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Incentivizing COVID-19 Vaccine Developers to Expand Manufacturing Capacity

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Safe and efficacious vaccines are our best tools for defeating COVID-19, and an unprecedented research and development effort has led to 12 vaccines being approved for full, emergency, or limited use, globally. But to vaccinate the global population as quickly as possible requires additional production capacity. The available global production capacity may be sufficient in aggregate across all vaccine manufacturing platforms over an 18- to 24-month window. However, the total manufacturing capacity is insufficient for accelerated immunization across countries globally in the short-term (e.g., next six months) and is not sufficient in a disaggregate sense, i.e., for each individual vaccine type.

There is a need to expand the manufacturing capacity for COVID-19 vaccines. There is continuing debate about how to create sufficient capacity of specific vaccine platforms such as mRNA which some argue are more versatile for future preparedness efforts (Moore and Offit 2021, Wilfredo et al. 2021). Castillo et al. (2021) estimate that installed capacity for 3 billion annual vaccine courses leads to a global benefit of $17.4 trillion, making it vital from both a health and an economic perspective to build sufficient manufacturing capacity for COVID-19 vaccines.

Some discussions focus on capacity expansion through the vaccine developers sharing intellectual property (IP) and manufacturing know-how, so that as many companies globally can manufacture COVID-19 vaccines (Prabhala et al. 2022). While it is a salient ideological debate with a long list of pros and cons, we focus in this note on the problem of incentivizing the vaccine developer to expand manufacturing capacity, either in-house, by adding more contract manufacturing sites, or through manufacturing partnerships with other manufacturers. Building upon our earlier work (Kazaz et al. 2021), we try to identify the least costly instrument that incentivizes the COVID-19 vaccine developer to build sufficient capacity to meet global demand.

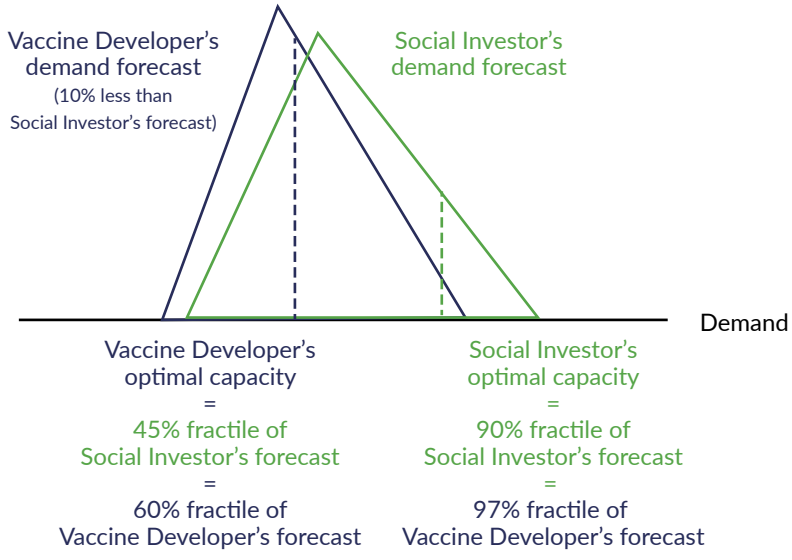
The development and construction of new manufacturing capacity for COVID-19 vaccines is both resource- and time-intensive. It can take up to 9 to 12 months to build capacity and/or ramp up production capability and obtain regulatory validation, and the capital expenditures can run as high as $500 million to $1 billion. Moreover, a firm which has developed a safe and efficacious vaccine requires

sufficient confidence in long-term demand in order to increase its production capacity. In the past, vaccines for SARS and H1N1 (IOM 2010), and antiviral agents such as Tamiflu, have seen significant fluctuations in demand during and after a pandemic (Kopczak et al. 2010); and demand for specific COVID-19 vaccines is highly uncertain. There are additional sources of uncertainty that hinder a vaccine developer's confidence in making additional investment to increase capacity: emergence of new variants, duration of protective immunity (Murray and Piot 2021), results of studies in pediatric and other patient groups which could lead to indication expansions, potential success of competing vaccines, and future investments by country government to purchase significant quantities of COVID-19 vaccines.

