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Each month, the COVID pandemic kills 300,000 people (as of Jan. 2021) and reduces global GDP by approximately $500 billion. The full cost, including losses to health and human capital is likely much larger. Cutler and Summers (2020) estimate total losses of $16 trillion (around $800 billion per month of the pandemic) for the US alone.

Beyond the epidemiological externalities that motivate governments to play a central role in vaccination programs, new issues arise in a pandemic. Vaccine candidates face substantial risk of failure or delay in proving safety and efficacy. Normally firms wait to resolve this uncertainty before scaling up manufacturing, a risky and time-consuming process requiring specialized facilities and specific investments. However, in a pandemic the benefit of speed makes it socially valuable to invest in manufacturing capacity in parallel with testing.

Social and political limits on vaccine prices during pandemics mean the social value far exceeds the commercial returns to vaccine manufacturers from installing capacity. In a companion piece (Castillo et. al 2020), we estimate that increasing the total supply of vaccine capacity available in January 2021 from 2 billion to 3 billion courses per year generated $1.75 trillion in social value, while additional firm revenue was closer to $30bn assuming a price of $15 per dose. Additional

profits would be smaller still. Since unprecedented acceleration of manufacturing involves substantial, risky investment, carefully crafted public intervention is needed to align social and private benefits. What magnitude and structure of public intervention is best?

Early in the pandemic, we analyzed alternative approaches to procurement, arguing that buyers should directly fund manufacturing capacity and shoulder most of the risk of failure in exchange for the right to buy doses at close to marginal cost should the vaccine candidate be successful, while maintaining some direct incentives for speed. We analyzed the optimal portfolio of vaccine investments for countries with different characteristics as well as the implications for international cooperation. Our analysis, considered in light of the experience of 2020, suggests lessons for future pandemics.

I. Design of Procurement Contracts

Since many aspects of the vaccine development process are beyond the full control of vaccine developers (e.g., the rate at which trial participants will be infected or the occurrence of adverse events that pause trials), bonus/penalty clauses for speed large enough to reflect its value would involve unacceptable levels of risk for firms and could have unintended consequences. Capacity installation is more predictable and contractible.

Buyers can incentivize early installation of capacity by reimbursing firms for the cost of installation (before testing and regulatory approval are complete), thus transferring risk of failure from firms to themselves (push contracts); or they might commit to purchase vaccines on specified terms, but only if regulatory approval is completed successfully, leaving the risk with firms (pull contracts). We analyze the costs and benefits of these alternatives in Online Appendix A.4. We consider a stylized environment in which firms have private information on their chance of success, buyers want many firms to invest--including those with only a modest chance of success--and the cost of capacity is observable.

When pull contracts are used, a large pull payment is required to induce at-risk capacity construction for candidates with a low chance of success. When it is not possible to observe and condition payments on the probability of success, governments wishing to induce a diverse set of firms to make at-risk investments must design pull contracts to offer all firms a price high enough to induce the marginal firms to invest. This price structure generates substantial rents for firms with a high probability of success and is therefore expensive compared to cost reimbursement.

Our analysis implies that buyers should contract directly on capacity, relying primarily on at-risk cost reimbursement (push funding). However, in practice, buyers have some information on probability of success, do not perfectly observe costs, and--critically--want to incentivize speed. We therefore recommend that push payments cover less than the full cost, giving firms "skin in the game" and deterring those with no realistic chance of success from accepting push funding. A pull component can be calibrated to induce the marginal firm to participate and structured to incentivize speed.

We contrast the situation we study with the classic case for an advance market commitment, in which resources are severely limited and intended to address a substantial research and development challenge. It is harder to estimate the cost of research and development than capacity installation, and more difficult to judge which activities or firms should be funded to give the best chance of success. In the classic case, pull funding induces investment only from firms that are likely to succeed, thus aligning incentives.

How do our recommendations compare with what happened in 2020? While full contracts are not public, many deals in 2020 incorporated push payments by governments, covering the costs of late-stage trials and scaling up of vaccine production, including investments in inputs such as syringes and vials. In exchange, firms committed to deliver a specified number of doses within a certain time frame. In contrast, Pfizer's contract included only pull funding. Buyers committed to purchase a given quantity by a given date. Pfizer built capacity in advance of clinical approval at its own risk, but not enough to serve the world in 2021.

