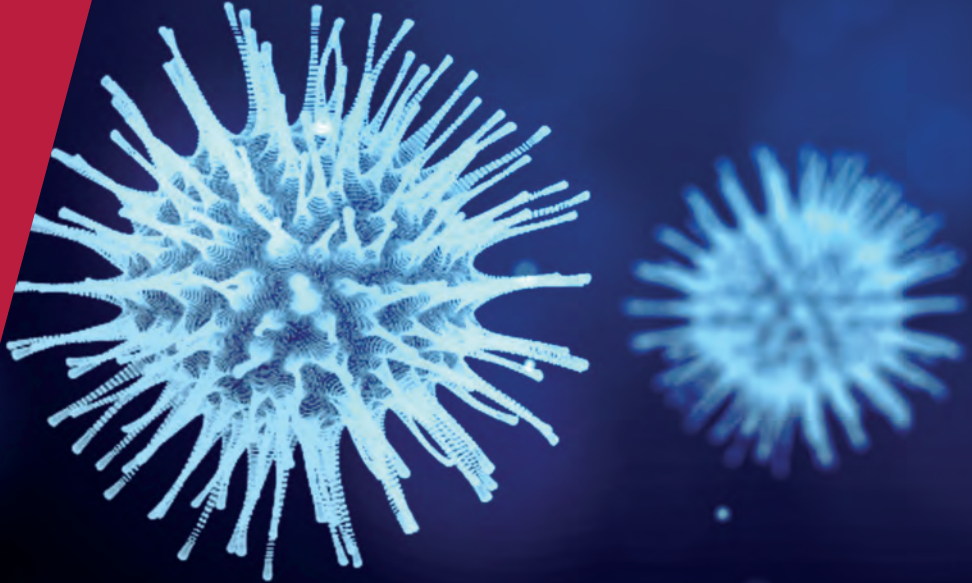


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COVID ECONOMICS
VETTED AND REAL-TIME PAPERS

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Covid Economics

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Ethics

Covid Economics will feature high quality analyses of economic aspects of the health crisis. However, the pandemic also raises a number of complex ethical issues. Economists tend to think about trade-offs, in this case lives vs. costs, patient selection at a time of scarcity, and more. In the spirit of academic freedom, neither the Editors of *Covid Economics* nor CEPR take a stand on these issues and therefore do not bear any responsibility for views expressed in the articles.

Submission to professional journals

The following journals have indicated that they will accept submissions of papers featured in *Covid Economics* because they are working papers. Most expect revised versions. This list will be updated regularly.

<i>American Economic Review</i>	<i>Journal of Econometrics*</i>
<i>American Economic Review, Applied Economics</i>	<i>Journal of Economic Growth</i>
<i>American Economic Review, Insights</i>	<i>Journal of Economic Theory</i>
<i>American Economic Review, Economic Policy</i>	<i>Journal of the European Economic Association*</i>
<i>American Economic Review, Macroeconomics</i>	<i>Journal of Finance</i>
<i>American Economic Review, Microeconomics</i>	<i>Journal of Financial Economics</i>
<i>American Journal of Health Economics</i>	<i>Journal of International Economics</i>
<i>Canadian Journal of Economics</i>	<i>Journal of Labor Economics*</i>
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	<i>Quarterly Journal of Economics*</i>
	<i>Review of Economics and Statistics</i>
	<i>Review of Economic Studies*</i>
	<i>Review of Financial Studies</i>

(*) Must be a significantly revised and extended version of the paper featured in *Covid Economics*.

Covid Economics

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Tracking inflation on a daily basis¹

Santiago E. Alvarez² and Sarah M. Lein³

Date submitted: 5 August 2020; Date accepted: 6 August 2020

Using online data for prices and real-time debit card transaction data on changes in expenditures for Switzerland allows us to track inflation on a daily basis. While the daily price index fluctuates around the official price index in normal times, it drops immediately after the lockdown related to the COVID19 pandemic. Official statistics reflect this drop only with a lag, specifically because data collection takes time and is impeded by lockdown conditions. Such daily real-time information can be useful to gauge the relative importance of demand and supply shocks and thus inform policy makers who need to determine appropriate policy measures.

1 We thank Rahel Braun, Matthias Gubler, Brigitte Guggisberg, and Barbara Rudolf for helpful comments and suggestions on an earlier draft. We furthermore thank Martin Brown, Matthias Fengler, Robert Rohrkemper, and Raphael Lalive for making their debit card data publicly available.

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1 Introduction

The COVID19 pandemic has led to dramatic changes in expenditures across product categories.¹ Moreover, prices may reflect both negative demand and supply shocks, which have arguably affected the economy to an unprecedented degree. This makes it difficult for statistical agencies to accurately measure consumer prices in real time because expenditures are usually collected at a low frequency and price collection is partially impossible because the retail outlets where statistical agencies usually collect prices are closed.²

Additionally, policymakers must counter the crisis with the appropriate measures. These may differ depending on the relative importance of supply and demand shocks. The large decline in overall aggregate production or nominal consumption cannot inform on this because negative demand and supply shocks move quantities in the same direction. Furthermore, prices reflect these opposing forces since demand and supply shocks of the same sign push prices in opposite directions. This makes a daily price index a useful source of information for policymakers.

In this paper, we construct a daily price index based on scraped online price data and expenditure weights based on debit card transactions by product category for Switzerland. This index allows us to monitor changes in the price level in real time and on a daily basis. We complement this index with data on the consumer price index (CPI) for categories for which we lack online prices or high-frequency changes in expenditure weights. We first show that the index is close to the official CPI before the lockdown, suggesting that we measure the same underlying dynamics. We then show that prices declined immediately after the lockdown, information that becomes available in official CPI figures only much later. Compared to the week before the lockdown, the daily price index declines by approximately 0.4% immediately after the lockdown and by approximately 0.7% until the time of this writing (the second week of July 2020). Using online prices during the lockdown can also be useful because many purchases have to be made online since retail stores are closed (for example, purchases of

¹See, for example, Brown et al. (2020), Carvalho et al. (2020), Baker et al. (2020), Coibion et al. (2020), or Andersen et al. (2020).

²See Diewert and Fox (2020) for a detailed exposition of the problems surrounding CPI construction and data collection during the pandemic.

apparel). According to recent evidence based on point-of-sale transaction data, online retail payments related to e-commerce more than doubled during the lockdown period, compared to the same period in 2019 (Kraenzlin et al., 2020). Thus, with local retail stores being closed, online prices arguably reflect most of the purchases made during that period.

We show two applications for which such high-frequency data could be informative. First, we can observe both changes in quantities and prices by sector from before the lockdown to the period where many businesses were closed. Changes in prices and expenditures are very heterogeneous across sectors. We show that expenditures on food and beverages (at home) increase somewhat in total, and also prices increase. Meanwhile, prices and expenditures in categories are directly (accommodation and restaurants; entertainment; personal and professional services; other retail) and indirectly (transport) affected by the lockdown decline. Observing prices and quantities moving in the same direction suggests that, while clearly supply and demand shocks are both present, demand shocks are somewhat more prevalent at the moment, suggesting a slightly positive demand shock in the food at home category, and negative ones in the other categories named above. Using a daily price index by category allows us to monitor these sectoral developments closely, since the strength of demand and supply shocks may fade more or less quickly.

Second, we can ask whether prices are more or less flexible during and after the lockdown period?³ Looking at weekly frequencies of price adjustments, we do not find a significant increase or decline in the frequency of price adjustments during the lockdown period. However, when looking at different product categories, we find a somewhat higher frequency of price increases in the food and beverages category, while price adjustment frequencies in the other sectors are either stable or decline slightly. Here, too, monitoring the frequency of price adjustment on a high-frequency and real-time basis may turn out useful in the aftermath of the lockdowns to track potential inflationary or deflationary pressures.

This paper is related to Diewert and Fox (2020), who suggest using online prices and real-time

³This question is related to the empirical literature on state- versus time-dependent pricing. One of the main findings in this literature is that the frequency of price adjustment looks very stable in periods where aggregate shocks are not very large on average, but the frequency of price adjustment can vary a lot when shocks are large, as shown for example in Gagnon (2009), Karadi and Reiff (2010), and Auer et al. (2018).

expenditure weights to construct the CPI during lockdown conditions. Our paper is an attempt to create such an index. It is also related to the literature on scraped online price data and their use in measuring the cost of living. Cavallo (2017) shows that online prices are similar to offline prices, suggesting that at least some of the prices underlying CPI calculations could be collected using scraping tools.⁴ We show that replacing approximately 25% of the CPI basket with online prices results in very similar dynamics to those of the official monthly CPI before the COVID19-related lockdown. Our paper is therefore also related to the recent studies that monitor the economic consequences of COVID19, in particular the effects on inflation.⁵ Balleer et al. (2020) use a monthly business tendency survey from Germany to infer the response of the price level to the COVID19 shock using firms' responses to questions about their prices in the coming months. They find that prices tend to decline, consistent with what our index shows for Switzerland.⁶

Our work also relates to Cavallo (2020) and Seiler (2020), who show that updating the CPI weights with changes in credit or debit card expenditures by product category results in higher aggregate price levels after lockdowns than those reported in official CPI figures with fixed pre-shock weights. Consistent with their findings, our price level is also higher when using CPI prices and adjusted weights. However, because online prices tend to decline on average by more than official CPI prices, which therefore results in a decline in the aggregate price level, also when the CPI adjusted weights are included.

Furthermore, our results on sectoral heterogeneity in responses of prices and quantities is related to (Baqaee and Farhi, 2020) and Guerrieri et al. (2020). Both show that differences across sectors are important to understand the propagation of (sectoral) supply and demand shocks. Monitoring both changes in quantities and prices for different product categories (or sectors) can thus be informative for the debate over whether the COVID19 shock is more of a supply or demand shock (see, for example, Baldwin and Weder di Mauro (2020), Balleer

⁴See also Cavallo and Rigobon (2016) and Cavallo et al. (2018).

⁵For daily indicators of economic activity, see for example, Burri and Kaufmann (2020), Eichenauer et al. (2020), or Lengwiler (2020).

⁶Overall, recent research suggests that price responses differ across sectors. Burghof et al. (2020) collect online prices for five supermarkets in Germany. They find a slight increase in these prices of approximately 0.8% between February and April.

et al. (2020), and Brinca et al. (2020).)

This paper is structured as follows. In section 2, we describe the online price data and the construction of price indexes. In section 3, we report the price indexes up to the most recent data point as of this writing. We also discuss potential biases in official statistics during the lockdown. Section 4 documents the frequency of price adjustments in the aggregate and by category. Section 5 draws some conclusions.

2 Data and methodology

Data for prices have been scrapped from various websites on a daily basis since May 2018 for supermarket goods and since May 2019 for other categories, such as clothing, electronics, furniture and heating oil. See Alvarez (2020) for a more detailed description. In this study, we focus on the data starting in May 2019 because we have a broader set of goods in the database. The data were extracted from six online retailers selling in the categories “Food, alcohol & tobacco”, “Clothing & footwear,” “Heating oil,” “Furniture,” “Electronics,” “Office material,” and other supermarket items.⁷ The majority of these retailers also have physical stores across Switzerland. These data allow us to identify products uniquely over time using shop-specific identifiers.

Table 1 provides an overview of the data and compares it to the official Swiss Federal Statistical Office (SFSO) main categories. Some of the categories are covered entirely by online prices such as “Food and non-alcoholic beverages” or “Clothing and footwear”. For some categories, such as “Housing and energy”, the substitution of official (SFSO) prices can be performed at lower levels of the CPI. Thus, online prices do not cover the entire main category weight (see Table A.1 in the Appendix for a detailed overview of the replaced categories at different levels of aggregation). As services account for approximately 60% of the CPI basket weight, we are able to update the index with daily online data representing more than half of the weight for goods. The total number of products used for this analysis

⁷These retailers are Interdiscount, Mediamarkt, Coop, Ikea, Zalando, and Heizoel.ch.

is 75,311.⁸

Table 1: *Used CPI Basket and weights*

Name	Source		Weight			
	Prices	Weight	SFSO	Online	Lockdown	Prod.
Food and non-alcoholic beverages	Online	Debit card	10.54	10.54	14.93	8221
Alcoholic beverages	Online	Debit card	2.76	2.76	3.91	351
Clothing and footwear	Online	Debit card	3.4	3.4	.91	26223
Housing and energy	Online*	SFSO	24.96	.69	33.14	9
Household goods and services	Online*	SFSO	3.79	3.35	5.03	13679
Healthcare	Online*	SFSO	15.69	.21	20.83	47
Transport	SFSO	Debit card	10.97	0	8.08	0
Communications	Online*	SFSO	2.94	.17	3.91	691
Recreation and culture	Online*	Debit card	8.37	2.12	4.509	22778
Education	SFSO	SFSO	1	0	1.32	0
Restaurants and hotels	SFSO	Debit card	9.46	0	1.17	0
Other goods and services	Online*	Debit card	6.12	1.59	1.92	3312
Total	Online*	Debit card*	100	24.502	100	75311

Notes: Categories in which source contains * are categories in which part of their weight was substituted either with online data or debit card data, but at lower levels of the CPI basket (see A.1 in the Appendix for the exact matching). SFSO weights are the official CPI basket weights, online weights indicates the part out of the official weights covered by online prices, and lockdown weights are weights for the first week after the lockdown adjusted using credit card transactions data.

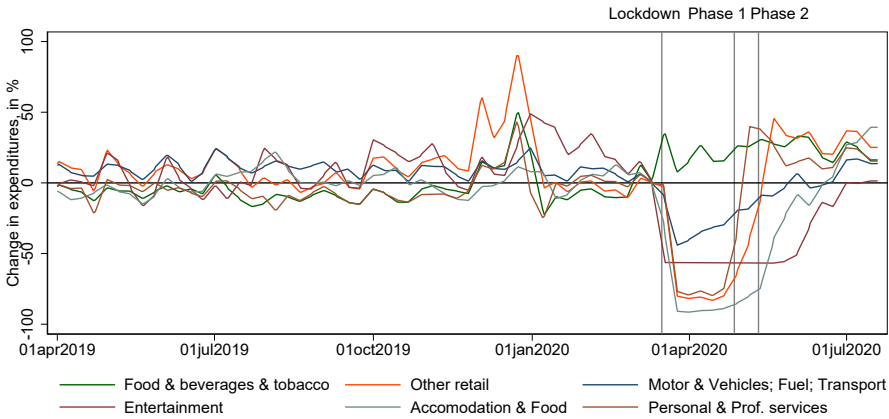
To construct representative consumption baskets, we use the product category weights provided by the SFSO. Beginning in January 2020, we update these weights to reflect changes in consumption patterns before, during, and after the lockdown, as suggested in Cavallo (2020) and applied for the Swiss CPI in Seiler (2020). Daily real-time data for quantities per product category are taken from daily debit card expenditures published by the Monitoring Consumption Initiative for Switzerland.⁹ We sum expenditures by category and week over regions (Grossregion). We sum the three categories “Motor & Vehicles”, “Fuel”, and “Transport”,

⁸Note that these can be a given good but identified at two different retailers (e.g., one specific PC that is sold by two different retailers) or in the case of heating oil the same good sold across different locations.

⁹See <http://monitoringconsumption.org/switzerland>, which is a joint initiative of the University of St. Gallen, the University of Lausanne, and Novalytica. The data are publicly available. They contain similar information to, for example, the OpportunityInsights data for the US described in Chetty et al. (2020) and used in Cavallo (2020).

because they are all included in the CPI category (“Transport”). We use weekly data because the daily data are noisier due to day-of-the-week effects (very small numbers of transactions on Sundays). We show the expenditure data by category relative to the week before the first lockdown phase that began on March 16, 2020 in Figure 1.¹⁰

Figure 1: *Changes in expenditures by category*



Notes: These figures show 7-day moving averages of weekly deviations of total expenditures by category, relative to the week before March 16, 2020, the date of the lockdown in Switzerland. The vertical lines indicate the dates of the lockdown (3/16/2020) and the phases of reopening (4/27/2020 and 5/11/2020). Data source: <http://monitoringconsumption.org/switzerland>

These shifts in consumption expenditures are then reflected in changes in CPI category weights during the lockdown. For example, the weight of the category “Food and non-alcoholic beverages” increases by almost 50% from 10.5% to 15.5% (Table 1, comparing the third with the fifth column). Meanwhile, the weight of “Restaurants and hotels” declines from 9.5% to only 1.2%. Related to these expenditure shifts, relative expenditures on categories, where nominal expenditures remain mostly constant, go up. “Housing and energy”, for example, includes rents, which probably do not change much during the lockdown (a weight of 24.3% in the total CPI). Since total expenditures on the debit card categories decline, the relative weight on rents increases to 35% (rents are arguably not paid with debit cards, but via regular

¹⁰Switzerland had strict restrictions in place from 3/16 to 4/26, opened lower-risk businesses and retail stepwise between 4/27 and 6/15, with openings of hairdressers, cosmetic studios, DIY stores, flower shops and garden centers in the first step, and shops, restaurants, markets, museums and libraries in the second step (as of 5/11).

bank account transactions).

One caveat of the debit card expenditure data is that it includes only debit cards and not credit cards. Arguably, online spending is mostly done via credit card transactions. This online spending is thus probably not included in our weights and may overstate the decline in retail products, that were not available in closed stores, but still available online. Our main price index, as we describe below, is an average of an index that fully reflects these expenditure shifts (Paasche) and an index that does not reflect these shifts (Laspeyres). This potential overstated decline is therefore muted in our main price index (Fisher).

To compute the price index on a daily basis, we proceed in two steps. First, we use the CPI weights, which do not reflect changes in consumption due to the lockdown. We replace prices in the CPI with daily online prices for all categories with online prices, as shown in Table 1. For each category $j = 1..J$, we construct a category-level Jevons index over the set of $i = 1..N$ products observed in the base period, which is the week before the lockdown (9/3/2020 – 15/3/2020) as

$$P_j^t = \prod_{i=1}^N \left(\frac{P_i^t}{P_i^0} \right)^{\frac{1}{N}} \tag{1}$$

We construct a daily version of a Laspeyres (1871) price index

$$P_{La}^t = \sum_{j=1}^J \frac{P_j^t}{P_j^0} w_j^{0,CPI} \tag{2}$$

where P_j^t equals the price index for online goods in equation 1 or the CPI category price index from the SF50 where online prices are not available. The weight w_j^{CPI} is from the CPI and thus does not reflect contemporaneous changes in consumption patterns due to the pandemic.

We then construct a daily version of a Paasche (1874) price index

$$P_{Pa}^t = \left[\sum_{j=1}^J \left(\frac{P_j^t}{P_j^0} \right)^{-1} w_j^{t,COVID} \right]^{-1} \tag{3}$$

where we include the COVID-adjusted current-day weights and measure the price of the COVID basket at prices in the base period.

As is well known, the Laspeyres (Paasche) index tends to be upward (downward) biased in normal periods because consumers substitute towards products that become relatively cheaper. This means that the Laspeyres index tends to underweight the products that become cheaper, while the Paasche index overweights them. However, during the lockdown period, consumers substantially shift expenditures towards food at home and away from categories that are produced by sectors that are temporarily shut down. This substitution is not a result of relative price shifts but of many products not being available.

The Fisher index, calculated as the geometric average of the Paasche and Laspeyres indexes, should be unbiased in normal periods because it averages out the upward and downward biases of the Laspeyres and Paasche indexes, respectively. The index is thus

$$P_t^{Fis} = (P_t^{Paa} \cdot P_t^{Las})^{0.5}, \quad (4)$$

which we use as our main index reflecting changes in both expenditures and prices.

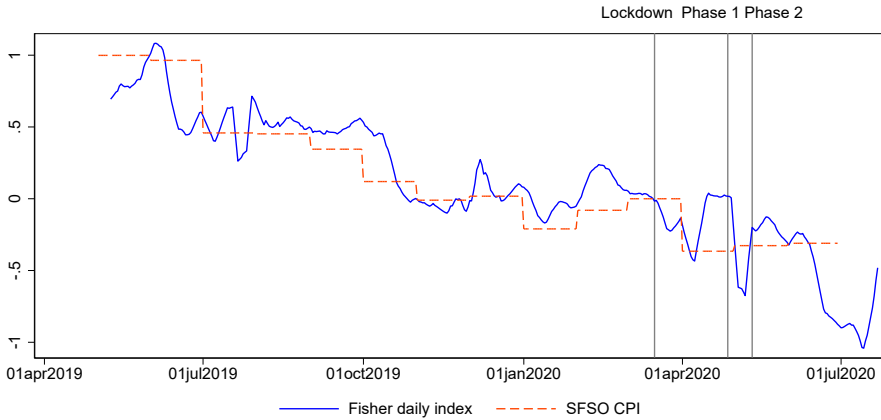
3 Daily price indexes before, during, and after the lockdown

This section first shows how the daily Fisher price index compares to the official monthly CPI when considering a longer horizon. It then shows the lockdown period in particular and discusses biases arising from large shifts in consumption patterns.

Can online prices track official statistics at all? Figure 2 plots the seven-day moving average of the daily price index (in logs) together with the official CPI statistics since mid-2019. The longer history of this daily price index shows that it fluctuates around the official index in 2019, even though it includes only online prices for approximately 25% of the total sample. This is consistent with the results in Cavallo (2017) that online and offline prices are similar in normal times and that online prices can be used as inputs for CPI calculations instead of offline prices. While Figure 2 includes the CPI prices for categories, for which we do not have online prices, the similarity is not only driven by these categories. Figure A.1 in the appendix shows the comparison of online prices with those of the CPI only for the categories where we

could replace CPI prices with online prices. The dynamics are similar.

Figure 2: *Daily price indexes from May 2019 to July 2020*

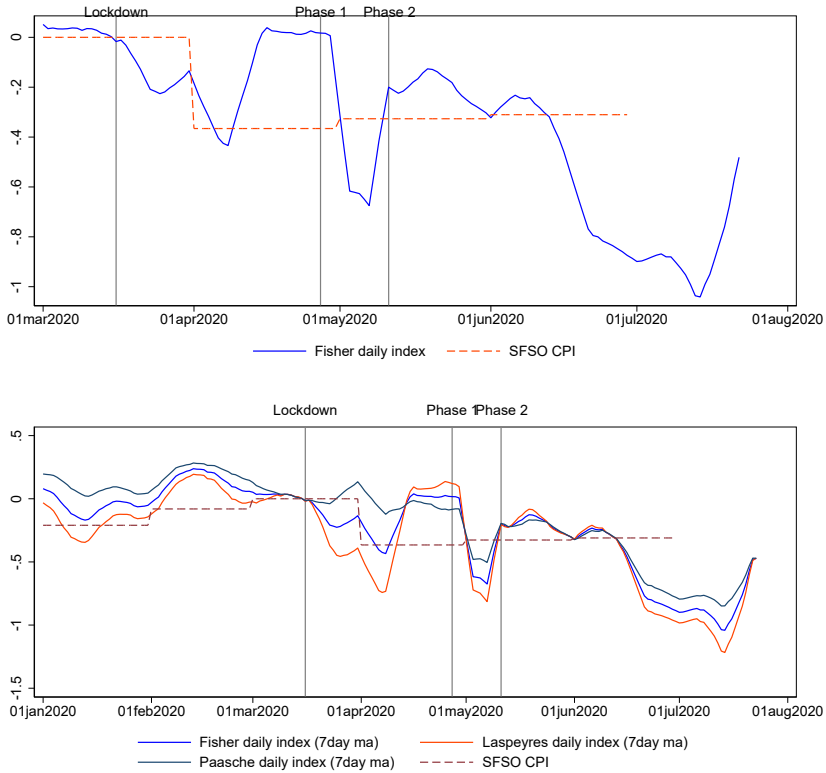


Notes: This figure shows the Fisher price index based on daily online prices and daily credit card expenditures (blue solid line; 7 day lagged moving average) and the official monthly CPI (red dashed line). The vertical lines indicate the dates of the lockdown (3/16/2020) and the two phases of reopening (4/27/2020 and 5/11/2020). The figure spans the period 5/1/2019 to 7/23/2020.

Figure 3 shows daily price indexes in 2020. The beginning of the lockdown is shown as a vertical line on March 16, and the beginning of the two reopening phases are shown for April 27 and May 11 (see also footnote 2). In the upper panel, we show the Fisher daily index and the official CPI around the lockdown and the reopening phases. The Fisher index shows that immediately after the lockdown, prices declined by approximately 0.4%. This information is available approximately six weeks earlier than the official index, which is released in early April for data collected for the month of March. The online index declines by a similar amount as the official index, after it has been updated with the prices that could be collected at the time.¹¹ This suggests that, in the very short run, negative demand shocks dominate negative supply shocks, consistent with findings for Germany based on producer surveys (Balleer et al., 2020).

¹¹According to press releases from the SFSO, approximately 20% of all prices could not be collected in April. This share increases to 25% for the sectors most affected by the pandemic.

Figure 3: Daily price indexes in 2020



Notes: The upper panel in this figure shows the Fisher price index based on daily online prices and daily credit card expenditures (blue solid line; 7 day lagged moving average) and the official monthly CPI (red dashed line) around the lockdown and reopening period. The lower panel shows the Fisher (blue), Laspeyres (red), and Paasche (gray) indexes during the lockdown and reopening periods together the official monthly CPI (red dashed line). The vertical lines indicate the dates of the lockdown (3/16/2020) and the two phases of reopening (4/27/2020 and 5/11/2020). The figure spans the period 5/1/2019 to 7/23/2020.

The bottom panel of Figure 3 shows the three daily price indexes: Paasche, Laspeyres, and Fisher. The difference between the Laspeyres and Fisher indexes illustrates the extent of substitution bias. It is larger in the period after the lockdown, which reflects the large shifts in spending patterns depicted in Figure 3. The bias amounts to up to 0.3 percentage points, which is approximately three times larger than the substitution bias estimated before the

pandemic.¹² In normal times, the Laspeyres index tends to overestimate inflation because consumers substitute towards products that become relatively cheaper. In this case, we observe the opposite: consumers substitute towards product categories where prices were more or less stable (mostly food, beverages, and tobacco), while expenditures on product categories with falling prices decrease substantially. This is also reflected in the Paasche index, which is nearly stable (see Figure 4). This suggests that consumers substitute away from product categories that become relatively cheaper. This is because consumers cannot demand many of the goods from these categories due to lockdown restrictions or because tastes shift away from these goods. However, the bias is relatively short lived and becomes smaller again after the end of the lockdowns.

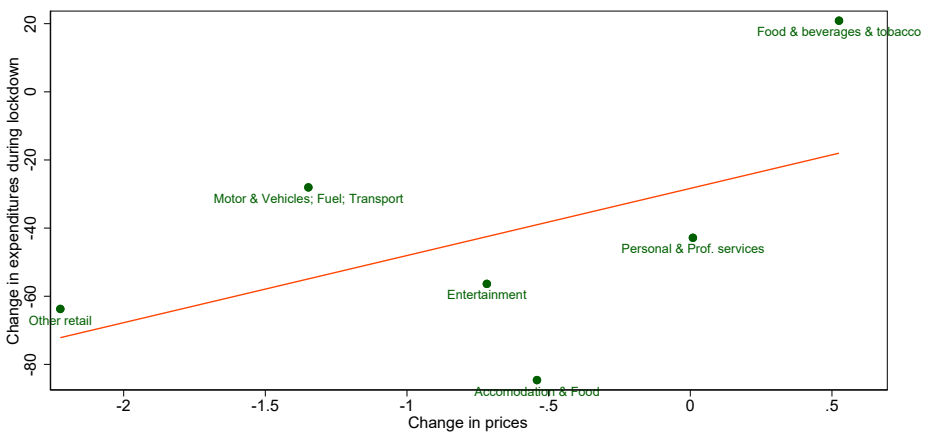
Shifts in prices and expenditures can also be compared across product categories, as it is very likely that some were affected more severely by demand shocks, while others were affected more by supply shocks (Baqae and Farhi, 2020). In general, prices and quantities tend to move in the same direction in the case of demand shocks, while they move in opposite directions in the case of supply shocks. Observing both changes in quantities and prices is thus interesting regarding the debate over whether the COVID19 shock is more of a supply or demand shock and how that differs across sectors.

Figure 4 plots the changes in prices and associated changes in spending. It shows that the price decline was particularly strong in the retail sector (excluding “Food, beverages & tobacco”), which also shows a relatively large decline in expenditures (approx. -50%). Similar movements, albeit less pronounced, can be seen in the sector “Transport”. These falling prices and even greater reductions in expenditure are typically accompanied by a negative demand shock. Consumer spending falls most sharply in the “Hotels and restaurants” and “Leisure and culture” sectors, which were not allowed to open or only partially open. Here, too, prices fall slightly, albeit less sharply than in the sectors mentioned above. Expenditures also fall in the “Services” sector, with prices remaining almost unchanged. This would indicate that here, the demand and supply shocks are roughly balanced. In the “Food, beverages &

¹²This is also consistent with Diewert et al. (2009), who report a substitution bias of 0.13% for the Swiss CPI for the period 1993-2002

tobacco” sector, which was not affected by the lockdown, spending actually increased while prices remained stable. This would indicate an approximately balanced expansion of demand and supply in this sector. This is consistent with anecdotal evidence that, although initial demand in supermarkets soared just before and after the lockdown due to stockpiling motives, supply was generally not constrained.

Figure 4: *Relationship between the change in prices and change in expenditures during the lockdown*

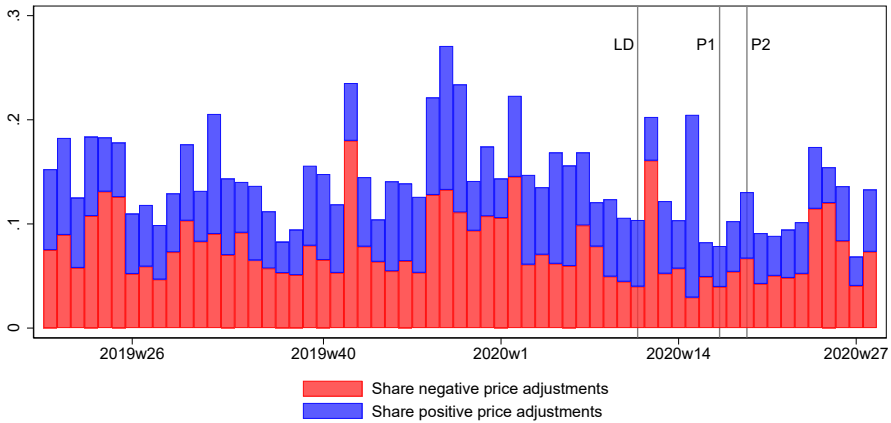


Notes: This figure shows a scatter plot of the change in average expenditures and average change in prices during the lockdown period from 3/16/2020 to 5/11/2020.

4 Price setting behaviour before, during, and after the lockdown

How flexibly do prices respond to the lockdown? For answering this question, we first show the share of all included products that adjust their prices on a weekly basis (Figure 5, which plots the frequency of positive and negative price changes in stacked bars). There is no significant change in the frequency of price adjustments when looking at all categories together. This, however, might be caused by different changes on pricing behaviour by categories of goods. Furthermore, there is no clear change in the frequency of positive or negative price changes.

Figure 5: Share of price adjustments



Notes: This figure shows the fraction of price increases and decreases (as a share of all prices observed) on a weekly basis (that is, a price change is observed if a price changes from one week to the next). Red bars are price decreases and blue bars price increases. The bars are stacked, such that the total length of the bar indicates the total fraction of price changes per week. LD, P1, P2, stand for lockdown, phase 1 and phase 2, respectively.

Table 2: Averages of weekly shares of price adjustments by period

Category	Period			
	Before LD	LD-P1	P1-P2	After P2
Food and non-alcoholic beverages	.0354	.0429	.0553	.0344
Clothing and footwear	.2181	.2268	.104	.1745
Household goods and services	.106	.0823	.1077	.1238
Recreation and culture	.1555	.1087	.0851	.0939
All products	.1412	.1128	.0907	.116

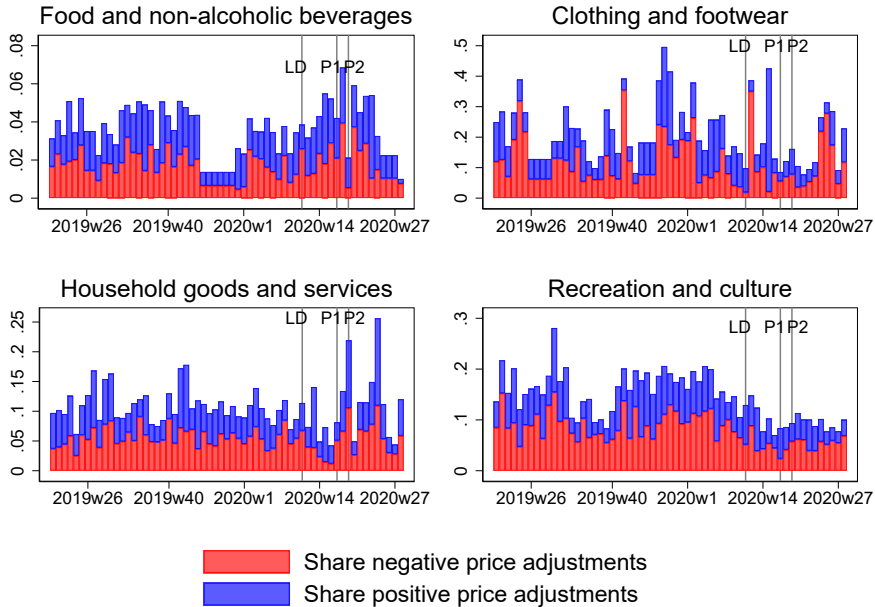
Notes: This table shows the average share of price adjustments by product category and in total during all weeks by period. LD, P1, P2, stand for lockdown (3/16/2020), phase 1 (4/27/2020) and phase 2 (5/11/2020), respectively. For example, in the product category food and non-alcoholic beverages, the weekly share of price changes is computed for each week and then we measure the average of all weeks before the LD and report it in the first column. Total includes all observed products, not only the products of the four categories displayed. Total includes all observed products, not only the products of the four categories displayed.

Table 2 shows the average share of price adjustments across the weeks included in each time interval for the four categories “Food and non-alcoholic beverages”, “Clothing and footwear”,

“Household goods and services”, and “Recreation and culture”. Similar to the heterogeneity in price and expenditure changes across categories reported above, there are some differences across categories in the frequency of price adjustments. While price adjustments in “Food and non-alcoholic beverages” become somewhat more prevalent during the two phases of the lockdown (first row in Table 2 and upper left panel in Figure 6), the price adjustments in the category “Recreation and culture” become less frequent (fourth row in Table 2 and lower right panel in Figure 6). Prices change less frequently during the lockdown in the category “Household goods and services”, but more frequently after the lockdown, and with more positive price adjustments (third row in Table 2 and lower left panel in Figure 6). The frequency of price adjustment in the category “Clothing and footwear” is somewhat lower on average (second row in Table 2 and upper right panel in Figure 6) between phase 1 and 2, but it is very volatile overall with weeks that show up to 50% of all prices changing (the scales across categories differ in Figure 6). This is likely due to frequent sales in this category.¹³

¹³Also, products traded online have on average higher price adjustment frequencies as suggested in Rudolf and Seiler (2020), who look at Swiss micro data underlying the CPI.

Figure 6: *Share of price adjustments by category*



Notes: This figure shows the fraction of price increases and decreases (as a share of all prices observed) on a weekly basis (that is, a price change is observed if a price changes from one week to the next) for selected product categories. Red bars are price decreases and blue bars price increases. The bars are stacked, such that the total length of the bar indicates the total fraction of price changes per week. LD, P1, P2, stand for lockdown, phase 1 and phase 2, respectively.

Sizes of price adjustments are similar before and after the lockdown, as reported in Appendix B.