While the need for a rapid and significant expansion of COVID-19 vaccine manufacturing capacity is clear (Wouters et al. 2021), the incentives for a vaccine developer to invest in sufficient capacity to serve the overall global needs are weak. Vaccine developers invest in capacity to achieve a level of profit that is commensurate with the level of risk. In this case, the risk largely stems from highly uncertain medium-term demand. In other products with high demand-side risks and significant capital cost for production capacity, manufacturers charge higher prices to compensate for such risks. However, COVID-19 vaccines are under intense public scrutiny. Pricing to recoup within a short time frame may create reputational risks for manufacturers. Furthermore, the full value to society from the availability of an effective therapeutic is unlikely to be captured in the manufacturer's profit calculus. In particular, there are large benefit externalities (beyond the benefit to the individual) from increases in vaccine manufacturing capacity stemming from reduced transmission of the disease and mitigation of negative effects on the economy (Castillo et al. 2021). In light of these factors, the manufacturing capacity investments by COVID-19 vaccine developers are likely to be significantly smaller as compared to the interests of society as a whole.

Figure 1 illustrates the differences in the level of capacity that maximizes social welfare and the capacity that a vaccine developer may choose based on its own risk return calculus. We use the triangular distribution to capture the uncertainty in demand. The difference in preferred capacity by the vaccine developer and the social investor, stated in terms of the percent fractile of a demand forecast in Figure 1, is largely due to the high social value of the vaccine compared to the vaccine developer's per unit gross margin. The difference is further exacerbated by the fact that the vaccine developer's demand forecast may be more conservative relative to the needs of the population.

Figure 1. The social investor's (green) and the vaccine developer's (blue) view of uncertain demand (triangular distributions) with preferred capacity indicated by vertical lines (green for social investor and blue for vaccine developer). The vaccine developer's forecast is 10 percent below the social investor's forecast in the figure.



INCENTIVE MECHANISMS

A *social investor*—such as a country government, a supranational entity, a development finance institution, or a private philanthropy—can use a range of financial instruments to encourage greater investment in manufacturing capacity. We outline four such instruments below:

1. *Production subsidy.* Production-linked tax credits or direct grants under which a firm that manufactures a COVID-19 vaccine gets a tax credit or payment for each unit of output.

2. *Capacity subsidy.* Grants to the manufacturer in an amount that is proportional to capacity. This differs from the preceding instrument because production output may be less than capacity.

3. *Concessional loan*. Low-interest loan for a portion or all of the capital investment.

4. *Volume guarantee*. The social investor guarantees a certain volume of the vaccine will be purchased over a set period of time (e.g., acts as a buyer of last resort). If market demand turns out to be lower than the guaranteed volume, then the social investor purchases the difference from the manufacturer.

Each of these instruments can incentivize a vaccine developer to increase manufacturing capacity, but each intervention results in a different expected cost to the social investor.

METHODS

Using mRNA vaccines as an example, we assess the costs of these financial instruments using a mathematical modeling and optimization framework. We replicate our analysis under various scenarios involving demand for mRNA vaccines, price, cost of capacity, and value to the society. These replications provide robust insights into the policy recommendations.

DATA AND SOURCES

We apply our framework to compare the costs of different incentive instruments. We use data from publicly available documents (e.g., Moderna SEC 10-K statements for 2020), and earlier reports (Snyder et al. 2020) to create reasonable estimates of costs and demand. We assume a three-year planning horizon for the capacity decision.

Demand

The demand (for mRNA vaccines) is assumed to follow a triangular distribution with the mode at 3.06 billion courses, the minimum is 20% less than the mode (2.45 billion courses) and the maximum is 50% greater than the mode (4.6 billion courses). The mRNA vaccine developer is more conservative in its forecast given uncertainties in future demand as described earlier. It forecasts that realized demand for its product over the next 12–24-month period will be the confirmed purchased orders it has already received and assumes the same rate of demand for the remaining 12 months in the three-year planning horizon. We consider three cases in our calculations. In the first case, forecasts for the vaccine developer and the social investor are aligned. In the next two cases, the social investor's forecast is 25% and 50% higher than the vaccine developer's forecast, respectively.

