

COVID-19 BIOPHARMACEUTICAL INNOVATION AND INDUSTRY APPROPRIATION¹

by

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Abstract

The rapid emergence of vaccines and therapeutics in response to the onset of the coronavirus (COVID-19) pandemic demonstrated the value of medical innovation. These advances not only led to enhanced patient welfare by reducing the disease's mortality and morbidity but also reduced the need for costly prevention measures, such as cuts in economic activity. This paper offers the first estimate of the portion of economic value generated by these medical innovations that was appropriated as earnings by the innovating companies, measured by the ratio of company earnings to the overall societal value generated by the innovations. To estimate the value and appropriation of COVID-19 innovations, one must necessarily make assumptions about what disease-specific and preventive activity would have been in the absence of these new innovations. To obtain robustness in our findings across such scenarios, we estimate industry appropriation across a wide range of counterfactual scenarios that would occur under no innovation. These scenarios include previous assessments of the contributing subparts of the value generated by the innovations. Our primary finding is that, within the large range of these counterfactual scenarios, upper-bound measures of the proportion of value appropriated by the industry ranged from 0.2% to 4.6%. Even though these are upper bound appropriation rates, they are significantly lower than have been documented for other significant health sciences innovations. This suggests that COVID-19 vaccines and treatments were remarkable, not only in their swift development but also in the considerable societal value they provided, which extended far beyond the rewards to the innovating companies.

¹ The views and opinions of the paper are solely attributable to the authors and not their institutions. All authors are at The University of Chicago except Fendrick who is at The University of Michigan. Philipson and Fendrick acknowledges partial financial support from Regeneron.

Section 1: Introduction

The onset of the Coronavirus disease (COVID-19) elicited an urgent response in medical innovation, marked by the development of new vaccines and therapeutics. This swift innovation enhanced welfare by reducing the mortality and morbidity associated with the disease and, in unprecedented ways, by mitigating costly prevention measures, such as cuts in economic activity. This paper provides the first estimate of the share of the value generated by this rapid innovation that was appropriated as earnings by the innovating companies. This issue is important in general, and for COVID-19 innovation, given the ongoing debate about the profitability of the industry in relation to the value of the products it creates. Our primary finding is that, across a series of counterfactual scenarios spanning the previous literature on innovation effects, industry appropriation ranged from 0.04% to 2.6% of the value generated by the vaccine and treatment innovations.

The paper is outlined as follows: Section 2 reviews the existing literature on the proportion of value captured by innovative companies relative to the value they generate. In section 3, we document the sales revenue of the COVID-19 innovations and motivate why we use them as upper bounds on earnings, given that research and development (R&D) and manufacturing cost, though government subsidized, lower earnings below revenue levels. Section 4 explores the value of these innovations and the upper bounds on the share appropriated as earnings by the innovating companies. To estimate this appropriation, we consider the effects of the innovations on diseases and preventive activities, leading to necessary assumptions about what could have happened without the innovation. For robustness, this paper adopts the approach of estimating industry appropriation across a wide range of counterfactual scenarios, which includes previous assessments of the subparts of the value generated by the innovations. Specifically, our scenarios included possibilities where, in the absence of innovation, excess deaths would have increased by 50% to 100%, accompanied by hypothetical quarterly declines in real GDP growth of up to 2%. We then totalled the benefits from the range of avoided deaths and reduced economic losses to estimate the societal value of innovations. Industry appropriation was then calculated by our revenue-based upper-bounds on earnings divided by these societal values across the range of counterfactual scenarios. We find that appropriation ranged between 0.2% and 2.6% for vaccine producers and 0.5% to 4.6% for treatment producers. These remarkably small upper-bound levels of appropriation stem from the fact that the innovations not only reduced disease incidence but also lessened the need for costly preventive activities such as reduced economic activity. In section 5, we discuss the limitations of our analysis. Section 6 provides a concluding discussion.

Section 2: Literature Review of the Value of Innovation Accruing to Innovators

The share of societal value generated by medical innovation, particularly how much of this value accrues to the innovators, has been previously studied for different categories of drugs and vaccines. This section reviews the existing research on the share of societal value generated from medical innovation that goes to innovators. The key findings from these studies are summarized in Table 1.