5 Conclusion

In this note, we propose a daily price index composed of daily scraped online prices for different product categories and debit card expenditures by product category. We update prices and weights of CPI categories for which we have this additional high-frequency information.

We show that the index reflects the official monthly CPI quite well in the period before the lockdown, thus confirming that online prices carry similar information as the prices

that are included in the CPI. The index shows that prices decline immediately after the lockdown and remain approximately 0.4% lower than those in the week just before the lockdown was implemented, supporting recent evidence suggesting that negative demand shocks are somewhat larger than negative supply shocks. This is also the case for most product categories, where prices and expenditures both fell and thus suggest that demand shocks dominated at this point in time.

While our index can be useful for policymakers to track inflation in real time, we do not make any statements about the longer-term effects of the pandemic recession on inflation. However, since prices that consumers observe in their daily lives are an important ingredient of consumers' inflation expectation formation process (D'Acunto et al., 2019), the daily inflation figures may carry some information about longer-term inflation expectations, which will be an important factor in determining inflation in the medium run.

References

ALVAREZ, S. E. (2020): “Online Price Dynamics,” work in progress, University of Basel.

ANDERSEN, A. L., E. T. HANSEN, N. JOHANNESSEN, AND A. SHERIDAN (2020): “Consumer Responses to the COVID-19 Crisis: Evidence from Bank Account Transaction Data,” Discussion Paper 14809, CEPR.

AUER, R., A. T. BURSTEIN, AND S. M. LEIN (2018): “Exchange rates and prices: evidence from the 2015 Swiss franc appreciation,” *BIS Working Paper*.

BAKER, S. R., R. FARROKHANIA, S. MEYER, M. PAGEL, AND C. YANNELIS (2020): “How Does Household Spending Respond to an Epidemic? Consumption During the 2020 COVID-19 Pandemic,” *Covid Economics*, 18.

BALDWIN, R. AND B. WEDER DI MAURO (2020): “Economics in the time of COVID-19: A new eBook,” Tech. rep., VoxEU.org.

BALLEER, A., S. LINK, M. MENKHOFF, AND P. ZORN (2020): “Demand or Supply? Price Adjustment during the Covid-19 Pandemic,” Discussion paper, CEPR.

BAQAEE, D. AND E. FARHI (2020): “Supply and Demand in Disaggregated Keynesian Economies with an Application to the Covid-19 Crisis,” Working Paper 27152, National Bureau of Economic Research.

BRINCA, P., J. DUARTE, AND M. FARIA-E CASTRO (2020): “Measuring Sectoral Supply and Demand Shocks during COVID-19,” *Covid Economics*, 20.

BROWN, M., M. FENGLER, R. LALIVE, R. ROHRKEMPER, AND T. SPYCHER (2020): “Spreading out: COVID-19 and the changing geography of consumption,” Tech. rep., LSE Business Review, <https://blogs.lse.ac.uk/businessreview/2020/06/30/spreading-out-covid-19-and-the-changing-geography-of>

BURGHOF, H.-P., J. SWIATKOWSKI, AND M. PUKE (2020): “Corona-Preise an der Supermarktkasse und die Geldpolitik der EZB,” Tech. rep., Universität Hohenheim.

- BURRI, M. AND D. KAUFMANN (2020): “A daily fever curve for the Swiss economy,” IRENE Working Papers 20-05, IRENE Institute of Economic Research.
- CARVALHO, V. M., S. HANSEN, A. ORTIZ, J. R. GARCIA, T. RODRIGO, S. RODRIGUEZ MORA, AND J. RUIZ (2020): “Demand or Supply? Price Adjustment during the Covid-19 Pandemic,” Discussion Paper 14642, CEPR.
- CAVALLO, A. (2017): “Are Online and Offline Prices Similar? Evidence from Large Multi-channel Retailers,” *American Economic Review*, 107, 283–303.
- (2020): “Inflation with Covid Consumption Baskets,” Working Paper 27352, National Bureau of Economic Research.
- CAVALLO, A., W. E. DIEWERT, R. C. FEENSTRA, R. INKLAAR, AND M. P. TIMMER (2018): “Using Online Prices for Measuring Real Consumption across Countries,” *AEA Papers and Proceedings*, 108, 483–87.
- CAVALLO, A. AND R. RIGOBON (2016): “The Billion Prices Project: Using Online Prices for Measurement and Research,” *Journal of Economic Perspectives*, 30, 151–178.
- CHETTY, R., J. N. FRIEDMAN, N. HENDREN, AND M. STEPNER (2020): “Real-Time Economics: A New Platform to Track the Impacts of COVID-19 on People, Businesses, and Communities Using Private Sector Data,” Paper, Harvard Kennedy School.
- COIBION, O., Y. GORODNICHENKO, AND M. WEBER (2020): “The Cost of the Covid-19 Crisis: Lockdowns, Macroeconomic Expectations, and Consumer Spending,” *Covid Economics*, 20.
- D’ACUNTO, F., U. MALMENDIER, J. OSPINA, AND M. WEBER (2019): “Exposure to Daily Price Changes and Inflation Expectations,” Working Paper 26237, National Bureau of Economic Research.
- DIEWERT, W. E. AND K. J. FOX (2020): “Measuring Real Consumption and CPI Bias under Lockdown Conditions,” Working Paper 27144, National Bureau of Economic Research.

- DIEWERT, W. E., M. HUWILER, AND U. KOHLI (2009): “Retrospective Price Indices and Substitution Bias,” *Swiss Journal of Economics and Statistics (SJES)*, 145, 127–135.
- EICHENAUER, V. E., R. INDERGAND, I. Z. MARTINEZ, AND C. SAX (2020): “Constructing Daily Economic Sentiment Indices Based on Google Trends,” Working Papers 484, KOF ETH Zurich.
- GAGNON, E. (2009): “Price Setting During Low and High Inflation: Evidence from Mexico,” *The Quarterly Journal of Economics*, 124, 1221–1263.
- GUERRIERI, V., G. LORENZONI, L. STRAUB, AND I. WERNING (2020): “Macroeconomic Implications of COVID-19: Can Negative Supply Shocks Cause Demand Shortages?” Working Paper 26918, National Bureau of Economic Research.
- KARADI, P. AND A. REIFF (2010): “Inflation Asymmetry, Menu Costs and Aggregation Bias – A Further Case for State Dependent Pricing,” Working Paper 2010-3, Magyar Nemzeti Bank.
- KRAENZLIN, S., C. MEYER, AND T. NELLEN (2020): “COVID-19 and regional shifts in Swiss retail payments,” mimeo, Swiss National Bank.
- LASPEYRES, E. (1871): “Die Berechnung einer mittleren Waarenpreissteigerung,” *Jahrbücher für Nationalökonomie und Statistik*, 16, 296–314.
- LENGWILER, Y. (2020): “Blacking out,” Working papers 2020/07, Faculty of Business and Economics - University of Basel.
- PAASCHE, H. (1874): “Über die Preisentwicklung der letzten Jahre nach den Hamburger Börsennotirungen,” *Jahrbücher für Nationalökonomie und Statistik*, 12, 168–178.
- RUDOLF, B. AND P. SEILER (2020): “Some evidence on the impact of e-commerce on price setting behaviour,” mimeo, Swiss National Bank.
- SEILER, P. (2020): “Weighting bias and inflation in the time of Covid-19: Evidence from Swiss transaction data,” *Covid Economics*, 35.

Appendix to “Tracking Inflation on a Daily Basis”

A Product categories with online prices	A2
B Size of price adjustments	A4

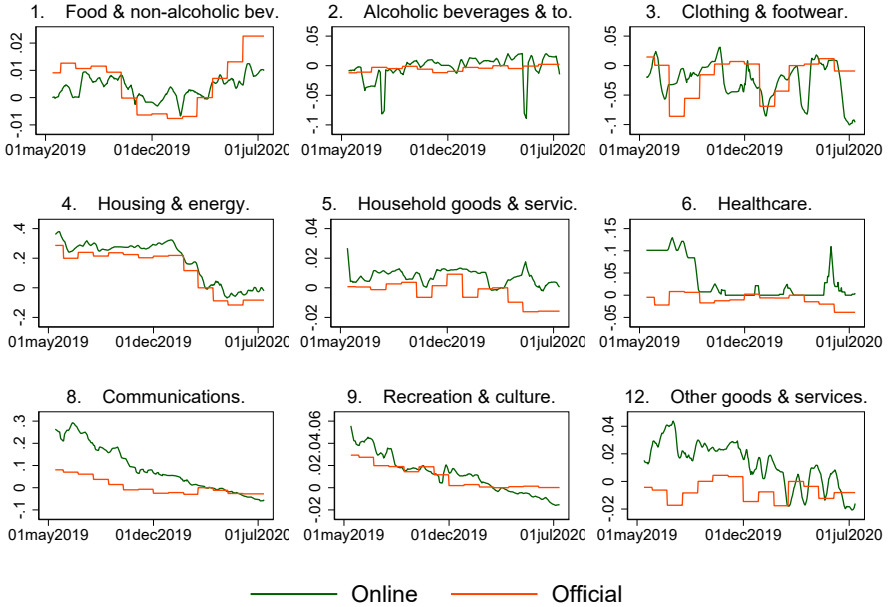
A Product categories with online prices

Table A.1: Matched CPI categories

Level 2 ID	ID	Name	Level	Weight	Products
1	1002	Bread, flour and cereal products	4	1.6	1554
1	1074	Meat, cold cuts and sausages	4	2.28	701
1	1179	Fish and seafood	4	.37	257
1	1198	Milk, cheese and eggs	4	1.6	1155
1	1284	Fats and edible oils	4	.26	143
1	1305	Fruit, vegetables, potatoes and mushrooms	4	2.12	412
1	1448	Sugar, jam, honey/other sugary foods	4	.66	1223
1	1481	Other food products	4	.72	1828
1	1518	Coffee, tea, cocoa and nutritional beverages	4	.42	463
1	1544	Mineral waters, soft drinks and juices	4	.51	485
2	2	Alcoholic beverages and tobacco	2	2.76	351
3	3	Clothing and footwear	2	3.4	26223
4	4090	Heating oil	4	.69	9
5	5001	Furniture, furnishings and floor coverings	3	1.36	5465
5	5070	Household textiles	3	.3	241
5	5100	Household appliances	3	.57	6299
5	5140	Glassware, tableware and household utensils	3	.29	280
5	5200	Tools for house and garden	4	.33	106
5	5221	Goods for routine household maintenance	4	.5	1288
6	6070	Medical products	4	.21	47
8	8006	Telecommunication equipment	3	.18	691
9	9001	Audiovisual, photographic and IT equipment	3	.79	9182
9	9211	Games, toys and hobbies	4	.37	12713
9	9300	Plants, flowers and garden products	4	.48	289
9	9555	Writing and drawing materials	4	.14	594
12	12021	Personal hygiene articles	4	.93	2741
12	12150	Electrical appliances for personal care	4	.05	421
12	12160	Personal effects	3	.61	150
Total	.	.	.	24.502	75311

Notes: Weights as in the official CPI for 2020.

Figure A.1: Only matched positions aggregated at level 2

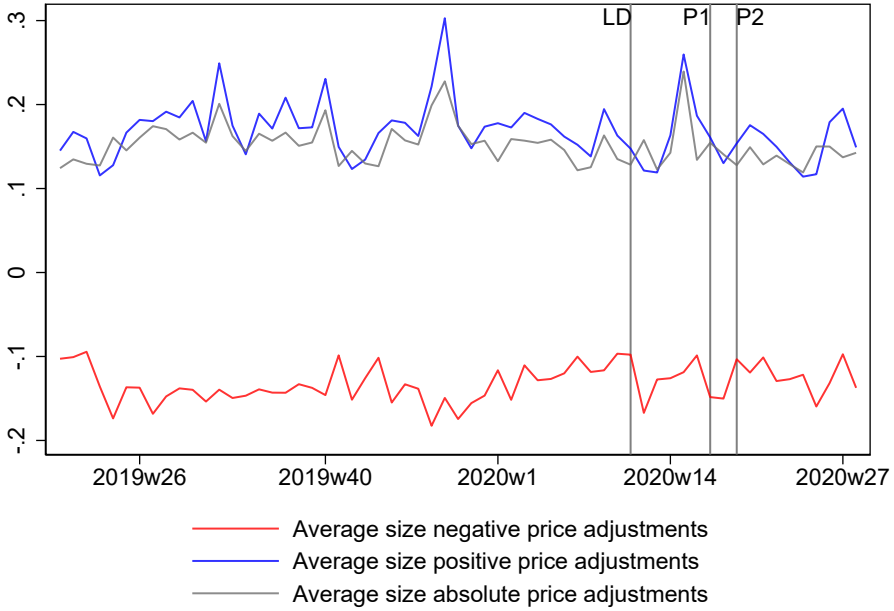


Notes: This figure shows the official and online inflations aggregated at level two keeping only the lower-level positions available online. Constant official weights for 2020 used.

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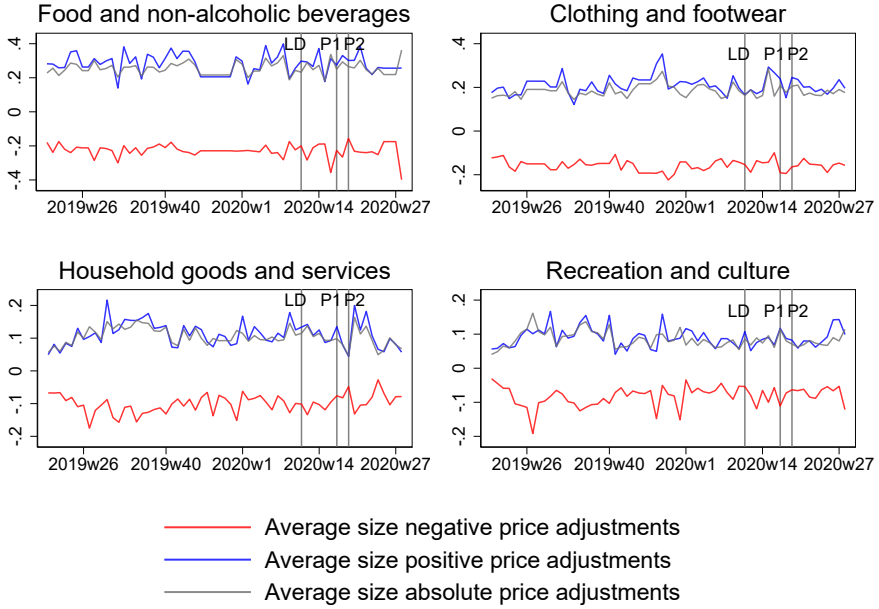
B Size of price adjustments

Figure B.1: Size of price adjustments



Notes: This figure shows the average nonzero size of price adjustments. LD, P1, P2, stand for lockdown, phase 1 and phase 2, respectively.

Figure B.2: Size of price adjustments by category



Notes: This figure shows the average nonzero size of price adjustments by product category. LD, P1, P2, stand for lockdown, phase 1 and phase 2, respectively.

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Mask Wars: China's exports of medical goods in times of COVID-19¹

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The COVID-19 outbreak has cut China's supply of and raised the world's demand for face masks, disinfectants, ventilators, and other critical medical goods. This article studies the economic and political factors that are associated with China's exports of medical equipment during the first two months of the global pandemic. Regression results show that—controlled for demand factors—countries with stronger past economic ties with China import more critical medical goods from China at both the national level and the level of Chinese provinces. Friendly political relations, such as the twinning of provinces, appear to work as a substitute for pre-existing economic ties at the provincial level. These findings imply that, to secure access to medical equipment in crises, countries are well advised to either diversify their sources or to develop closer relations with Beijing and China's provinces.

1 We are grateful to Xing-Jian Liu for generously sharing his data on twinning relations with us. We thank Laura Mahoney for proof-reading an earlier version of this article.

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Felix Turbanisch, and Feicheng Wang

“America first” will not help us to cope with this crisis. [...] The protective materials available here are currently only sufficient for a few days. [...] I therefore ask the People’s Republic of China for support.

Stephan Pusch, Administrator of Heinsberg District, Germany, in an open letter to China’s President Xi Jinping, March 23, 2020 (own translation)

1 Introduction

With the outbreak of the coronavirus disease (COVID-19) hitting the worldwide scale in March 2020, the demand for critical medical equipment has skyrocketed and outstripped the global supply of these goods by far. The global health crisis has transformed simple medical products, such as face masks, gowns, and disinfectants, into very scarce goods.¹ Countries, companies, hospitals, and individuals started competing for these goods—with sometimes questionable means. For example, newspapers reported on April 4th that the United States had “confiscated” masks intended for the German capital Berlin at Bangkok Airport and diverted them to the United States. In response to these events, the Interior Minister of Berlin, Andreas Geisel, spoke of an “act of modern piracy” and demanded that “even in times of global crisis there should be no wild west methods” ([The Guardian 2020a](#)). This was everything but an isolated incident. The French Interior Minister Christophe Castaner called the situation within France a *guerre de masques*—a mask war between the local authorities and the state ([Le Monde 2020](#)).

China plays the central role in these “mask wars.” The emerging economy is the world’s largest supplier of such medical equipment. According to [UN Comtrade \(2020\)](#) statistics, 44% of the world’s exports of face masks originated from China in 2018, whereas the next largest exporters, Germany (7%) and the United States (6%), play a comparatively minor role. However, while global demand for vital medical equipment from China surged during the outbreak of the pandemic in March 2020, their supply was low due to the shutdown of the Chinese economy. In fact, China itself ran short of medical equipment and was dependent

¹In the week of March 15th, the global search interest in the topic “masks” outnumbered the interest in otherwise popular topics like “food” and “soccer,” according to Google Trends.

on imports in February 2020, when the virus was still mainly within Chinese borders.² The European Commission limited its own exports of medical gear in mid-March, which was interpreted as a reaction to uncertainty about Europe's access to medical supplies from China (Bown 2020). This all resulted in fierce competition between countries over *Chinese* medical goods (Evenett 2020).³

This article analyzes the drivers of Chinese exports of face masks and other medical equipment in March and April 2020. These are the first two months in which the COVID-19 outbreak was considered a “global pandemic,”⁴ and thus global competition over Chinese medical supplies was particularly fierce. The basic gravity model of international trade suggests that China sells more to countries that are economically larger and geographically closer. Moreover, the willingness to pay should depend on the severity of the coronavirus outbreak in a given country. Controlling for these demand factors, we focus on two less obvious drivers of China's medical exports: pre-existing economic ties and political relations.

First, given the reliance of the Chinese economy on trade, we expect that exports of crucial goods build on pre-existing commercial ties, with new trade ties showing a network character (Chaney 2014). In the Chinese context, Liu et al. (2001) observe a “virtuous circle” between trade and foreign direct investment (FDI) in the sense that economic ties in one of the two trigger links in the other. Similarly, Morgan and Zheng (2019) find that past Chinese aid promotes FDI today. We expect a similar effect of pre-existing economic ties when it comes to obtaining China's medical equipment during the pandemic.

Second, we expect that political relations shape China's export pattern of critical medical goods. Beijing has a track record of using trade to pursue its foreign-policy goals (Du et al. 2017, Fuchs 2018). We therefore analyze the extent to which China's exports of such vital goods are linked to the state of political relations with its trade partner countries, both at the national level and the level of Chinese provinces.

The role of political ties in China's exports is likely to be stronger for donations than for

²China's production of face masks had been cut by half to ten million per day in early February 2020. A spokeswoman from China's Ministry of Foreign Affairs summarized the situation as follows: “What China urgently needs at present are medical masks, protective suits and safety goggles” (BBC 2020).

³For example, *The Guardian* (2020b) reported on April 3rd that “US buyers waving wads of cash [had] managed to wrest control of a consignment of masks as it was about to be dispatched from China to one of the worst-hit coronavirus areas of France.”

⁴The World Health Organization declared a global pandemic on March 11, 2020. See statement of Director-General Tedros Adhanom Ghebreyesus at <https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020> (accessed June 16, 2020).

commercial exports. Previous research shows, for example, that countries who have a close voting alignment with China in the United Nations receive significantly more aid, while countries that recognize the government in Taipei, rather than the one in Beijing, are largely excluded from any aid receipt (Dreher and Fuchs 2015, Dreher et al. 2018). Concerns loom large that Chinese aid spurs corruption and promotes authoritarian norms (Isaksson and Kotsadam 2018, Gehring et al. 2019). China's ambiguous role as an aid donor and as an aid recipient has been particularly prominent during the COVID-19 crisis. While asking for discretion from donors such as the European Union when medical supplies were sent to Hubei Province in January 2020, China successfully turned its own giving in March into a media campaign (Popescu 2020).

To test our predictions, this article analyzes China's export pattern of critical medical goods using monthly dyadic trade data from the General Administration of Customs of the People's Republic of China (GACC 2020), published at the level of pairs of Chinese provinces and partner countries. Specifically, we test whether previous economic linkages through trade and investment, as well as political relations (including aid and donations to China in the early phases of the medical crisis and sister linkages of provinces) are associated with the export pattern.

Our results show significant positive correlations between past trade ties and the value of exported medical equipment at the country level. With the exception of aid and donations, exports of medical equipment, do not appear to follow political factors at the national level. Since this non-finding could be the result of aggregation and omitted-variable biases, we carry out dyadic regressions that exploit variation between province-country pairs only, while controlling for country and province fixed effects. Country fixed effects fully capture demand factors, such as the degree of affectedness by the COVID-19 pandemic. Province fixed effects fully capture supply factors, such as the production capacities of the medical industry in Chinese provinces. This allows us to move closer to a causal interpretation of our results. In the dyadic setting, we observe that countries can source more than double the amount of donations from sister provinces than they would obtain otherwise. Moreover, China reciprocates past aid receipts through significantly larger exports of medical equipment. Interactions with economic linkages further suggest that political ties can compensate a lack of past economic ties.

Our paper builds on previous research in economics and political science that discusses the extent to which political relations matter for international commerce (Hirschman 1945, Baldwin 1985). In a seminal contribution, Pollins (1989) develops a public-choice model in

which importers reward political friends through trade increases and punish adversaries through trade reductions. A subsequent stream of research documents that diplomatic relations, as operationalized by embassies and state visits, can foster bilateral trade (Nitsch 2007, Rose 2007).⁵ While interlinked supply chains as well as bilateral and multilateral trade agreements could prevent governments from politicizing trade due to sunk costs (Davis and Meunier 2011), the persistent government control over economic activities may explain why Chinese trade still follows the flag (Davis et al. 2019). Consumer reactions to the state of bilateral relations are another mechanism through which politics affects commerce (Pandya and Venkatesan 2016).

Recent empirical evidence indeed suggests that Chinese trade has remained politicized in the aftermath of bilateral tensions. Political tensions caused by governments receiving the Dalai Lama lead to a reduction of their countries' exports to China (Fuchs and Klann 2013), which appears to mainly operate through state-owned enterprises (Lin et al. 2019). Various episodes of Sino-Japanese tensions also led to substantial declines in Chinese imports from Japan (Fisman et al. 2014, Heilmann 2016).

This paper distinguishes itself from the bulk of the literature in that it studies the role of politics in *export* decisions in the face of an unprecedented global surge in demand for medical goods.⁶ There are reasons to expect that exports would be less likely to be politicized than imports, as export restrictions are considered to be costlier from the sender's perspective. Nevertheless, given the extent to which the Chinese state controls the production of medical equipment, we expect to observe a politicization of its export decisions. Tellingly, China's state-owned enterprises, including PetroChina and Sinopec, entered the mask business in February 2020 and jointly produced up to 38.5 metric tons of mask components per day (Lo 2020).

The major innovation of our paper is that we analyze the effects of contemporaneous international political relations on trade at the provincial level. Previous decentralization efforts (e.g., Jin et al. 2005) strengthen the expectation that subnational economic and political ties play a substantial role for trade. While Che et al. (2015) also analyze political factors in Chinese trade at the provincial level, they focus on political tensions rooted in history. They find that Chinese provinces that suffered more casualties during the Japanese Invasion from 1937 to 1945 trade less with Japan "today" (in 2001). Our paper in contrast focuses on contemporaneous

⁵See Moons and van Bergeijk (2017) for a meta analysis on the trade effects of economic diplomacy.

⁶In comparison to the large literature on the politicization of import decisions, relatively few studies exist that study political influences on export decisions. Exceptions include work on weapon embargoes and export restrictions on strategic technologies (e.g., Crozet and Hinz 2020, DellaVigna and La Ferrara 2010).

political relations and investigates friendly relations, such as donations and sister linkages of provinces at the provincial level. Moreover, our empirical design outperforms cross-country regressions and moves us closer to a causal interpretation of estimation results.

We proceed as follows. In Section 2, we analyze the cross-country pattern of China's exports of medical equipment to the rest of the world during the first two months of the COVID-19 pandemic. Section 3 moves to the provincial level and investigates the dyadic drivers of exports. We give our conclusions in Section 4.

2 Cross-country patterns of Chinese medical exports

2.1 Descriptive evidence

To study China's export patterns of medical equipment during the first months of the global COVID-19 pandemic, we rely on official monthly dyadic export data for all commodities for pairs of Chinese provinces and trade partner countries (GACC 2020). We identify 80 medical commodities (at the 6-digit level of the Harmonized System, HS6) that were classified as "critical" by the World Customs Organization and the World Health Organisation in regards to the pandemic (WCO/WHO 2020). For descriptive purposes, as well as for further robustness checks, we also rely on an alternative list of 11 medical products. These products are measured at the 8-digit level (HS8) and were deemed essential by the Chinese government for COVID-19 treatment and control.⁷ Our main dependent variable measures *Total medical exports* from China during March and April 2020 (aggregating over 80 HS6 product categories). We further decompose these trade flows into *Commercial medical exports* and *Donation medical exports*, and also consider selected medical equipment, *Masks* and *Ventilators*, separately (measured at HS8 level).

As a result of the COVID-19 pandemic, China's exports of disinfectants and masks both increased by more than 1,000% and exports of ventilators almost tripled from March and April 2019 to March and April 2020 (see also Figure C.1 in the Appendix). Table D.1 in the Appendix lists 11 essential medical products (according to Chinese definitions) together with their aggregate value, quantity, average price, the most important exporting province, and the top three importing countries. Surgical masks top the list of essential medical equipment in terms of total export value, followed by surgical shoe covers and surgical gowns. Infrared

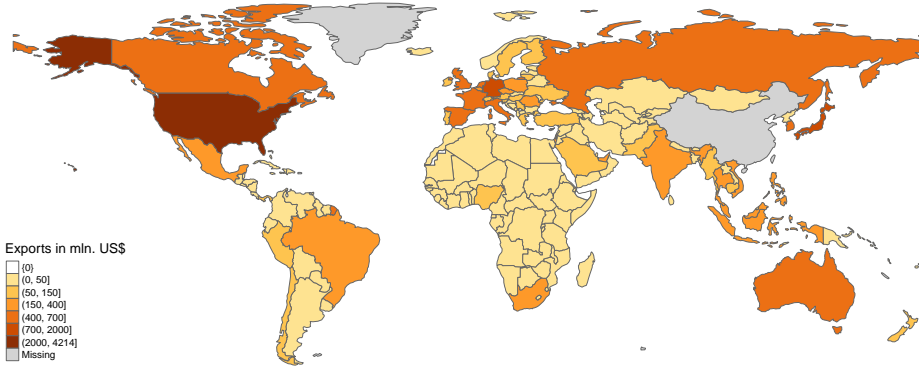
⁷See Appendix A for more detailed information on all variables used as well as coding procedures and data sources.

thermometers and ventilators are the two top traded items amongst the more complex medical equipment. From the 11 essential products, ventilators are by far the most expensive (with average unit prices of about US\$ 2,500), reflecting their relatively larger complexity. For all 11 products, the United States is the most important importer, typically followed by Germany or Japan. In our product-specific regressions, we especially focus on surgical masks (as the most exported product) as well as ventilators (as the most complex and highest unit value product among the top-traded pieces of medical equipment), both of which received special and widespread global attention. The huge predominance of masks among the key supplies and the strong government interference led to frequent references to a new “mask diplomacy,” whereas ventilator shortages were a major policy issue at the beginning of the pandemic (Hornung 2020).

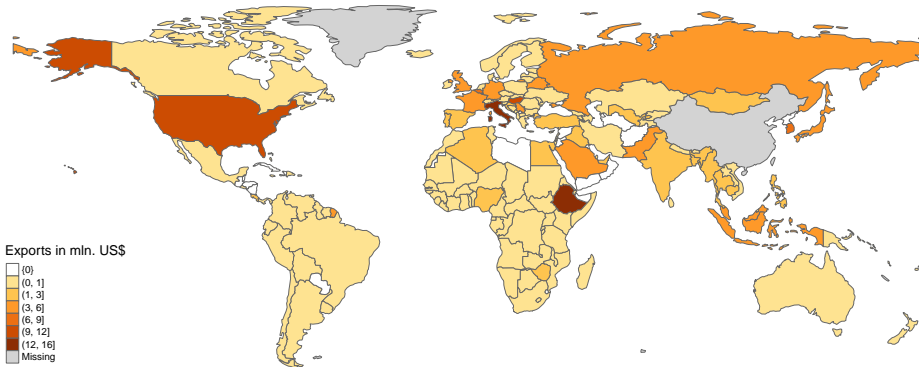
Among total medical exports, commercial trade constitutes the major bulk (with 99%), whereas donations (with 1%) are of a minor economic importance, but of a much larger symbolic value. Donations of medical products in March and April 2020 increased by more than 400% relative to the same period in 2019, while commercial exports of medical products nearly doubled in the same reference period (see again Figure C.1 in the Appendix). The two world maps in Figure 1 show that there is virtually no country that did not import critical medical goods from China in March and April of 2020. Medical donations were also widely spread globally. On aggregate, the top commercial importers, as in the case of selected products, include the largest economies and are strongly dominated by the United States, followed by Japan and Germany. By contrast, the list of countries who receive the greatest amount of medical donations is led by Ethiopia, Italy, the United States, Hungary, South Korea, and Luxembourg. It thus includes smaller and/or economically less advanced countries. Some countries on the list of aid beneficiaries were especially affected by an earlier outbreak (like Italy or Luxembourg). For other top beneficiaries (like Ethiopia or Hungary), this new “mask diplomacy ” must have followed other political and economic motives that go beyond a simple targeting of the largest humanitarian needs (Hornung 2020).

2.2 Econometric model and variables

We first run simple regression models at the cross-country level to analyze descriptively which trading partner country characteristics are more closely associated with the volume of Chinese exports of medical equipment at the beginning of the pandemic. We estimate the following



(a) Commercial exports of medical equipment



(b) Donation exports of medical equipment

Figure 1 – Exports of medical equipment from China by partner country, March and April 2020

regression equation:

$$Y_j = \alpha + \beta X_j + \epsilon_j, \tag{1}$$

where Y_j denotes the inverse hyperbolic sine of the value of Chinese medical exports to partner country j in March and April 2020, X_j is a vector of explanatory variables introduced below, and ϵ_j is an error term.⁸ We run separate regressions for total exports, commercial exports, and donations, and report results also for masks and ventilators.

The vector X_j includes four sets of explanatory variables, capturing bilateral economic

⁸All monetary values are measured in US\$. We compute all log transformations by applying an inverse hyperbolic sine transformation, which is defined as $\sinh^{-1}(x) = \ln(x + \sqrt{x^2 + 1})$, is continuous through zero, and is well approximated for larger values by a log transformation.

ties, bilateral political ties, proxies for the demand for medical equipment, and typical gravity controls. We expect that both past economic and political ties make it more likely that medical equipment is sourced from China. We capture the importance of past economic ties for the sourcing of medical equipment by controlling for past trade and investment linkages. We measure past trade in the form of medical exports (decomposed into commercial exports and donations) as well as non-medical exports during the same months of the previous year (March and April 2019). While past medical exports capture the existence of direct trade linkages within the same sector, non-medical exports account for more generic trade ties. Focusing on the same months of the year helps to deal with seasonality-induced variations in trade flows. We measure investment linkages by the average annual value of *Inward FDI* flows by partner countries in China from 2015 to 2017 (MOFCOM 2019).

We measure four dimensions of bilateral political ties. *UN voting distance* captures past political (mis-)alignment between partner countries and China (Bailey et al. 2017). This measure exploits differences in voting behavior between China and its trade partners within the United Nations General Assembly (UNGA) between 2017 and 2019 and has been widely used to capture bilateral political relationships (see e.g., Allen et al. 2020, Rommel and Schaudt 2020). *Recognition of Taiwan* indicates whether a country recognizes the government in Taipei on Taiwan rather than the one in Beijing. Since China considers such diplomatic ties a breach of its so-called “One-China policy,” we expect this proxy to capture a relevant indicator of a strenuous political relationship with China (e.g., Johnston et al. 2015).

As a further proxy of the quality of bilateral diplomatic ties, *Donations to China in Jan.-Feb.* of 2020 capture the total value of all donations made by partner countries at the peak of the Chinese health crisis. Within the first two months of 2020, the United States had exported the most aid to China (US\$ 19.3 million), followed by South Korea and Japan. Altogether 112 countries donated goods to China, including many instances of South-South cooperation. Countries donated mostly medical equipment (96% of total donation imports), but our measure also includes other donations, like that of 30,000 sheep by Mongolia (Damdinsuren and Namjildorj 2020). We expect that such donations may have been systematically followed up by reciprocal diplomatic gestures. For instance, the *New York Times* (2020) cites an official from the Ministry of Commerce in Beijing stating: “In the previous stage of prevention and control, many countries have offered to help us, and we are willing to offer affected countries our share of help while we can.”

The fourth dimension of political ties, *Sister linkages*, identifies countries that maintain at least one sister relationship to a Chinese province (Liu and Hu 2018). More than half of all countries fall into this category (51%). Sister province relations have evolved from other areas such as education towards trade (Mascitelli and Chung 2008) as, for example, in the case of the German State Schleswig-Holstein and Zhejiang Province (Liu and Hu 2018). This way, sister linkages measure broader political relationships, which extend to personal bonds and communication channels through liaison offices and among firms. Those may increase the exchange of medical equipment beyond an existing trade relationship. Anecdotal evidence suggests that sister relations have been helpful to attract Chinese medical equipment during the COVID-19 pandemic: Many Chinese provinces sent masks or other medical equipment to their respective sister entity, such as Fujian province to the US state Oregon, or Hunan province to the UK county of Lincolnshire (People's Daily 2020, The Lincolnite 2020).

In terms of demand factors, *COVID-19 infection rates* control for the urgent need of medical equipment by measuring the spread of the pandemic in each importing country by the end of April 2020 (Wahlteiz 2020). We recognize, however, that this variable is likely to suffer from substantial measurement error as testing and reporting practices vary greatly across countries (Bommer and Vollmer 2020, Stock 2020). We control for *Government effectiveness* as it may have also affected early demand for medical products by determining the extent to which governments were capable to take early response measures in face of a global health crisis (Kaufmann et al. 2011). Finally, we control for the typical variables that enter a gravity model of trade, such as logged partner-country GDP and population size (Azevedo 2011, World Bank 2020), as well as geographic distance and contiguity (Mayer and Zignago 2011).

2.3 Results

Table 1 reports the cross-country regression results. Column 1 refers to all medical exports in March and April of 2020, combining 80 medical products according to the HS6 classification by the WCO/WHO. Columns 2 and 3 split total exports into commercial exports and donations. The last two columns repeat the same regressions for masks and ventilators.