II. Selecting a Portfolio

How should a buyer decide how many vaccine candidates to support and how much capacity to procure prior to regulatory approval? We consider a model in which the buyer accelerates delivery of a successful candidate by 3 to 6 months by choosing the capacity for each candidate (courses per month) that will be installed at the buyer's risk.

Based on expert opinions, historical data, and a database of the vaccine pipeline (WHO, 2020), we constructed estimates of the probability of success for each vaccine, updated throughout 2020; Online Appendix A.1 presents the base case probabilities as of August 2020. We made assumptions about the correlation of success among vaccines using similar technologies and calculated the expected number of successful courses across vaccines. Diversification across candidates and platforms increases the probability of success. Using country-specific estimates of mortality

and GDP loss, we estimate the total health and economic benefits a country can expect from investing in different vaccine portfolios. One critical and uncertain parameter is the elasticity of supply of vaccine capacity. Many experts in industry and in international organizations believed there were hard limits on how much supply could be created in the relevant time. A standard economic analysis would suggest that prices would reflect the value of obtaining early doses of vaccine for the marginal country, which would be immense, and that if supply is inelastic and prices are subject to a ceiling, shortages ensue. To illustrate this, Online Appendix A.2 considers a range of assumptions about supply elasticity.

Across scenarios, we find early at-risk investments in vaccine manufacturing capacity would have had, in expectation, large net benefits for countries for all levels of income (Online Appendix Table A.1). However, with elastic supply, global net benefits are roughly two times larger. The portfolio that maximizes net benefits varies substantially across countries. Higher income countries (HICs) find it worthwhile to purchase more courses per capita and a larger portfolio of candidates, while lower-income candidates invest only in candidates most likely to succeed.

How does this model compare with actual deals made during 2020? Many countries made bilateral deals. HICs, especially the U.S. and U.K., invested billions of dollars at risk, contracting for large numbers of courses across multiple candidates. These investments will accelerate the end of the pandemic. Upper middle-income countries made deals for a smaller number of doses and candidates (Duke Global Health Innovation Center, 2020). While most lower income countries (LICs) did not purchase doses, they anticipated receiving them from donors through COVAX. The unprecedented investments that countries made were still smaller than our model suggested.

Because our model assumed a relatively low chance of success for each vaccine candidate and only a modest correlation between these probabilities, it suggested that it was optimal to invest in significant capacity for each of many candidates, including some early-stage candidates. Ex post, multiple candidates turned out to be successful, including the never-before used mRNA platforms. Perhaps this was a lucky realization, or perhaps we underestimated the chance of success or correlation. However, investing in the amount of capacity recommended by our model (as of August 2020) would have allowed the U.S. to complete vaccination by March 2021 rather than waiting until summer as is currently expected, and the world to complete vaccination by October 2021 rather than June

2022. Using a more conservative approach to computing economic harm from the pandemic than Cutler and Summers (2020), and also accounting for diminishing returns from vaccination in a conservative way, we estimate that this acceleration would have had benefits of $167 billion for the U.S. and $1.14 trillion for the world (Table 1), substantially higher than likely costs.

Table 1: Advance capacity expansion effects

Advance capacity investment	At-Risk Capacity of Approved Vaccines (bn courses)	Benefits relative to Zero At-Risk ($bn)	Vaccination complete by
Panel A, U.S.			
Recommended	1.05	556.9	Mar 2021
Actual	0.45	389.9	Jul 2021
Zero	—	—	Oct 2021
Panel B, World			
Recommended	7.12	2748.7	Oct 2021
Actual	3.75	1606.4	Jun 2022
Zero	—	—	Sep 2022

See Online Appendix A.3 for full calculation.

In a companion piece (Castillo et. al), we estimate that even at this late stage, investment to expand manufacturing capacity would have large benefits. This could mean repurposing facilities, adding lines to existing ones or increasing throughput along the supply chain. There have also been interesting proposals to wring more output out of existing factories, for example by producing lower-dose vaccines. Governments could elicit bids from firms to identify ways to produce more doses.

III. International Considerations

Many observers voiced concern about "vaccine nationalism" during 2020. This included fears that countries would prevent export of vaccines, and some producer countries such as India reportedly considered the idea, according to the CEO of Serum Institute, the largest vaccine producer in India. As a result of the risk, countries have distorted investment disproportionately towards domestic vaccine candidates. To date, most international export contracts have been honored. This fact has allowed countries to diversify their portfolios, which our analysis suggests is extremely valuable. Given that many vaccine candidates have proved successful, diversification has so far not been critical, but this could not have been predicted and may not be the case in future pandemics. Reinforcing norms of honoring contracts and not banning exports would be valuable.