Table 1 Literature on Pharmaceutical Innovation

Author	Category	Country	Results
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Philipson et al. (2017)	Childhood Vaccination	U.S.	- Lifetime societal value is \$184.1 billion - Manufacturers' share: \$3.4 billion (1.85%) - Societal share: \$180.7 billion (98.15%)
Carrico et al. (2022)	Childhood Vaccination	U.S.	- Disease-related averted costs are \$63.6 billion - Vaccination cost: \$8.5 billion
Herlihy et al. (2016)	Papillomavirus Vaccine	Global	- Worldwide HPV vaccine sales between 2006 to 2014: \$14.1 billion - Total costs: \$2.9 billion - Producer surplus stood at \$11.2 billion
Kirson et al. (2022)	COVID-19 Vaccine	U.S.	- Societal economic value of COVID-19 vaccines for the U.S. is estimated to be \$5.0 trillion.
Grabowski et al. (2012)	Statin Therapy	U.S.	- From 1987 to 2008, consumers captured \$947.4 billion (76%) of the total social value of the survival gains. - Innovators captured only 24% of the social surplus.
Lindgren and Bengt (2012)	Statin Therapy	Sweden	- From 1987 and 2018 of the social surpluses generated; the producer appropriated 20–43% of the value during the on-patent period. - This figure dropped to 1% following the loss of exclusivity, reducing the total producer surplus to 2–5% of the total social surplus.
Camejo et al. (2014)	Statin Therapy	England and Wales	- Results are similar to those in Carlsson's paper
Carlsson and Bengt (2017)	Statin Therapy	Europe	- The producer surplus, or the profit, was estimated at 52 EUR per capita, corresponding to 5% of the total economic surplus, namely, consumer and producer surpluses.
Berdud et al. (2023)	Statin Therapy	U.K. and Sweden	- Consumer surplus accounts for approximately 72% of the total surplus before patent expiration and about 95% after patent expiration. - In Sweden, the consumer surplus constitutes approximately 94% of the total surplus before patent expiration and about 99% after generic competition.
Hult and Philipson (2023)	General	Global	- The median share appropriated for drugs on the supply side is approximately 6%, based on the assumption that patients assign a quality-adjusted life-year (QALY) at \$450,000. - Assuming patients value a quality-adjusted life-year at \$150,000, the median share appropriated for drugs on the supply side are approximately 18% for drugs and 27% for other healthcare interventions, respectively.
Philipson TJ and Jena (2006)	HIV	U.S.	- For human immunodeficiency virus/acquired immunodeficiency syndrome therapies that entered the market from 1996 onward, innovators appropriated only 5% of the social surplus arising from these new technologies.
Kremer and Snyder (2018)	HIV	Global	- Using 2003 as the baseline year and estimating 344 million consumers worldwide are willing to pay a price of \$130, the producer surplus is 44% of the social surplus based on complete relief of the disease burden. - Consumers receive 16% of the social surplus. - The residual—41% —is the Harberger deadweight loss.
Garrison et al. (2009)	Cancer	U.S.	- Depending on the societal willingness-to-pay threshold, the manufacturer's potential share of the surplus varies between 24% (at a high threshold) and 71% (at a low threshold) of the social surplus created by trastuzumab treating breast cancer.
Lakdawalla et al. (2010)	Cancer	U.S.	- Between 1988 and 2000, innovations in cancer survival created 23 million additional life years and roughly \$1.9 trillion of additional social value. - Healthcare providers and pharmaceutical companies appropriated 5–19% of this total, with the rest accruing to patients.
Jena and Philipson (2008)	Medical Technologies	Global	- The median technology appropriation is about 15%.
Mulligan (2021b)	General	U.S.	- Innovators in the pharmaceutical industry capture about a quarter of the social surplus.

Initial investigations by Philipson and Jena (2005, 2006) found that for HIV/AIDS therapies introduced post-1996, innovators appropriated only 5% of the social surplus. Conversely, Kremer and Snyder (2018) found a significantly higher appropriation, 44%, for the same disease starting from 2003, with consumers receiving 16% of the social surplus, and the remaining 41% representing the deadweight loss due to pricing above marginal cost.

Philipson et al. (2017) examined the social value of guideline-recommended vaccines for 14 diseases in children born in the United States. They estimated a lifetime social value of \$184.1 billion, with manufacturers accruing 1.8% (\$3.4 billion) in net profits, while the rest benefited society. Focusing on the 2017 United States birth cohort, Carrico et al. (2022) estimated disease-related averted costs at \$63.6 billion, while vaccination costs were \$8.5 billion. Herlihy et al. (2016) estimated worldwide HPV vaccine sales from 2006 to 2014 to be \$14.1 billion, with the producer surplus standing at \$11.2 billion, thus capturing about 10% of the social surplus.

Kirson et al. (2022) estimated the societal economic value of COVID-19 vaccines for the United States to be \$5 trillion but did not quantify the producer surplus. Grabowski et al. (2012) observed that for statin therapy from 1987 to 2008, consumers captured 76% of the total social value, leaving 24% for innovators. Lindgren and Jonsson (2012) estimated that producers appropriated 20–43% of the social surplus during the on-patent period, which dropped to 1% post exclusivity loss. Carlsson et al. (2017) and Refoios Camejo et al. (2014) provide similar findings for simvastatin in different regions and timeframes: the producer surplus was 5% of the total surplus.

Lakdawalla et al. (2010) estimated that innovations in cancer survival between 1988-2000 generated roughly \$1.9 trillion in social value, with 5-19% appropriated by healthcare providers and pharmaceutical companies. Garrison et al. (2009, 2010) found the manufacturer surplus to range from 24-71%, based on societal willingness-to-pay thresholds for trastuzumab in treating breast cancer. Sun et al. (2009) estimated 5-19% of the social returns from cancer drugs. Hult and Philipson (2023) found a median appropriation of 6-27% for drugs on the supply side. Jena and Philipson (2008) found a median technology appropriation of around 15%. Mulligan (2021b) estimated that pharmaceutical innovators capture around 25%. Although these studies show some variation, they collectively suggest that only a small minority of the total value of innovation is appropriated by innovators.

Section 3: Revenues from COVID-19 Related Products

This section reviews the literature and evidence related to the revenues of companies producing COVID-19 vaccines and treatments. Due to the challenges in assessing proprietary R&D costs and the significant public subsidies for such expenses provided by Operation Warp Speed (OWS) and the Biomedical Advanced Research and Development Authority (BARDA), we concentrate on revenue as an upper bound estimate of earnings, assuming that total R&D and production costs, after accounting for subsidies, were positive. For vaccine producers, we estimate revenues based on two sources: sales data from the Kaiser Family Foundation (KFF) (2023) and financial reports submitted to the Securities and Exchange Commission (SEC). Our findings indicate that vaccine producers generated total revenues of \$25.6 billion and \$56.7 billion using the two methods, respectively. For treatment producers, we exclusively use financial SEC reports for our analysis, which show aggregate revenues of \$33.3 billion.

Section 3.1: Revenues for Vaccine Manufacturers

We consider four vaccine producers as a part of our sample: Pfizer, Moderna, Johnson&Johnson, and AstraZeneca.