Results generally confirm that past economic ties matter for sourcing medical equipment in the face of the pandemic. Commercial exports seem to build not only on past ties of medical exports, but also depend positively on other prior non-medical export links. In column 2, the estimated elasticity of new medical trade w.r.t. previous non-medical exports (0.5%) is

Table 1 – Cross-country correlates of Chinese medical exports (March–April 2020)

Exports by type (<i>asinh</i>):	Total (1)	Comm. (2)	Donat. (3)	Masks (4)	Ventil. (5)
<i>asinh</i> Commercial medical exports 2019	0.202*** (0.055)	0.195*** (0.061)	-0.009 (0.221)	0.369* (0.208)	0.438 (0.283)
<i>asinh</i> Donation medical exports 2019	0.014 (0.010)	0.014 (0.011)	0.115** (0.045)	0.026 (0.020)	-0.020 (0.063)
<i>asinh</i> Non-medical exports 2019	0.432*** (0.159)	0.508*** (0.155)	0.190 (0.262)	-0.109 (0.224)	-0.145 (0.445)
<i>asinh</i> Product exports 2019				0.107 (0.068)	0.234** (0.102)
<i>asinh</i> Inward FDI	0.026 (0.030)	0.035 (0.030)	0.060 (0.115)	-0.072* (0.038)	-0.066 (0.120)
UN voting distance	0.211 (0.141)	0.215 (0.142)	-0.292 (0.515)	-0.056 (0.191)	0.348 (0.476)
Recognition of Taiwan	-0.409 (0.700)	-0.163 (0.695)	-9.355*** (0.741)	-0.141 (0.586)	-1.367 (1.035)
<i>asinh</i> Donations to China in Jan.-Feb.	0.008 (0.014)	0.005 (0.014)	0.070 (0.071)	0.039 (0.024)	0.104 (0.064)
Sister linkages	-0.054 (0.181)	-0.049 (0.179)	1.810** (0.703)	0.121 (0.236)	0.168 (0.600)
<i>asinh</i> COVID-19 infection rates	0.205*** (0.055)	0.216*** (0.058)	0.170 (0.314)	0.496*** (0.107)	0.459 (0.321)
Government effectiveness	0.059 (0.141)	0.026 (0.139)	1.108 (0.718)	0.783*** (0.228)	0.064 (0.533)
R-squared	0.872	0.878	0.569	0.865	0.696

Note: Dependent variables measure the value of exports from China to each partner country in March and April 2020. Columns distinguish between total medical exports, commercial medical exports, donation medical exports, total exports of masks, and total exports of ventilators, all transformed by *asinh*. Columns 4 and 5 are based on HS 8-digit product classifications. All regressions control for a set of gravity determinants (contiguity, log of distance, log of population, and log GDP). $N = 187$ in all regressions. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

larger than w.r.t. previous medical exports (0.2%). This finding is very much in line with the anecdotal evidence that has been widely reported about various Chinese businesses with global links switching into the medical equipment trade ([Financial Times 2020](#)).

Donations follow a somewhat different logic (see column 3). Instead of following past commercial ties, they build on past donation trade links, which points towards a more sustained foreign aid relationship from China. By contrast, generic non-medical trade links do not seem to matter for donations. When analyzing the exports of the two signature goods only, we observe again that countries which have had past trade relations with China source significantly more goods from China in the times of supply shortages as well. Product-specific trade ties matter for procuring ventilators (column 4) and total commercial medical goods trade matters for masks (column 3). Our alternative measure of economic linkages, past FDI flows to China, is

not consistently related to medical exports at the cross-country level, and is even marginally negatively correlated with the export of masks.

The reliance of medical commercial exports on past trade ties contrasts the political variables, none of which seem to be relevant for explaining where commercial medical exports go on aggregate. China appears to be exporting medical equipment to “friends” and “foes” alike. By contrast, political factors matter crucially though for donations. Countries with sister linkages to Chinese provinces receive substantially more donations of medical equipment, whereas countries that recognize Taiwan do not receive any donations from China at all (which results in very large coefficients in column 3). Among the political variables, it is only the ideal point distance in UNGA voting that is not significantly linked to Chinese donations after the outbreak of the global pandemic.

Turning to demand factors, we observe that more Chinese exports of medical equipment go into countries with higher COVID-19 infection rates. Despite the substantial scope for measurement error in infection rates, the estimated coefficient is positive and statistically significant at the one-percent level for total, commercial, and mask trade. It is remarkable that Chinese donations of medical equipment do not appear to respond to the severity of the pandemic. Political calculus appears to dominate here. Finally, trading partners’ government effectiveness is not linked to overall Chinese medical exports, but more effective governments have been sourcing more masks over March and April 2020 from China.⁹

Further product-specific results on masks and ventilators in Table D.5 in the Appendix show that most of the observed effects are driven by variation in quantities, whereas there is little correlation of bilateral economic and political relations with average prices. The only highly significant factor explaining mask prices is the partner country’s COVID-19 infection rate. It thus appears that countries with extremely high demand were willing to pay a substantial surcharge for masks at the height of the first global outbreak. This indication of price discrimination yields some support to the anecdotal evidence on a “bidding war” for masks.

Summing up our cross-country results, we find that past trade ties are associated with larger commercial exports of critical medical goods during the early months of the pandemic. Political ties appear to play a role for donations only. However, the absence of evidence for a role of

⁹Disaggregating results into March and April in Tables D.3 and D.4 in the Appendix reveals that needs and government effectiveness particularly play a role in April, when infections peaked in high-income countries.

politics in China's medical exports may be driven by an aggregation bias. This is why we now investigate the regional political economy of China's exports, focusing on Chinese provinces.

3 The regional sourcing of Chinese medical exports

3.1 Descriptive evidence

So far we treated China as an aggregate. However, the production of medical equipment is widely spread across China. Figure 2 shows the geographical distribution of the regional sourcing of medical exports within China, again split into commercial exports and donation exports. While Beijing and the coastal regions in the Southeast dominate as exporters of medical equipment, all Chinese provinces export at least some medical equipment, including both commercial trade and donation exports. The largest commercial exporter in March and April 2020 was Guangdong Province (20%), whereas Beijing provided the largest share of medical donations (34%). At the beginning of the crisis, the regional sourcing of medical equipment became more widely spread as compared to one year before. The Herfindahl-Hirschman Index of exporter market concentration across Chinese provinces went down from 0.16 to 0.12 in the case of masks, and from 0.31 to 0.16 in the case of ventilators. This suggests that the pandemic led to a significant creation of new trade links. The substantial sub-national variation in bilateral trade linkages allows us to study the importance of past economic and political ties at the level of Chinese provinces.

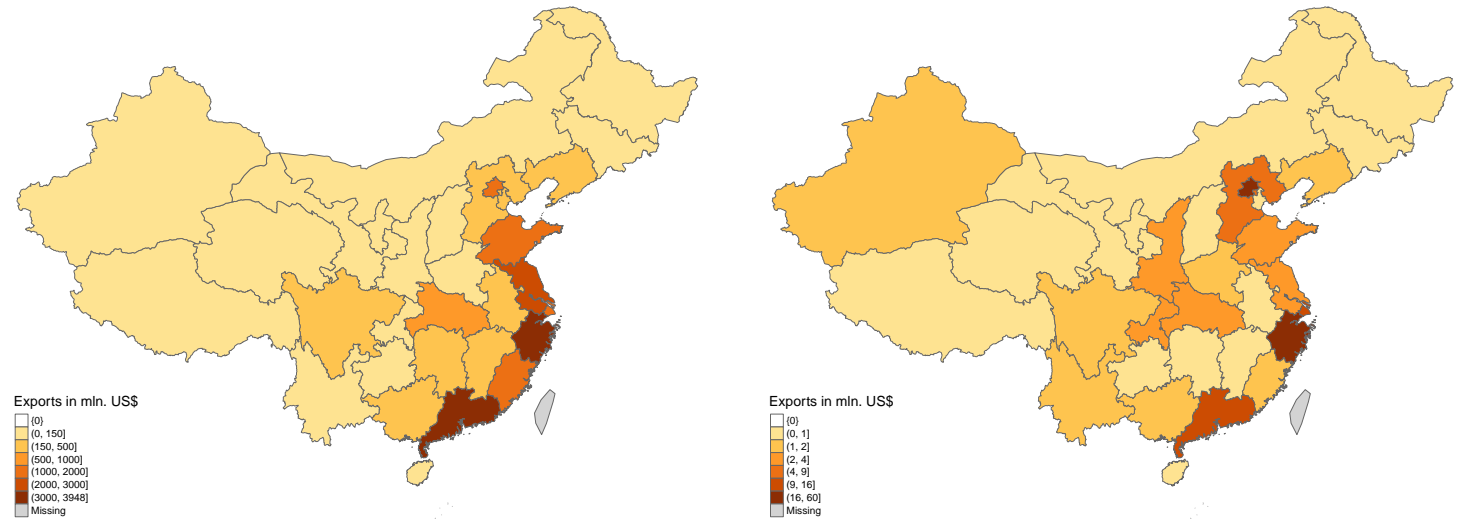
3.2 Econometric models and variables

We investigate the sourcing of medical equipment exports within China by estimating the following dyadic trade model:

$$Y_{ij} = \delta_1 E_{ij} + \delta_2 P_{ij} + \theta_i + \rho_j + \epsilon_{ij}, \quad (2)$$

where Y_{ij} denotes the inverse hyperbolic sine of the value of medical equipment exported from Chinese province i to partner country j , E_{ij} and P_{ij} denote dyadic explanatory variables introduced below, and θ_i and ρ_j are fixed effects for Chinese provinces and trade partner countries, respectively.¹⁰

¹⁰Table D.6 in the Appendix provides descriptive statistics for all variables used in the dyadic analysis.



(a) Commercial exports of medical equipment

(b) Donation exports of medical equipment

Figure 2 – Exports of medical equipment from Chinese provinces to all partner countries, March and April 2020

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The major advantage of this model over the previous cross-country regression is that we can now control for unobserved province-of-origin and destination-country factors. Province fixed effects, θ_i , account for the average differences across Chinese provinces in their supply of medical equipment to the rest of the world and their average trade openness. They thus absorb cross-province variation in the location of medical industries within China and in general market access. They also capture variation in the extent to which Chinese provinces were affected by the pandemic themselves, which may have also reduced their ability or willingness to export critical medical goods. Country fixed effects, ρ_j , capture variation in the total level of medical equipment bought from China by each partner country j . They thus fully capture differences in demand across China's trade partners, as well as all other political and economic determinants that drive aggregate trade relations between China and each country (e.g., geographic distance and trade agreements). This stricter specification allows us to focus on the within-country sourcing of exports and, by that, to move closer to a causal interpretation of our coefficients.¹¹ As we now focus on the variation across province-country pairs, we can isolate the effects of past bilateral linkages on the regional sourcing of China's medical exports.

Our vectors of measures of bilateral economic relations, E_{ij} , and political relations, P_{ij} , build on the economic and political proxies that we used in the cross-country analysis and that also have a dyadic component that varies across province-country pairs. We measure bilateral economic ties, E_{ij} , by the inverse hyperbolic sine of past medical and non-medical export values during the same months (March and April) of the previous year, from China's province i to country j . We again distinguish between commercial exports, donations, and non-medical exports. As a further proxy for economic linkages between trading partners and Chinese provinces, we employ the inverse hyperbolic sine of the average annual value of FDI inflows over the years 2015 to 2017, originating from partner country j and targeting province i .

We capture bilateral political ties, P_{ij} , with two variables. First, we use the (transformed) value of donations from each partner country j to province i in January and February 2020. Second, we include a binary variable that takes the value of one if a province i has a sister linkage with country j . In line with our earlier reasoning, we expect that foreign donations

¹¹ While the cross-sectional setup does not allow us to control for constant province-country-pair characteristics, using previous year's exports as an explanatory variable captures many of those factors. Further robustness tests to capture cultural ties based on dyadic tourism data and country-specific Google search interest in Chinese provinces leave our results unchanged (not reported).

trigger reciprocal behavior, whereas sister linkages capture a wide range of dyadic ties built from the past, and both ease the sourcing of medical equipment from the provinces that were receiving those donations.

3.3 Results

The results show that economic ties do not only matter for medical exports at the national level, but also for the sourcing within China. As can be seen from Table 2, all types of medical exports are significantly related to past medical commercial exports and hence build on past commercial ties.¹² In the case of masks and ventilators, past product-specific bilateral trade is among the strongest determinants of dyadic exports, indicating that established commercial ties also matter in crisis situations. The additional significance of past commercial medical exports also shows that not only direct but also indirect commercial linkages play a role, and, in the case of masks, the elasticities of past mask and past commercial exports are relatively close to each other (0.28 and 0.21).¹³ By contrast, for the sourcing of the much more specialized ventilators, the more generic commercial medical exports matter substantially less than past exports of ventilators (with an elasticity of 0.03 vs. 0.50). While not related to our aggregate export measures, non-medical export ties are even negatively linked to bilateral exports of masks and ventilators.¹⁴ Exports of these special products seem to follow different dyadic routes as their exports in 2019 were also negatively related to contemporaneous non-medical exports (not shown). Donations are building on past donation linkages, whereas past medical donations by Chinese provinces do not result in more commercial exports during the pandemic. Unlike in the aggregate cross-country setting, inward FDI also turns out positive and highly significant. Countries that invested in Chinese provinces in the past sourced significantly more medical supplies from these provinces during the first months of the pandemic in all forms.

In contrast to our results at the aggregate level, we find that political linkages also matter for the sourcing of commercial trade flows. First, Chinese provinces tend to reciprocate donations that they received just two months before, although with relatively low elasticities. A one-

¹²Whereas aggregates in Table 2 refer to the 80 HS6 products listed as critical medical goods by the WCO/WHO, Table D.7 in the Appendix reruns the same regressions based on the 11 HS8 products that were selected by China Customs as essential, with qualitatively comparable results.

¹³The results for commercial ties are robust to the application of a Poisson Pseudo-Maximum-Likelihood estimation (Silva and Tenreyro 2006), which accounts in Table D.8 in the Appendix for the larger fraction of zeros in the dyadic setting.

¹⁴The same negative correlation appears when regressing mask and ventilator exports in 2019 on non-medical exports in 2019. This indicates that selected medical exports are differently spread across countries than generic non-medical export ties would predict.

Table 2 – Determinants of medical exports between province-country pairs (March–April 2020)

Exports by type (<i>asinh</i>):	Total (1)	Comm. (2)	Donat. (3)	Masks (4)	Ventil. (5)
<i>asinh</i> Commercial medical exports 2019	0.409*** (0.019)	0.428*** (0.019)	0.018* (0.009)	0.205*** (0.017)	0.031*** (0.009)
<i>asinh</i> Donation medical exports 2019	0.034 (0.047)	0.031 (0.045)	0.180** (0.070)	0.067 (0.051)	-0.072 (0.060)
<i>asinh</i> Non-medical exports 2019	-0.002 (0.016)	-0.026 (0.016)	-0.004 (0.010)	-0.073*** (0.016)	-0.064*** (0.009)
<i>asinh</i> Product exports 2019				0.278*** (0.023)	0.502*** (0.029)
<i>asinh</i> Inward FDI	0.087*** (0.020)	0.099*** (0.021)	0.127*** (0.023)	0.161*** (0.026)	0.118*** (0.021)
<i>asinh</i> Donations to province in Jan.-Feb.	0.027* (0.014)	0.033** (0.015)	0.086*** (0.020)	0.064*** (0.021)	0.086*** (0.022)
Sister linkages	0.085 (0.176)	0.209 (0.190)	0.874*** (0.252)	0.318 (0.219)	0.228 (0.204)
R-squared	0.782	0.781	0.436	0.720	0.555

Note: Dependent variables measure the value of exports from each Chinese province to each partner country in March and April 2020. Columns distinguish between total medical exports, commercial medical exports, donation medical exports, total exports of masks, and total exports of ventilators, all transformed by *asinh*. All regressions control for province and country fixed effects. $N = 6045$ in all regressions. Standard errors clustered at the country level are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

percent larger receipt of donations by a province increases total exports of medical equipment from this province by only 0.03 percent. The estimated elasticity is—with an increase of 0.09 percent—larger for donations, but still small. Second, donations of medical equipment are significantly (and substantially) larger to sister countries of Chinese provinces than to countries without such close political ties. Quantitatively, the financial value of donations is more than twice as large (2.66-fold when evaluated at the mean of all other variables) for countries that are connected to the exporting province through a sister relationship. If we analyze the first month of the global pandemic only, the sister-province effect extends to commercial exports in addition to aid and donations (see Tables D.9 and D.10 in the Appendix for monthly results).

One mechanism through which past economic and political ties foster exports of medical equipment during the pandemic is related to the creation of new trade linkages. Table D.11 in the Appendix focuses on the extensive margin of trade. It restricts the sample to province-country pairs with no previous medical (or product) trade in March and April 2019 and regresses an indicator of new medical trade linkages in March and April 2020 on the same dyadic covariates. Within this subsample, 16% of province-country pairs formed a new medical trade link at the beginning of the pandemic. Columns 1 and 2 for total and commercial medical exports support

the notion that more general economic linkages (non-medical exports and inward FDI) matter for the establishment of new trade relations. Both sister linkages and donations to China in early 2020 play a strong role for both donations and masks exports according to columns 3 and 4. In short, in addition to past commercial linkages, political ties matter and facilitate the establishment of new trade ties.

Finally, we explore whether countries were able to compensate for the weakness of their past economic ties with certain provinces with stronger political ties. We rely on a set of interactions by varying the measure of past economic ties (using bilateral medical exports in March and April of 2019 as well as past dyadic inward FDI) and interacting these economic linkages with dyadic political factors (sister linkages and past donations).¹⁵ The results in Table 3 show that, while economic linkages matter in general, they can be compensated with political ties. Bilateral diplomatic relations captured by donations to the province in early 2020 result in significantly more medical exports in the following two months, but at the same time they also reduce the relevance of the previous strength of economic linkages in both specifications. *Sister linkages* show the same pattern and emphasize that economic and political ties are imperfect substitutes. Table D.12 in the Appendix examines the robustness of these findings by using total medical exports aggregated across the 11 HS8 products as the dependent variable, and the results are similar.

Table 3 – Interactions between economic and political relations in dyadic medical exports (March–April 2020)

Economic linkages:	Total Medical Exports (1)	Inward FDI (2)
<i>asinh</i> Economic linkages	0.418*** (0.019)	0.234*** (0.029)
× <i>asinh</i> Donations to province in Jan.-Feb.	-0.011*** (0.004)	-0.021*** (0.002)
× Sister linkages	-0.032 (0.037)	-0.118*** (0.038)
<i>asinh</i> Donations to province in Jan.-Feb.	0.190*** (0.056)	0.163*** (0.021)
Sister linkages	0.641 (0.515)	0.850*** (0.254)
R-squared	0.781	0.743

Note: Dependent variables measure the value of exports from each Chinese province to each partner country in March and April 2020, transformed by *asinh*. Column titles refer to the interacted variables that are used to capture economic linkages. All regressions control for province and country fixed effects. $N = 6045$ in all regressions. Standard errors clustered at the country level are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

¹⁵We present the corresponding regression equation of the interaction model in Appendix B.

4 Conclusion

The first weeks of the COVID-19 pandemic revealed the dependence of many economies on vital goods imported from China. Countries entered a race on who can source Chinese medical equipment to secure the sufficient amount of face masks, protective equipment, and ventilators. This article investigated the factors that explain the resulting trade pattern. To do so, we collected data on trade in critical medical equipment between China and trade partner countries. Controlled for demand factors, we observed significant positive correlations between past trade ties and the value of traded medical equipment at the country level. With the exception of aid and donations, China's exports of medical equipment do not appear to follow political factors. However, this non-finding could be the result of aggregation and omitted-variable biases.

To mitigate these biases, we carried out dyadic regressions that exploit variation between province-country pairs only. Country fixed effects fully captured demand factors, such as the degree of affectedness by the COVID-19 pandemic. Province fixed effects captured supply factors, such as the production capacities of the medical industry in Chinese provinces. In this conservative setting, countries were shown to receive more than double the amount of donations from sister provinces than they would otherwise obtain. Moreover, China reciprocated recent aid receipts through significantly larger exports of medical equipment. Interactions with economic linkages further suggested that political ties can work as substitutes for economic ties.

These findings imply that, to secure access to Chinese medical equipment in crises, countries are well advised to either diversify their sources of strategic goods or to develop closer relations with Beijing and China's provinces. Future research could delve deeper into the role of migrant networks as a facilitator of trade once dyadic diaspora data at the level of Chinese provinces are available. Moreover, rather than exploring the drivers of China's trade in medical equipment, scholars may want to study their effects on attitudes towards China in its trade partner countries. Finally, in light of anecdotal evidence on "poor quality" mask and ventilator exports, future analyses of China's exports of medical equipment could account for quality differences.

References

- Allen, M. A., M. E. Flynn, C. M. Machain, and A. Stravers (2020). Outside the Wire: US Military Deployments and Public Opinion in Host States. *American Political Science Review* 114(2), 326–341.
- Azevedo, J. (2011). wboappendata: Stata Module to Access World Bank Databases. Statistical Software Components S457234. Newton, MA: Boston College Department of Economics.
- Bailey, M. A., A. Strezhnev, and E. Voeten (2017). Estimating Dynamic State Preferences from United Nations Voting Data. *Journal of Conflict Resolution* 61(2), 430–456.
- Baldwin, D. A. (1985). *Economic Statecraft*. Princeton, NJ: Princeton University Press.
- BBC (2020). Coronavirus: Does China Have Enough Face Masks to Meet Its Needs? BBC News, February 6th, 2020. Available at <https://www.bbc.com/news/world-asia-china-51363132> (accessed June 18, 2020).
- Bommer, C. and S. Vollmer (2020). Average Detection Rate of SARS-CoV-2 Infections Is Estimated around Six Percent. Goettingen, Germany: University of Goettingen. Available at www.uni-goettingen.de/de/606540.html (accessed June 24, 2020).
- Bown, C. P. (2020). EU Limits on Medical Gear Exports Put Poor Countries and Europeans at Risk. Washington, DC: Peterson Institute for International Economics, published March 19, 2020. Available at <https://www.piie.com/blogs/trade-and-investment-policy-watch/eu-limits-medical-gear-exports-put-poor-countries-and> (accessed June 18, 2020).
- Chaney, T. (2014). The Network Structure of International Trade. *American Economic Review* 104(11), 3600–3634.
- Che, Y., J. Du, Y. Lu, and Z. Tao (2015). Once an Enemy, Forever an Enemy? The Long-run Impact of the Japanese Invasion of China from 1937 to 1945 on Trade and Investment. *Journal of International Economics* 96(1), 182–198.
- Correia, S., P. Guimarães, and T. Zylkin (2020). Fast Poisson Estimation with High-dimensional Fixed Effects. *Stata Journal* 20(1), 95–115.
- Crozet, M. and J. Hinz (2020). Friendly Fire: The Trade Impact of the Russia Sanctions and Counter-Sanctions. *Economic Policy*, forthcoming, early view at <https://doi.org/10.1093/epolic/eiaa006>.
- Damdinsuren, O. and E. Namjildorj (2020). Sheep Diplomacy and a Troubled Economy: Mongolia Amid COVID-19. Coronabrief. Singapore: Friedrich Ebert Stiftung, published

- April 30, 2020. Available at <https://www.fes-asia.org/news/sheep-diplomacy-and-a-troubled-economy-mongolia-amid-covid-19/> (accessed June 24, 2020).
- Davis, C. L., A. Fuchs, and K. Johnson (2019). State Control and the Effects of Foreign Relations on Bilateral Trade. *Journal of Conflict Resolution* 63(2), 405–438.
- Davis, C. L. and S. Meunier (2011). Business as Usual? Economic Responses to Political Tensions. *American Journal of Political Science* 55(3), 628–646.
- DellaVigna, S. and E. La Ferrara (2010). Detecting Illegal Arms Trade. *American Economic Journal: Economic Policy* 2(4), 26–57.
- Dreher, A. and A. Fuchs (2015). Rogue Aid? An Empirical Analysis of China’s Aid Allocation. *Canadian Journal of Economics* 48(3), 988–1023.
- Dreher, A., A. Fuchs, B. Parks, A. M. Strange, and M. J. Tierney (2018). Apples and Dragon Fruits: The Determinants of Aid and Other Forms of State Financing from China to Africa. *International Studies Quarterly* 62(1), 182–194.
- Du, Y., J. Ju, C. D. Ramirez, and X. Yao (2017). Bilateral Trade and Shocks in Political Relations: Evidence from China and Some of its Major Trading Partners, 1990–2013. *Journal of International Economics* 108, 211–225.
- Evenett, S. J. (2020). Sicken Thy Neighbour: The Initial Trade Policy Response to COVID-19. *World Economy* 43(4), 828–839.
- Financial Times (2020). Chinese Companies Rush to Exploit Global Medical Equipment Shortages. Financial Times, May 11th, 2020. Available at <https://www.ft.com/content/875d9cf3-b5db-43da-8045-fa28c84cf972> (accessed June 22, 2020).
- Fisman, R., Y. Hamao, and Y. Wang (2014). Nationalism and Economic Exchange: Evidence from Shocks to Sino-Japanese Relations. *Review of Financial Studies* 27(9), 2626–2660.
- Fuchs, A. (2018). China’s Economic Diplomacy and the Politics-Trade Nexus. In P. A. van Bergeijk and S. Moons (Eds.), *Research Handbook on Economic Diplomacy*, Chapter 18, pp. 297–316. Cheltenham, UK: Edward Elgar Publishing.
- Fuchs, A. and N.-H. Klann (2013). Paying a Visit: The Dalai Lama Effect on International Trade. *Journal of International Economics* 91(1), 164–177.
- GACC (2020). Customs Statistics. Import and Export Data at Country-Province Level. Beijing, China: General Administration of Customs of the People’s Republic of China. Available at <http://43.248.49.97/indexEn> (accessed June 18, 2020).

- Gehring, K., L. C. Kaplan, and M. H. Wong (2019). China and the World Bank: How Contrasting Development Approaches Affect the Stability of African States. CESifo Working Paper 7856. Munich, Germany: CESifo.
- Heilmann, K. (2016). Does Political Conflict Hurt Trade? Evidence from Consumer Boycotts. *Journal of International Economics* 99, 179–191.
- Hirschman, A. O. (1945). *National Power and the Structure of Foreign Trade*. Los Angeles, CA: University of California Press.
- Hornung, J. W. (2020). Don't Be Fooled by China's Mask Diplomacy. Santa Monica, CA: RAND Corporation. Available at <https://www.rand.org/blog/2020/05/dont-be-fooled-by-chinas-mask-diplomacy.html> (accessed June 24, 2020).
- Isaksson, A.-S. and A. Kotsadam (2018). Chinese Aid and Local Corruption. *Journal of Public Economics* 159, 146–159.
- Jin, H., Y. Qian, and B. R. Weingast (2005). Regional Decentralization and Fiscal Incentives: Federalism, Chinese Style. *Journal of Public Economics* 89(9–10), 1719–1742.
- Johnston, L. A., S. L. Morgan, and Y. Wang (2015). The Gravity of China's African Export Promise. *World Economy* 38(6), 913–934.
- Kaufmann, D., A. Kraay, and M. Mastruzzi (2011). The Worldwide Governance Indicators: Methodology and Analytical Issues. *Hague Journal on the Rule of Law* 3(2), 220–246.
- Le Monde (2020). Coronavirus : une “guerre des masques” sur les tarmacs entre l'Etat et les collectivités locales. Le Monde, April 10th, 2020. Available at https://www.lemonde.fr/societe/article/2020/04/10/coronavirus-l-etat-tente-d-eteindre-sa-guerre-des-masques-avec-les-collectivites-locales_6036169_3224.html (accessed June 20, 2020).
- Lin, F., C. Hu, and A. Fuchs (2019). How Do Firms Respond to Political Tensions? The Heterogeneity of the Dalai Lama Effect on Trade. *China Economic Review* 54, 73–93.
- Liu, X. and X. Hu (2018). Are 'Sister Cities' from 'Sister Provinces'? An Exploratory Study of Sister City Relations (SCRs) in China. *Networks and Spatial Economics* 18(3), 473–491.
- Liu, X., C. Wang, and Y. Wei (2001). Causal Links between Foreign Direct Investment and Trade in China. *China Economic Review* 12(2-3), 190–202.
- Lo, I. (2020). Carrots, Sticks, and Masks: The Control of Medical Supply Chains in East Asia. Vancouver, Canada: Asia Pacific Foundation of Canada.

Available at <https://www.asiapacific.ca/publication/carrots-sticks-and-masks-control-medical-supply-chains-east> (accessed June 24, 2020).

Mascitelli, B. and M. Chung (2008). Using Sister City Relationships to Access the Chinese Market. *Journal of International Trade Law and Policy* 7(2), 203–215.

Mayer, T. and S. Zignago (2011). Notes on CEPII's Distances Measures: The GeoDist Database. CEPII Working Paper 2011–25. Paris, France: Centre d'Etudes Prospectives et d'Informations Internationales.

MOFCOM (2019). Registration of Foreign Invested Enterprises. Department of Foreign Investment Administration, Ministry of Commerce of the People's Republic of China: Foreign direct investment between 2015 and 2017 at country-province level. Available at <http://wzs.mofcom.gov.cn/> (accessed October 22, 2019).

Moons, S. J. and P. A. van Bergeijk (2017). Does Economic Diplomacy Work? A Meta-analysis of its Impact on Trade and Investment. *World Economy* 40(2), 336–368.

Morgan, P. and Y. Zheng (2019). Tracing the Legacy: China's Historical Aid and Contemporary Investment in Africa. *International Studies Quarterly* 63(3), 558–573.

New York Times (2020). The World Needs Masks: China Makes Them, but Has Been Hoarding Them. The New York Times, Apr 13th, 2020. Available at <https://www.nytimes.com/2020/03/13/business/masks-china-coronavirus.html> (accessed June 20, 2020).

Nitsch, V. (2007). State Visits and International Trade. *World Economy* 30(12), 1797–1816.

Pandya, S. S. and R. Venkatesan (2016). French Roast: Consumer Response to International Conflict—Evidence from Supermarket Scanner Data. *Review of Economics and Statistics* 98(1), 42–56.

People's Daily (2020). China's Fujian Province Donates 50,000 Face Masks to Sister State Oregon. People's Daily Online, Apr 29th, 2020. Available at <http://en.people.cn/n3/2020/0429/c90000-9685576.html> (accessed June 24, 2020).

Pollins, B. M. (1989). Conflict, Cooperation, and Commerce: The Effect of International Political Interactions on Bilateral Trade Flows. *American Journal of Political Science* 33(3), 737–761.

Popescu, N. (2020). How the Coronavirus Threatens a Geopolitical Europe. London, UK: European Council on Foreign Relations. Available at https://www.ecfr.eu/article/commentary_how_the_coronavirus_threatens_a_geopolitical_europe (accessed June

22, 2020).

Rommel, T. and P. Schaudt (2020). First Impressions: How Leader Changes Affect Bilateral Aid. *Journal of Public Economics* 185, 104107.

Rose, A. K. (2007). The Foreign Service and Foreign Trade: Embassies As Export Promotion. *World Economy* 30(1), 22–38.

Silva, J. S. and S. Tenreyro (2006). The Log of Gravity. *Review of Economics and Statistics* 88(4), 641–658.

Stock, J. H. (2020). Data Gaps and the Policy Response to the Novel Coronavirus. *Covid Economics* 3, 1–11.

The Guardian (2020a). US Accused of ‘Modern Piracy’ after Diversion of Masks Meant for Europe. The Guardian, April 4th, 2020. Available at <https://www.theguardian.com/world/2020/apr/03/mask-wars-coronavirus-outbidding-demand> (accessed June 20, 2020).

The Guardian (2020b). US Hijacking Mask Shipments in Rush for Coronavirus Protection. The Guardian, April 3rd, 2020. Available at <https://www.theguardian.com/world/2020/apr/02/global-battle-coronavirus-equipment-masks-tests> (accessed June 18, 2020).

The Lincolnite (2020). Chinese Province Donates 10k Masks to Lincolnshire. The Lincolnite, Apr 9th, 2020. Available at <https://thelincolnite.co.uk/2020/04/chinese-province-donates-10k-masks-to-lincolnshire/> (accessed June 24, 2020).

UN Comtrade (2020). UN Comtrade Database. Export data at country level. Available at <https://comtrade.un.org/data> (accessed June 19, 2020).

Wahlteiz, O. (2020). Open COVID-19 Dataset. Available at <https://github.com/open-covid-19/data> (accessed June 18, 2020).

WCO/WHO (2020). HS Classification Reference for Covid-19 Medical Supplies. (2nd Edition, as updated 9 April 2020). World Customs Organization. Available at http://www.wcoomd.org/-/media/wco/public/global/pdf/topics/nomenclature/Covid_19/hs-classification-reference_edition-2_en.pdf?la=en (accessed June 15, 2020).

World Bank (2020). World Development Indicators. Washington, DC: The World Bank. Available at <https://data.worldbank.org/indicator/> (accessed June 18, 2020).

APPENDIX of “Mask Wars: China’s Exports of Medical Goods in Times of COVID-19”

A Data generation and description of variables

Estimation sample Our cross-country results are based on 187 trading partners of China. We exclude 11 countries and territories (Democratic People’s Republic of Korea, Holy See, Hong Kong, Liechtenstein, Macao, Monaco, Palestine, San Marino, South Sudan, Taiwan, and Western Sahara) due to missing political or gravity controls.

Our dyadic results are based on bilateral linkages between 195 partner countries and 31 Chinese provinces, which results in a total of 6,045 province-country pairs.

Classifying medical exports We classify exports into medical and non-medical exports primarily by relying on a list of 80 commodities, jointly established by the World Customs Organization (WCO) and the World Health Organisation (WHO) within the *HS Classification Reference for Covid-19 Medical Supplies*. It relies on the 6-digit level classification according to the Harmonized System (HS6) and its purpose is to provide a guideline to countries in order to facilitate trade in medical equipment. We consider all products on this list as related to *Medical exports* and all other products as *Non-medical exports*.

Alternatively, for robustness checks and descriptive evidence, we rely on a list of 11 essential medical products, which was announced in early April 2020 by the General Administration of Customs of China as a response to mounting quality complaints with respect to Chinese medical exports. The 11 medical products cover 19 HS 10-digit codes, which we concord to 17 HS 8-digit codes, for which export data are available. Products on the list require statutory quality inspections before being exported.

Source: For the 80-product list (HS6), see [WCO/WHO \(2020\)](#); for the official announcement on the product list (HS8) see <http://www.customs.gov.cn/customs/302249/302266/302267/2961602/index.html> (accessed June 18, 2020).

Distinguishing between commercial exports and donation exports We rely on the custom reporting system by the official monthly China Custom Statistics to distinguish between commercial exports and donations. Donations refer to exports under the custom

regimes “Aid or Donation between Governments and International Organizations” (code 11) and “Other Donations” (code 12). Commercial exports cover all other custom regimes, including, among others, ordinary trade and processing trade.

Source: China Customs Statistics ([GACC 2020](#)).

Measuring monthly exports Our dependent variables measure the total US\$ value of exports (medical and non-medical, commercial exports, and donations, product exports of masks and ventilators) over the first two months of the global pandemic, March and April 2020. We sum up export values over these two months, but re-run regressions by month in robustness checks. We transform all export values using an inverse hyperbolic sine transformation.

To control for economic links, we compute past exports during the same two months of the previous year (March and April 2019). We decompose past exports into the mutually exclusive categories of *Commercial medical exports 2019*, *Donation medical exports 2019*, and *Non-medical exports 2019*, which are distinguished based on the 80-product HS6 list by [WCO/WHO \(2020\)](#) and jointly add up to total exports.

By contrast, *Product exports 2019* (used as additional control in regressions for exports of masks and ventilators) is based on the Chinese list of 11 essential medical products at the HS8 level and refers to the exports of the specific product under analysis.

In cross-country regressions, exports are aggregated for each partner country, and in dyadic regressions they refer to country-province pairs.

Source: Official Monthly China Customs Statistics ([GACC 2020](#)).