Vaccines delivered earlier are more valuable than those delivered later. This distinction creates challenges if countries sign contracts believing that they are entitled to doses soon after a vaccine is approved but are in fact

placed in a "queue" behind other countries for the output of the same capacity. International norms that encourage firms to commit to construct sufficient manufacturing capacity to meet promised delivery timelines might increase capacity creation while reducing uncertainty.

Many commentators have emphasized that there may be negative externalities on other countries from ordering vaccines if the supply of manufacturing capacity is inelastic, leading to high prices or, if there are constraints on pricing, shortages. However, our analysis suggests that, to the extent that supply is elastic, there will also be positive externalities by expanding global capacity, allowing manufacturers to serve other countries faster than they would have otherwise. If supply is perfectly elastic, the negative externality is eliminated, while the world as a whole benefits from faster vaccination. The fact that actual capacity available at the end of 2020 exceeds initial forecasts suggests substantial elasticity even in the short run. Indeed, Pfizer argued that earlier investments in its supply chain could have accelerated capacity expansion (LaFraniere and Thomas, 2020).

For future pandemics, elasticity of supply of vaccine capacity is a policy variable. It can be increased through investment in supply chains, either by stockpiling or by building extra manufacturing capacity for key intermediate inputs, such as bioreactors, delivery devices, or adjuvants. These actions would not only be directly valuable, they would reduce incentives for governments to use emergency authority to prohibit exports, or race to secure supplies in ways that could create negative externalities for other countries. If we anticipate social constraints on pricing during a pandemic, reaching the efficient level of input capacity or stockpiling will require public subsidy.

There have been some attempts to centralize global vaccine procurement. This is not necessary to diversify vaccine portfolios, since this can be achieved through trade, but it may have other benefits. First, monopsony power can be used to hold down prices. However, during the current pandemic, prices have not skyrocketed. Second, a central procurement vehicle can be used to coordinate donations to lower income countries, which is desirable on humanitarian grounds and to prevent disease spread from these countries. In 2020, the COVAX facility played this role. Third, there can be economies of scale in contracting, planning and supply chain investment. Finally, centralization can facilitate efficient prioritization. From a global health perspective, the allocation should respond to local conditions as well as target individuals by vulnerability or their externalities.

International agreements require agreement about size, scope, and allocation. In Online Appendix A.3, we analyze the incentives of countries to participate in agreements with alternative configurations of countries as well as allocation schemes. Our analysis shows that if a centralized arrangement allocates vaccines to countries in proportion to population, then HICs prefer to purchase bilaterally instead. Linking allocation to contributions more closely strengthens incentives for HICs to invest. Moreover, as the optimal portfolio differs across countries, centralized agreements could allow flexibility in how much to invest and in what candidates.

How does this reasoning match the events of 2020? Most deals have been bilateral. Early in 2020, attempts at enlisting HIC countries in international cooperation faltered, other than through the E.U., which invested conservatively and serves a group of countries with similar incomes and similar needs. COVAX now allows countries to buy different quantities of vaccine, and most self-financing countries opted for an "optional purchase agreement", giving them flexibility about which vaccine to purchase.

IV. Conclusions

During a pandemic, expanding manufacturing capacity for a wide portfolio of vaccine candidates has large benefits. It is efficient to contract on capacity rather than doses and to primarily use push funding. Investing in capacity for or stockpiles of intermediate inputs used in vaccine production could enable faster and cheaper capacity installation during future pandemics, yielding significant benefits for the global economy and global health.

REFERENCES

Castillo, Juan C, Susan Athey, Arthur Baker, Eric Budish, Rachel Glennerster, Scott Duke Kominers, Michael Kremer et al. 2020. *Accelerating Broad Availability of a COVID-19 Vaccine.* Unpublished.

Cutler, David M., and Lawrence H. Summers. 2020. *The COVID-19 pandemic and the $16 trillion virus*. Jama 324, no. 15 (2020): 1495-1496.

Duke Global Health Innovation Center. 2020. "Launch and Scale Speedometer." Accessed Dec. 29, 2020. https://launchandscalefaster.org/covid-19.

LaFraniere, Sharon, and Katie Thomas. 2020. "Pfizer Nears Deal With Trump Administration to Provide More Vaccine Doses." The New York Times, December 22, 2020, sec. U.S.

WHO. 2020. "Draft Landscape of COVID-19 Candidate Vaccines." July 31, 2020.