it comes to transportation infrastructure.

However, level 5 self-driving vehicles require significant upgrades to transportation infrastructure, many of which have not been invented. For example, having sensors in roads to direct the cars, or major upgrades to the communication network for cars are must-have items for self-driving cars to work. Other more mundane tasks such as fixing potholes or dedicating certain lanes for autonomous vehicles are also need necessary. Individual self-driving car manufactures neither have the finanical incentive, or the technical skills to develop and deploy such infrastructure. Therefore it is only by providing an AMC, that new startups, telecommunication companies, and traditional construction companies can come together to solve these infrastructure issues. To support multiple car manufacturers, common standards will need to be established for self-driving car infrastructure.

To execute a level 5 self-driving car infrastructure, we propose that the US government form an industry consortium with government agency participation to upgrade American's transportation infrastructure.

- AMC can include commitments in fleet purchasing; usage of self-driving transportation services for government contracts; support for level 5 self-driving compliant roadways and other transportation infrastructure; and support for state and local investment in relevant infrastructure.
- The first milestone can be scoped to just interstates because it is likely easier to enable level 5 self-driving than urban areas.
- New startups, telecommunication companies, self-driving car manufacturers, and traditional construction companies will collaborate to accomplish the goals set forth by the AMC through an industry consortium.

- A consortium will provide the suggestions on the structure of the AMC, and ensure that there are common standards put in place to allow multiple self-driving car vendors share the same transportation infrastructure.

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