Inward FDI In cross-country regressions, the variable measures the average annual value of inward foreign direct investment inflows into China originating from each of the partner countries from 2015 to 2017, measured in US\$. In dyadic regressions, the variable measures the average annual value of inward foreign direct investment inflows into each province originating from each of the partner countries from 2015 to 2017, measured in US\$.

Source: China’s Ministry of Commerce ([MOFCOM 2019](#)).

UN voting distance In cross-country regressions, the variable records the ideal-point distance between China and each partner country. Ideal-point distance measures disagreement among country pairs during UN voting sessions, weighting each roll call according to the

relative importance of any given topic for a reference country. In order to flatten out yearly variation, we rely on a sum of all sessions from 2017 to 2019 in ideal-point distance, which ranges from 0.04 (Seychelles) to 3.12 (United States), as depicted in the descriptive statistics in Table D.2.

Source: Bailey et al. (2017).

Recognition of Taiwan In cross-country regressions, this binary variable takes the value of one for countries officially recognizing the Republic of China on Taiwan (capital: Taipei) instead of the People's Republic of China (capital: Beijing). In 2020, the following 15 countries have diplomatic relations with Taipei according to the website of the Ministry of Foreign Affairs of the Republic of China (Taiwan): Belize, Eswatini, Guatemala, Haiti, Holy See, Honduras, Marshall Islands, Nauru, Nicaragua, Palau, Paraguay, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, and Tuvalu.

Source: <https://www.mofa.gov.tw/en/AlliesIndex.aspx?n=DF6F8F246049F8D6&sms=A76B7230ADF29736> (accessed June 19, 2020).

Donations to China/province in Jan.-Feb. In cross-country regressions, *asinh Donations to China in Jan.-Feb.* measures the inverse hyperbolic sine of the US\$ value of total aid and donation imports to China by each partner country between January and February of 2020. In dyadic regressions, *asinh Donations to province in Jan.-Feb.* records the inverse hyperbolic sine of the US\$ value of total aid and donations imports to each Chinese province by each partner country.

Source: Official Monthly China Customs Statistics (GACC 2020).

Sister linkages In cross-country regressions, the indicator variable takes a value of one if any administrative entity in a partner country maintained a sister relationship with at least one Chinese province at the beginning of 2020. In dyadic regressions, the indicator variable takes one if a partner country maintained a sister relationship with the Chinese province in question at the beginning of 2020. The variables are based on a dataset of 662 province-level sister relationships from China International Friendship Cities Association (CIFCA).

Source: Liu and Hu (2018).

COVID-19 infection rates In cross-country regressions, *COVID-19 infection rates* are

calculated per 10 million people by the end of April 2020 and are transformed by an inverse hyperbolic sine transformation. They provide us a proxy for the early spread of the pandemic in each importing country. By the end of April, San Marino showed the largest infection rate, followed by Andorra, and Luxembourg.

Source: Open COVID-19 Dataset ([Wahlteiz 2020](#)).

Government effectiveness In cross-country regressions, this variable is captured by an index that measures the quality of public services, the capacity of the civil service and its independence from political pressures, and the quality of policy formulation. The index is provided yearly and we average it over the years 2014 to 2016. In our sample, its values range from -2.3 to 2.2.

Source: Worldwide Governance Indicators ([Kaufmann et al. 2011](#)).

Gravity controls Partner-country GDP in constant US\$ as well as population size have been accessed via *wbopendata* ([Azevedo 2011](#)) and always refer to the latest available year. The partner country's geographic distance is measured from China's most populous city, Shanghai. *Contiguity* encodes a binary variable for a common border with China. GDP, population, and distance are all converted by the inverse hyperbolic sine transformation.

Source: [World Bank \(2020\)](#) for GDP and population, CEPII ([Mayer and Zignago 2011](#)) for distance and contiguity.

B Interaction model

To investigate whether economic and political ties can also act as substitutes when sourcing medical supplies from Chinese provinces, we extend our bilateral trade model from Equation (2) to include interactions of past economic and political linkages $E_{ij} \times P_{ij}$:

$$Y_{ij} = \gamma_0 P_{ij} + \gamma_1 E_{ij} + \gamma_2 E_{ij} \times P_{ij} + \theta_i + \rho_j + \epsilon_{ij}. \quad (3)$$

As before, our political measures, P_{ij} , capture prior donations to provinces and bilateral sister linkages between countries and provinces. In each specification, we only include one selected measure of past economic ties, E_{ij} , which captures either past medical trade or inward FDI. Additionally, we interact our dyadic measures of political ties with the selected economic ties indicators. This estimation strategy allows us to investigate whether political factors enhance or mitigate the importance of past economic linkages.

C Figure

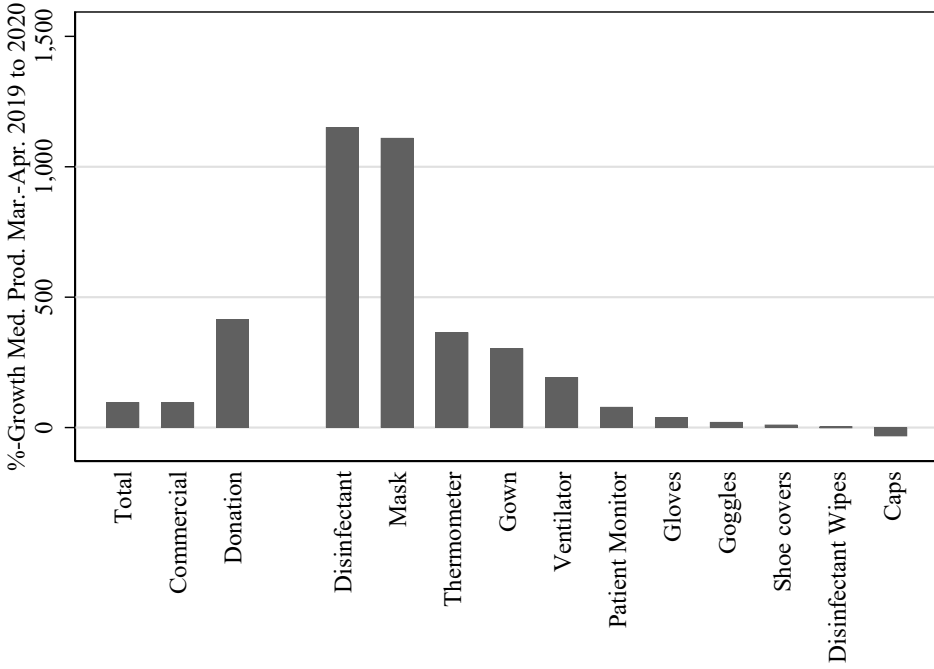


Figure C.1 – Growth in medical equipment exports in March and April between 2019 and 2020

Note: The graph shows the growth rate for total, commercial and donation exports of medical equipment (based on HS 6-digit classification), as well as for 11 medical products measured at the 8-digit level (HS8) that are deemed essential by the Chinese government for COVID-19 treatment and control. Data are taken from [GACC \(2020\)](#). Rates refer to the percent increase between March and April 2020 and the reference months in 2019.

D Tables

Table D.1 – Essential medical equipment exports from China in March and April 2020

Product	Value	Quantity	Av. Price	Main exporter	Top three importers
Surgical masks	9430.9	226.7	72.4	Zhejiang	USA, Germany, Japan
Shoe covers	2319.2	410.6	17.3	Guangdong	USA, Japan, S. Korea
Surgical gowns	1031.1	53.8	33.5	Zhejiang	USA, Spain, Russia
Surgical gloves	419.4	105.2	12.3	Shandong	USA, Japan, Germany
Infrared thermometers	353.3	55.9	95.0	Guangdong	USA, India, Singapore
Ventilators	342.8	142.3	2590.1	Guangdong	USA, Italy, Hungary
Surgical goggles	242.0	10.8	37.9	Zhejiang	USA, Germany, Czech Rep.
Medical disinfectants	218.6	62.1	13.3	Guangdong	USA, Australia, UK
Surgical caps	212.7	391.7	2.0	Jiangsu	USA, Japan, S. Korea
Medical disinfectant wipes	144.9	23.2	21.6	Jiangsu	USA, Japan, Germany
Patient monitors	144.5	5.5	580.6	Guangdong	USA, Netherlands, Italy

Notes: This table shows export value, quantity, average price, main exporting Chinese province, and top three importers of 11 medical products that were designated as essential for COVID-19 treatment and control by Chinese authorities. The 11 medical products are from a list released by the General Administration of Customs of China in early April 2020 that require statutory quality inspections before their shipment to other countries. Export values are measured in millions of US dollar, export prices in US dollar. Export quantities are measured in million number of units for infrared thermometers, ventilators, surgical caps, and patient monitors, and million kilograms for others. The last two columns show the main Chinese exporting province and top three importing countries for each product.

Table D.2 – Descriptive statistics of key variables at the country level

	Mean	St. dev.	Min.	Max.
DEPENDENT VARIABLES:				
<i>asinh</i> Total med. exports 2020	16.718	2.812	0.000	22.857
<i>asinh</i> Commercial med. exports 2020	16.618	2.919	0.000	22.855
<i>asinh</i> Donation med. exports 2020	11.231	4.755	0.000	17.241
<i>asinh</i> Product exports: Masks 2020	15.132	3.390	0.000	22.086
<i>asinh</i> Product exports: Ventilators 2020	10.527	5.718	0.000	18.390
EXPLANATORY VARIABLES:				
<i>asinh</i> Commercial med. exports 2019	15.999	2.858	0.000	22.365
<i>asinh</i> Donation med. exports 2019	2.084	4.470	0.000	16.884
<i>asinh</i> Non-medical exports 2019	19.817	2.382	11.912	25.511
<i>asinh</i> Product exports: Masks 2019	11.795	4.261	0.000	20.193
<i>asinh</i> Product exports: Ventilators 2019				
<i>asinh</i> Inward FDI	7.822	4.080	0.000	15.669
UN voting distance	0.656	0.599	0.043	3.121
Recognition of Taiwan	0.075	0.264	0.000	1.000
<i>asinh</i> Donations to China in Jan.-Feb.	7.531	6.442	0.000	17.477
Sister linkages	0.513	0.501	0.000	1.000
<i>asinh</i> COVID-19 infection rates	1.764	1.647	0.000	6.207
Government effectiveness	-0.074	0.972	-2.274	2.209
Contiguity	0.070	0.255	0.000	1.000
<i>asinh</i> Distance	9.702	0.495	7.556	10.561
<i>asinh</i> Population	16.344	2.120	10.044	21.718
<i>asinh</i> GDP	25.007	2.355	18.260	31.347

Note: The number of observations is 187.

Table D.3 – Cross-country correlates of Chinese medical exports (March 2020)

	Total (1)	Comm. (2)	Donat. (3)	Masks (4)	Ventil. (5)
<i>asinh</i> Comm. med. exports 2019	0.361** (0.150)	0.837*** (0.132)	-0.415** (0.202)	0.072 (0.202)	0.096 (0.143)
<i>asinh</i> Donation med. exp. in 2019	0.036** (0.014)	0.057*** (0.015)	0.105 (0.104)	0.045 (0.043)	0.040 (0.080)
<i>asinh</i> Non-medical exports in 2019	0.550*** (0.205)	0.208 (0.212)	0.488 (0.495)	0.346 (0.298)	0.089 (0.397)
<i>asinh</i> Product exports in 2019				0.389*** (0.108)	0.260*** (0.088)
<i>asinh</i> Inward FDI	0.028 (0.034)	-0.014 (0.038)	0.357** (0.142)	0.040 (0.067)	0.075 (0.106)
UN voting distance	0.106 (0.150)	0.077 (0.160)	-0.631 (0.880)	-0.112 (0.305)	-0.879* (0.488)
Recognition of Taiwan	-0.496 (0.660)	0.561 (0.665)	-4.070*** (1.171)	-1.548* (0.908)	-0.313 (0.817)
<i>asinh</i> Donations to China in Jan.-Feb.	-0.012 (0.017)	-0.011 (0.018)	0.018 (0.107)	0.018 (0.036)	0.174** (0.083)
Sister linkages	-0.138 (0.180)	-0.070 (0.183)	1.686 (1.057)	0.086 (0.375)	-0.401 (0.701)
<i>asinh</i> COVID-19 infection rates	0.097 (0.074)	0.086 (0.070)	0.073 (0.441)	-0.026 (0.175)	0.072 (0.338)
Government effectiveness	-0.004 (0.155)	0.119 (0.194)	0.790 (0.867)	-0.024 (0.334)	-0.603 (0.608)
R-squared	0.882	0.887	0.289	0.819	0.706

Note: Dependent variables measure the value of exports from China to each partner country in March 2020. Columns distinguish between total medical exports, commercial medical exports, donation medical exports, total exports of masks, and total exports of ventilators, all transformed by *asinh*. Columns 4 and 5 are based on HS 8-digit product classifications. All regressions control for a set of gravity determinants (contiguity, the log of distance, log of population, and log GDP). $N = 187$ in all regressions. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.4 – Cross-country correlates of Chinese medical exports (April 2020)

	Total (1)	Comm. (2)	Donat. (3)	Masks (4)	Ventil. (5)
<i>asinh</i> Comm. med. exports in 2019	0.106** (0.047)	0.089* (0.047)	-0.026 (0.229)	0.221 (0.158)	0.231 (0.208)
<i>asinh</i> Donation med. exp. in 2019	-0.003 (0.015)	0.003 (0.016)	0.165** (0.067)	0.044* (0.024)	-0.128 (0.107)
<i>asinh</i> Non-medical exports in 2019	0.414*** (0.149)	0.499*** (0.139)	0.427 (0.305)	0.065 (0.212)	0.363 (0.454)
<i>asinh</i> Product exports in 2019				0.044 (0.055)	0.249** (0.104)
<i>asinh</i> Inward FDI	0.035 (0.033)	0.049 (0.035)	-0.058 (0.132)	-0.088* (0.048)	-0.138 (0.129)
UN voting distance	0.239 (0.150)	0.244 (0.152)	-0.624 (0.625)	-0.086 (0.216)	0.664 (0.497)
Recognition of Taiwan	-0.425 (0.703)	-0.130 (0.691)	-8.612*** (0.800)	-0.199 (0.642)	-0.301 (1.053)
<i>asinh</i> Donations to China in Jan.-Feb.	0.015 (0.014)	0.012 (0.014)	0.094 (0.078)	0.050* (0.027)	0.119 (0.081)
Sister linkages	-0.012 (0.179)	-0.013 (0.179)	1.956** (0.758)	0.090 (0.275)	0.827 (0.759)
<i>asinh</i> COVID-19 infection rates	0.258*** (0.062)	0.281*** (0.064)	0.463 (0.370)	0.575*** (0.132)	0.870** (0.343)
Government effectiveness	0.131 (0.148)	0.061 (0.145)	1.281* (0.735)	0.965*** (0.267)	0.514 (0.566)
R-squared	0.869	0.875	0.466	0.838	0.645

Note: Dependent variables measure the value of exports from China to each partner country in April 2020. Columns distinguish between total medical exports, commercial medical exports, donation medical exports, total exports of masks, and total exports of ventilators, all transformed by *asinh*. Columns 4 and 5 are based on HS 8-digit product classifications. All regressions control for a set of gravity determinants (contiguity, the log of distance, log of population, and log GDP). $N = 187$ in all regressions. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.5 – Cross-country results: Quantities and prices of masks and ventilators (March and April 2020)

Dependent (<i>asinh</i>):	Quantities		Prices	
	Masks (1)	Ventilators (2)	Masks (3)	Ventilators (4)
<i>asinh</i> Product export quantities 2019	0.175*** (0.056)	0.465*** (0.067)		
<i>asinh</i> Product export prices 2019			0.167 (0.131)	0.556*** (0.131)
<i>asinh</i> Commercial med. exports 2019	0.227** (0.105)	0.027 (0.132)	-0.017 (0.104)	-0.334 (0.687)
<i>asinh</i> Donation med. exports 2019	0.022 (0.016)	-0.015 (0.035)	0.002 (0.013)	-0.005 (0.056)
<i>asinh</i> Non-med. exports 2019	0.078 (0.144)	0.215 (0.296)	-0.111 (0.115)	-0.137 (0.653)
<i>asinh</i> Inward FDI	-0.045 (0.035)	-0.073 (0.067)	-0.017 (0.026)	0.050 (0.110)
UN voting distance	-0.092 (0.144)	-0.075 (0.328)	0.059 (0.111)	0.136 (0.407)
Recognition of Taiwan	0.059 (0.387)	0.296 (0.630)	0.117 (0.325)	-1.124 (1.155)
<i>asinh</i> Donations to China in Jan.-Feb.	0.022 (0.019)	0.157*** (0.052)	0.021* (0.012)	-0.127* (0.070)
Sister linkages	0.164 (0.187)	0.740 (0.495)	0.072 (0.111)	-0.287 (0.584)
<i>asinh</i> COVID-19 infection rates	0.239*** (0.088)	0.203 (0.228)	0.248*** (0.058)	0.129 (0.277)
Government effectiveness	0.579*** (0.172)	-0.383 (0.358)	0.173 (0.139)	0.805* (0.473)
Observations	187	187	174	128
R-squared	0.905	0.848	0.303	0.458

Note: Dependent variables measure the quantities and prices of masks and ventilators exported from China to each partner country in March and April 2020, all transformed by *asinh*. All regressions control for a set of gravity determinants (contiguity, the log of distance, log of population, and log GDP). Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.6 – Descriptive statistics of key variables at the province level

	Mean	St. Dev.	Min.	Max.
DEPENDENT VARIABLES:				
<i>asinh</i> Total med. exports 2020	7.188	6.832	0.000	21.361
<i>asinh</i> Commercial med. exports 2020	7.063	6.839	0.000	21.361
<i>asinh</i> Donation med. exports 2020	1.129	3.444	0.000	17.195
<i>asinh</i> Product exports: Masks 2020	5.084	6.413	0.000	20.513
<i>asinh</i> Product exports: Ventilators 2020	1.486	3.918	0.000	17.604
EXPLANATORY VARIABLES:				
<i>asinh</i> Total med. exports 2019	6.842	6.511	0.000	20.949
<i>asinh</i> Donation med. exports 2019	0.078	0.916	0.000	16.884
<i>asinh</i> Commercial med. exports 2019	6.821	6.509	0.000	20.949
<i>asinh</i> Product exports: Masks 2019				
<i>asinh</i> Product exports: Ventilators 2019				
<i>asinh</i> Inward FDI	1.654	3.414	0.000	15.117
<i>asinh</i> Donations to prov. in Jan.-Feb.	1.340	3.708	0.000	16.298
Sister linkages	0.094	0.292	0.000	1.000

Note: The number of observations is 6045.

Table D.7 – Determinants of dyadic medical exports between province-country pairs (March and April 2020): Robustness check based on the HS 8-digit medical product list

	Total (1)	Comm. (2)	Donat. (3)
<i>asinh</i> Comm. med. exports in 2019	0.412*** (0.021)	0.436*** (0.022)	0.016 (0.011)
<i>asinh</i> Donation med. exp. in 2019	0.089 (0.075)	0.053 (0.069)	0.333*** (0.096)
<i>asinh</i> Non-medical exports in 2019	-0.004 (0.015)	-0.028* (0.015)	-0.004 (0.010)
<i>asinh</i> Inward FDI	0.092*** (0.021)	0.098*** (0.021)	0.125*** (0.023)
<i>asinh</i> Donations to prov. in Jan.-Feb.	0.030* (0.016)	0.039** (0.017)	0.088*** (0.020)
Sister linkages	0.117 (0.188)	0.264 (0.195)	0.880*** (0.254)
R-squared	0.771	0.771	0.441

Note: Dependent variables measure the value of medical exports from each Chinese province to each partner country in March and April 2020, aggregated from the HS 8-digit medical product list. Columns distinguish between total medical exports, commercial medical exports, and donation medical exports, all transformed by *asinh*. All regressions control for province and country fixed effects. $N = 6045$ in all regressions. Standard errors clustered at the country level are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.8 – Determinants of dyadic medical exports between province-country pairs (March and April 2020): Robustness check using Poisson Pseudo-Maximum-Likelihood estimation

	Total (1)	Comm. (2)	Donat. (3)	Masks (4)	Ventil. (5)
<i>asinh</i> Comm. med. exports 2019	0.338*** (0.060)	0.347*** (0.061)	0.058 (0.051)	0.217*** (0.063)	0.322** (0.132)
<i>asinh</i> Donation med. exp. 2019	-0.027 (0.044)	-0.022 (0.046)	-0.199* (0.102)	-0.041 (0.068)	0.059 (0.072)
<i>asinh</i> Non-medical exports 2019	0.318*** (0.088)	0.310*** (0.088)	0.489*** (0.139)	0.323*** (0.113)	-0.247 (0.176)
<i>asinh</i> Product exports 2019				0.030* (0.017)	0.072** (0.029)
<i>asinh</i> Inward FDI	0.020* (0.012)	0.021* (0.012)	-0.007 (0.056)	0.014 (0.013)	-0.018 (0.034)
<i>asinh</i> Donations to province in Jan.-Feb.	0.012** (0.006)	0.012** (0.006)	0.010 (0.036)	0.017** (0.008)	0.024 (0.026)
Sister linkages	0.106 (0.069)	0.103 (0.069)	-0.054 (0.395)	0.086 (0.100)	0.182 (0.343)
Observations	5,952	5,952	5,115	5,921	3,473
Pseudo R-squared	0.954	0.747	0.954	0.948	0.772

Note: Dependent variables measure the value of exports from each Chinese province to each partner country in March and April 2020. Columns distinguish between total medical exports, commercial medical exports, donation medical exports, total exports of masks, and total exports of ventilators in levels. The regressions are estimated with the *ppmlhdfe* command in Stata 15.1 by [Correia et al. \(2020\)](#). All regressions control for province and country fixed effects. Standard errors clustered at the country level are reported in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.9 – Determinants of dyadic medical exports between province-country pairs (March 2020)

	Total (1)	Comm. (2)	Donat. (3)	Masks (4)	Ventil. (5)
<i>asinh</i> Comm. med. exports in 2019	0.430*** (0.020)	0.442*** (0.020)	0.001 (0.008)	0.095*** (0.013)	0.008 (0.007)
<i>asinh</i> Donation med. exp. in 2019	0.071 (0.060)	0.075 (0.064)	0.049 (0.072)	0.020 (0.067)	-0.050 (0.069)
<i>asinh</i> Non-medical exports in 2019	-0.043*** (0.013)	-0.050*** (0.013)	-0.017*** (0.006)	-0.069*** (0.011)	-0.048*** (0.006)
<i>asinh</i> Product exports in 2019				0.399*** (0.023)	0.475*** (0.034)
<i>asinh</i> Inward FDI	0.136*** (0.024)	0.144*** (0.024)	0.053*** (0.017)	0.141*** (0.023)	0.127*** (0.020)
<i>asinh</i> Donations to prov. in Jan.-Feb.	0.074*** (0.015)	0.079*** (0.015)	0.058*** (0.016)	0.128*** (0.020)	0.061*** (0.020)
Sister linkages	0.399** (0.182)	0.442** (0.188)	0.470** (0.205)	0.985*** (0.209)	0.423** (0.186)
R-squared	0.765	0.766	0.296	0.672	0.502

Note: Dependent variables measure the value of exports from each Chinese province to each partner country in March 2020. Columns distinguish between total medical exports, commercial medical exports, and donation medical exports, all transformed by *asinh*. All regressions control for province and country fixed effects. $N = 6045$ in all regressions. Standard errors clustered at the country level are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.10 – Determinants of dyadic medical exports between province-country pairs (April 2020)

	Total (1)	Comm. (2)	Donat. (3)	Masks (4)	Ventil. (5)
<i>asinh</i> Comm. med. exports in 2019	0.381*** (0.020)	0.395*** (0.020)	0.025*** (0.009)	0.208*** (0.020)	0.034*** (0.010)
<i>asinh</i> Donation med. exp. in 2019	-0.013 (0.065)	-0.039 (0.066)	0.279*** (0.077)	-0.010 (0.079)	-0.033 (0.087)
<i>asinh</i> Non-medical exports in 2019	0.032* (0.017)	0.016 (0.017)	-0.002 (0.009)	-0.046*** (0.016)	-0.051*** (0.008)
<i>asinh</i> Product exports in 2019				0.252*** (0.024)	0.456*** (0.031)
<i>asinh</i> Inward FDI	0.112*** (0.020)	0.121*** (0.021)	0.104*** (0.023)	0.182*** (0.029)	0.101*** (0.021)
<i>asinh</i> Donations to prov. in Jan.-Feb.	0.054*** (0.016)	0.060*** (0.016)	0.072*** (0.019)	0.091*** (0.020)	0.096*** (0.021)
Sister linkages	0.099 (0.186)	0.215 (0.200)	0.821*** (0.231)	0.367 (0.233)	0.193 (0.173)
R-squared	0.761	0.759	0.366	0.710	0.489

Note: Dependent variables measure the value of exports from each Chinese province to each partner country in April 2020. Columns distinguish between total medical exports, commercial medical exports, and donation medical exports, all transformed by *asinh*. All regressions control for province and country fixed effects. $N = 6045$ in all regressions. Standard errors clustered at the country level are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.11 – Dyadic determinants of new trade linkages

	Total (1)	Comm. (2)	Donat. (3)	Masks (4)	Ventil. (5)
<i>asinh</i> Non-medical exports 2019	0.006*** (0.002)	0.005*** (0.002)	-0.000 (0.001)	-0.002 (0.001)	-0.005*** (0.001)
<i>asinh</i> Inward FDI	0.014** (0.007)	0.014* (0.007)	0.010*** (0.002)	0.023*** (0.004)	0.009*** (0.002)
<i>asinh</i> Donations to province in Jan.-Feb.	0.005 (0.010)	0.000 (0.011)	0.007*** (0.002)	0.011*** (0.004)	0.004** (0.002)
Sister linkages	0.080 (0.053)	0.059 (0.055)	0.079*** (0.022)	0.064** (0.032)	0.002 (0.019)
Observations	2,690	2,699	5,997	4,463	5,369
R-squared	0.327	0.297	0.399	0.421	0.208

Note: Dependent variable is a binary variable which equals one for province-country pairs exporting in 2020, but not in 2019, and is zero for those without export linkages in both 2019 and 2020. We, hence, estimate those regressions for a subsample of province-country pairs with no exports in 2019. All regressions control for province and country fixed effects. Standard errors clustered at the country level are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.12 – The role of economic linkages in dyadic medical exports (March and April 2020): Robustness check based on the HS 8-digit medical product list

Economic linkages:	Total Medical Exports (1)	Inward FDI (2)
<i>asinh</i> Economic linkages	0.432*** (0.021)	0.257*** (0.032)
× <i>asinh</i> Donations to province in Jan.-Feb.	-0.009*** (0.003)	-0.020*** (0.003)
× Sister linkages	-0.070* (0.037)	-0.108** (0.042)
<i>asinh</i> Donations to province in Jan.-Feb.	0.160*** (0.047)	0.181*** (0.022)
Sister linkages	1.003** (0.474)	1.017*** (0.286)
R-squared	0.771	0.735

Note: Dependent variables measure the value of exports from each Chinese province to each partner country in March and April 2020, aggregated from the HS 8-digit medical product list and all transformed by *asinh*. Column titles refer to the interacted variables that are used to capture economic linkages. All regressions control for province and country fixed effects. $N = 6045$ in all regressions. Standard errors clustered at the country level are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

COVID-19: What if immunity wanes?

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Using a simple economic model in which social-distancing reduces contagion, we study the implications of waning immunity for the epidemiological dynamics and social activity. If immunity wanes, we find that COVID-19 likely becomes endemic and that social-distancing is here to stay until the discovery of a vaccine or cure. But waning immunity does not necessarily change optimal actions on the onset of the pandemic. Decentralized equilibria are virtually independent of waning immunity until close to peak infections. For centralized equilibria, the relevance of waning immunity decreases in the probability of finding a vaccine or cure, the costs of infection (e.g., infection-fatality rate), and the presence of other NPIs that lower contagion (e.g., quarantining and mask use). In simulations calibrated to July 2020, our model suggests that waning immunity is virtually unimportant for centralized equilibria until at least 2021. This provides vital time for individuals and policymakers to learn about immunity against SARS-CoV-2 before it becomes critical.

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1 Introduction

We do not know yet the duration of immunity against severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causing coronavirus infectious disease 2019 (COVID-19). But early evidence points to waning immunity against SARS-CoV-2 (Seow et al., 2020) and we know that immunity against other coronaviruses wanes within two years (Edridge et al., 2020; Huang et al., 2020; Kellam and Barclay, 2020).

If immunity against COVID-19 indeed wanes, then COVID-19 likely becomes endemic and herd immunity cannot be naturally reached. Therefore, ignoring waning immunity may lead to costly policies with irreversible consequences. Despite these risks, almost all the economics literature on the COVID-19 pandemic assumes permanent immunity.¹ Our paper fills this gap in the literature by assessing the implications of waning immunity for decentralized and centralized equilibria in an economic model of an epidemic.

In the model, decision makers are constrained by disease contagion and maximize the difference between the utility from social activity and the cost of infection. The utility from social activity captures, in a stylized way, all the payoffs from economic and social actions that require physical proximity. Our approach is grounded in three reasons.² First, the main economic impact of the pandemic has been on sectors that rely on physical proximity (Chetty et al., 2020). Second, there are also other significant costs of constrained social activity such as anxiety, distress, fatigue, and domestic violence (Ravindran and Shah, 2020; Serafini et al., 2020). Third, contagion of virus causing respiratory diseases is mostly unrelated with consumption and work (Ferguson et al., 2006; Eichenbaum, Rebelo and Trabandt, 2020a) but can be influenced by behavior.

The epidemiological dynamics in the model is based on recurrence relations between three (main) health states: susceptible (S), infected (I), and recovered (R) with the flow pattern $S \rightarrow I \rightarrow R \rightarrow S$ (and hence the conventional labeling SIRS).³ An SIRS model nests both SIR and SIS models.⁴ The canonical SIR model (Kermack and McK-

¹In an already large and fast-growing economics literature addressing the COVID-19 pandemic, we are only aware of three papers allowing for waning immunity. We contrast our paper with these three papers below. The assumption of permanent immunity is also common outside of the economics literature: e.g., Ferguson et al. (2020) and Wang et al. (2020).

²Among various approaches to study epidemics in economic models, ours follows Farboodi, Jarosch and Shimer (2020), Garibaldi, Moen and Pissarides (2020), Guimarães (2020), and Toxvaerd (2020) by directly modeling the choice of social activity. Another approach is to assume contacts are a function of the level and type of i) consumption (Eichenbaum, Rebelo and Trabandt, 2020a,b; Krueger, Uhlig and Xie, 2020) and/or ii) labor (Eichenbaum, Rebelo and Trabandt, 2020a,b; Glover et al., 2020). Yet another approach is treating pandemics as exogenous shifts in state variables (e.g., human capital) (Boucekkine, Diene and Azomahou, 2008). Such an approach resembles the MIT shock assessed by Guerrieri et al. (2020) in the context of the COVID-19 pandemic. See also Philipson and Posner (1993), Kremer (1996), Chakraborty, Papageorgiou and Pérez Sebastián (2010) and Greenwood et al. (2019) for an economic perspective of HIV and malaria.

³The flow from recovered to susceptible stems from waning immunity.

⁴For an accessible review of epidemiological models, see Hethcote (2000).

endrick, 1927) assumes that agents are permanently immune after they recover from the infection and is widely used in the economics literature addressing the COVID-19 pandemic (e.g., Alvarez, Argente and Lippi, 2020; Atkeson, 2020; Eichenbaum, Rebelo and Trabandt, 2020a; Farboodi, Jarosch and Shimer, 2020). The canonical SIS model assumes that agents are never immune and, thus, is employed in studying the economics of recurrent diseases (e.g., Goenka and Liu, 2012, 2019; Goenka, Liu and Nguyen, 2014). An SIRS model is between an SIR and an SIS model by allowing agents to be immune but only temporarily. In light of the evidence on immunity against SARS-CoV-2 and other coronaviruses, an SIRS model is warranted to study the COVID-19 pandemic (Kellam and Barclay, 2020).

In the canonical SIRS model, immunity is a binary variable: agents are either immune or not. And after agents lose immunity they become as susceptible as any other susceptible agent. Waning immunity, however, does not necessarily mean that agents who lose immunity are as unprotected as those who were never infected (Punt et al., 2018; Huang et al., 2020).⁵ Immunological memory (e.g., antibody count) might not be enough to avoid a reinfection but is likely enough for the body to react faster to a reinfection. For this reason, our SIRS block allows susceptible agents to differ among themselves based on infection history. The heterogeneity in infection history can be captured by distinct i) probabilities of being infected, ii) recovery speed, iii) viral shedding, and iv) cost of infection. These possible distinctions are important as they may prevent an endemic COVID-19.

In Section 4, we analyze the simplest case in which all susceptible agents, irrespective of their infection history, are alike. We reach two main conclusions. First, if immunological memory wanes, there is no vaccine or cure, and there is no major exogenous change in the contagiousness of the virus, then COVID-19 becomes endemic because of the continuous flow of agents into the susceptible health state. In this scenario, both a social planner and decentralized individuals choose to social-distance forever. Second, the duration of immunity may not meaningfully change optimal choices in the initial months of the pandemic. We find that the decentralized equilibria is virtually independent of waning immunity for more than six months and until close to peak infections because agents abstract from how their actions affect the probability that they are reinfected later. In slight contrast, we find that the centralized equilibria may vary with waning immunity depending on the costs of infection and the probability of finding a vaccine or cure.

An endemic COVID-19, induced by waning immunity, implies a higher present value of infection costs than a non-endemic one. In response to these higher costs, the social planner mandates further social-distancing. Yet, this extra social-distancing stemming from waning immunity can be small in the short run. If a vaccine is expected in 18 months and the costs of infection reflect an infection-fatality rate of 0.64%, we find

⁵In particular, Huang et al. (2020) report that individuals can be infected with the same human coronavirus one year after first infection but with lower severity.

that optimal centralized policies are almost independent of waning immunity for more than 12 months. In this case, the short-term costs of infection are so high that the social planner severely constrains social activity to postpone those costs and wait for a vaccine. As social activity is already highly constrained, the marginal cost for society to further increase social-distancing is huge. Thus, the social planner finds that the expected costs due to the endemic steady-state are of little relative importance in the short-term and almost does not react to them. In other words, when the short-term costs of the pandemic are very large, waning immunity is relatively unimportant at the early months of the pandemic.

If, on the other hand, the costs of infection are low (e.g., reflecting an infection-fatality rate close to 0.2%), the costs of the pandemic are lower and the social planner mandates less social-distancing. As the costs are lower, the marginal cost of social-distancing are not prohibitively high, giving the social planner room for maneuver to act early to the prospect of the endemic steady-state. Therefore, when immunity wanes, the social planner prefers to mandate relatively more social-distancing in the early months of the pandemic to reduce the costs of the endemic steady-state and gain time for a vaccine to arrive. Finally, a lower probability of discovering a vaccine increases the weight of future utility in the objective function in the same way as a lower discount factor does. This has an entirely different effect depending on waning immunity. When immunity is permanent, future utility is relatively high as the pandemic asymptotically disappears, which demotivates the social planner to postpone infections and mandate social-distancing. But, if immunity wanes in 10 months or two years on average, the present value of the costs of an endemic COVID-19 increase when a vaccine is expected to arrive late. Therefore, the social planner prefers to social-distance even more in the early days of the pandemic and act early to the problem of waning immunity. In sum, waning immunity only meaningfully changes centralized policies when the probability of discovering a vaccine is low or the societal marginal costs of acting early to the endemic steady-state are not unbearably high.