According to data reported by KFF (2023), that measures federal purchases of vaccines between June 2020 and September 2022, we find that the sales price of Pfizer's vaccine

averaged \$23.3, a high of \$24.6 and low of \$19.5, with 655 million doses sold, and its revenue implied was \$14.4 billion. Similarly, Moderna's vaccine had an average price of \$17.6 with 566 million doses sold, yielding a revenue of \$8.55 billion. Johnson&Johnson's vaccine had an average price of \$10 with 100 million doses sold, with a revenue of \$1 billion. AstraZeneca had an average price of \$5.3 with 300 million doses, yielding revenue of \$1.6 billion. The aggregate revenue across all four companies from federal purchases was \$25.6 billion.

We complemented the KFF data with a second way to assess revenues from the quarterly financial SEC reports filed by these public companies. We examine results from the first quarter of 2020 to the end of the second quarter of 2023. Over these 14 quarters, Pfizer's revenue was \$17.1 billion, Moderna's revenue was \$38.4 billion, Johnson&Johnson's was revenue \$0.8 billion, and AstraZeneca's revenue was \$0.5 billion. Thus, the aggregate revenues of Moderna and AstraZeneca obtained from company reports were substantially different from the KFF data. This variation can be attributed to KFF only measuring federal purchases, while the company reports from the SEC include both federal and commercial purchases.

Section 3.2: Revenues for Treatment Manufacturers

For therapeutics, we obtain the revenue data from companies' SEC reports and news releases (Appendix I). For time periods when data on the sales of a treatment was unavailable, we used linear interpolation to estimate revenues. We consider the impact by examining five major treatments: Veklury, Regen-Cov, Bamlanivimab and Etesevimab, Paxlovid, and Lagevrio.

Veklury (remdesivir) generated \$7.6 billion in sales revenue, at \$1,560 per treatment course (Gottlieb et al., 2022; Labban, 2020). We calculate that this means 4.9 million people received one course of Veklury.

Regen-Cov (casirivimab and imdevimab) produced revenues of \$6 billion, at \$2,100 per treatment dose (Regeneron, 2021b, c, d; Regeneron, 2020). This means around 2.9 million courses were administered.

Bamlanivimab and Etesevimab, whose authorization were revoked by the FDA (FDA, 2021), are reported to have a sales revenue of \$5 billion at a price of \$3,750 per treatment course (Lilly, 2021a, b; GlobalData Healthcare, 2020). Since the company reports sales revenue for the entire category of COVID-19 antibodies, we assume this revenue is equivalent to the sales revenue for Bamlanivimab and Etesevimab. We estimate that approximately 1.3 million courses were administered.

Paxlovid, which received its authorization later during the period, is reported to have a total revenue of \$12.6 billion at \$530 per course (Mishra, 2021; HHS, 2023a; Katella, 2023). We estimate that 23.7 million courses of Paxlovid were administered.

Lagevrio, is reported to have a total revenue of \$2.2 billion at \$700 per course (Mishra, 2021; HHS, 2023b; GoodRx, 2023). Approximately 3.1 million courses of Lagevrio were administered.

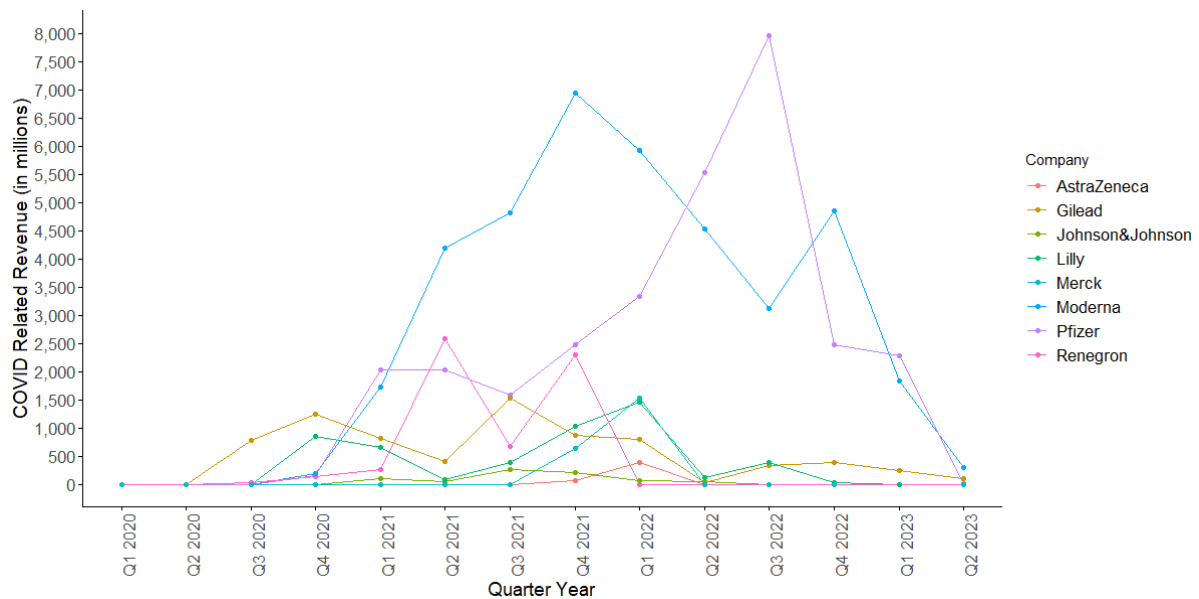
Table 2 Prices and Doses Sold Across Treatments

Company / Drug Name	Company Revenue (in \$ billions)	Price per Dose (Source)	Number of Doses Sold (in millions)
Gilead / Veklury	7.59	\$1,560 (Gottlieb et al. 2022)	4.86
Regeneron / REGEN-COV	6.01	\$2,100 (Regeneron 2021)	2.86
Lilly / Bamlanivimab & Etesevimab	5.01	\$3,750 (Lilly 2021)	1.34
Pfizer / Paxlovid	12.63	\$530 (Mishra 2021)	23.58
Merck / Lagevrio	2.16	\$700 (Mishra 2021)	3.08

Section 3.3: Trends in Product Revenues

Figure 1 presents the quarterly COVID-19-related revenue reported by firms between Q1 2020 and Q1 2023. The average quarterly COVID-19-related revenue stood at \$634 million, with a peak of \$7,952 million recorded by Pfizer in Q3 2022. The general trend shows an initial rise and followed by a fall. Most firms saw an initial jump in revenue in 2021, followed by a gradual decline after Q2 2022.