Costs

We rely on a combination of public financial documents, earlier process cost modeling studies, and news reports to estimate the fixed costs of installing capacity and variable costs of manufacturing. We use the average interest rate (6.7%) for Moderna's debt obligation as a proxy for the vaccine developer's cost of capital. We assume that the loan interest rate for the concessional loan is 1.25% per year. The cost of building capacity has two components: fixed and variable costs. We use $1 billion as our base case estimate for the total cost to build mRNA vaccine manufacturing capacity of 1 billion doses per year. We use an industry benchmark of $250 million in fixed facility, building, and auxiliary equipment costs, which are not dependent on the volume of production (Blanchard 2000). Our estimates of the cost of manufacturing capacity are based on a new production site based in a high income country and include the cost of drug substance and drug product manufacturing, finishing, and packaging. mRNA vaccine manufacturing requires more complex manufacturing steps and other COVID-19 vaccines may or may not require some production steps resulting in lower fixed costs. The cost of capacity may be lower if manufacturing sites are located in lower cost production regions. We carry out sensitivity analysis on these costs with significantly lower fixed costs and also model a scenario with much higher fixed costs.

We use $4.68/dose as our base case estimate of the unit variable cost of production based on the percentage of COGS (cost of goods sold) from Moderna's 2020 financial statement (including the cost of previous inventory). We consider a lower variable cost of $2.02 from a modelling study (Kis et al. 2021). We also include an additional scenario with a higher variable manufacturing cost of $5.85/dose.

Prices

We consider three different prices for mRNA vaccines in our calculations. From the publicly available prices in different countries, we choose $19.50 as the base case price, $37 as the high price, and $7 as the low price. Purchase prices reported for Moderna's COVID-19 vaccine are $15 for the United States, $18 for the European Union, and $32 for low-volume deals. For Pfizer/BioNTech, reported data shows $7 for the African Union, $14.70 for the EU, and $19.50 for the US (UNICEF COVID-19 Vaccine Dashboard). The prices used in our analysis are consistent with the currently observed market prices for the two authorized mRNA vaccines.

We use three different values of the societal value of a COVID-19 vaccine. We use $989 per course as our base case estimate, $576 per course as the lower estimate, and $5,800 as the higher estimate for societal benefits from COVID-19 vaccines (Source: Castillo et al. 2021).

DISCUSSION AND CONCLUSIONS

COVID-19 vaccine developers may underinvest in building vaccine manufacturing facilities due to the significant investments required and uncertainty in future demand. Such underinvestment in manufacturing capacity would slow down the pace of vaccination and create significant health and economic losses.

We examine three types of instruments that can be used by national governments, development finance institutions, and supranational agencies to incentivize manufacturing capacity expansion: capacity subsidy, concessional loan and volume guarantee. Our findings suggest that

1. A full loan for the capital expenditure is never sufficient to increase the vaccine developer's capacity to the social investor's preferred level.

2. When the forecasts of the vaccine developer and the social investor are aligned, the least costly instrument in each of the scenarios analyzed is the combination of a *concessional loan* with additional *capacity subsidy*.

3. When the medium-term demand forecast of the social investor is higher than the vaccine developer (in both scenarios of 25% and 50% greater demand), *volume guarantee* is the only viable instrument to incentivize socially optimal manufacturing capacity.

These findings are robust as to hold under various scenarios of demand, price, capacity costs, and social values. One important assumption we make in this analysis is that there is a single government or development finance institution that is providing such instruments, or when there are multiple, there is policy cooperation across them. If there are more than one and each one implements different instruments, it can lead to gaming behavior which can make these instruments infeasible or ineffective in some cases. We do not capture such multi-actor dynamics in our analysis.

Depending on the differences in the social investor's and the vaccine developer's forecast of future vaccine demand, either a concessional loan combined with capacity subsidy or a demand/volume guarantee are the best ways to incentivize vaccine developers to expand production capacity. Such instruments should be evaluated not only for final steps of vaccine manufacturing capacity, but for all critical inputs, such as glass vials, lipids, and single-use bioreactors. The framework developed can be easily extended to evaluate the least expensive instruments for expanding capacity of key input materials.

The success and applicability of specific instruments depends on policy cooperation across country governments, global agencies, private philanthropies, and development finance institutions who are all working to figure out ways expand vaccine production. But if we can achieve policy cooperation and select the right instruments as described in this note, we can expand production capacity to serve global needs. Expanding production will speed up the pace of vaccination across countries and will reduce the ongoing conflicts over access to scarce vaccine doses.

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