In Section 5, we analyze the case in which immunity wanes but susceptible agents differ based on infection history. Consistent with our previous results, if a vaccine is expected in 18 months and the costs of infections reflect an infection-fatality rate of 0.64%, knowing whether susceptible agents differ based on infection history is not critical in the initial months of the epidemic. Furthermore, if agents that lost immunity are less likely to be infected or shed less virus, then COVID-19 does not become endemic. In this scenario, lower costs of infection and lower probability of finding a vaccine lead to markedly different choices in the short run. Thus, it is important to know whether immunity wanes and whether susceptible agents notably differ based on infection history. Finally, we find that susceptible agents that were immune can be excessively active from a social viewpoint, especially if they suffer much less from a reinfection, because they abstract from the risk of infecting others. Thus, policymakers should be aware of this extra source of risk if immunity wanes.

In a last set of simulations, in Section 6, we change the starting date of the simu-

lations. Our previous results are based on initial conditions matching the start of the COVID-19 pandemic. But, our results might differ as we are about six months past that in July 2020 and as other non-pharmaceutical interventions (NPIs) are in place besides social-distancing (e.g., mandatory mask use and quarantining of identified infected individuals). We find that, even if COVID-19 becomes endemic, the other NPIs in place allow for much more social activity. Furthermore, learning how the infection history affects the protection of individuals against reinfections becomes less important as contagion falls substantially. In fact, even a low probability of finding a vaccine or low costs of infection do not lead to markedly different centralized responses for many months. We conclude that individuals and policymakers have at least until 2021 to learn about the duration of immunity before it becomes truly important for decision making.

We are aware of three papers in the economics literature allowing for waning immunity: [Eichenbaum, Rebelo and Trabandt \(2020b\)](#), [Giannitsarou, Kissler and Toxvaerd \(2020\)](#), and [Malkov \(2020\)](#). These papers, however, differ from ours in crucial aspects including the object of study, approach, and modeling choices. [Eichenbaum, Rebelo and Trabandt](#) study the role of testing and quarantines in a model with health state uncertainty and check the robustness of their findings if immunity wanes; thus, they do not fully explore how the duration of immunity affects contagion in the context of the current pandemic. [Malkov](#) focus on how waning immunity affects the epidemiological dynamics during the COVID-19 pandemic, but he does not allow individuals and the social planner to endogenously react in his simulations. [Giannitsarou, Kissler and Toxvaerd](#) assess the centralized problem during the pandemic in case immunity wanes, but they do not contrast the centralized and decentralized equilibria and their results differ from ours due to modeling and calibration choices.⁶ In Section 4.2, we contrast in more detail our results with those in the three papers.

2 Model

We build an economic model of an epidemic in which agents face a trade-off between social activity and exposure to the virus. This trade-off results from the link between the epidemiological and utility-maximization blocks of the model. The link, in turn, stems from our assumption, following [Farboodi, Jarosch and Shimer \(2020\)](#), [Garibaldi, Moen and Pissarides \(2020\)](#), and [Guimarães \(2020\)](#), that new infections depend on the number of susceptible and infected agents and the social activity chosen by susceptible agents. The model is set in discrete time. The population is constant and of measure one. We focus on symmetric equilibria in which agents with the same health state be-

⁶There are two other relevant differences. As [Eichenbaum, Rebelo and Trabandt](#) and [Malkov, Giannitsarou, Kissler and Toxvaerd](#) assume that all susceptible agents are alike irrespective of infection history. And, as [Eichenbaum, Rebelo and Trabandt, Giannitsarou, Kissler and Toxvaerd](#) place their simulations at the start of the pandemic and assume that only one non-pharmaceutical intervention is in place (testing in the case of [Eichenbaum, Rebelo and Trabandt](#) and mandatory social-distancing in the case of [Giannitsarou, Kissler and Toxvaerd](#)). Our last set of simulations in which we include the effects of other NPIs brings, thus, further insights to the current policy discussion.

have the same. With this and applying the law of large numbers, we do not separately denote individual and aggregate variables.

We distinguish agents that become susceptible after recovery from agents that were never infected because the former, although no longer immune, may still have some immunological memory. The remaining immunological memory may allow for a lower probability of infection, faster recovery, lower viral shedding, and lower costs of infection. We refer to agents that were never infected as *primary* and agents that were infected at least once as *secondary*. To further ease our exposition, we use the index $j \in \{p, q\}$, when referring primary and secondary agents, respectively.

2.1 Epidemiological Block

The population in period t consists of five groups of agents: primary susceptible, $s_{p,t}$, primary infected, $i_{p,t}$, recovered, r_t , secondary susceptible, $s_{q,t}$, and secondary infected, $i_{q,t}$. The number of new infections for each type is given by

$$\beta_j a_{j,t} s_{j,t} i_t,$$

where β_j is the measure of contagiousness for susceptible agents of type j with $\beta_q \leq \beta_p$, $a_{j,t} \in [0, 1]$ is the social activity of susceptible agents of type j , and

$$i_t = i_{p,t} + \sigma i_{q,t} \tag{1}$$

is the number of infected agents. We adjust $i_{q,t}$ with $\sigma \leq 1$ to allow secondary infected individuals shedding less virus than primary infected ones.

The laws of motion governing the transitions between health states are the following:

$$s_{p,t+1} = (1 - \beta_p a_{p,t} i_t) s_{p,t}, \tag{2}$$

$$i_{p,t+1} = \beta_p a_{p,t} s_{p,t} i_t + (1 - \gamma_p) i_{p,t}, \tag{3}$$

$$r_{t+1} = \sum_j \gamma_j i_{j,t} + (1 - \alpha) r_t, \tag{4}$$

$$s_{q,t+1} = \alpha r_t + (1 - \beta_q a_{q,t} i_t) s_{q,t}, \tag{5}$$

$$i_{q,t+1} = \beta_q a_{q,t} s_{q,t} i_t + (1 - \gamma_q) i_{q,t}, \tag{6}$$

where γ_j is the probability that an infected individual of type j recovers and α is the probability that a recovered individual loses immunity. If $\alpha = 0$ and $a_{p,t} = 1$ for all t , the model reduces to the canonical SIR model. If $\alpha > 0$, $\sigma = 1$, $\beta_p = \beta_q$, $\gamma_p = \gamma_q$, and $a_{j,t} = 1$ for all j and t , the model reduces to the canonical SIRS model.⁷

2.2 Decentralized Problem

⁷Under permanent immunity, $\alpha = 0$, the number of secondary susceptible agents remains zero. Under waning immunity, $\alpha > 0$, with $\sigma = 1$, $\beta_p = \beta_q$, and $\gamma_p = \gamma_q$, identifying secondary agents is trivial.

2.2.1 Utility Maximization

In this section, we detail the lifetime utility maximization problem of a primary susceptible agent. Agents derive utility from their social activity. The utility function, denoted by $u(a)$ is single-peaked and its maximum is normalized to zero at $a = 1$. The maximization problem of a primary susceptible agent is given by

$$\max_{\{a_{p,t}, a_{p,t}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \sum_j \Lambda^t (s_{j,t} u(a_{j,t}) - \gamma_j \kappa_j i_{j,t}),$$

subject to Eqs. (2–6). In this maximization problem, the fraction of agents in each health state group corresponds to the (subjective) probability of the agent being in that state; Λ is the discount factor; and κ_j captures all the costs of recovering from the infection. As primary and secondary infected agents may respond differently to the infection (e.g., differ in symptoms severity), we set $\kappa_q \leq \kappa_p$. The decentralized optimum social activity is, then, governed by

$$u'(a_{j,t}) = \beta_j i_t (V_{s_j,t} - V_{i_j,t}), \tag{7}$$

$$\frac{V_{s_j,t}}{\Lambda} = u(a_{j,t+1}) + V_{s_j,t+1} - \beta_j a_{j,t+1} i_{t+1} (V_{s_j,t+1} - V_{i_j,t+1}), \tag{8}$$

$$\frac{V_{i_j,t}}{\Lambda} = V_{i_j,t+1} - \gamma_j (\kappa_j + V_{i_j,t+1} - V_{r,t+1}), \tag{9}$$

$$\frac{V_{r,t}}{\Lambda} = V_{r,t+1} + \alpha (V_{s_q,t+1} - V_{r,t+1}), \tag{10}$$

for both $j \in \{p, q\}$ and $V_{x,t}$ denotes the (shadow) value of the agent in state $x \in \{s_p, s_q, i_p, i_q, r\}$. Eq. (7) summarizes the trade-off. Its left-hand side is the marginal utility of social activity while its right-hand side is expected marginal costs resulting from the possibility of infection. Marginal costs depend on how likely they are exposed by marginally increasing activity, $\beta_j i_t$. And it also depends on the change in the value caused by exposure, which is always positive, $V_{s_j,t} - V_{i_j,t} > 0$. Thus, susceptible agents restrain their social activity, $a_{j,t} \leq 1$, to reduce exposure risk.

Eqs. (7-10), determining the behavior of primary agents, are symmetric along j . Given that these equations do not depend on the (subjective) probability of being in any health state, the same equations also determine the behavior of secondary agents. Therefore, for brevity, we do not present the utility maximization problem of secondary agents.

2.2.2 Decentralized Equilibrium

A decentralized equilibrium corresponds to a path of social activities, $\{a_{p,t}, a_{q,t}\}$, the number of infected agents, i_t , state variables, $\{s_{p,t}, s_{q,t}, i_{p,t}, i_{q,t}, r_t\}$, and shadow values, $\{V_{s_p,t}, V_{s_q,t}, V_{i_p,t}, V_{i_q,t}, V_{r,t}\}$, that satisfy Eqs. (1–10).

2.3 Centralized Problem

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2.3.1 Utility Maximization

In this section, we present the maximization problem of the social planner. The social planner chooses socially optimal activity by directly influencing aggregate variables. In particular, the maximization problem of the social planner is given by

$$\max_{\{a_{p,t}, a_{q,t}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \sum_j \Lambda^t (s_{j,t} u(a_{j,t}) - \gamma_j \kappa_j i_{j,t}),$$

subject to Eqs. (1-6). Relative to the decentralized problem, Eq. (1) is the additional constraint because the social planner internalizes how infected individuals affect contagion. The socially optimum social activity is, then, governed by

$$u'(a_{j,t}) = \beta_j i_t (V_{s_j,t} - V_{i_j,t}), \tag{11}$$

$$\frac{V_{s_j,t}}{\Lambda} = u(a_{j,t+1}) + V_{s_j,t+1} - \beta_j a_{j,t+1} i_{t+1} (V_{s_j,t+1} - V_{i_j,t+1}), \tag{12}$$

$$\frac{V_{i_j,t}}{\Lambda} = V_{i_j,t+1} - \gamma_j (\kappa_j + V_{i_j,t+1} - V_{r,t+1}) - \sigma_j \sum_j \beta_j a_{j,t+1} s_{j,t+1} (V_{s_j,t+1} - V_{i_j,t+1}) \tag{13}$$

$$\frac{V_{r,t}}{\Lambda} = V_{r,t+1} + \alpha (V_{s_q,t+1} - V_{r,t+1}), \tag{14}$$

for both $j \in \{p, q\}$, and $\sigma_j = \begin{cases} 1 & \text{if } j = p, \\ \sigma & \text{if } j = q. \end{cases}$ Comparing this set of equations govern-

ing the optimal choice of the social planner with that governing the optimal choice of agents in the decentralized problem (Eqs. 7-10), we can see that the only difference is in the shadow values of the infected states. This difference reflects a key externality emphasized in the literature: in a decentralized equilibrium, agents decide their social activity without considering the risk of infecting others. As a result, both $V_{i_p,t}$ and $V_{i_q,t}$ are lower in the social planner's problem, which (*ceteris paribus*) restrains social activity relative to the decentralized equilibrium. Part of our objective in this paper is to analyze how the possibility of recovered agents losing immunity distances decentralized and centralized choices.

2.3.2 Centralized Equilibrium

A centralized equilibrium corresponds to a path of social activities, $\{a_{p,t}, a_{q,t}\}$, the number of infected agents, i_t , state variables, $\{s_{p,t}, s_{q,t}, i_{p,t}, i_{q,t}, r_t\}$, and shadow values, $\{V_{s_p,t}, V_{s_q,t}, V_{i_p,t}, V_{i_q,t}, V_{r,t}\}$, that satisfy Eqs. (1-6) and Eqs. (11-14).

3 Calibration

We summarize our parameter choices in Table 1. Each period in the model corresponds to one day. The discount factor includes both a time discount rate, ρ , and the probability of finding a cure-for-all, δ , that would end the problem. In particular, we set $\Lambda = \frac{1}{1+\rho} \frac{1}{1+\delta}$, $\rho = 0.05/365$, and $\delta = 0.67/365$ reflecting a yearly discount rate of 5% and

the probability of finding the cure-for-all of 67% within a year (see, e.g., Alvarez, Argente and Lippi, 2020; Farboodi, Jarosch and Shimer, 2020).

Table 1: Benchmark Calibration

Discount factor:	$\Lambda = \frac{1}{1+0.05/365} \frac{1}{1+0.67/365}$
Cost of infection:	$\kappa_p = \kappa_q = 512$
Average number of days as infected:	$\gamma_p^{-1} = \gamma_q^{-1} = 18$
Infectiousness:	$\beta_p = \beta_q = 2.4/18$
Average number of days immune:	$\alpha^{-1} = 750$
Relative viral shedding of secondary infected:	$\sigma = 100\%$

As in Farboodi, Jarosch and Shimer (2020) and Guimarães (2020), the utility of social activity is determined by:

$$u(a) = \log(a) - a + 1, \tag{15}$$

which guarantees that $u(a)$ is single-peaked with maximum at $a = 1$ and $u(1) = u'(1) = 0$. We also closely follow Farboodi, Jarosch and Shimer to find the cost of infection, κ_p . Assuming that the value of life is US\$10 million and assessing how much agents would be willing to permanently reduce their consumption to permanently lower the probability of dying by 0.1%, we find that the value of life is 80000 in model units. Based on this, we obtain κ_p using the probability of dying conditional on infection. The meta-analysis of Meyerowitz-Katz and Merone (2020) suggests that about 0.64% of those infected with the virus, die. Thus, we set $\kappa_p = 512$.

We follow Atkeson (2020) and most of the economics literature assessing the COVID-19 pandemic and assume that infected individuals remain so for 18 days, $\gamma_p^{-1} = 18$. To calibrate β_p , we follow Acemoglu et al. (2020) and assume $\beta_p = 2.4/18$, implying a basic reproduction number, R_0 , of 2.4. This number is relatively optimistic in light of, for example, the R_0 assumed in Alvarez, Argente and Lippi (2020) of 3.6.

At this stage, the duration of immunity against COVID-19 and how secondary agents differ from primary agents is unknown. To calibrate the probability that recovered individuals lose immunity, we use the evidence regarding other coronaviruses surveyed in Huang et al. (2020) and also the assumption in Eichenbaum, Rebelo and Trabandt (2020b) and set $\alpha^{-1} = 1/750$, implying that agents have immunity for about two years. Regarding the remaining parameters, in our benchmark we simply assume that $\beta_q = \beta_p$, $\gamma_q = \gamma_p$, $\kappa_q = \kappa_p$ and $\sigma = 100\%$. Therefore, our benchmark calibration implies a SIRS model augmented with the endogenous choice of social activity.

We solve the model using a shooting algorithm as detailed in Garibaldi, Moen and

Pissarides (2020). As a starting point, we assume that 1 in a million agents are primary infected, $i_p = 1/10^6$, and the remaining are primary susceptible.

4 Results

4.1 Main Results

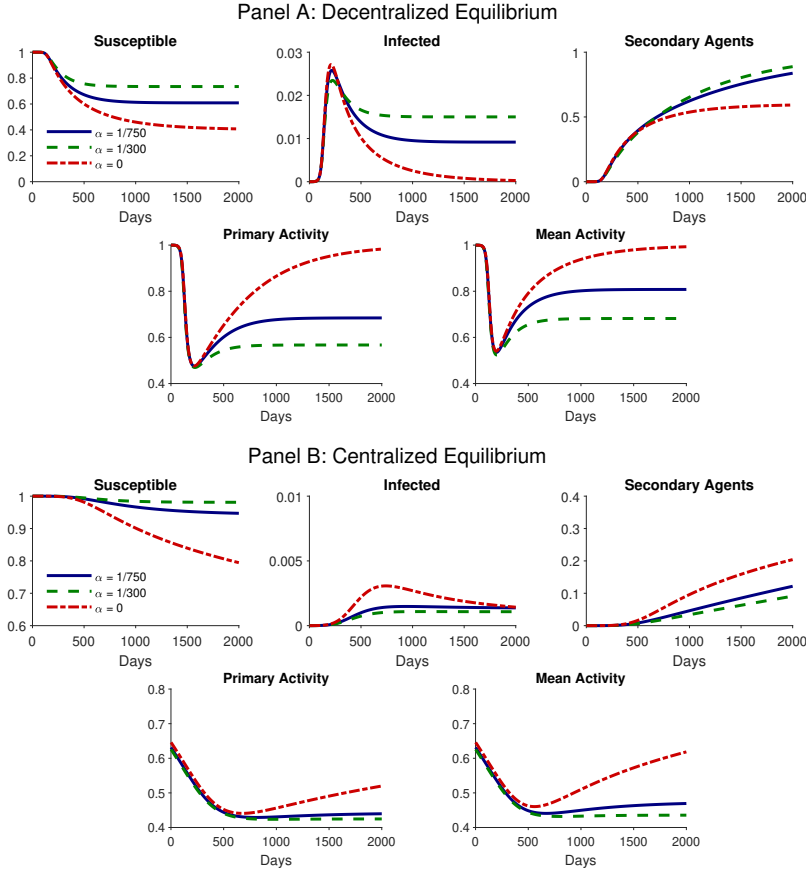
Panels A and B of Figure 1 present how a waning immunological memory affects optimal decentralized and centralized dynamics, respectively. The blue (solid) lines assume our benchmark, i.e., agents are immune for two years on average. The green (dashed) lines assume, as a lower bound and consistent with Huang et al. (2020) and Kissler et al. (2020), that immunological memory lasts only 10 months. The red (dot-dashed) lines assume, as an upper bound and as in the economics literature (e.g. Alvarez, Argente and Lippi, 2020; Eichenbaum, Rebelo and Trabandt, 2020a; Farboodi, Jarosch and Shimer, 2020), that immunity lasts forever (implying an SIR model).

Two of our findings in Figure 1 are striking. First, if immunological memory wanes ($\alpha > 0$), then in both centralized and decentralized equilibria, social activity is severely and permanently curtailed until the discovery of a vaccine or cure. This results from the continuous flow of agents from immune to susceptible, implying a continuous flow from susceptible to infected and, therefore, a permanent exposure risk. Thus, if immunity wanes, COVID-19 reaches an endemic steady-state. In the centralized equilibrium, social activity stabilizes at about 55% lower than absent the epidemic. In the decentralized equilibrium, social activity reaches its minimum after about 200 days and then recovers slightly to its long run value, 30% lower than absent the epidemic. If agents never lose immunity, $\alpha = 0$, the results are very different. In this case, all agents return to normal activity as infections asymptotically disappear. This happens faster, albeit at a higher social cost, in the case of the decentralized equilibrium, leading to much higher peak infections. Furthermore, in the decentralized equilibrium, approximately 60% of the agents are infected at least once within three years, which differs substantially from about 5% in the centralized equilibrium.

Second, the underlying duration of immunity barely moves the initial dynamics of epidemiological variables and social activity for around 200 days in the decentralized and 400 days in the centralized equilibrium. This result is partly explained by the low accumulation of secondary agents as few agents obtain and lose immunity in the initial months of the epidemic even when immunity wanes after 10 months, $\alpha = 1/300$. But other factors play important roles, especially in centralized equilibria. In decentralized equilibria, agents do not take into account how their actions, by affecting infections, change the pace at which they might be reinfected. As a result, social activity in decentralized equilibria is mostly affected by the dynamics of infected agents. As soon as many agents start losing immunity and become susceptible and infected again, the effects of waning immunity become visible in optimal social activities.

In centralized equilibria, however, the externalities of social activity are considered

Figure 1: The Role of Immunity Duration



Note: Susceptible agents are $s_{p,t} + s_{q,t}$; infected agents are $i_{p,t} + i_{q,t}$; secondary agents are $s_{q,t} + i_{q,t} + r_t$; primary activity is $a_{p,t}$ (which, in this case, equals secondary activity, $a_{q,t}$); and mean activity is $s_{p,t}a_{p,t} + s_{q,t}a_{q,t} + i_{p,t} + i_{q,t} + r_t$.

in decision-making. The social planner knows that by reducing social activity, it lowers and postpones infections and, thereby, decreases the number of secondary agents that lose immunity. Furthermore, the social planner is aware of the costs of the endemic steady-state. These two factors combined motivate the social planner to constrain social activity by more when waning immunity induces an endemic COVID-19. Yet, surprisingly, in our benchmark case, the optimal centralized social activity is almost unmoved by the duration of immunity for 400 days.

The social planner aims to minimize the sum of the present value of the costs of infection and of social-distancing. If immunity is permanent, Panel B of Figure 1 shows that the best option to minimize social costs is to endure high social-distancing, postpone infections, and wait for the vaccine. If, on the other hand, immunity wanes, future infection costs increase but their present value is substantially discounted because the vaccine or cure is expected in 18 months. Furthermore, as social activity is heavily constrained even if immunity is permanent, the marginal costs of social-distancing are high and very sensitive to further increases in social-distancing due to the curvature of the utility function. Put differently, the social planner lacks room to maneuver to strongly react to waning immunity in the early months of the pandemic. These two factors combined explain why waning immunity is relatively unimportant for many months in determining optimal social-distancing.

To gain further insight, in Figure 2, we show how two key parameters change the number of infected agents and social activity of primary agents in centralized equilibria. Panel A depicts again the benchmark cases to ease comparison. Panel B depicts the results when expected time to find a vaccine or cure is 4.5 years, implying δ is a third of its benchmark value. Panel C depicts the results when the infection-fatality rate is approximately 0.21%, implying κ_j is a third of its benchmark value. This figure shows that waning immunity matters in these two deviations from benchmark in the centralized equilibria.⁸ The results are particularly staggering in the case of low δ : in this scenario, peak infections occur much earlier and is more than 20 times higher when immunity is persistent than when immunity wanes.

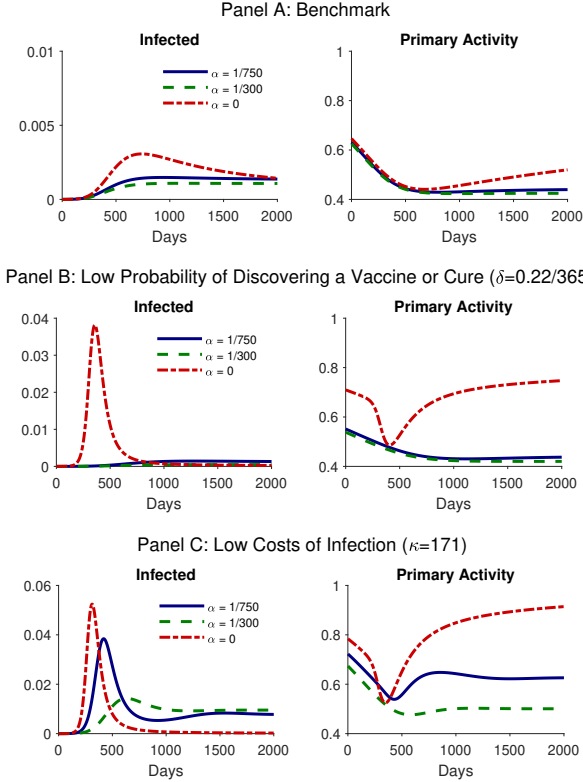
A lengthier period to discover a vaccine or cure, captured by a lower δ , implies that the social planner must restrict social activity for more time to avoid infections and wait for the vaccine or cure. We find that the corresponding increase in the present value of social-distancing costs greatly exceeds the increase in the present value of the costs of infection if immunity is permanent. Therefore, the social planner allows for more infections. The opposite holds when immunity wanes. Technically, a lower δ reduces the discount factor, increasing the present value of the infection costs caused by waning immunity and the endemic COVID-19. Therefore, the social planner reacts even stronger to the pandemic when it emerges if immunity wanes and the vaccine is expected later in time.

A reduction in the infection-fatality rate, captured by a lower, κ_j , implies less costs of infection and, thus, more social activity whatever is α . But the rise in social activity increases in the duration of immunity (i.e., decreases in α). When the costs of infection, κ_j , are lower, the implied point of the reduced social activity is under the flatter range of the curved utility.⁹ Thus, the marginal cost of additional social-distancing is also relatively low, increasing the room to maneuver of the social planner. Therefore,

⁸Figure A1 in the Appendix shows that the way waning immunity affects decentralized equilibria relies much less on κ_p and δ .

⁹In an experiment (not reported), we varied the curvature of the utility function and find that the changes in social activity brought by waning immunity decrease in the curvature.

Figure 2: The Role of Immunity Duration - Centralized Equilibria



Note: Infected agents are $i_{p,t} + i_{q,t}$; primary activity is $a_{p,t}$ (which, in this case, equals secondary activity, $a_{q,t}$).

the social planner acts stronger from the onset of the pandemic to reduce the costs of an endemic COVID-19 and gain time for the discovery of a cure or vaccine. This difference in optimal choices lead to clearly different disease dynamics: the faster immunity wanes, the more the social planner postpones and reduces peak infections.

In sum, waning immunity implies a persistent reduction in social activity either individually chosen or mandated. But because individuals lack altruism, implying a weaker link between choice and (re)infection, the early response to the pandemic in decentralized equilibria is not dependent on waning immunity. In centralized equilibria, however, waning immunity may affect the early response to the pandemic depending on the magnitude of the costs of infection and critically on how likely a vaccine or cure is expected to arrive. Yet, in our benchmark calibration, which we find plausible,

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waning immunity barely affects early optimal choices of social activity in the centralized equilibria.

4.2 Discussion

In this section, we contrast our findings with the three papers in the economics literature that study waning immunity. [Eichenbaum, Rebelo and Trabandt \(2020b\)](#) study the role of testing and quarantining in a model linking consumption and labor choices to contagion. They also find that decentralized individuals permanently reduce their activity (consumption and labor supply) due to the endemic steady-state caused by waning immunity. Furthermore, their Figure 9 suggests that, for over a year, waning immunity is virtually irrelevant for decentralized decisions. Yet, waning immunity affects their centralized equilibria in a way different from ours because of the different policy instruments considered. Their testing and quarantining policies rule out endemic steady states because asymptotically all individuals are continuously tested and infected ones are quarantined. Therefore, waning immunity neither restricts social planner's actions nor permanently constrains economic activity in [Eichenbaum, Rebelo and Trabandt \(2020b\)](#).

[Giannitsarou, Kissler and Toxvaerd \(2020\)](#) study the effects of waning immunity on social-distancing policy. Notable differences between our paper and theirs are as follows. They assume that the pandemic ends in six years (by the discovery of a vaccine), ruling out any endemic steady state. As a result, social activity returns to normal in their simulations. Moreover, the costs of infection and social-distancing are much lower in their model. They assume that the costs of infection are 10% lower output by infected and zero output by deceased only for the time span of the pandemic. The costs of social-distancing are quadratic and finite in a mandated full-lockdown, which provide a vast room to maneuver for the social planner to act. Therefore, when immunity wanes, they obtain deferment of peak infections and a negative relation between immunity duration and mandated social distancing (similar to our results in the low cost of infection case, Figure 2, Panel C).

[Malkov \(2020\)](#) studies how waning immunity affects the dynamics of an epidemiological model under different calibrations of the basic reproduction number. He concludes that until close to peak infections, waning immunity barely changes the disease dynamics. Although [Malkov](#) does not include endogenous decision making in his model, his findings are relatively close to our findings in the decentralized equilibria as waning immunity also only matters close to peak infections. But his findings differ substantially from our results in the centralized equilibria. In this case, the social planner takes into account the future costs of waning immunity in his early response to the pandemic, which in turn, leads to different disease dynamics.

5 Heterogeneous Susceptible Agents

So far, we have analyzed an SIRS model augmented with endogenous social activity. Using our benchmark calibration, in Figure 3, we illustrate how our results change when secondary susceptible and infected agents differ from their primary counterparts in three aspects. Figure 4 complements our illustration in Figure 3 by showing how our results differ if δ and κ_p are low. Green (dashed) lines show the case in which secondary susceptible agents are 75% less likely to be infected than primary susceptible agents;¹⁰ red (dot-dashed) lines show the case in which secondary infected individuals shed 75% less virus than primary infected; yellow (dotted) lines show the case in which the costs of infection are 75% lower for secondary agents; and blue (solid) lines show the benchmark. In the first two cases, even though all agents eventually lose immunity, asymptotic $R0$ is below 1 and, thus, the epidemic will asymptotically disappear as secondary agents gradually replace primary agents. In the case of $\kappa_q = 0.25\kappa_p$, the cost of a reinfection is much lower but the flows between states do not asymptotically converge to zero. That is, asymptotically, individuals are continuously infected but suffering much less than in the beginning of the epidemic. In this case, COVID-19 converges to an endemic steady-state, which is similar to that of other coronaviruses giving rise to flu-like symptoms (Edridge et al., 2020; Huang et al., 2020; Kellam and Barclay, 2020).

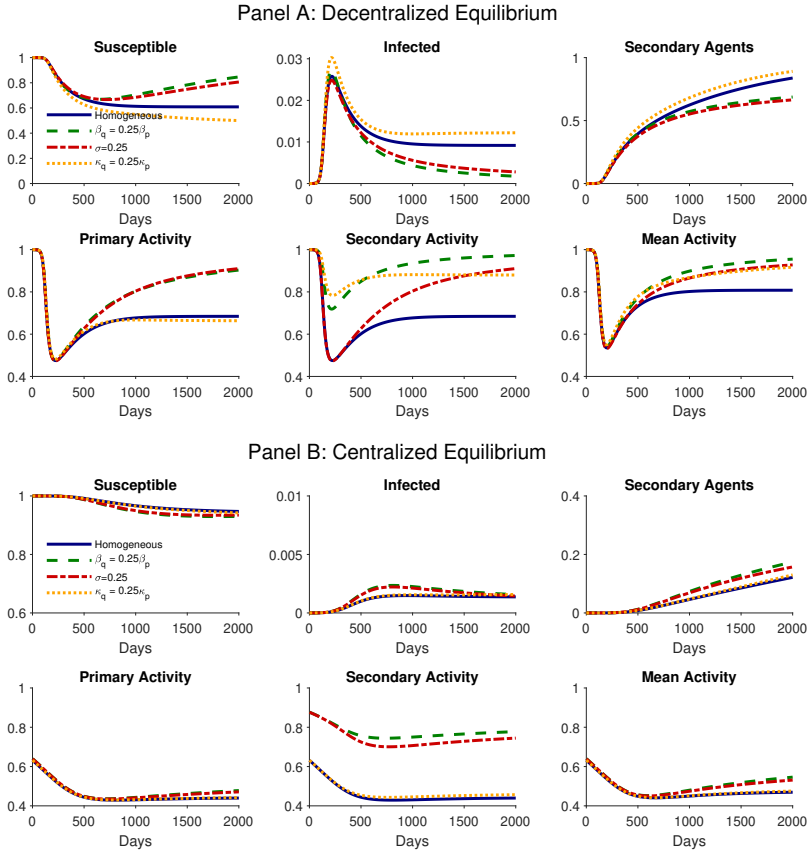
Figure 3 and Panel A in Figure 4 show that if secondary and primary agents differ, there are little changes to the optimal social activity of primary susceptible agents for approximately a year and a half in both centralized and decentralized equilibria. This contributes to a similar path for the number of susceptible (both primary and secondary) agents for many months. Thus, as in the previous section, our benchmark calibration implies that any uncertainty caused by waning immunity is not much relevant for several months after the start of the epidemic.

Our results in the centralized equilibria depend, again, on δ and κ_p . When it is unlikely to discover a vaccine or cure (low δ), the early response to the pandemic critically depends on whether COVID-19 becomes endemic. If it becomes endemic (benchmark and $\kappa_q = 0.25\kappa_p$), the social planner restricts social activity further as the present value of the costs of the endemic steady-state are larger. But if COVID-19 does not become endemic ($\beta_q = 0.25\beta_p$ or $\sigma = 0.25$), the social planner is more lenient. A low cost of infection of primary agents, κ_p , grants room for maneuver for the social planner to act early to endemic steady-states due to the curvature of the utility function. Therefore, mandated social-distancing visibly increases with the overall costs of the pandemic in Panel C of Figure 4.

The optimal behavior of secondary susceptible agents is much different from that of primary susceptible agents irrespective of δ and κ_p . If it is unlikely that secondary agents are reinfected (β_q is low), they restrain social activity by much less than primary ones, which is problematic from a social perspective because they expose other agents

¹⁰This implies a reduction of 75% in $R0$. Different combinations of changes in β_j and γ_j leading to the same fall in $R0$ imply similar results.

Figure 3: Heterogeneous Susceptible Agents

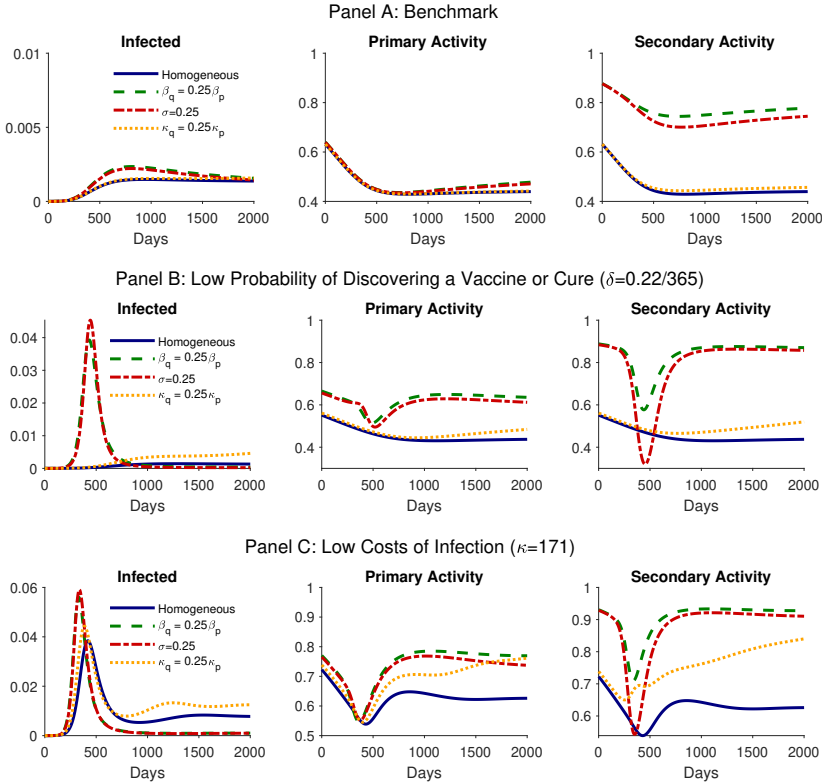


Note: Homogeneous refers to the case in which secondary and primary agents are alike. Susceptible agents are $s_{p,t} + s_{q,t}$; infected agents are $i_{p,t} + i_{q,t}$; secondary agents are $s_{q,t} + i_{q,t} + r_t$; primary activity is $a_{p,t}$; secondary activity is $a_{q,t}$; and mean activity is $s_{p,t}a_{p,t} + s_{q,t}a_{q,t} + i_{p,t} + i_{q,t} + r_t$.

(especially primary) significantly. Thus, even if susceptible agents are unlikely to be reinfected, policymakers should be aware that these agents are likely to be excessively active.