Figure 1 COVID-Related Revenue Over Quarters



Section 4: Value of COVID-19 Medical Innovation and Upper Bounds on Industry Appropriations

This section presents our estimates of the overall value of the new COVID-19 innovations across a wide range of counterfactual scenarios, considering what may have occurred in the absence of the innovations. Section 4.1 addresses vaccines, while Section 4.2 focuses on therapeutics.

Section 4.1: Value of COVID-19 Vaccine Innovation

Given that vaccines may contribute to impeding excess mortality and preventing cuts in economic activities, we estimate the societal value of such innovation as the sum of excess deaths averted and the avoided losses in Gross Domestic Product (GDP). Our baseline numbers, derived from the Centers for Disease Control and Prevention (CDC) excess death data, are labelled as ‘actual’. However, due to the lack of counterfactual data in the time frame evaluated, we constructed multiple counterfactuals to assess how our results would vary and to gain robustness in findings across scenarios.

We created two counterfactuals for value derived from avoided deaths. We estimated the economic losses of the excess deaths of COVID-19 without COVID-vaccines by multiplying the number of excess deaths by the Value of a Statistical Life (VSL) of \$11.4 million used by the Department of Health and Human Services (HHS)². The first counterfactual assumes that 50% more excess deaths would have occurred without vaccines, while the second assumes a 100% increase. These counterfactuals are in line with excess death rate estimates from other papers.

We considered three counterfactual losses in economic activity without the vaccines, by assuming real GDP growth would decrease by 0.5%, 1%, and 2% quarterly if there were no effective vaccines. These trends are depicted in Figures 2 and 3, while the corresponding values are presented in Table 3 below. These figures are lower than those predicted by Mulligan (2021a), who estimates a monetized welfare effect of a 25.4% negative impact on GDP for the entirety of the lockdown. Since this metric encompasses non-market loss and measures GDP levels rather than growth, it is higher than our counterfactual losses. This leads us to overestimate appropriation relative to such larger losses absent of innovation.