This problem of excessive social activity in the decentralized equilibrium is even worse if $\kappa_q = 0.25\kappa_p$. As agents are not altruistic, they only care about their own risks. A lower cost of reinfection then significantly lowers their incentives to social-distance. In contrast, the social planner would like secondary agents to substantially constrain their

Figure 4: Heterogeneous Susceptible Agents - Centralized Equilibria



Note: Homogeneous refers to the case in which secondary and primary agents are alike. Infected agents are $i_{p,t} + i_{q,t}$; primary activity is $a_{p,t}$; secondary activity is $a_{q,t}$.

activity because their viral shedding and probability of infection are unchanged and many susceptible agents are still primary susceptible.¹¹ The scenario of $\kappa_q = 0.25\kappa_p$ also shows that agents asymptotically constrain social activity, even in the decentralized equilibrium, because COVID-19 becomes endemic and the costs of infection remain high (these costs imply a probability of dying of 0.16% in the benchmark). If these costs were lower, closer to those of endemic human coronaviruses, agents in a decentralized equilibrium would behave almost as if there was no virus which is what we observed until the COVID-19 pandemic.

¹¹In this regard, secondary agents are similar to young agents in models that breakdown agents based on age (Acemoglu et al., 2020; Gollier, 2020). In those models, because young agents know that they are less likely to suffer if infected, they are too active from a social perspective as they increase exposure of older individuals.

The results are very different if $\sigma = 0.25$. Recall that σ measures how likely secondary infected shed virus onto susceptible. Since σ pertains only to the externality caused by secondary agents' actions, it does not affect decisions in the decentralized equilibrium: secondary susceptible agents act as primary susceptible agents. A social planner, in contrast, would allow secondary agents to enjoy relatively more social activity. Both primary and secondary agents, however, benefit indirectly from the lower viral-shedding of secondary infected agents, which allows them to enjoy more social activity, converging asymptotically to full social activity in both equilibria.

6 What If It Was Today?

Following the SARS-CoV2 outbreak, governments around the world have combined several NPIs to change the natural course of the pandemic. To account for this change, in this section, we base our simulations on initial conditions matching the current (epidemiological) state of the COVID-19 pandemic.

In the (new) initial conditions, we accommodate a compromise between the epidemiological state in the US and four European countries, France, Italy, Spain, and the UK, as of 1 July 2020. On this day, the fraction of (currently) infected population was approximately 0.46% in the US; 0.09% in France and 0.02% in Italy.¹² These numbers are likely to be understated as authorities fail to test and identify many of infected and especially asymptomatic people (see references in [Stock, 2020](#) for evidence on the proportion of asymptomatic). Bearing in mind the understatement and cross-country differences in the numbers, we find a compromise at $i = 0.2\%$. To set the initial number of recovered agents, we look at the evidence from antibody surveys. In France, Spain, and the UK, antibody surveys suggest that slightly more than 5% of the population has antibodies against SARS-CoV-2.¹³ Given that the fraction of infected population ratio is two to three times higher in the US than in France, Spain, and the UK, we find a compromise at $r = 6\%$.

In all countries that we examined for this section, identified infected individuals are quarantined. This NPI naturally reduces contagion and we model it as an exogenous reduction in the social activity of some infected agents. In particular, we assume that 50% of infected agents, which is within the current estimated range of asymptomatic cases, are identified and cannot enjoy maximum social activity. In case infected individuals are identified, they enjoy 40% of normal social activity, which increases the expected costs of infection. Thus, average social activity of infected individuals falls by 30%. Other NPIs, like mandatory mask use, differ across countries. In France and the UK, mask use is only mandatory in public transport, whereas in Spain, it is manda-

¹²Statistics consulted in <https://coronavirus.jhu.edu/map.html> on 2 July 2020.

¹³See the ONS COVID-19 Infection Survey for the UK; for France and Spain, see [Salje et al. \(2020\)](#) and [Pollán et al. \(2020\)](#).

tory even in open-air spaces if it is not possible to maintain physical distance.¹⁴ In our model, we treat mask use (mandatory or not) as an exogenous reduction in contagiousness, β_p and β_q , by 30%. In sum, these NPIs reduce β_p and β_q by slightly over 50%.¹⁵

We depict the results in Figures 5 and 6. Blue (solid) lines assume the benchmark values for the the rest of the parameters. Green (dashed) lines assume that agents are permanently immune. Red (dot-dashed) lines assume that in their contagiousness and cost of infection, secondary agents differ substantially from primary agents: $\beta_q = 0.25\beta_p$, $\sigma = 0.25$, and $\kappa_q = 0.25\kappa_p$.¹⁶ Compared to our previous simulations, the other NPIs significantly elevate social activity because of the fall in contagiousness. Furthermore, the simulations suggest that individuals and policymakers do not need to know the duration of immunity and how secondary agents differ from primary ones until at least 2021 even if δ and κ_p are low.¹⁷ Thus, the combination of lower contagiousness and relatively high initial infections reduce the relevance of waning immunity even in centralized equilibria, making the the social planner less responsive to future infection costs. This suggests that if current NPIs remain in place, there is still substantial time to learn about the duration of immunity. Yet, given the implications of the mortality rate for social activity, and consistent with Hall, Jones and Klenow (2020), learning about the actual infection-fatality rate seems highly important.

7 Concluding Remarks

It is likely that immunity against COVID-19 eventually wanes and those that are immune today will face the risk of a reinfection (Edridge et al., 2020; Huang et al., 2020; Kellam and Barclay, 2020; Seow et al., 2020). This scenario is especially problematic if COVID-19 becomes endemic as other human endemic coronaviruses. We show that if COVID-19 reaches an endemic steady-state and a vaccine or cure is not discovered, social-distancing is here to stay. But, on the bright side, we also show that optimal decentralized and centralized choices do not necessarily depend on waning immunological memory for many months following the initial outbreak/contagion. This is especially the case if a vaccine is expected soon, the costs of infection are already large in the short run, and other NPIs that lower contagiousness remain in place. Before making irreversible decisions, individuals and policymakers seem to have time to learn more about immunological memory against SARS-CoV-2 and answer the call for serological studies from Kellam and Barclay (2020), Kissler et al. (2020), and Lerner et al.

¹⁴At the time that we write this paper, France and the UK have announced mandatory mask use in shops.

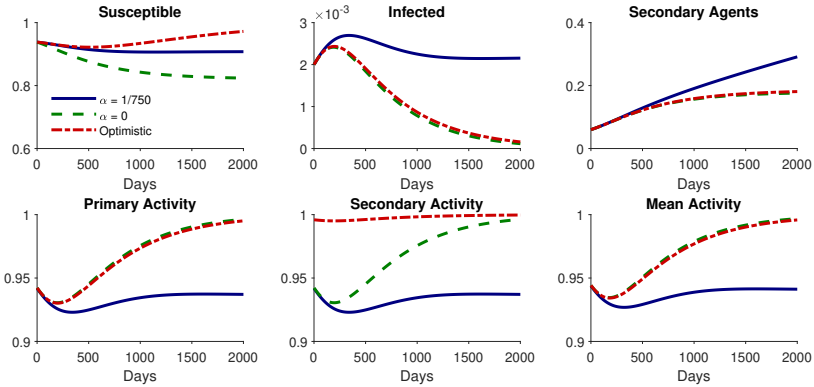
¹⁵Crucially, R_0 is still above one as the pandemic would asymptotically disappear if $R_0 < 1$. But R_0 permanently below one seems unlikely as pointed by the second wave of infections in Australia and South Korea.

¹⁶In these simulations, we assume that the initial fraction of secondary susceptible and infected individuals is zero.

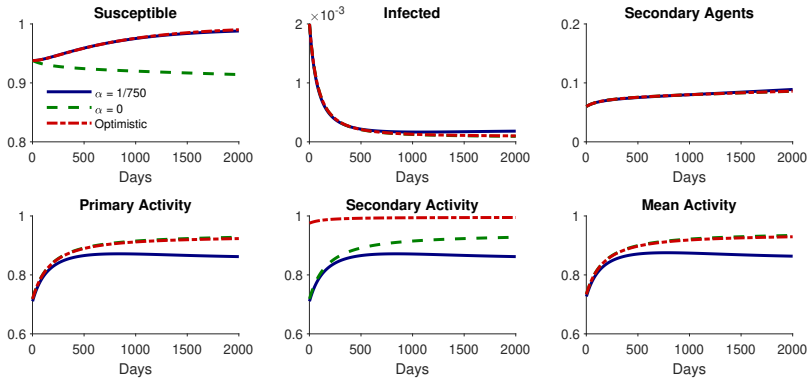
¹⁷Although there are slightly visible differences in terms of optimal primary activity if δ and κ_p are low, the implied dynamics of infected individuals is almost unchanged. Optimal secondary activity depends much more on the scenario for waning immunity, but there are very few agents that are secondary susceptible.

Figure 5: What if It Was Today?

Panel A: Decentralized Equilibrium



Panel B: Centralized Equilibrium

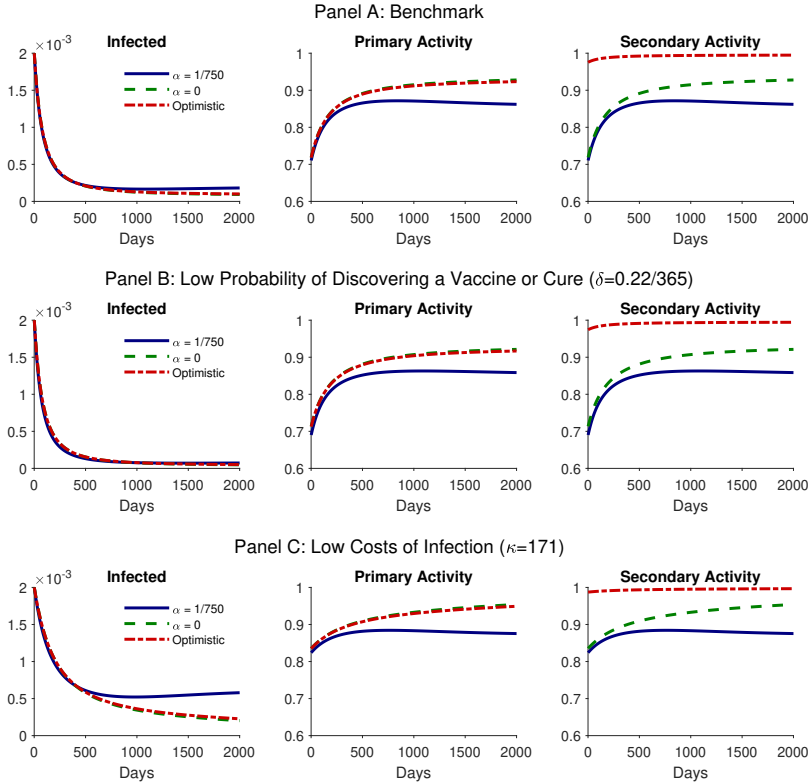


Note: Optimistic refers to the case in which $\beta_q = 0.25\beta_p$, $\sigma = 0.25$, and $\kappa_q = 0.25\kappa_p$. Susceptible agents are $s_{p,t} + s_{q,t}$; infected agents are $i_{p,t} + i_{q,t}$; secondary agents are $s_{q,t} + i_{q,t} + r_t$; primary activity is $a_{p,t}$; secondary activity is $a_{q,t}$; and mean activity is $s_{p,t}a_{p,t} + s_{q,t}a_{q,t} + 0.7(i_{p,t} + i_{q,t}) + r_t$.

(2020).

Yet, in 6-12 months, we do need to know more about how antibodies and T-cells defend the human body against SARS-CoV-2. In particular, we must know how long immunity lasts and whether individuals that were infected (secondary agents) differ substantially from those that were never infected (primary agents). The longer immunity lasts, the less demanding should social-distancing be. And, in the limit, if immunity lasts a lifetime, then COVID-19 does not reach an endemic steady-state and social-

Figure 6: What if It Was Today? - Centralized Equilibria



Note: Optimistic refers to the case in which $\beta_q = 0.25\beta_p$, $\sigma = 0.25$, and $\kappa_q = 0.25\kappa_p$. Infected agents are $i_{p,t} + i_{q,t}$; primary activity is $a_{p,t}$; secondary activity is $a_{q,t}$.

distancing will sooner or later be unwarranted. Furthermore, if secondary agents may be reinfected but are somewhat protected against the virus, then COVID-19 may not become endemic. Yet, the way in which secondary agents differ from primary agents is crucial to design policy. For example, if most of the gains from the additional protection are private – because secondary agents are less likely to die or less likely to be reinfected – then secondary agents are excessively active from a social viewpoint. If, on the other hand, most of the gains from the additional protection are social – because secondary agents shed less virus – then the decentralized and centralized equilibria are closer and less social-planning is required.

Even though most of the economics literature assumes permanent immunity, this simplification may not have dire consequences in the short run. If a vaccine or cure is

expected soon, the costs of infection are not small, and other NPIs are in place, then our model suggests that the optimal response in the initial months of the pandemic is virtually independent of waning immunity. The same is true if secondary agents, despite no longer immune, develop a strong protection against SARS-CoV-2 or shed much less virus. But, if these conditions do not hold, many of the policy prescriptions need to be revised as they rely on the possibility of herd immunity.

References

- Acemoglu, Daron, Victor Chernozhukov, Iván Werning, and Michael D Whinston.** 2020. “Optimal Targeted Lockdowns in a Multi-Group SIR Model.” National Bureau of Economic Research Working Paper 27102.
- Alvarez, Fernando E, David Argente, and Francesco Lippi.** 2020. “A Simple Planning Problem for COVID-19 Lockdown.” National Bureau of Economic Research Working Paper 26981.
- Atkeson, Andrew.** 2020. “What Will Be the Economic Impact of COVID-19 in the US? Rough Estimates of Disease Scenarios.” National Bureau of Economic Research Working Paper 26867.
- Boucekkine, Raouf, Bity Diene, and Théophile Azomahou.** 2008. “Growth Economics of Epidemics: A Review of the Theory.” *Mathematical Population Studies*, 15(1): 1–26.
- Chakraborty, Shankha, Chris Papageorgiou, and Fidel Pérez Sebastián.** 2010. “Diseases, Infection Dynamics, and Development.” *Journal of Monetary Economics*, 57(7): 859 – 872.
- Chetty, Raj, John N Friedman, Nathaniel Hendren, Michael Stepner, and The Opportunity Insights Team.** 2020. “How Did COVID-19 and Stabilization Policies Affect Spending and Employment? A New Real-Time Economic Tracker Based on Private Sector Data.” National Bureau of Economic Research Working Paper 27431.
- Edridge, Arthur WD, Joanna M Kaczorowska, Alexis CR Hoste, Margreet Bakker, Michelle Klein, Maarten F Jebbink, Amy Matser, Cormac Kinsella, Paloma Rueda, Maria Prins, Patricia Sastre, Martin Deijns, and Lia van der Hoek.** 2020. “Coronavirus Protective Immunity Is Short-Lasting.” *medRxiv*.
- Eichenbaum, Martin S, Sergio Rebelo, and Mathias Trabandt.** 2020a. “The Macroeconomics of Epidemics.” National Bureau of Economic Research.
- Eichenbaum, Martin S, Sergio Rebelo, and Mathias Trabandt.** 2020b. “The Macroeconomics of Testing and Quarantining.” National Bureau of Economic Research Working Paper 27104.
- Farboodi, Maryam, Gregor Jarosch, and Robert Shimer.** 2020. “Internal and External Effects of Social Distancing in a Pandemic.” National Bureau of Economic Research Working Paper 27059.
- Ferguson, Neil, Daniel Laydon, Gemma Nedjati Gilani, Natsuko Imai, Kylie Ainslie, Marc Baguelin, Sangeeta Bhatia, Adhiratha Boonyasiri, Zulma Cucunuba Perez, Gina Cuomo-Dannenburg, Amy Dighe, Ilaria Dorigatti, Han Fu, Katy Gaythorpe, Will Green, Arran Hamlet, Wes Hinsley, Lucy Okell, Sabine van Elsland, Hayley Thompson, Robert Verity, Erik Volz, Haowei Wang, Yuanrong Wang, Patrick GTWalker, Caroline Walters, Peter Winskill, Charles Whittaker, Christl Donnelly,**

Steven Riley, and Azra Ghani. 2020. “Report 9: Impact of Non-Pharmaceutical Interventions (NPIs) to Reduce COVID-19 Mortality and Healthcare Demand.”

Ferguson, Neil M., Derek A. T. Cummings, Christophe Fraser, James C. Cajka, Philip C. Cooley, and Donald S. Burke. 2006. “Strategies for mitigating an influenza pandemic.” *Nature*, 442: 448 – 452.

Garibaldi, Pietro, Espen R. Moen, and Christopher A. Pissarides. 2020. “Modelling Contacts and Transitions in the SIR Epidemics Model.” *Covid Economics Vetted and Real-Time Papers, CEPR*.

Giannitsarou, Chryssi, Stephen Kissler, and Flavio Toxvaerd. 2020. “Waning Immunity and the Second Wave: Some Projections for SARS-CoV-2.” CEPR Discussion Papers 14852.

Glover, Andrew, Jonathan Heathcote, Dirk Krueger, and José-Víctor Ríos-Rull. 2020. “Health versus Wealth: On the Distributional Effects of Controlling a Pandemic.” National Bureau of Economic Research.

Goenka, Aditya, and Lin Liu. 2012. “Infectious Diseases and Endogenous Fluctuations.” *Economic Theory*, 50(1): 125–149.

Goenka, Aditya, and Lin Liu. 2019. “Infectious Diseases, Human Capital and Economic Growth.” *Economic Theory*, 1–47.

Goenka, Aditya, Lin Liu, and Manh-Hung Nguyen. 2014. “Infectious Diseases and Economic Growth.” *Journal of Mathematical Economics*, 50: 34 – 53.

Gollier, Christian. 2020. “If the Objective Is Herd Immunity, On Whom Should It Be Built?” *EconPol Policy Brief*, 29(4).

Greenwood, Jeremy, Philipp Kircher, Cezar Santos, and Michèle Tertilt. 2019. “An Equilibrium Model of the African HIV/AIDS Epidemic.” *Econometrica*, 87(4): 1081–1113.

Guerrieri, Veronica, Guido Lorenzoni, Ludwig Straub, and Iván Werning. 2020. “Macroeconomic Implications of COVID-19: Can Negative Supply Shocks Cause Demand Shortages?” National Bureau of Economic Research Working Paper 26918.

Guimarães, Luís. 2020. “Antibody Tests: They Are More Important than We Thought.” mimeo.

Hall, Robert E, Charles I Jones, and Peter J Klenow. 2020. “Trading Off Consumption and COVID-19 Deaths.” National Bureau of Economic Research Working Paper 27340.

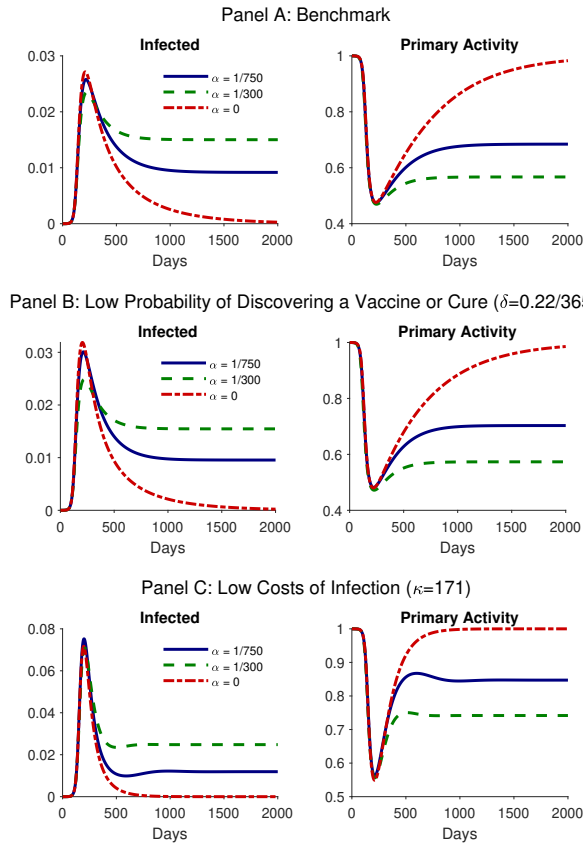
Hethcote, Herbert W. 2000. “The Mathematics of Infectious Diseases.” *SIAM review*, 42(4): 599–653.

- Huang, Angkana T., Bernardo Garcia-Carreras, Matt D.T. Hitchings, Bingyi Yang, Leah Katzelnick, Susan M Rattigan, Brooke Borgert, Carlos Moreno, Benjamin D. Solomon, Isabel Rodriguez-Barraquer, Justin Lessler, Henrik Salje, Donald S. Burke, Amy Wesolowski, and Derek A.T. Cummings.** 2020. "A Systematic Review of Antibody Mediated Immunity to Coronaviruses: Antibody Kinetics, Correlates of Protection, and Association of Antibody Responses with Severity of Disease." *medRxiv*.
- Kellam, Paul, and Wendy Barclay.** 2020. "The Dynamics of Humoral Immune Responses Following SARS-CoV-2 Infection and the Potential for Reinfection." *Journal of General Virology*.
- Kermack, William Ogilvy, and Anderson G McKendrick.** 1927. "A Contribution to the Mathematical Theory of Epidemics." *Proceedings of the royal society of london. Series A, Containing papers of a mathematical and physical character*, 115(772): 700–721.
- Kissler, Stephen M., Christine Tedijanto, Edward Goldstein, Yonatan H. Grad, and Marc Lipsitch.** 2020. "Projecting the Transmission Dynamics of SARS-CoV-2 Through the Postpandemic Period." *Science*, 368(6493): 860–868.
- Kremer, Michael.** 1996. "Integrating Behavioral Choice into Epidemiological Models of AIDS*." *The Quarterly Journal of Economics*, 111(2): 549–573.
- Krueger, Dirk, Harald Uhlig, and Taojun Xie.** 2020. "Macroeconomic Dynamics and Reallocation in an Epidemic." National Bureau of Economic Research Working Paper 27047.
- Lerner, Andrea M., Robert W. Eisinger, Douglas R. Lowy, Lyle R. Petersen, Rosemary Humes, Matthew Hepburn, and M. Cristina Cassetti.** 2020. "The COVID-19 Serology Studies Workshop: Recommendations and Challenges." *Immunity*.
- Malkov, Egor.** 2020. "Covid-19 In the US: Estimates of Scenarios with Possibility of Reinfection."
- Meyerowitz-Katz, Gideon, and Lea Merone.** 2020. "A Systematic Review and Meta-Analysis of Published Research Data on COVID-19 Infection-Fatality Rates." *medRxiv*.
- Philipson, Tomas J., and Richard A. Posner.** 1993. *Private Choices and Public Health: The AIDS Epidemic in an Economic Perspective*. Harvard University Press.
- Pollán, Marina, Beatriz Perez-Gomez, Roberto Pastor-Barriuso, Jesús Oteo, Miguel Hernán, Mayte Pérez-Olmeda, Jose Sanmartín, Aurora Fernández-García, Israel Cruz, Nerea Larrea, Marta Molina, Francisco Rodríguez-Cabrera, Mariano Martín, Paloma Merino-Amador, Jose Paniagua, Juan Muñoz-Montalvo, Faustino Blanco, Raquel Yotti, Rodrigo Fernández, and Antonia Villa.** 2020. "Prevalence of SARS-CoV-2 in Spain (ENE-COVID): a Nationwide, Population-Based Seropidemiological Study." *The Lancet*.

- Punt, Jenni, Sharon Stranford, Patricia Jones, and Judith A. Owen.** 2018. *Kuby Immunology, Eighth Ed.* Macmillan Learning.
- Ravindran, Saravana, and Manisha Shah.** 2020. "Unintended Consequences of Lock-downs: COVID-19 and the Shadow Pandemic." National Bureau of Economic Research Working Paper 27562.
- Salje, Henrik, Cécile Tran Kiem, Noémie Lefrancq, Noémie Courtejoie, Paolo Bosetti, Juliette Paireau, Alessio Andronico, Nathanaël Hozé, Jehanne Richet, Claire-Lise Dubost, Yann Le Strat, Justin Lessler, Daniel Levy-Bruhl, Arnaud Fontanet, Lulla Opatowski, Pierre-Yves Boelle, and Simon Cauchemez.** 2020. "Estimating the Burden of SARS-CoV-2 in France." *Science*.
- Seow, Jeffrey, Carl Graham, Blair Merrick, Sam Acors, Kathryn J.A. Steel, Oliver Hemmings, Aoife O'Bryne, Neophytos Kouphou, Suzanne Pickering, Rui Galao, Gilberto Betancor, Harry D Wilson, Adrian W Signell, Helena Winstone, Claire Kerridge, Nigel Temperton, Luke Snell, Karen Bisnauthsing, Amelia Moore, Adrian Green, Lauren Martinez, Brielle Stokes, Johanna Honey, Alba Izquierdo-Barras, Gill Arbane, Amita Patel, Lorcan OConnell, Geraldine O Hara, Eithne MacMahon, Sam Douthwaite, Gaia Nebbia, Rahul Batra, Rocio Martinez-Nunez, Jonathan D. Edgeworth, Stuart J.D. Neil, Michael H. Malim, and Katie Doores.** 2020. "Longitudinal Evaluation and Decline of Antibody Responses in SARS-CoV-2 Infection." *medRxiv*.
- Serafini, G, B Parmigiani, A Amerio, A Aguglia, L Sher, and M Amore.** 2020. "The Psychological Impact of COVID-19 on the Mental Health in the General Population." *QJM: An International Journal of Medicine*.
- Stock, James H.** 2020. "Data Gaps and the Policy Response to the Novel Coronavirus." *Harvard Environmental Economics Program Discussion Paper Series*.
- Toxvaerd, Flavio.** 2020. "Equilibrium Social Distancing." *Covid Economics Vetted and Real-Time Papers, CEPR*.
- Wang, Huwen, Zezhou Wang, Yinqiao Dong, Ruijie Chang, Chen Xu, Xiaoyue Yu, Shuxian Zhang, Lhakpa Tsamtag, Meili Shang, Jinyan Huang, et al.** 2020. "Phase-Adjusted Estimation of the Number of Coronavirus Disease 2019 Cases in Wuhan, China." *Cell discovery*, 6(1): 1–8.

A Robustness Checks of Decentralized Equilibria

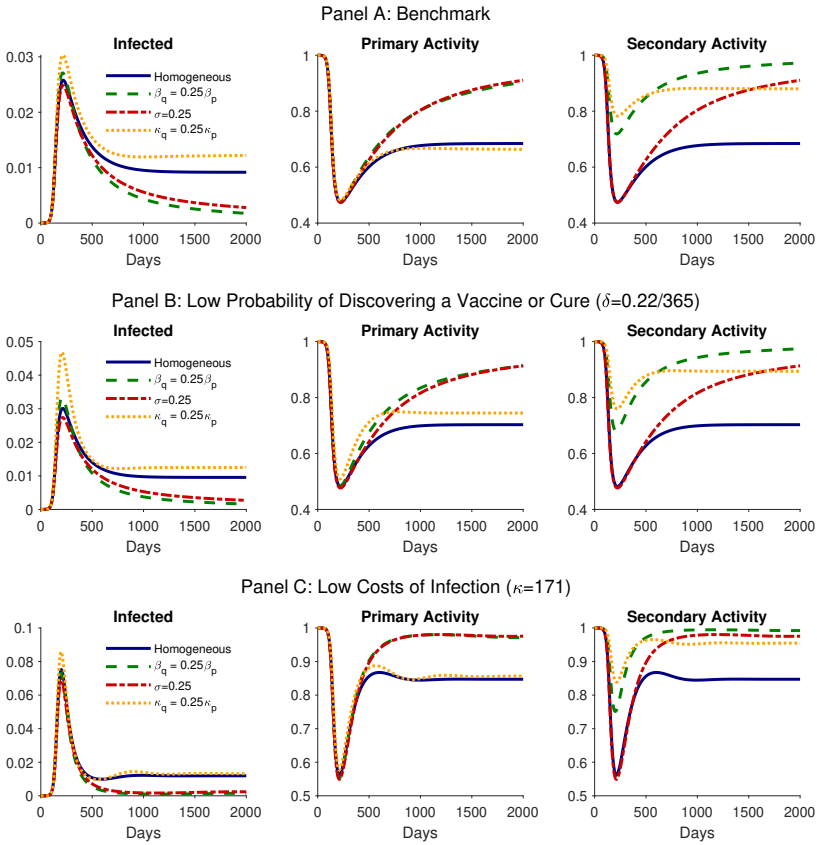
Figure A1: The Role of Immunity Duration - Decentralized Equilibria



Note: Infected agents are $i_{p,t} + i_{q,t}$; primary activity is $a_{p,t}$ (which, in this case, equals secondary activity, $a_{q,t}$).

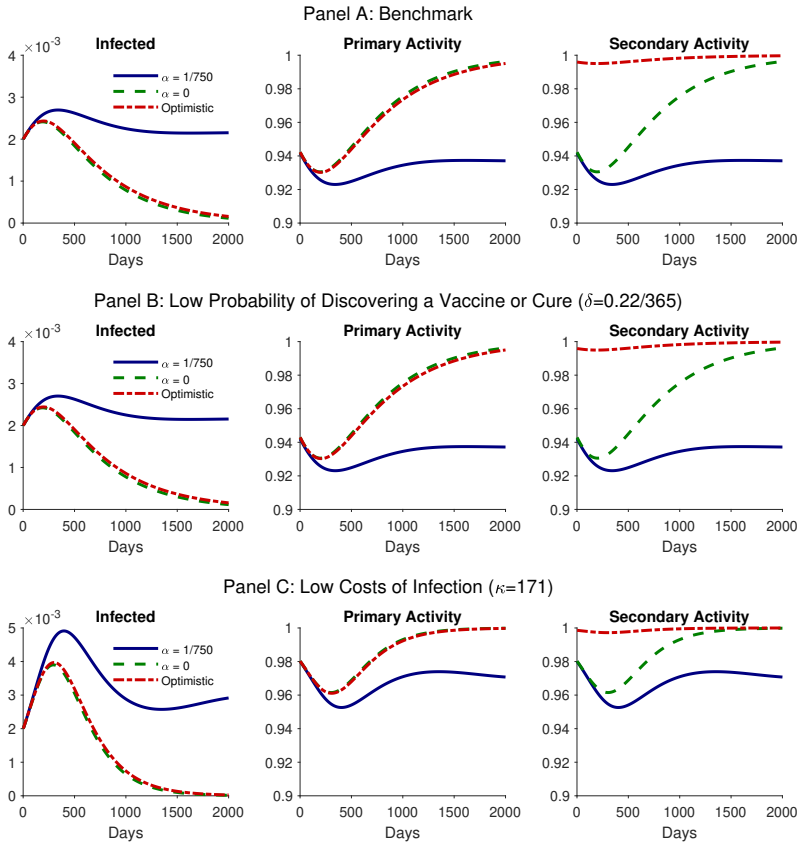
Covid Economics 42, 19 August 2020: 65-93

Figure A2: What if Primary and Secondary Agents Differ? - Decentralized Equilibria



Note: Homogeneous refers to the case in which secondary and primary agents are alike. Infected agents are $i_{p,t} + i_{q,t}$; primary activity is $a_{p,t}$; secondary activity is $a_{q,t}$.

Figure A3: What if It Was Today? - Decentralized Equilibria



Note: Optimistic refers to the case in which $\beta_q = 0.25\beta_p$, $\sigma = 0.25$, and $\kappa_q = 0.25\kappa_p$. Infected agents are $i_{p,t} + i_{q,t}$; primary activity is $a_{p,t}$; secondary activity is $a_{q,t}$.

Covid-19 across European regions: The role of border controls

Matthias Eckardt,¹ Kalle Kappner² and Nikolaus Wolf³

Date submitted: 12 August 2020; Date accepted: 18 August 2020

Attempts to constrain the spread of Covid-19 included the temporal reintroduction of travel restrictions and border controls within the Schengen area. While such restrictions clearly involve costs, their benefits have been disputed. We use a new set of daily regional data of confirmed Covid-19 cases from the respective statistical agencies of 18 Western European countries. Our data starts with calendar week 10 (starting 2nd March 2020) and extends to calendar week 17 (ending 26th April 2020), which allows us to test for treatment effects of border controls. Based on PPML methods and a Bayesian INLA approach we find that border controls had a significant effect to limit the pandemic.

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1 Introduction

The outbreak of the Covid-19-pandemic led to a massive return of the nation state. National governments around the world took far-reaching measures to control the spread of the disease, from decisions to close shops, restaurants and schools to a full-blown lock-down of public life. In Europe, the crisis is a fundamental challenge to the principles of the European Union, notably solidarity, policy coordination and free movement across national borders.

In this paper we focus on the temporal reintroduction of national border controls within the Schengen area. Border controls are obviously costly, even though it is hard to estimate such costs. For example, Felbermayr, Gröschl, and Steinwachs (2016) suggest that the controls imposed in the wake of the refugee crisis in 2015 amounted to a reduction of EU28 real GDP by over 12 billion Euro (or 0.10%) per year. For the current crisis, Meninno and Wolff (2020) argue that these costs must be substantially larger, given the increase in cross-border commuting since 2015. The major question is whether the (temporary) closure of borders had benefits that could justify such costs. According to Nicolas Schmit, Jobs and Social Rights Commissioner the closure of borders, such as the border between Germany and Luxembourg was *just a reflex, which doesn't add anything to health security*. (cf. The New York Times, 17th April 2020). But maybe border controls did help to contain Covid-19?

Attempts to conduct an encompassing cost-benefit analysis for policy measures to contain Covid-19 are difficult and contentious (see for example Gros (2020), Broughel and Kotrous (2020)). Instead we focus on one crucial aspect: to what extent did the reintroduction of border controls reduce the number of infections? Arguably, if we would not find any systematic evidence for the effectiveness of controls on limiting the spread of the disease it would be hard to justify them.

There is a growing literature, which attempts to evaluate which type of non-

pharmaceutical interventions are most effective to limit the spread of Covid-19 and similar diseases, including several international studies, notably Bonardi et al. (2020), and Askitas, Tatsiramos, and Verheyden (2020). Both studies find that the closure of borders or travel restrictions had very little effect. Instead, the reduction of movements within countries, such as cancelling large public events or school closures had quantitatively important effects. Similarly, Weber (2020) finds that the cancellation of mass events, school and childcare closures played an important role, while the closure of external borders had no measurable effect. This stands in contrast to studies, which focus on international air travel (Chinazzi et al. (2020) or Keita (2020)) and find sizeable effects, particularly if measures were implemented early. The major challenges to identify the treatment effect of border controls on the spread of Covid-19 include the construction of a proper control group, the distinction between border controls and other measures introduced simultaneously, and an account of the spatial nature of the data.

Our approach is to collect daily data at the level of European regions within nation states. Our data starts roughly one week before the introduction of border controls, which allows us to test for treatment effects. Based on two quite different approaches, we find that border controls reduced the number of Covid-19 cases significantly, by about 6% to 25%, depending on the specification.

The rest of our paper is organized as follows: we first provide a short survey of the spread of Covid-19 across European regions and the introduction of border controls. Next, we describe our data and our main estimation strategy using a PPML estimator. We then discuss the robustness of our findings using a Bayesian count specification implemented through the integrated nested Laplace approximation introduced by Rue, Martino, and Chopin (2009) to capture unobserved heterogeneity in the spatial structure of our data, and conclude.

2 The spread of Covid-19 and border controls

According to the WHO, the pandemic reached Europe on 25th January 2020 with first cases reported in France, followed by Germany on 28th January and Italy on 30th January 2020 (WHO Situation Reports, 5, 8, 11, 2020). By 1st March 2020, there were 1,457 confirmed cases (with 31 deaths) in the European region (WHO definition), spreading rapidly. One month later, by 1st April 2020 there were 463,677 cases and 30,085 deaths, most of which occurred within the European Union (WHO SR 41 and 72, 2020). Italy introduced the first large-scale measures on 21st February 2020 with a lock-down of initially 11 municipalities, next 4 provinces and on 8 March for the whole country (Maurice et al. 2020). At the European level, the Commission mobilized additional funds for research on 1st February, extended on 24th February, set-up a “response team” on 2nd March 2020 and suggested to relax the fiscal rules of the Stability and Growth Pact. Most importantly, the European Central Bank announced on 18th March 2020 measures of unprecedented scale to support economic activity in the Euro-Zone. While this was a very quick response to the pandemic, notably if compared to the financial crisis, it still left the impression that the European Union was caught off guard and unprepared.