Figure 2 Counterfactual Excess Deaths

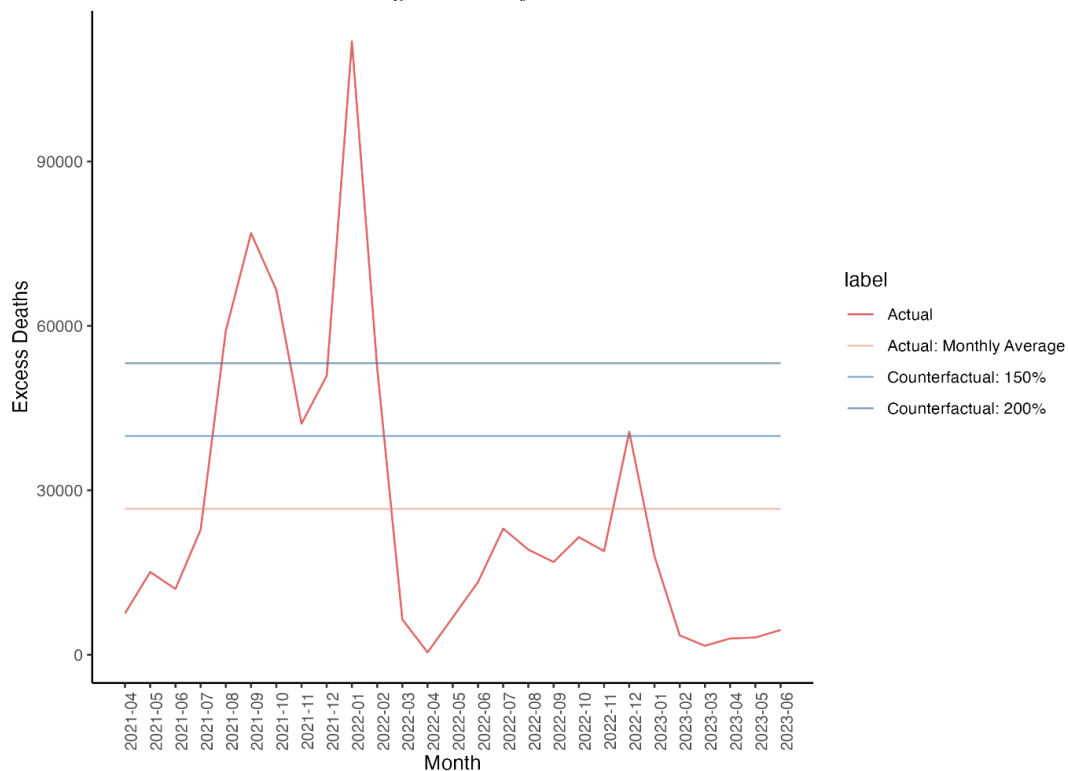


Figure 3 Counterfactual GDP Growth

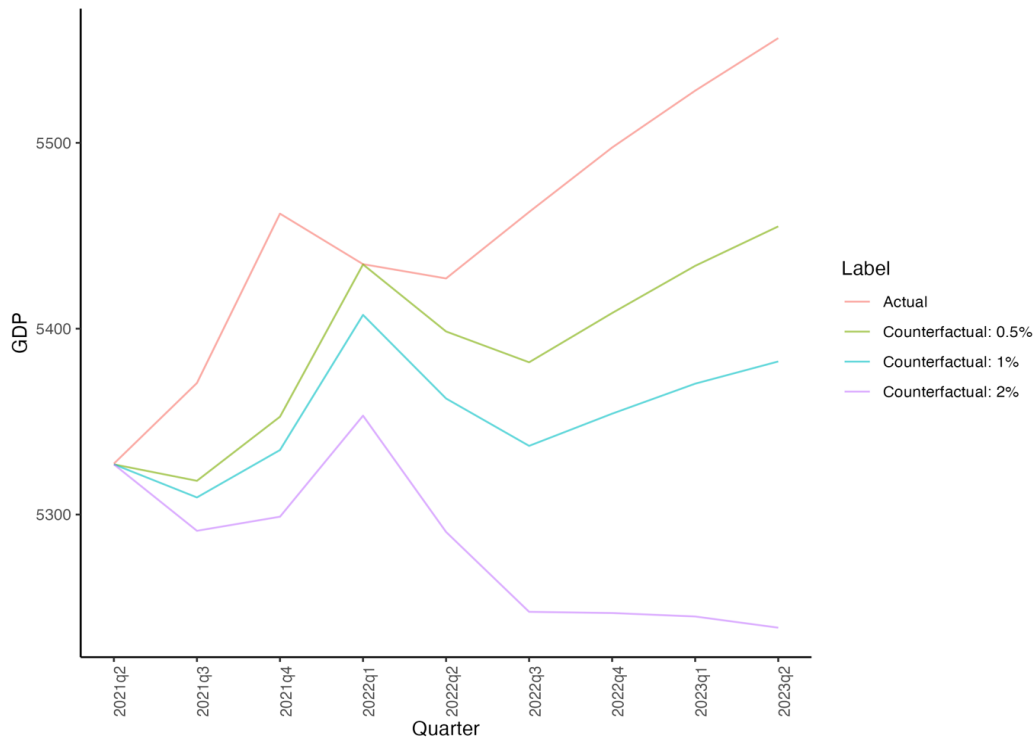


Table 3 Value of Vaccines and Treatments under Different Counterfactuals

Excess Death Counterfactuals	Value of Excess Deaths (\$ trillion)	GDP Loss Counterfactuals	Avoided Economic Losses (\$ trillion)
50%	4.09	0.5%	0.56
100%	8.19	1%	0.88
-	-	2%	1.53

Industry appropriation refers to the ratio of a company’s earnings to the overall societal value generated by its innovations. To calculate the societal value, we combined the value of both avoided deaths and averted economic losses for each counterfactual scenarios in the absence of effective vaccines. Our analysis, which is summarized in Table 4a, shows that the societal value varies significantly across different counterfactual scenarios, ranging from \$2.3 trillion to \$12.5 trillion. We then computed the proportion of company revenues – used as an upper bound on earnings – relative to the societal values for each scenario. The estimated upper bounds on industry appropriation, as detailed in Table 4b, range from 0.2% to 2.6%.

Table 4a Industry Appropriation under Different Counterfactuals: Sum of Values

Decrease in GDP / Excess Deaths	50% (in trillions)	100% (in trillions)
0.5%	2.28	4.56
1%	3.61	7.22
2%	6.25	12.50

Table 4b Industry Appropriation under Different Counterfactuals

No-Innovation Scenario	Societal Value of Innovations (\$ Trillion)	Total Appropriation Across 4 vaccines (KFF) (%)	Total Appropriation Across 4 vaccines (Quarterly Reports) (%)
ED50 + GDP 0.5	2.28	1.32	2.63
ED50 + GDP 1	3.61	0.83	1.66
ED50 + GDP 2	6.25	0.48	0.96
ED100 + GDP 0.5	4.56	0.66	1.32
ED100 + GDP 1	7.22	0.42	0.83
ED100 + GDP 2	12.50	0.24	0.48

Notes:

1. ED50 and ED100 correspond to the counterfactuals with 50% and 100% excess deaths respectively;
2. GDP 0.5, 1, and 2 correspond to counterfactuals with 0.5%, 1%, and 2% GDP growth rate reduction quarterly.

Our assumed range of counterfactuals covers specific aspects of losses discussed in previous analyses. For instance, our quarterly GDP growth rate varies between -0.5% and -2%, corresponding to an annual GDP growth rate that ranges from -2% to -8%. Hafner et al. (2022) estimated the global cost of COVID-19 in the absence of an effective vaccine to be \$3.4 trillion per year, with the United States potentially losing approximately 2.2% of its GDP annually without effective vaccines. However, Cutler and Summers (2020) estimated the cumulative lost GDP to be \$7.6 trillion from the outbreak of COVID-19 to the fall of 2021, potentially leading to a decrease of approximately 7.3% in the annual GDP growth rate. The estimated growth rates from other studies also fall within the range covered by our range.

Similarly, for excess deaths, Fitzpatrick et al. (2022) found that without vaccination, there may have been approximately 3.2 million deaths, representing an excess of approximately 2.5 million deaths (77%) in the United States. Agrawal et al. (2023) found that the vaccination potentially reduced the death rate by approximately 2.4 million excess deaths globally between December 2020 and December 2021, while the United States avoided 429,486 excess deaths. When Agrawal used excess deaths to estimate the pandemic's true effect, this estimate increased eightfold to 19.8 million deaths prevented by effective vaccination, indicating that vaccination was responsible for a 63% reduction in total deaths. Other studies assessed the effect of vaccination over shorter windows. For instance, Steele et al. (2021) found that the vaccination was estimated to avoid 58% of expected deaths in adults 18 years or older in the United States between December 2020 and September 2021. In the United States, Yamana et al. (2023) indicated that vaccination prevented an additional 120,000 deaths (about 30%) between December 2020 to May 2021, while Vilches et al. (2022) reported that vaccination prevented 240,797 excess deaths (about 59%) between December 2020 and June 2021.

Our research encompasses the range of estimated excess death rates found in other studies, with counterfactual scenarios accounting for up to 100% excess mortality.