The main reason for this perception is that only national and regional governments could take immediate action against the disease, because health care falls within the competence of the member states, according to the Treaty of Lisbon (Brehon 2020). Among the first actions taken by national governments were the reintroduction of border controls. On 11th March 2020 Austria introduced controls on the land border with Italy, followed by Hungary on the border with Austria and Slovenia on 12nd March, Switzerland on the continental borders with Italy on 13th March. Within a few weeks most countries in the Schengen area have reintroduced border controls, with few exceptions such as the border

between the Netherlands and Germany.

3 Data, method and main results

While we still lack the data to fully understand the dynamics of the pandemic, we can approximate the spread of the disease by looking at confirmed Covid-19 cases across regions within nation-states and over time. To this end, we collected daily regional data of confirmed new Covid-19 cases from the respective statistical agencies of 18 Western European countries¹ from calendar week 10 (starting 2nd March 2020) to calendar week 17 (ending 26th April 2020). For France, we approximate daily new cases by the number of hospitalized per day and region and rescale them to the number of confirmed cases with national data. We aggregate the data to the level of 213 roughly equally sized sub-national regions that closely follow the definition of European NUTS2 regions. Finally, we rescale all regional daily case counts to match the national totals reported by Johns Hopkins University's Coronavirus Resource Center.

Figure 1 shows the spread of Covid-19 across European regions during this period in terms of new confirmed cases per two-week period. As we can see, the spread of the disease shows a very strong regional pattern, while the effects of national borders are not obvious. During the first two weeks of our sample (panel 1a), incidence was concentrated in Northern Italy and parts of Spain. Calendar weeks 12 and 13 (panel 1b) saw a quick spread, in many cases across national borders (with interesting exceptions – see France-Spain). During this period, border controls were enacted. Weeks 14 and 15 (panel 1c) saw the apex of new cases, with incidence all over the map. Calendar weeks 16 and 17 (panel 1d) already saw a reduction in new cases as most countries surpassed the height

¹Those are Andorra, Austria, Belgium, Denmark, France, Finland, Germany, Ireland, Italy, Liechtenstein, Luxembourg, the Netherlands, Norway, Portugal, Spain, Switzerland, Sweden and UK – in other words: All of Western Europe except for the isolated island of Iceland.

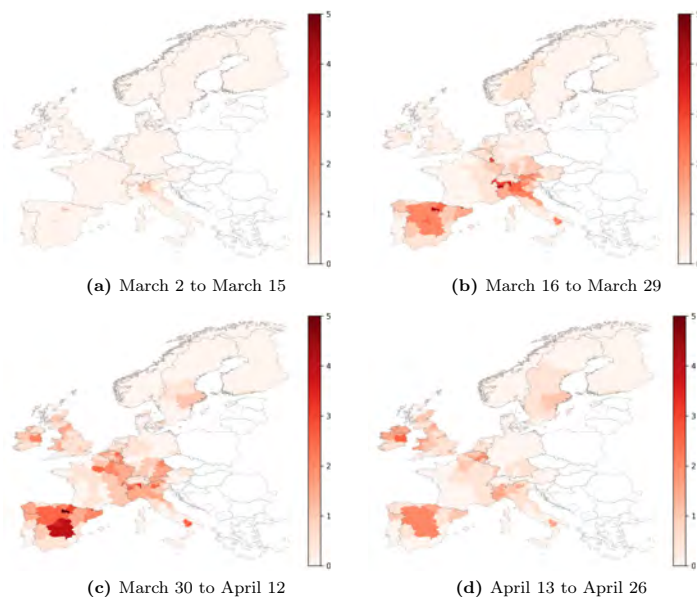


Figure 1: New confirmed Covid-19 cases per 1,000 inhabitants in specified calendar weeks. See text for details on the data sources.

of their incidence curve during the first wave of 2020.

The spatial patterns in the raw daily case data are hard to interpret due to differences in national testing and reporting schemes, differences in data quality, and possible confounding factors. For the remainder of the paper, we thus condition our data on region fixed effects, and country-specific time fixed effects.²

How did borders and border controls matter? The first thing to note is that epidemiological data have a spatial dimension. Intuitively, the effect of controls

²Since we include region fixed effects, we do not need to control for population or GDP and absolute case numbers are just as informative as case rates. Also, country-specific time trends should absorb major differences in testing and reporting behavior, and crucially changes in nationwide containment policies such as the cancellation of large public events or school closures.

should vary with the extent of cross-border relations. Border regions should be more affected than others, and border regions with intense cross-border relations before the controls should be affected most. Hence, the definition of our treatment and control groups is important. Figure 2 illustrates the introduction of border controls and two definitions of our treatment group. We also list the date of border control enactments for each country pair. Note that we always assume a symmetric impact of border controls: If France controls its border with Germany, both French and German border regions are treated, even if Germany technically introduces border controls only later (or not at all).

To test for the role of national borders for the spread of the disease we estimate a series of difference-in-differences regressions of the form

$$I_{r,n,d} = \exp(\alpha_i + \beta_{d,(n)} + \gamma D_{r,d} + \epsilon_{r,d}) \quad (1)$$

where $I_{r,n,d}$ are new cases in region r , in country n on day d , α_i and $\beta_{d,(n)}$ are region and time fixed effects (which in some specifications are allowed to be country-specific), $D_{r,d}$ is a dummy for regions affected by border controls. Since our sample extends well before the onset of border controls, this dummy is time-varying. γ is our coefficient of interest, capturing the causal effect of border controls on daily cases.³

We present results for two different definitions of the treatment: a broad definition and a narrow definition. In our first set of results, we distinguish regions located at controlled borders from those not located at controlled borders. In this specification γ will pick up variation between the two groups over time that is not explained by average (or country-specific) time effects, depending on the specification. However, borders might have mattered for some regions much

³We note that due to the staggered treatment timing, the estimated coefficients present weighted averages of the underlying group-time average treatment effects that are likely to underestimate the actual average treatment effect (Callaway and Sant'Anna 2019).

more than for others in the first place: the introduction of travel restrictions should have mattered a lot for regions that experienced intense cross-border commuting beforehand, such as regions on the border between Belgium and Germany, but much less (or not at all) for border regions with little cross-border commuting.

Therefore, in an alternative specification we consider only those border regions as treated that experienced intense cross-border commuting before the introduction of border controls: in this case, the treated regions are all border regions with an above-mean share of their workforce ($> 0.9\%$) commuting to a workplace across a national border in 2019. For example, 30 % of the workforce of the Belgian region Luxembourg and 11.3 % of the workforce of bordering French Lorraine were cross-border commuters in 2019, hence both regions belong to our intensity-based treatment definition. In contrast, Spanish Aragon and bordering French Midi-Pyrénées both had no significant cross-border commuting in 2019, hence they are excluded from the intensity-based treatment definition.

Moreover, we account for the possibility of a time lag in the effect of border controls. In one specification we assume that controls can have an immediate effect on the spread of the disease. In a second specification we assume that controls have an effect only with a time lag of at least one week, following Lauer et al. (2020).

Before we consider the findings of our difference-in-differences regressions, we need to discuss whether regions in both, treatment and control groups followed similar trends before the treatment. If not, our results might be spurious as they would pick up differences in trends rather than effects from some treatment (Bertrand, Duflo, and Mullainathan 2004). A major challenge in our setting is the staggered introduction of border controls across European regions, together with the relatively limited number of pre-treatment observations. Hence, we lack

the data to formally test for common trends. Instead, we rely on a graphical analysis as shown in figure 3. Note that we show the narrow definition of the treatment group here, based on border regions with above average commuting before the treatment and country-specific time effects.

The key takeaway from figure 3a is that treated regions showed a somewhat higher level of (conditional) confirmed Covid-19 cases compared to control regions before the (staggered) introduction of controls, but that trends in both groups were similar. After the introduction of border controls, the levels in treated regions converge to those in control regions, i.e. there is evidence for a trend break sometime after the treatment. In figure 3b we plot the exponentiated γ -coefficients over time, where an exponentiated coefficient significantly lower than 1 indicates a reduction in cases. The effect of being a treated border region becomes consistently (and significantly) negative only after the introduction of border controls, whereas we see no clear pattern before the treatment(s).

Table 1 shows our first set of results, using a PPML estimator. This method consistently estimates average marginal effects even if the data is not (conditionally) Poisson-distributed. The first three models allow for immediate effects of border controls. The last three models “shift” the onset of border controls by 7 days to take the incubation time and reporting delay into account. We report heteroscedasticity-robust standard errors clustered on the region level.

The point estimates for γ in all models suggest that border controls led to a reduction in the number of reported Covid-19 cases. In table 1 we transform them to report the percentage change in cases relative to the control group together with the p-values. We see that the size of the effect is much larger, once we use the narrow, intensity-based treatment definition (compare columns 1, 2 and 4, 5). Intuitively, the introduction of border controls mattered much more for regions with a substantial number of cross-border commuters beforehand,

	Instant impact			7-day lagged impact		
	(1) Location	(2) Intensity	(3) Intensity	(4) Location	(5) Intensity	(6) Intensity
Border control	-7.04 (0.75)	-40.83 (0.21)	-42.93*** (0.00)	-18.31 (0.22)	-30.92 (0.29)	-25.08** (0.02)
Fixed effects	region day	region day	region day*country	region day	region day	region day*country
Observations	11928	11928	11462	11928	11928	11462
Regions	213	213	210	213	213	210
Pseudo R2	0.81	0.81	0.91	0.81	0.81	0.91

Table 1: The reported coefficients are the percentage changes in cases relative to the control group due to border controls, i.e. $(e^\gamma - 1) * 100$. Numbers in parentheses are p-values.

compared to border regions with little or no commuting. The effects become statistically significant once we use an intensity-based definition of the treatment together with country-specific time effects.⁴ Importantly, neither the slight change in the number of observations nor the introduction of country-specific time effects itself are driving our results. Compared for example to the results in Weber (2020) this suggests that the use of regional instead of state-level data and accordingly the definition of the control group is quite important.

How to read these coefficients? Our preferred specification is shown in column 6, where we control for region effects and country-specific time effects, use a narrow definition of the treatment group and test for lagged effects. A value of -25.08 (column 6) means that daily cases are reduced by 25.08 % due to border controls. Using the mean number of daily new cases across our whole sample (92.387), this amounts to a reduction by $92.387 * 0.251 = 23.189$, about 23 cases per day less for an “average” region.

⁴The number of observations decreases because three countries composed of a single region (Andorra, Liechtenstein, Luxembourg) drop out of the sample.

4 Robustness

A major challenge in our setting is the spatial nature of our data and the fact that we cannot control for temporal variation of local containment policies that differed from national policies (see for example Weber (2020) on Germany). As indicated by figure 1, the spread of Covid-19 followed a particular spatial pattern, which is not well captured by our PPML model. In figure 4 below we provide a measure of spatial correlation in our dependent variable, conditional on region and country-time effects. To this end, we first compute from table 1, col. 6 the spatial lag of the residuals for each region. Next, we group the (standardized) residuals into 100 equally sized bin and plot each bin's mean against the average spatial lag in that bin. Given the strong spatial patterns seen in figure 1 this suggests that our PPML method helps to reduce spatial correlation in the residuals, but does not eliminate it.

Moreover, it is likely that our PPML estimation overstates the true treatment effect from border controls, because the higher incidence in some border regions before the treatment (see figure 3a) would have led to the implementation of local containment policies before they were introduced at the national level. Our country-specific time effects would thus not control for such local measures, which should bias our estimated treatment effects upwards.

To control for both the spatial structure and temporal dynamics of the data and also account for potentially unobserved spatio-temporal heterogeneity (e.g. due to time-varying local policies), we specify a Bayesian spatial-temporal count data model which we implement using the INLA formalism for Bayesian inference in latent Gaussian models. This is provided by the *R-INLA* project (www.r-inla.org) using the capacities of the R environment (R Core Team 2020). Bayesian methods have become widespread in applied epidemiology and public health research, notably due to the development of Markov Chain

	Global effect	Std. Dev.	Implied percentage change
Border control	-0.06	0.01	-6.20***
Constant	-4.18	0.88	

Table 2: Main coefficients from the INLA model. See text for details on the specification.

Monte Carlo methods (MCMC) and, more recently, the development of more computationally efficient alternatives including INLA and variational Bayes approaches, see Blangiardo et al. (2013), Bakka et al. (2018). To this end, we construct a first-order spatial lag structure over the regional entities defined through a contiguity-based spatial weighting matrix which we use to set up a conditional autoregressive specification of the spatial effect (Besag 1972; Besag 1974). Further, to allow for potentially unobserved spatial heterogeneity, we additionally included a spatial random effect assuming an iid Gaussian distribution. By this, we allow for both structured and unstructured spatial effects such that the model also absorbs unobserved spatial heterogeneity (Fahrmeir, Kneib, and Lang 2004). Again, treating the number of new confirmed Covid-19 cases as outcome, the spatio-temporal count model includes time effects, the distance from a continental border, the share of commuters in the workforce, a time-varying dummy for border controls and an offset.⁵ Table 2 shows the main parametric results, figure 5 shows the distribution of the structured and unstructured component of spatial effects.

The main finding from this exercise is that spatio-temporal heterogeneity matters a lot. Our PPML approach with nationwide time effects must have missed the impact of local containment policies, but also spatial spillovers. However, even if we allow for a very flexible form of unobserved spatio-temporal effects, we still find that border controls reduced the number of confirmed Covid-

⁵We model both the temporal dependence and the duration of the border controls by a second-order random walk specification of the effect.

19 cases significantly. According to the INLA approach, the introduction of border controls reduced the number of daily new cases by roughly 6 %, compared to 25 % suggested by the PPML estimator.

5 Conclusion

The temporal reintroduction of border controls within the Schengen area helped to contain the spread of Covid-19. While such restrictions clearly involve costs, their benefits have been disputed. In this paper we used a new set of daily regional data of confirmed Covid-19 cases from the respective statistical agencies of 18 Western European countries, running from calendar week 10 (starting 2 March 2020) to calendar week 17 (ending 26 April 2020). This allowed us to test for treatment effects of border controls. Based on a PPML estimator with region fixed effects and country-specific time effects, we show that border controls were associated with a 25% reduction in daily cases. Importantly, we show that border controls mattered only for regions with a substantial number of cross-border commuters prior to the crisis, which has been missed by the previous literature. As a robustness check, we use a Bayesian INLA approach to take unobserved spatio-temporal heterogeneity into account, for example due to local containment policies that might have differed from nation-wide measures. With this we find smaller, but still significant effects in the area of 6 %. We conclude that the temporal introduction of border controls was certainly costly, but made a measurable contribution to contain the spread of Covid-19. At the same time it is likely that better policy coordination at the European level could have generated these benefits at lower economic (and political) costs, for example if based on a closer monitoring of cross-border commuting flows. We leave this question for further research.

References

- Askatas, Nikos, Konstantinos Tatsiramos, and Bertrand Verheyden (2020). “Lockdown strategies, mobility patterns and Covid-19”. In: *Covid Economics* 23, May 28, pp. 263–302.
- Bakka, Haakon et al. (2018). “Spatial modeling with R-INLA: A review”. In: *WIREs Computational Statistics* 10:e1443.
- Bertrand, Marianne, Esther Duflo, and Sendhil Mullainathan (2004). “How Much Should We Trust Differences-In-Differences Estimates?” In: *Quarterly Journal of Economics* 119.1, pp. 249–275.
- Besag, Julian (1972). “Nearest-neighbor systems and the auto-logistic model for binary data”. In: *Journal of the Royal Statistical Society, Series B, Statistical Methodology* 34.1, pp. 75–83.
- (1974). “Spatial interaction and the statistical analysis of lattice systems”. In: *Journal of the Royal Statistical Society, Series B, Statistical Methodology* 36, pp. 192–236.
- Blangiardo, Marta et al. (2013). “Spatial and spatio-temporal models with R-INLA”. In: *Spatial and Spatio-temporal Epidemiology* 4, pp. 33–49.
- Bonardi, Jean-Philippe et al. (2020). “Fast and local: How lockdown policies affect the spread and severity of covid-19”. In: *Covid Economics* 23, May 28, pp. 325–351.
- Brehon, Nicholas-Jean (2020). “The European Union and the Coronavirus”. In: *Fondation Robert Schuman Policy Paper* 553.7 April.
- Broughel, James and Michael Kotrous (2020). “The Benefits of Coronavirus Suppression. A Cost-Benefit Analysis of the Response to the First Wave of COVID-19”. In: *Mercatus Center, Mercatus Working Paper*.

- Callaway, Brantly and Pedro H. C. Sant'Anna (2019). "Difference-in-Differences with Multiple Time Periods". In: *Working Paper*. URL: http://conference.iza.org/conference_files/EVAL_2019/28549.pdf.
- Chinazzi, Matteo et al. (2020). "The effect of travel restrictions on the spread of the 2019 novel coronavirus (COVID-19) outbreak". In: *Science* 368.6489, 24 April 2020, pp. 395–400.
- Fahrmeir, Ludwig, Thomas Kneib, and Stefan Lang (2004). "Penalized Structured Additive Regression for Space-Time Data: A Bayesian Perspective". In: *Statistica Sinica* 14.3, pp. 731–761.
- Felbermayr, Gabriel, Jasmin Gröschl, and Thomas Steinwachs (2016). "Trade costs of border controls in the Schengen area". In: *VOXEU* 27 April 2016.
- Gros, Daniel (2020). "The great lockdown: was it worth it?" In: *CEPS Policy Insights* No 2020–11, May 2020.
- Keita, Sekou (2020). "Air passenger mobility, travel restrictions, and the transmission of the covid-19 pandemic between countries". In: *Covid Economics* 9, April 24, pp. 77–96.
- Lauer, Stephen A. et al. (2020). "The Incubation Period of Coronavirus Disease 2019 (Covid-19) From Publicly Reported Confirmed Cases: Estimation and Application". In: *Annals of Internal Medicine* 172.9, pp. 577–582.
- Maurice, Eric et al. (2020). "Covid-19: European Responses, a complete picture". In: *Fondation Robert Schuman Policy Paper* 28 April 2020.
- Menimmo, Raffaella and Guntram Wolff (2020). "As the Coronavirus spreads, can the EU afford to close its borders?" In: *VOXEU* 28 February 2020.
- R Core Team (2020). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. URL: <https://www.R-project.org/>.

- Rue, Håvard, Sara Martino, and Nicolas Chopin (2009). “Approximate Bayesian inference for latent Gaussian models by using integrated nested Laplace approximations”. In: *Journal of the Royal Statistical Society: Series B (Statistical Methodology)* 71.2, pp. 319–392.
- Weber, Enzo (2020). “Which measures flattened the curve in Germany”. In: *Covid Economics* 24, June 1, pp. 205–217.

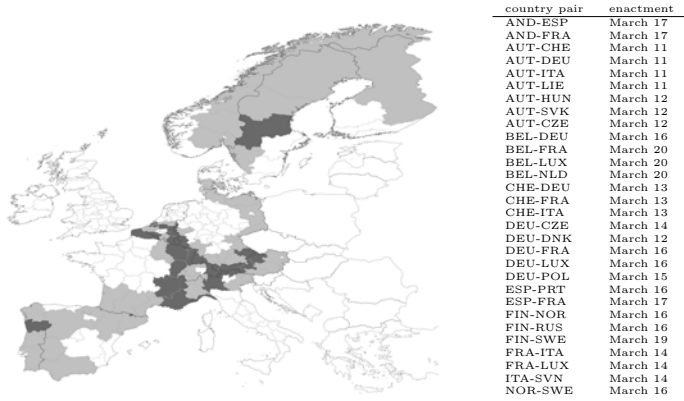


Figure 2: Border controls in European regions. The map on the left shows our treatment and control groups. Light-gray regions (■) are located at controlled borders. Dark-gray regions (■) are a subset of the former with high levels of cross-border commuting in 2019. The table on the right lists the dates of border control enactment for all country pairs, including East European countries not included in our sample.

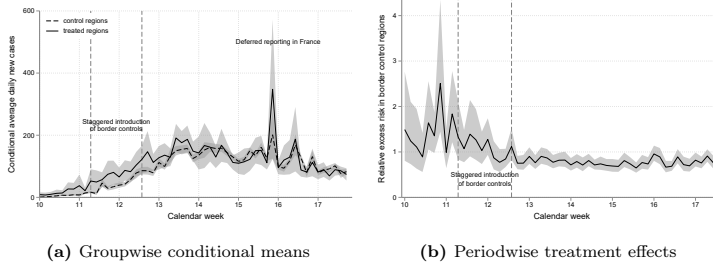


Figure 3: Visual checks for parallel trends. Panel 3a plots average daily new cases in the treatment and control groups, conditional on day and region fixed effects. Panel 3b shows (exponentiated) coefficients of the treatment group dummy for each day, conditional on country-day and region fixed effects. In both panels, gray areas show the 10 % confidence interval for robust standard errors clustered at the region level. Also note that the “France spike” seen in panel 3a does not show up in panel 3b, because it is absorbed by the France-specific time effects.

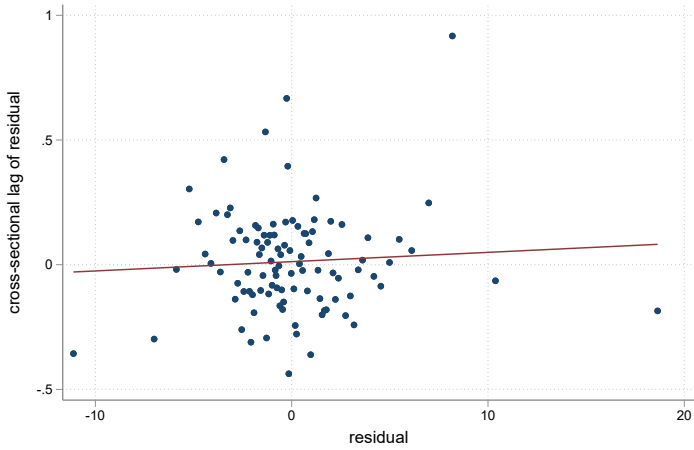


Figure 4: Binscatter of residuals against their cross-sectional lag. We first compute the cross-sectional spatial lag of the residuals from table 1, col. 6, counting as neighbors all regions with a shared border. We then group the (standardized) residuals into 100 equally sized bins and plot each bin’s mean against the average spatial lag in that bin.

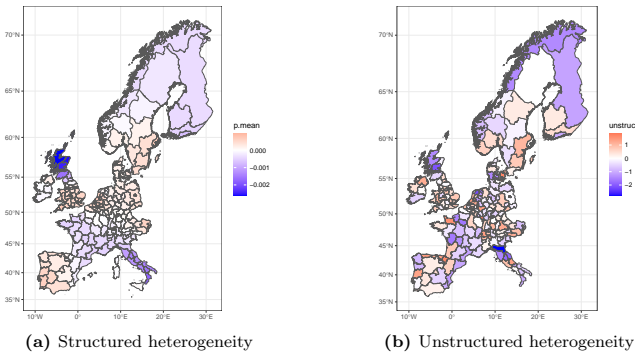


Figure 5: Spatial heterogeneity

The role of IMF in the fight against COVID-19: The IMF COVID RESPONSE INDEX

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This paper establishes a methodology that can be used to measure the behavior of International Monetary Fund (IMF) program design and eventually the outcomes of IMF programs in response to the COVID-19 crisis. We create an IMF COVID RECOVERY INDEX by coding IMF programs based on the extent to which they recommend or condition that borrowing countries increase efforts to combat the virus, protect the vulnerable, and stage a green recovery in accordance with direction from IMF leadership and fiscal guidance notes generated by the IMF Fiscal Affairs Department. Relative to earlier research that suggests the IMF falls short in making such policies part of recovery efforts during times past, our preliminary research indicates that the IMF is indeed prioritizing health and social spending during this crisis—albeit more so in programs where it has little leverage over the implementation of such recommendations. However, IMF support for greening the recovery does not match the rhetoric from IMF leadership or from fiscal guidance notes issued by the IMF Fiscal Affairs department at this time. The IMF COVID RECOVERY INDEX will be updated in real time on the internet, and eventually be used in econometric exercises that examine the extent to which IMF support for confronting the virus, protecting the vulnerable, and mounting a green recovery is associated with those desired outcomes.

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1. Introduction

The COVID-19 pandemic came as an unprecedented shock to the world economy and many countries had to quickly resort to aid of the International Monetary Fund (IMF). The central banks and finance ministries of most advanced economies swiftly advanced swap lines, domestic liquidity support, and expansionary fiscal measures to shore up dollar markets and provide lifelines to the vulnerable. Few emerging markets and developing countries had access to these measures and lacked their own monetary or fiscal space to confront the virus, protect the vulnerable, and mount a sustainable recovery.

Indeed, the pandemic panic and very act of securing dollar markets resulted in a ‘flight to safety’ in the form of the largest levels of capital flight from emerging market and developing countries recorded. Exchange rates subsequently plummeted and external debt ballooned across the developing world at a time when tourism dropped alongside commodity prices—leaving fewer sources of export revenue to pay foreign debt. At exactly the time when many developing countries needed the fiscal space to fight the virus and protect their economies, they were faced with mounting external debt. Both the IMF and the United Nations Conference on Trade and Development (UNCTAD) estimate that liquidity needs for emerging markets and developing countries in 2020 alone was least \$2.5 trillion and that over 100 countries went to the IMF for emergency support (Wheatley, 2020; Georgieva, 2020a; UNCTAD, 2020)

On April 9, 2020 IMF Managing Director Kristalina Georgieva said that ‘These are the times for which the IMF was created—we are here to deploy the strength of the global community, so we can help shield the most vulnerable people and revitalize the economy’ and committed the IMF to a four point ‘all hands on deck’ approach to the crisis that would focus on supporting health systems, protecting vulnerable firms and people, containing financial panic, and mounting a recovery (Georgieva, 2020b). Over ten times between April and July of 2020 Georgieva and senior staff articulated that it is essential that ‘for our world is to become more resilient—we must do everything in our power to promote a ‘green recovery’ (Georgieva, 2020c). Expanding on this notion IMF Deputy Managing Director Tao Zhang emphasized that a green recovery should ‘promote a just transition. That means assisting vulnerable households, workers, regions, and trade-exposed or fuel producing firms. And using carbon pricing revenues in broad tax reductions or public investments that boost growth and benefit all households. (Zhang, 2020).

To back up these statements, the IMF’s Fiscal Affairs Department developed and published a set of guidances, called *Special Series on COVID-19*,¹ oriented to assist countries in their responses to the pandemic. Among these we highlight the following three given their parallels with the top-level guidance in Managing Director speeches and remarks:

¹ A complete list of the guidances and documents can be found in the IMF’s webpage. <https://www.imf.org/en/Publications/SPROLLS/covid19-special-notes>.

- **Health Expenditure** (IMF, 2020a). Outlining principles and considerations that countries should take into account in the design of actions oriented to support the monitoring, containment, and mitigation of the pandemic.
- **Support for the Vulnerable** (IMF, 2020b). Highlights different sets of fiscal measures and considerations that countries should take into consideration in the design of programs oriented to support the most vulnerable (firms and households) to address the consequences of the shock.
- **Greening the recovery** (IMF, 2020c). This document highlight different measures oriented to support a 'green' recovery. Among the possible measures, the IMF considers that the governments could finance 'green' activities, rather than "brown" ones; like climate-smart infrastructure and technologies, support adaptation, or avoid carbon-intensive investments. In addition, governments could raise carbon taxes and eliminate fossil fuel subsidies, in the context of low oil prices and fiscal reallocation needs.

In historical perspective, this is a very different set of directives than the IMF has given in the past. In response to past crises, the IMF has long prescribed fiscal consolidation that explicitly or implicitly directed countries to engage in contractionary policies that reduced spending on health and social expenditure (Kentikelenis et al, 2016). Indeed, in a study of 16 Western African countries from 1995 to 2014, Stubbs et al (2017) found that IMF programs curtailed the fiscal space for health spending in those per capital by 0.24 percent. In a broader study of IMF programs in 137 developing countries between 1980 and 2014, Forster et al (2019a) found that IMF programs lowered health system access and increased neonatal mortality. In another paper by Forster (2019b) and others, using the same sample, they found that IMF programs during that period also accentuated inequality. Other papers however, have argued IMF conditionality can potentially increase social spending through higher growth during the program period (Gupta et al, 2000, Gupta 2010). In response to these findings, before the COVID the IMF had begun to add a number of social safeguards to its programs, such as social spending floors, social benefits and transfers, and expanding unemployment assistance. While the literature on the impact of these programs on outcomes is in its infancy, there is evidence that they have been ineffective in the medium term (Gupta et al, 2018).

This short paper develops an IMF COVID RECOVERY INDEX that attempts to quantify the extent to which IMF communications and guidance on the pandemic response has become operationalized in the IMF response to the COVID-19 crisis. This short paper identifies the methodology deployed to create the index, displays preliminary results of the analysis covering 75 IMF programs from March to July 2020, and outlines a research agenda for using this new variable to examine IMF policy behavior and social outcomes.

2. Data and Methodology

In this section of the paper we share the methodology devised to code IMF programs in order to create an IMF COVID Recovery Index that assesses the extent to which various country programs are tailored to attack the COVID-19 virus, protect the vulnerable, and stage a green recovery.

2.1 The IMF's Emergency Response to the COVID-19 crisis

The IMF has received upwards of 100 requests for emergency financing since the COVID-19 crises began. At this writing, we analyze programs granted between March 23 and July 27 and will be continuing to track and code programs as the crisis continues. Table 1 shows that the IMF has supported 77 countries with 93 disbursements in the selected time frame. In dollar terms, the actions of the IMF implies a financial approval of almost US\$83.1 billion (SDR 60.5 billion) during this period.

Table 1
SUMMARY OF IMF FINANCIAL SUPPORT INTERVENTION

	Countries	Programs	Total Disbursements		Average Disbursements per Program		
			US\$ Million	SDR Millions	US\$ Million	SDR Millions	% of Quota
Total	77	93	83,052	60,471	893	650	94.2
Conditional	10	11	13,008	9,392	1,183	854	241.6
Augmentation of Stand-by Arrangement (SBA)	2	3	10,375	7,489	3,458	2,496	139.5
Augmentation of Extended Fund Facility (EFF)	3	3	1,767	1,266	589	422	156.7
Augmentation of Extended Credit Facility (ECF)	3	3	248	183	83	61	54.5
Multiple Instruments	2	2	619	455	309	227	122.0
Unconditional	67	82	70,044	51,079	854	623	68.7
Rapid Credit Facility (RCF)	36	44	7,142	5,234	162	119	60.5
Rapid Financing Instrument (RFI)	28	35	17,173	12,546	491	358	78.5
Flexible Credit Line (FCL)	3	3	45,730	33,299	15,243	11,100	661.3
Middle East and Central Asia	12	18	13,549	9,860	753	548	74
Sub-Saharan Africa	30	36	10,637	7,765	295	216	65
Western Hemisphere	20	20	50,907	37,085	2,545	1,854	176
Asia Pacific	8	11	1,841	1,342	167	122	64
Europe	7	8	6,119	4,419	765	552	90

Source: IMF

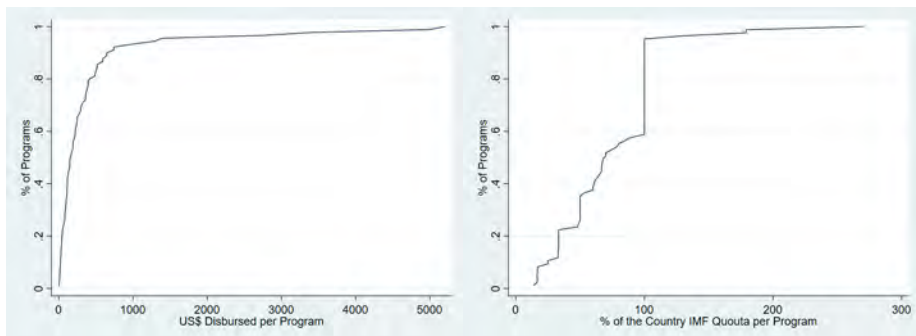
The majority of programs have been unconditional ones, disbursed through the Rapid Credit Facility (RCF), the Rapid Financing Instrument (RFI) and the Flexible Credit Line (FCL). Almost 85 percent of the disbursement programs were channeled through the RCF and RFI, which are instruments designed to help countries with urgent balance of payments needs. However, in dollar terms, more than half of the approved programs were channeled through FCL at US\$45 billion to Chile, Peru, and Colombia. Interestingly, at this writing these countries are yet to draw on these credit lines.

Some programs are augmentations of conditional programs approved before the crisis ensued (11 programs, 12 percent of the total). In these cases, the countries and the IMF modified the

agreements in order to incorporate more resources and, in some cases, re-evaluated the conditionalities associated with the programs.

The remaining 45 percent of the resources have been allocated into programs in which funds were immediately disbursed or committed to be disbursed. In these cases, the average disbursement was US\$414.7 million (SDR 301.9 million); representing roughly 74.2 percent of the countries' quota to the IMF. As can be seen in the left panel of Figure 1, close to 90 percent of the disbursements are below US\$1 billion. While as can be observed in the right panel of Figure 1, given the characteristics previously described of the RCF and RFI instruments, the majority of the programs consist of disbursements of, at maximum, 100 percent of a country's quota.

Figure 1
DISTRIBUTION OF DISBURSEMENTS PROGRAMS BY AMOUNT AND COUNTRY QUOTA TO THE IMF



2.2 Constructing the IMF COVID RECOVERY INDEX

Our first objective is to evaluate the degree of commitment that the IMF and member countries have made relative to the guidances previously discussed: 1) health expenditure; 2) support for the most vulnerable; and, 3) 'green' recovery (hereafter 'three pillars'). In this sense, we reviewed the language used in the IMF Country Reports related to each disbursement program. We focus on two parts of the reports: 1) the IMF Staff Report; and, 2) the Country's Letter of Intent (LOI) sent to the IMF by the country authorities.

We score each program on a scale of 0 to 3. Zero if a country does not request or address the need to address any of the three pillars of a COVID-19 recover; three if the IMF not only endorses a country request to at least one of the three pillars, but either strongly recommends or conditions that such investments be made as part of the program. Box 1 delineates the range of indicators.

Box 1
CODING THE IMF COVID RECOVERY INDEX

- **Indicator = 0;** if the Country Letter of Intent (LOI) does not request or address the need to the three pillars of the recovery
- **Indicator = 1;** if the LOI requests to address a pillar but that act is not highlighted or acknowledged by the IMF in their staff and subsequent reports.
- **Indicator = 2;** if the IMF, in their staff report, highlights, acknowledges, and/or explicitly endorses at least one pillar requested to be addressed by the country.
- **Indicator = 3;** if the IMF, in their staff report, recommends that a pillar be addressed or conditions the accomplishment of at least one pillar in order to obtain a disbursement.

We create individual indicator score on a scale of 0 to 3 for each of the three pillars for each program. Then, we create a composite index of those pillars to arrive at one indicator for each program, averaging the three indicator scores. We refer this composite index to as the “IMF Covid Recovery Index.” To create the index, we calculate the weighted average of each indicator associated with a particular disbursement, using the disbursement amount in SDR as weights. The appendix elaborates on the coding methodology and provides illustrative documentation of how each indicator is arrived at.