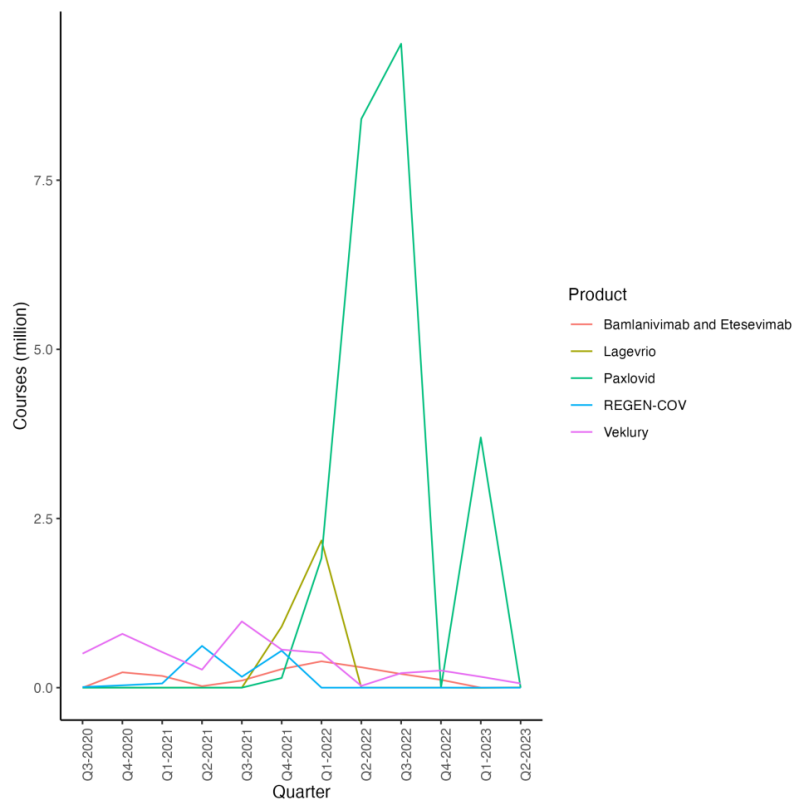
Section 4.2: Value of COVID-19 Therapeutics Innovation

We also examine COVID-19 treatments from the period prior to the start of mass vaccination in April 2021 up to the latest data available from Q1 2023, focusing on their direct health impact. We estimate that all treatments combined prevented 0.3 million deaths, which

have an economic value of \$3.36 trillion, assuming a VSL of \$11.4 million³. Our assessment indicates that manufacturers have captured between 0.5% to 4.6% of the drugs' direct health value through their innovation.

We consider the impact by examining our five major treatments: Veklury, Regen-Cov, Bamlanivimab and Etesevimab, Paxlovid, and Lagevrio. To calculate their health effect, we first estimate the total volume of treatments administered and then use the reported effectiveness of each treatment multiplied by its volume to determine the aggregate health impact. The usage trends for each treatment are depicted in Figure 4. It is important to note, however, that Lagevrio experienced negative sales in the most recent quarter according to our findings. According to the company, this decrease can be attributed to lower cases of COVID-19 in both the United Kingdom and the United States., coupled with changes in exchange rates. Given the controversy surrounding behavioural responses to therapeutics, we omit discussing their impact on GDP to provide a conservative estimate.

Figure 4 Treatment Courses Administered by Quarter and Product



Next, using the average probability of 30-day death from hospitalization across all age groups as reported by Jovanoski et al. (2022), we arrive at a 30-day probability of death following hospitalization due to COVID-19 to be 14.3%. We apply this probability to all cases except those treated with Regen-Cov to estimate the number of deaths avoided by all therapeutic treatments. This produces a conservative estimate, as the average probability may underestimate the likelihood of death for different age groups, such as senior patients, and assumes that all other treatments merely avoided hospitalizations. Lastly, we value these lives assuming a VSL of \$11.4 million⁴.

³ <https://aspe.hhs.gov/sites/default/files/2021-07/hhs-guidelines-appendix-d-vsl-update.pdf>

⁴ *Ibid*

To illustrate our method using hypothetical figures, let's consider a treatment that generates \$1 million in sales revenue, priced at \$100 per course. Therefore, we estimate 10,000 courses were administered to 10,000 patients. Assume the treatment had an absolute risk of hospitalization and deaths of 0% for the treated group and 20% for the placebo group. This would imply an absolute reduction in the risk of hospitalization and deaths by 10%, the difference between the outcomes for the two groups. Therefore, the total reduction in hospitalization and deaths to be 1,000 from this drug. Among these, applying the 14.3% probability of death following hospitalization, as determined by Jovanoski et al. (2022), we can infer that approximately 143 deaths were prevented. It is critical to note, however, that our estimates may not fully capture the actual health impact due to unreported rebates and subsidies which are included in the sales revenue but not reported in list price of the treatment. These factors could introduce a downward bias in our estimated health effects. Consequently, the economic value of the 143 avoided deaths, calculated using a VSL of \$11.4 million⁵, amounts to \$1.63 billion. This example demonstrates our approach to quantifying the direct health benefits and economic value of COVID-19 treatments, highlighting the potential for significant societal impact.

We estimate that approximately 4.9 million people received one course of Veklury, produced by Gilead Sciences. Each treatment course is associated with a 4.6% absolute reduction in the risk of hospitalization and death (Gottlieb et al., 2022).⁶ Thus, multiplying by the health effect, we estimate around 0.22 million hospitalizations and deaths to be avoided by Veklury. Veklury helped avoid 0.03 million deaths which are valued at \$0.36 trillion.

Regeneron's Regen-Cov reduces the absolute risk of hospitalization or death by 2.9% (Weinrich et al. 2021).⁷ Consequently, around 2.9 million courses were administered, leading to an estimated 0.08 million hospitalizations or deaths avoided by Regen-Cov. This results in 0.01 million avoided deaths, valued at \$0.14 trillion.

One treatment course of Lilly's Bamlanivimab and Etesevimab reduces a patient's risk of hospitalization and death by 5% (Dougan et al. 2021).⁸ Based on this efficacy, we estimate that out of the approximately 1.3 million courses administered, roughly 0.07 million hospitalizations and deaths were avoided. This results in 0.01 million avoided deaths, valued at \$0.11 trillion.

According to reports, Pfizer's Paxlovid is reported to reduce a patient's risk of hospitalization or death by 6.2% (Hammond et al 2022).⁹ Based on this efficacy, we estimate that out of the approximately 23.7 million courses administered, around 1.48 million cases of hospitalization and fatalities were avoided. This results in 0.21 million avoided deaths, valued at \$2.41 trillion.

⁵ *ibid*

⁶ A total of 2 of 279 patients (0.7%) in the remdesivir group and 15 of 283 (5.3%) in the placebo group had a Covid-19-related hospitalization by day 28.

⁷ Event occurred in 25 of 2091 patients in the REGEN-COV group (1.2%) and in 86 of 2089 patients in the placebo group (4.12%).

⁸ There were four (n = 511) events in patients taking bamlanivimab with etesevimab (0.78%) and 15 (n = 258) events in patients taking placebo (5.81%).

⁹ The incidence was 0.77% (3 of 389 patients) in the treatment group compared with 7.01% (27 of 385 patients) in the placebo group.

Merck’s Lagevrio, which is reported to reduce a patient’s risk of hospitalization or death by 6.8% (Jayk Bernal et al., 2022),¹⁰ was administered in approximately 3.1 million courses, resulting in about 0.21 million avoided hospitalizations or deaths. This means 0.03 million deaths were avoided valued at \$0.34 trillion.

Summing up the avoided deaths from the therapeutics discussed above, we conclude that approximately 0.3 million deaths were prevented, collectively valued at \$3.4 trillion, assuming a VSL of \$11.4 million.

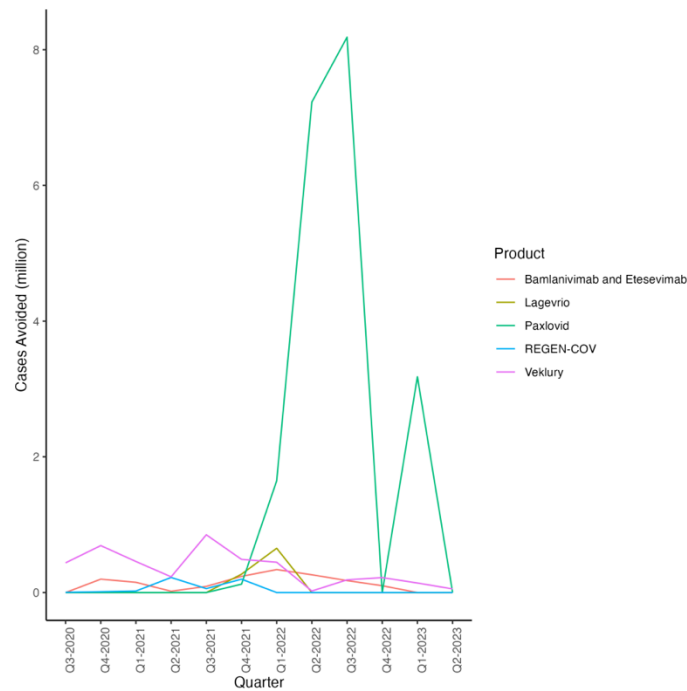
Table 5 Avoided Deaths Across Treatments

Company / Drug Name	Number of Doses (in millions)	Efficacy Rate (Source)	Implied Number of Avoided Deaths and Hospitalizations (in millions)	Avoided Deaths (in millions)	Economic Value of Avoided Deaths (in \$ trillions)
Gilead / Veklury	4.86	4.6% (Gottlieb et al. 2022)	0.22	0.03	0.36
Regeneron / REGEN-COV	2.86	2.92% (Weinrich et al 2021)	0.08	0.01	0.14
Lilly / Bamlanivimab & Etesevimab	1.34	5.03% (Dougan et al 2021)	0.07	0.01	0.11
Pfizer / Paxlovid	23.68	6.24% (Hammond et al 2021)	1.48	0.21	2.41
Merck / Lagevrio	3.08	6.8% (Jayk Bernal 2022)	0.21	0.03	0.34

By March 2023, there have been 676.6 million COVID-19 cases reported in the United States according to Johns Hopkins University (JHU) (2023). Given that the population of the United States is approximately 332 million, this indicates an average of more than 2 infections per person. The overall trend of avoided hospitalization or deaths from all treatments can be seen in Figure 5 below, which resembles Figure 4, as the estimated avoided hospitalizations and deaths are proportional in number to the courses administered.

¹⁰ Incident occurred in 28 of 385 participants (7.3%) in the treatment group and in 53 of 377 participants (14.1%) in the placebo group.

Figure 5 Hospitalization or Deaths Avoided by Quarter and Product



In Table 6, the revenues for companies manufacturing treatments are considered alongside the value generated by each company. The data shows that the appropriation of these revenues by treatment manufacturers ranges from 0.5% to 4.6%. Since we do not consider costs incurred by manufacturers, this is an upper bound on the share appropriated by treatment manufacturers. This proportion appears to be higher than the estimated industry appropriation for vaccine producers, which ranges from 0.2% to 2.6% across various counterfactual scenarios.

Table 6 Appropriation Across Therapeutics

Company / Drug Name	Covid-19 Therapeutic Revenue (\$ Billion)	Estimated Value from Avoided Deaths (\$ Trillion)	Appropriation (%)
Gilead / Veklury	7.59	0.36	2.11
Regeneron / REGEN-COV	6.01	0.14	4.30
Lilly / Bamlanivimab & Etesevimab	5.01	0.11	4.57
Pfizer / Paxlovid	12.55	2.41	0.52
Merck / Lagevrio	2.16	0.34	0.63

Note: The COVID-19 related revenues have been sourced from each company's quarterly financial results.

Section 5: Limitations

In this paper, we have omitted certain topics from our discussion that may affect our overall findings, but generally these limitations imply lower levels of appropriations than reported. For instance, Yamana et al. (2023) found that the reduction in hospitalizations enabled by vaccines and treatments were associated with health care cost savings. We are also unable to account for the impact the reduced hospitalization has on worker productivity and education outcomes due to fewer absentee days.

Given that production costs associated with a particular drug were proprietary, our estimates based on product revenues are an upper bound. Additionally, most studies measure

reduced risk of deaths and hospitalizations, but not deaths alone. Therefore, we extrapolate and estimate the avoided deaths. Our counterfactuals are wide in range but arbitrarily chosen but in a way such that they cover a variety of scenarios considered in past analyses. Lastly, reported revenues earned by the company are usually through negotiated prices, which are typically lower than list prices. Thus, our estimates may underestimate the number of doses sold and consequently the economic value of avoided deaths, leading us to overestimate appropriation.

Section 6: Concluding Discussion

The swift development and deployment of vaccines and therapeutics during the COVID-19 pandemic have underscored the essential clinical and economic role of medical innovation in addressing critical health crises. These advancements not only enhanced patient outcomes by reducing mortality and morbidity associated with the disease but also lessened the dependence on costly preventive strategies, such as cuts in economic activity.

Building on insights from the comprehensive research on parts of the pandemic's extensive impacts (Liang et al., 2020; UNESCO, 2021; UNWTO, 2022), our study offers a thorough analysis of industry appropriation – the portion of the societal value from innovation that accrues as earnings to innovators. We considered a wide range of counterfactual scenarios in the absence of innovation, including increased mortality rates and economic downturns. We also attempt to capture the elusive nature of earnings by correlating them with the more tangible metric of revenue. Under these robust and conservative assumptions industry appropriation varied between 0.2% and 2.6% for vaccine producers and 0.04% to 0.40% for treatment producers. Remarkably, these appropriation percentages are considerably lower than those in the existing evidence base for other medical innovations, as detailed in our study.

In conclusion, our findings indicate that the industry appropriation for COVID-19 medical innovations is modest compared to previous estimates for innovations in vaccines and medical treatments of other disease categories, indicating the significant value generated by these rapidly developed new COVID-19 innovations.

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Appendix I: List of Company Reports and News Releases

- https://s28.q4cdn.com/781576035/files/doc_financials/2021/q4/Q4-2021-PFE-Earnings-Release.pdf
- https://s28.q4cdn.com/781576035/files/doc_financials/2022/q1/Q1-2022-PFE-Earnings-Release.pdf
- https://s28.q4cdn.com/781576035/files/doc_financials/2022/q2/Q2-2022-PFE-Earnings-Release.pdf
- https://s28.q4cdn.com/781576035/files/doc_financials/2022/q3/Q3-2022-PFE-Earnings-Release.pdf
- https://s28.q4cdn.com/781576035/files/doc_financials/2022/q4/Q4-2022-PFE-Earnings-Release.pdf
- https://s28.q4cdn.com/781576035/files/doc_financials/2023/q1/Q1-2023-PFE-Earnings-Release.pdf
- <https://investor.regeneron.com/news-releases/news-release-details/regeneron-reports-third-quarter-2020-financial-and-operating>
- <https://investor.regeneron.com/news-releases/news-release-details/regeneron-reports-fourth-quarter-and-full-year-2020-financial>
- <https://investor.regeneron.com/news-releases/news-release-details/regeneron-reports-first-quarter-2021-financial-and-operating>
- <https://newsroom.regeneron.com/news-releases/news-release-details/regeneron-reports-second-quarter-2022-financial-and-operating>
- <https://newsroom.regeneron.com/news-releases/news-release-details/regeneron-reports-third-quarter-2022-financial-and-operating>
- <https://newsroom.regeneron.com/news-releases/news-release-details/regeneron-reports-fourth-quarter-and-full-year-2022-financial>
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- <https://newsroom.regeneron.com/news-releases/news-release-details/regeneron-reports-second-quarter-2022-financial-and-operating>
- <https://newsroom.regeneron.com/news-releases/news-release-details/regeneron-reports-third-quarter-2022-financial-and-operating>
- <https://newsroom.regeneron.com/news-releases/news-release-details/regeneron-reports-fourth-quarter-and-full-year-2022-financial>

- <https://investor.regeneron.com/news-releases/news-release-details/regeneron-reports-first-quarter-2023-financial-and-operating>
- <https://www.gilead.com/news-and-press/press-room/press-releases/2020/10/gilead-sciences-announces-third-quarter-2020-financial-results>
- <https://www.gilead.com/news-and-press/press-room/press-releases/2022/2/gilead-sciences-announces-fourth-quarter-and-full-year-2021-financial-results>
- <https://www.gilead.com/news-and-press/press-room/press-releases/2022/4/gilead-sciences-announces-first-quarter-2022-financial-results>
- <https://www.gilead.com/news-and-press/press-room/press-releases/2022/8/gilead-sciences-announces-second-quarter-2022-financial-results>
- <https://www.gilead.com/news-and-press/press-room/press-releases/2022/10/gilead-sciences-announces-third-quarter-2022-financial-results>
- <https://www.gilead.com/news-and-press/press-room/press-releases/2022/2/gilead-sciences-announces-fourth-quarter-and-full-year-2021-financial-results>
- <https://www.gilead.com/news-and-press/press-room/press-releases/2022/4/gilead-sciences-announces-first-quarter-2022-financial-results>
- <https://www.gilead.com/news-and-press/press-room/press-releases/2022/8/gilead-sciences-announces-second-quarter-2022-financial-results>
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