2.3 Data Analysis

We apply this method to the IMF disbursements that have IMF country files published on the IMF webpage and were immediately disbursed or committed to be disbursed to the requesting countries.² These programs are summarized in Table 2, resulting in a subset of for 75 programs in 65 countries, or 84 percent of those approved in our original sample. In terms of the amount disbursed, the subset accounts for almost US\$21.3 billion (or around SDR 15.6 billion), which represents 25.7 percent (or 25.8 percent in terms of SDR) of the total IMF emergency financing during the period first analyzed.

² At the moment we conduct the analysis, the IMF’s webpage did not publish the associated Country Reports related to the following disbursements:

- Congo (RCF approved on April 22 for SDR 266.50 million or almost US\$363.27 million)
- Dominica (RCF approved on April 28 for SDR 10.28 million or almost US\$14.00 million)
- Egypt (RFI approved on May 11 for SDR 2,037.10 million or almost US\$2,772.00 million)
- Guinea (RCF approved on June 19 for SDR 107.10 million or almost US\$148.00 million)

In parallel, the IMF following Flexible Credit Lines (FCL) but, at the moment we conduct the analysis, countries have not used the resources:

- Chile (FLC approved on May 29 for SDR 17,443.00 million or almost US\$23.930.00 million)
- Colombia (FLC approved on May 1 for SDR 7,849.00 million or almost US\$10,800.00 million)
- Peru (FLC approved on May 28 for SDR 8,007.00 million or almost US\$11,000.00 million)

Table 2
SUMMARY OF IMF FINANCIAL SUPPORT INTERVENTION

	Programs	Disbursements	
		US\$ Million	SDR Millions
Total	75	25,539	18,622
Conditional	7	6,065	4,378
Unconditional	68	19,474	14,243

Source: IMF

Table 3 exhibits our preliminary results of the IMF Covid Recovery Index under the methodology previously described.

Table 3
SUMMARY OF INDICATORS

	Composite	Health Policies	Support to the Vulnerable	Green Recovery
Total	1.83	2.35	2.56	0.59
Conditional	1.68	2.00	2.84	0.19
Unconditional	1.88	2.45	2.48	0.72

Our preliminary analysis of programs analyzed to date is that the overall score for IMF programs in response to the COVID crisis is a **1.83 of a total possible score 3**. This implies that the IMF is falling short of fully putting into practice the pillars that the institution is mentioning in high-level speeches and policy directives.

Looking more closely however, this relatively lower overall score is largely driven by very poor performance with respect to a green recovery. When the index is disaggregated into each specific guidance we observe that the overall results are positively affected by the commitments towards the health policies and support of the vulnerable guidances. In both cases, the indicator results were significantly greater than the overall composite index. **The indicator for the health policies reaches a value of 2.35, and the score representing support for the vulnerable is 2.56.**

It is interesting to note the difference between the conditional and non-conditional programs. Concerning health policy guidance, the conditional programs only receive, on average, a score, on average, of 2.00. Unconditional programs, a significant share receive recommendations from the IMF score, on average, 2.45. With respect to support to the vulnerable policy guidance, in both types of programs a significant share of disbursements received recommendations from the IMF. However, we observe a larger share of programs that receive recommendations in the case of conditional programs than unconditional ones. Nevertheless, the ability of the IMF to ensure that its recommendations are implemented is limited under unconditional programs.

On its own **the indicator for the green recovery is very low, at 0.59**. This implies that borrowing countries and the IMF are not requesting, singling out, recommending, or requiring that recovery programs address environmental degradation and climate change. The score is significantly lower in the conditional programs, even though they are tied to structural reforms.

These aggregated global results are a reflection of the results scored for each IMF program. The full distribution of our scoring are displayed in Figures 2 and 3. As can be observed in the Figure 2, the majority of IMF programs (41 programs or 54.7 percent of the total of programs evaluated) present a composite indicator of 1.33. Meanwhile, there a significant number of programs (22 programs or 29.3 percent of the total of programs evaluated) that have a composite indicator of 2.00 or above.

Figure 2
DISTRIBUTION OF THE COMPOSITE POLICY INDICATOR RESULTS

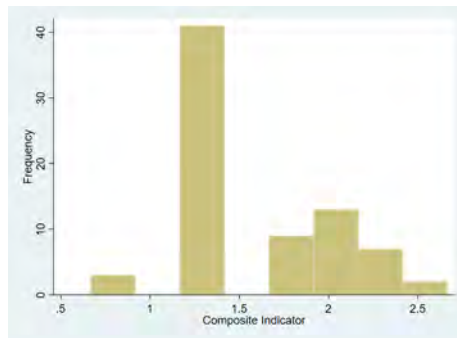


Figure 3 disaggregates the individual program scores by each recovery pillar: health policy, protecting the vulnerable, and greening the recovery. This figure shows that the vast majority of programs have recognized or recommended policies towards the improvement of the health system and the support of the vulnerable. This is different in the case of “green” recovery policies. As we observe in the lower part of Figure 3, 63 of the programs evaluated (84.0 percent of the total) do not include any mention of greening the recovery by the borrower or the IMF.

Figure 3
DISTRIBUTION OF THE GUIDANCES POLICY INDICATORS

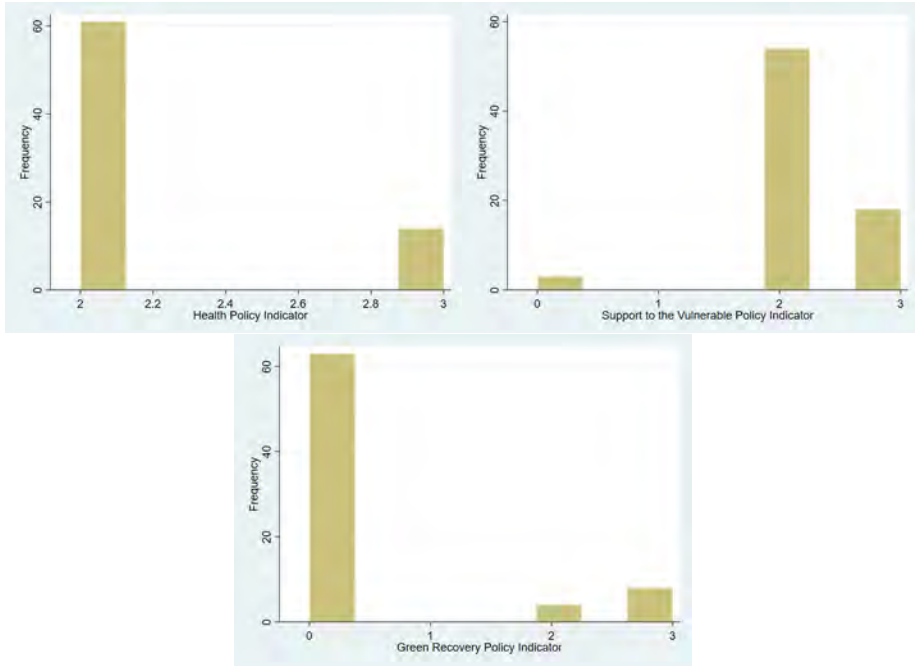


Table 4 provides an illustrative list by summarizing the countries disbursement programs that received the top ten overall index scores according to our methodology.

Table 4
TOP 10 DISBURSEMENT PROGRAMS

Country	Composite	Health Policies	Support to the Vulnerable	Green Recovery
1 Nigeria	2.67	3.00	3.00	2.00
2 Costa Rica	2.67	2.00	3.00	3.00
3 Bahamas	2.33	2.00	2.00	3.00
4 Bangladesh	2.33	2.00	2.00	3.00
5 El Salvador	2.33	2.00	2.00	3.00
6 Georgia	2.33	2.00	2.00	3.00
7 Solomon Islands	2.33	2.00	2.00	3.00
8 Bolivia	2.00	3.00	3.00	0.00
9 Dominican Republic	2.00	3.00	3.00	0.00
10 Gabon	2.00	3.00	3.00	0.00

Note: Gambia, Ghana, Grenada, Keynia, Maldives, Mauritania, Mozambique, Niger, Pakistan and Tunisia had the same score as Bolivia, Dominican Republic and Gabon.

The best performing disbursement programs correspond to Nigeria and Costa Rica³, which both received a composite score of 2.67. In both cases, the programs receive a score of 3.00 in the support for vulnerable population policy guidance; which implies that both countries requested financing for this issue and received recommendations from the IMF related to do so. Indeed, in both cases, the IMF recommended to implement or to scale-up targeted transfers to protect the vulnerable (IMF, 2020d, p. 8; IMF, 2020e, p. 8).

However, the scores for health and “green” recovery policies differ in both countries. In the case of compliance with the health policy guidance, Nigeria received a score of 3.00 and Costa Rica received a score of 2.00. In the first case, IMF Staff recommended that Nigerian authorities present a supplementary budget to the parliament that increases health spending. (IMF, 2020d, p. 8). In the case of Costa Rica, IMF staff highlighted and justified Costa Rica’s additional spending in response to the crisis to protect the vulnerable (IMF, 2020e, p. 11). In the case of “green” recovery policies, Nigeria received a score of 2.00 and Costa Rica received a score of 3.00. Nigeria receives a score of 3.00 because the IMF staff acknowledged and endorsed the elimination of fuel subsidies and the introduction of automatic price formulas (IMF, 2020d, p. 8 and 12). Meanwhile, in the case of Costa Rica, IMF staff recommended to raise excise duties on petrol and diesel, and to increase the property and environmental taxes (IMF, 2020e, p. 8).

The IMF programs that perform receive the lowest index scores are found in programs for the Central African Republic and the first disbursement programs to Kyrgyz.⁴ In both cases, the programs receive a score of 0.67, largely due to the fact these program documents have few if any references to protecting the vulnerable or a green recovery and receive a zero in each instance. Meanwhile, both programs commitments to the health policy guidance receive a score of 2.00, as the IMF Staff recognized the countries health response. For instance, in the case of the Central African Republic, the Staff recognize a health plan of 2 percent of the GDP that not only seeks to address the current situation, but includes measures to strengthen the capacity of the healthcare system for the future (IMF, 2020f, p. 7 and 10). In the case of Kyrgyz, the Staff acknowledges the fiscal plan of 3.1 percent of the GDP for the health sector (IMF, 2020g, p. 5).

3. Preliminary conclusions and further research directions

This paper establishes a methodology that can be used to measure the behavior of IMF program design and eventually the outcomes of IMF programs in response to the COVID-19 crisis. We create an IMF COVID RECOVERY INDEX by coding IMF programs based on the extent to which they recommend or condition that borrowing countries increase efforts to combat the virus, protect the vulnerable, and stage a green recovery. Relative to earlier research that suggests the IMF falls short in making such policies part of the recovery, our preliminary show that the IMF is

³ Nigeria and Costa Rica received a Rapid Financing Instrument (RFI). The first was approved on April 28 for US\$3,400.00 million (SDR 2,454.50 million), while the second was approved on April 29 for US\$508.00 million (SDR 369.40 million). In both cases, the disbursements represent 100 percent of the country’s quota to the IMF.

⁴ Central African Republic received a Rapid Credit Facility (RCF), which was approved on April 20 for US\$38.00 million (SDR27.85 million), which represents 25 percent of the country’s quota to the IMF. Kyrgyz received two programs, a Rapid Financing Instrument (RFI) and a RCF, both approved March 26 for a total of US\$120.90 million (SDR 88.80 million), which represents 50 percent of country’s quota.

prioritizing health and social spending during this crisis. However, IMF support for greening the recovery does not match the rhetoric from IMF leadership or from fiscal guidance notes issued by the IMF Fiscal Affairs department.

We will continue to improve this index and to score the remainder of the IMF programs during the COVID era. However, the best use of the IMF COVID Recovery Index will be to serve as an independent variable to gauge the impact of IMF programs on health, social, and environmental outcomes in the wake of the pandemic. At this writing, other entities are tracking the developing country responses to the crisis on the ground. The OECD is tracking and creating a database of fiscal and tax measures for health and protecting the vulnerable across the world (OECD, 2020). Vivid Economics has created a 'Greenness of Stimulus Index' to track the extent to which country recovery programs are 'green' with respect to climate change and biodiversity (Vivid Economics, 2020). As these indicators are developed, and when more basic information is available from the IMF such as quarterly health and social spending over time, we plan to use the IMF COVID Recovery Index (and/or its individual parts) as an independent variable to examine the extent to which IMF support for health, social, and environmental outcomes during the recovery is positively correlated with such outcomes. In the meantime, we plan to publish a Tableau-based interactive web page that will make the index available to other researchers, policy-makers, the media, and civil society as part of the broader effort to foster more evidence-based decision-making and discourse on responses to the COVID crisis.

References:

Forster, T., A. Kentikelenis, T. Stubbs, and L. King (2019a). "Globalization and Health Equity: The Impact of Structural Adjustment Programs in Developing Countries." *Social Science & Medicine*.

Forster, T., A. Kentikelenis, B. Reinsberg, T. Stubbs, and L. King. (2019b.) "How Structural Adjustment Programs Affect Inequality: A Disaggregated Analysis of IMF Conditionality, 1980–2014." *Social Science Research*. 80: 83-113.

Georgieva, Kristalina (2020a), "Transcript of Press Briefing by Kristalina Georgieva following a Conference Call of the International Monetary and Financial Committee", March 27, Washington, D.C.: International Monetary Fund.
<https://www.imf.org/en/News/Articles/2020/03/27/tr032720-transcript-press-briefing-kristalina-georgieva-following-imfc-conference-call>

Georgieva, Kristalina (2020b), Confronting the Crisis: Priorities for the Global Economy, April 9, Washington, D.C, International Monetary Fund.
<https://www.imf.org/en/News/Articles/2020/04/07/sp040920-SMs2020-Curtain-Raiser>

Georgieva, Kristalina (2020c) Managing Director's Opening Remarks at the Petersberg Climate Dialogue XI, April 29, Washington, DC, International Monetary Fund.
<https://www.imf.org/en/News/Articles/2020/04/29/sp042920-md-opening-remarks-at-petersberg-event>

Gupta, S., 2010, "Response of the International Monetary Fund to its critics," *International Journal of Health Services* 40.2: 323-326.

Gupta, S., R.S. Khemani, C. A. McDonald, L. Dicks-Mireaux, and M. Verhoeven, 2000, "Social issues in IMF-supported programs," IMF Occasional Paper No. 191.

Gupta, S., Schena, M., & Yousefi, R. (2018). Expenditure conditionality in IMF-supported programs. *International Monetary Fund Working Paper*, 18/225.

IMF (2020a), Managing the Impacts of the Coronavirus: Guidance on Health Spending Policies, <https://www.imf.org/~media/Files/Publications/covid19-special-notes/enspecial-series-on-covid19managing-the-impacts-of-the-coronavirus-guidance-on-health-spending-polic.ashx?la=en>

IMF (2020b), Expenditure Policies in Support of Firms and Households, <https://www.imf.org/~media/Files/Publications/covid19-special-notes/en-special-series-on-covid-19-expenditure-policies-in-support-of-firms-and-households.ashx?la=en>

IMF (2020c), Greening the Recovery, <https://www.imf.org/~media/Files/Publications/covid19-special-notes/en-special-series-on-covid-19-greening-the-recovery.ashx?la=en>

IMF (2020d), Nigeria: Request for Purchase under the Rapid Financing Instrument -Press Release; Staff Report; and Statement by the Executive Director for Nigeria, <https://www.imf.org/~media/Files/Publications/CR/2020/English/1NGAEA2020001.ashx>

IMF (2020e), Costa Rica: Request for Purchase Under the Rapid Financing Investment-Press Release; Staff Report; and Statement by the Executive Director for Costa Rica, <https://www.imf.org/~media/Files/Publications/CR/2020/English/1CRIEA2020001.ashx>

IMF (2020f), Central African Republic: Request for Disbursement under the Rapid Credit Facility-Press Release; Staff Report; and Statement by the Executive Director for the Central African Republic, <https://www.imf.org/~media/Files/Publications/CR/2020/English/1CAFEA2020002.ashx>

IMF (2020g), Kyrgyz Republic: Request for Purchase Under the Rapid Financing Instrument and Disbursement Under the Rapid Credit Facility-Press Release; Staff Report; Informational Annex; and Debt Sustainability Analysis, <https://www.imf.org/~media/Files/Publications/CR/2020/English/1KGZEA2020001.ashx>

Kentikelenis, A., T. Stubbs, and L. King. 2016. "IMF Conditionality and Development Policy Space, 1985-2014," *Review of International Political Economy*. 23(4): 534-582

OECD (2020), Tax and fiscal policy in response to the Coronavirus crisis: Strengthening confidence and resilience, Paris, OECD. <https://www.oecd.org/coronavirus/policy-responses/tax-and-fiscal-policy-in-response-to-the-coronavirus-crisis-strengthening-confidence-and-resilience-60f640a8/>

Stubbs, T., A. Kentikelenis, D. Stuckler, M. McKee, and L. King. 2016. "The Impact of IMF Conditionality on Government Health Expenditure: A Cross-national Analysis of 16 West African Nations." *Social Science & Medicine*. 174: 220-227.

UNCTAD (2020), "The Covid-19 Shock to Developing Countries: Towards a 'whatever it takes' programme for the two-thirds of the world's population being left behind", Geneva: United Nations Conference on Trade and Development.

Vivid Economics (2020), Greenness of Stimulus Index, London, Vivid Economics: <https://www.vivideconomics.com/casestudy/greenness-for-stimulus-index/>

Wheatley, Jonathan (2020), "Emerging Market Debt Burdens May be Solely Understated", *Financial Times*, April 3.

Zhang, Tao (2020), COVID-19: Opportunities for a Green Recovery, May 22, 2020, Washington, International Monetary Fund. <https://www.imf.org/en/News/Articles/2020/05/22/sp052220-opening-remark-zhang>

Appendix

For this paper we evaluate the level that the IMF financial support to the countries facing the negative shock of the COVID-19 pandemic was in line with their previously developed guidances: 1) health expenditure policies; 2) support for the most vulnerable; and, 3) “green” recovery (hereafter ‘three pillars’). In order to achieve this goal, we develop a methodology that codes the IMF response using the country reports associated to each disbursements program during the COVID-19 pandemic.

Each country report the IMF addresses the previous and the current economic situation and the policies implement by the requesting countries, in order to analyze, among others, the country needs, space to reforms and their ability of repayment.

Given this information, first, we identify which policies have been implemented or proposed to be implemented by the countries related to any of the three pillars. Second, we identify which is the IMF Staff appraisal of those policies. Third, we identify is the IMF Staff recommend or conditions certain policies as part of the program.

Based on this, we translate our findings into a code that assigns a value between 0 to 3 according to the following:

- **Indicator = 0;** if the Country Letter of Intent (LOI) does not request or address the need to the three pillars of the recovery
- **Indicator = 1;** if the LOI requests to address a pillar but that act is not highlighted or acknowledged by the IMF in their staff and subsequent reports.
- **Indicator = 2;** if the IMF, in their staff report, highlights, acknowledges, and/or explicitly endorses at least one pillar requested to be addressed by the country.
- **Indicator = 3;** if the IMF, in their staff report, recommends that a pillar be addressed or conditions the accomplishment of at least one pillar in order to obtain a disbursement.

Finally, we create a composite index of those pillars from the average of the three indicators for each program. We refer this composite index to as the “IMF Covid Recovery Index”.

Below, we provide an illustrative list of examples of the analysis made for each program and their corresponding values for each pillar and the IMF Covid Recovery Index.

1. Afghanistan

- Disbursement date: April 29, 2020
- Instrument: Rapid Credit Facility (RCF)
- Amount disbursed: US\$220 million (SDR 161.9 million), 50 percent of quota
- Country report link:
<https://www.imf.org/~media/Files/Publications/CR/2020/English/1AFGEA2020002.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.33	2	2	0
	The IMF acknowledges authorities’ plan to spend about 2 percent of GDP for critical pandemic-related spending during the year, with about 1/3 directed to health. (Page 5 of Staff Report)	The IMF acknowledges the developing, with the support of the World Bank, other development partners and humanitarian agencies, of a social relief package to be provided to the most vulnerable via the most effective means—including through cash transfers, initially to the most vulnerable households. (Pages 5 and 6 of Staff Report)	No mention.

2. Albania

- Disbursement date: April 10, 2020
- Instrument: Rapid Financing Instrument (RFI)
- Amount disbursed: US\$190.4 million (SDR 139.3 million), 100 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1ALBEA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.33	2	2	0
	The IMF highlights authorities’ fiscal package of 1.4 percent of GDP, which adds to the previous earthquake relief and reconstruction package (1.2 percent of GDP), that include higher spending on the health sector. (Page 5 of Staff Report)	The IMF highlights authorities’ fiscal package of 1.4 percent of GDP, which adds to the previous earthquake relief and reconstruction package (1.2 percent of GDP), that include, among others: additional unemployment benefits and social assistance, guarantee scheme for companies allowing them to continue wage payments to workers forced to stay at home due to the pandemic, accelerated pension increases in April, support	No mention.

		for small firms including the rescheduling of profit-tax installments in 2020. (Page 5 of Staff Report)	
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3. Armenia

- Disbursement date: May 18, 2020
- Instrument: Extend of Stand-By Arrangement (SBA)
- Amount disbursed: US\$175 million (SDR 128.8 million), 100 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1ARMEA2020002.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.33	2 The IMF acknowledges an estimated additional health spending of almost 0.6 percent of GDP. IMF highlights that the Government equipped the Ministry of Health with additional resources and legislative powers to expeditiously acquire medical supplies and necessary health equipment, including testing kits. (Pages 6 and 11 of Staff Report)	2 The IMF acknowledges an estimated additional resources to support households and firms for around 0.9 percent of GDP that include, among others: direct social assistance transfers to the vulnerable (families with children and parents lost their jobs, pregnant women, families facing social problems), subsidize utilities, labor subsidies to help SME employers maintain core employees. (Pages 6 and 11 of Staff Report)	0 No mention.

4. Bahamas

- Disbursement date: June 1, 2020
- Instrument: Rapid Financing Instrument (RFI)
- Amount disbursed: US\$250 million (SDR 182.4 million), 100 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1BHSEA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
2.33	2	2	3

Covid Economics 42, 19 August 2020: 112-142

	The IMF supports authorities' fiscal measures, including the support to the health care system that with resources that rise to 0.4 percent of the GDP. (Pages 5 and 8 of Staff Report)	The IMF supports authorities' fiscal measures, including the ones oriented ensure the adequate food supply and protecting employment and scale to almost 3.3 percent of the GDP. (Pages 5 and 8 of Staff Report)	The IMF recommends putting in place mandatory hurricane insurance would strengthen private sector resilience; improving data collection, sharing, and management among agencies would enhance the resilience of the social safety net. (Pages 1 and 9 of Staff Report)
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5. Bangladesh

- Disbursement date: May 29, 2020
- Instrument: Rapid Credit Facility (RCF) and Rapid Financing Instrument (RFI)
- Amount disbursed: US\$244 million (SDR 177.77 million), 16.67 percent of quota; and US\$488 million (SDR 355.53 million), 33.33 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1BGDEA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
2.33	2	2	3
	The IMF highlights authorities' stimulus package measures, which includes: resources for the Ministry of Health's Preparedness and Response Plan, and support for health care sector. (Pages 9 and 14 of Staff Report)	The IMF highlights authorities' stimulus package measures, which includes: transfer programs that benefit the poor, workers in the informal economy, and other vulnerable populations, support for agriculture sector, wage support for the export industries, interest payment subsidies for working capital loans by banks to businesses. (Pages 9 and 14 of Staff Report)	As part of the Structural Reform the IMF recommend to address climate change risks through continuous efforts in mitigation and adaptation will be required to enhance the resilience and sustainability of economic growth. (Page 12)

6. Barbados

- Disbursement date: June 3, 2020
- Instrument: Augmentation of Extended Fund Facility (EFF)

- Amount disbursed: US\$91 million (SDR 66.15 million), 70 percent of quota
- Country report link:
<https://www.imf.org/~media/Files/Publications/CR/2020/English/1BRBEA2020001.ash>
[x](#)

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.33	2	2	0
	The IMF highlights a higher health spending of about 0.25 percent of GDP, in addition to 0.5 percent already spent in FY2019/20. (Page 11 of Staff Report)	The IMF highlights the following measures: temporary transfers to public institutions who will face pandemic-related revenue shortfalls (about 0.5 percent of GDP), enhanced welfare schemes (about 0.25 percent of GDP), higher capital expenditure of about 0.5 percent of GDP. (Page 12 of Staff Report)	No mention.

7. Benin

- Disbursement date: May 15, 2020
- Instrument: Augmentation Extended Credit Facility (ECF)
- Amount disbursed: US\$103.5 million (SDR 76.013 million), 61.4 percent of quota
- Country report link:
<https://www.imf.org/~media/Files/Publications/CR/2020/English/1BENEA2020002.ash>
[x](#)

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.67	2	3	0
	The IMF supports the health response. In particular, the budget envelope for public health expenditure will be increased by 0.7 percent of GDP to allow for the purchase of medical equipment and the construction of temporary health facilities and retention areas for quarantined people.	The IMF supports the response to grant cash transfers to vulnerable households, and provide support to impacted businesses. (Pages 8 and 15 of Staff Report) The IMF also recommends, in the short term and if the situation deteriorates, that the authorities could contemplate the	No mention.

	(Pages 8 and 15 of Staff Report)	following additional measures to support economic activity: increasing the size or expanding the coverage of transfers to vulnerable households; improving access to credit for cash-constrained businesses through guarantees or subsidized loans; broadening the range of inputs or production factors concerned by cost-based tax incentives; accelerating government payments to private sector suppliers; and reducing the turnover tax for micro and small enterprises. (Page 11 of Staff Report)	
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8. Bolivia

- Disbursement date: April 17, 2020
- Instrument: Rapid Financing Instrument (RFI)
- Amount disbursed: US\$327 million (SDR 240.1 million), 100 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1BOLEA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
2.00	3	3	0
	The IMF highlights the increased health spending. In addition, the IMF recommends that should health spending needs prove larger than expected, some limited margin for maneuver may be gained through additional reductions in public investment. (Pages 5 to 7 of Staff Report)	The IMF highlights the efforts to protect the more vulnerable. In addition, the IMF recommends that will be important, in light of the limited fiscal space available, to protect other social welfare spending. (Pages 6 and 7 of Staff Report)	No mention.

9. Bosnia and Herzegovina

- Disbursement date: April 20, 2020
- Instrument: Rapid Financing Instrument (RFI)
- Amount disbursed: US\$361 million (SDR 265.2 million), 100 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1BIHEA2020002.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.67	3	2	0
	The IMF highlights and supports the higher spending on the health sector. In addition, the IMF recommends that medical supplies need to be secured and deployed immediately to treat patients and reduce contagion by testing and monitoring. (Pages 4 and 7 of Staff Report)	The IMF supports the authorities' plans to pay unemployment benefits on a timely basis and expand social benefit programs for the most vulnerable. (Page 4of Staff Report)	No mention.

10. Burkina Faso

- Disbursement date: April 14, 2020
- Instrument: Rapid Credit Facility (RCF)
- Amount disbursed: US\$115.3 million (SDR 84.28 million), 70 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1BFAEA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.33	2	2	0
	The IMF highlights and supports the increase of health care spending and the measures for provision of free testing, care for the infected and preventive care in all regions of the country. (Pages 8 and 12 of Staff Report)	The IMF supports the authorities' plan to mitigate the economic impact of the pandemic, which includes, among others, cash transfer, particularly through the strong existing programs, local small businesses and household associations, and time-tested channels	No mention.

		of the World Food Program. (Pages 8 and 12 of Staff Report)	
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11. Cabo Verde

- Disbursement date: April 22, 2020
- Instrument: Rapid Credit Facility (RCF)
- Amount disbursed: US\$32.3 million (SDR 23.70 million), 100 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1CPVEA2020002.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.33	2	2	0
	The IMF highlights authorities' measures of prevention and preparedness, and the emergency plan to cover additional expenses for personnel, training and medical equipment. (Page 6 of Staff Report)	The IMF highlights the social protection actions and the measures to support to the corporate sector. (Page 6 of Staff Report)	No mention.

12. Cameroon

- Disbursement date: May 4, 2020
- Instrument: Rapid Credit Facility (RCF)
- Amount disbursed: US\$ 226 million (SDR 165.6 million), 60 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1CMREA2020002.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.67	2	3	0
	The IMF highlights authorities' preparedness and response plan, which increases health spending to ensure adequate infection prevention and control and improved case management. (Page 7 of Staff Report)	The IMF highlights and supports authorities' measures to mitigate the negative financial impact of the COVID-19 pandemic on the most vulnerable, which will include strengthening existing social safety nets	No mention.

		and providing support to affected businesses and households. In addition, the IMF recommends that measures to mitigate the negative financial impact of the COVID-19 pandemic on the private sector, which could include strengthening social safety nets, subsidizing basic medications, and providing support to affected companies should be effectively implemented. (Pages 7 and 11 of Staff Report)	
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13. Central African Republic

- Disbursement date: April 20, 2020
- Instrument: Rapid Credit Facility (RCF)
- Amount disbursed: US\$38 million (SDR 27.85 million), 25 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1CAFEA2020002.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
0.67	2	0	0
	The IMF highlights and supports authorities' health response plan to strength the national healthcare system, which estimated cost is 2 percent of GDP and was elaborated with the support of the WHO. (Pages 3 and 10 of Staff Report)	No mention.	No mention.

14. Chad

- Disbursement date: April 14, 2020
- Instrument: Rapid Credit Facility (RCF)
- Amount disbursed: US\$115.1 million (SDR 84.12 million), 60 percent of quota

- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1TCDEA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.33	2	2	0
	The IMF highlights authorities' plan that will increase health-related spending by about 0.3 percent of non-oil GDP (60 percent expected to be financed by donors) to mitigate the impact of the pandemic, which includes: training of medical and technical staff, purchase of necessary medical equipment, the construction of seven health centers in remote areas, the construction of three mobile hospitals, and securely managing entry points. (Pages 7 and 8 of Staff Report)	The IMF highlights authorities' measures to help soften the impact of the crisis on the economy, which includes: temporary suspension of payments of electricity and water bills, the establishment of a Youth Entrepreneurship Fund, reduce the business license fees and the presumptive tax, tax breaks such as carryforward losses and delays in tax payments. (Page 8 of Staff Report)	No mention.

15. Comoros

- Disbursement date: April 22, 2020
- Instrument: Rapid Credit Facility (RCF) and Rapid Financing Instrument (RFI)
- Amount disbursed: US\$4.05 million (SDR 2.97 million), 16.7 percent of quota; and US\$8.08 million (SDR 5.93 million), 33.3 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1CODEA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.67	2	3	0
	The IMF highlights authorities' plan to minimize the risk of the pandemic is estimated at US\$2.2 million, which is expected to be financed	The IMF highlights authorities' fiscal stimulus, which includes: temporarily reduction of customs duties for certain products (food, medical,	No mention.

	by two donors. (Pages 7 and 8 of Staff Report)	and hygiene products), delayed deadlines for tax filings. Further the authorities intend to provide income support to SOE workers who have seen their hours reduced, and to support to the poor through direct cash transfers (not factored into projections as this measure is not firmly planned) or, if impossible, through free water or electricity supplies. In addition, the IMF recommends to consider giving targeted and temporary support for affected households, particularly among the most vulnerable. (Pages 7 and 9 of Staff Report)	
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16. Costa Rica

- Disbursement date: April 29, 2020
- Instrument: Rapid Financing Instrument (RFI)
- Amount disbursed: US\$504 million (SDR 369.4 million), 100 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1CR1EA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
2.67	2	3	3
	The IMF highlights authorities’ higher health expending (Pages 7 and 8 of Staff Report)	The IMF acknowledges authorities’ measures that consist, among others: subsidies and transfers for three months to the most vulnerable families economically affected by the crisis, 3-month moratorium on tax payments, targeted support to SMEs, deferred payment of social security contributions and making them proportional to the	The IMF recommends to raise excise duties on petrol and diesel, given the sharp decline in oil prices; and to impose property and environmental taxes to provide additional revenue. (Page 8 of Staff Report)

		time worked. In addition, the IMF recommends that fiscal measures should be designed to protect the vulnerable through targeted transfers, subject to ex post accountability and controls to ensure spending efficiency. (Pages 5 and 8 of Staff Report)	
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17. Cote d'Ivoire

- Disbursement date: April 17, 2020
- Instrument: Rapid Credit Facility (RCF) and Rapid Financing Instrument (RFI)
- Amount disbursed: US\$295.4 million (SDR 216.8 million), 33.3 percent of quota; and US\$590.8 million (SDR 433.6 million), 66.7 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1CIVEA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.33	2	2	0
	The IMF highlights authorities' public health response package, which was elaborated with the support of the WHO and accounts for 1.25 percent of GDP. (Pages 5 and 6 of Staff Report)	The IMF acknowledges authorities' public economic support package of 1.5 percent of GDP, oriented to support vulnerable households (0.3 percent of GDP), businesses, including the informal sector and SMEs (0.4 percent of GDP), the agriculture sector (0.2 percent of GDP), to public entities (0.2 percent of GDP), and in form of tax relief to the formal sector (0.3 percent of GDP). (Page 6 of Staff Report)	No mention

18. Djibouti

- Disbursement date: May 08, 2020
- Instrument: Rapid Credit Facility (RCF)
- Amount disbursed: US\$43.4 million (SDR 31.8 million), 100 percent of quota

- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1DJIEA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.33	2	2	0
	The IMF highlights government’s policy response to scale up the healthcare system and other emergency related spending, accounting for 0.8 percent of GDP. (Pages 6 and 10 of Staff Report)	The IMF acknowledges authorities’ policy response to support families and firms affected by the outbreak, 1.7 percent of GDP. (Pages 6 and 10 of Staff Report)	No mention

19. Dominican Republic

- Disbursement date: April 29, 2020
- Instrument: Rapid Financing Instrument (RFI)
- Amount disbursed: US\$650 million (SDR 477.4 million), 100 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1DOMEA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
2.00	3	3	0
	The IMF highlights government’s health plan. In addition, the IMF considers the authorities would need to allocate more resources to health, including by redirecting budgetary appropriations from other areas. Staff estimates conservatively that central government expenditures could be 1.25 percent of GDP higher than before the shock. (Pages 5 and 6 of Staff Report)	The IMF highlights government’s measures to support the vulnerable. In addition, the IMF considers the authorities would need to allocate more resources to social benefits, including by redirecting budgetary appropriations from other areas. Staff estimates conservatively that central government expenditures could be 1.25 percent of GDP higher than before the shock. The government needs to ensure that these public spending measures are both targeted and temporary,	No mention

		focusing on protecting those most vulnerable to the shock and on supporting demand. (Pages 5 and 6 of Staff Report)	
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20. Ecuador

- Disbursement date: May 2, 2020
- Instrument: Rapid Financing Instrument (RFI)
- Amount disbursed: US\$643 million (SDR 469.7 million), 67.3 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1ECUEA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.67	2	3	0
	The IMF highlights government’s additional health spending of about US\$350 million (0.35 percent of GDP), though the estimated health costs vary widely (from US\$100 million to US\$800 million). (Page 8 of Staff Report)	The IMF highlights government’s additional social assistance spending of about US\$250 million (0.25 percent of GDP). The IMF recommends to expand the cash transfer mechanisms, both in amount and coverage. (Pages 8 and 14 of Staff Report)	No mention

21. El Salvador

- Disbursement date: April 14, 2020
- Instrument: Rapid Financing Instrument (RFI)
- Amount disbursed: US\$ 389 million (SDR 287.2 million), 100 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1SLVEA2020002.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
2.33	2	2	3
	The IMF highlights government’s measures to mitigate the effects of the pandemic on public health, which include	The IMF highlights government’s measures among them: relief to individuals and companies affected by the pandemic,	IMF recommend increasing excise duties on petrol and diesel given the sharp decline in oil

	stocked hospitals with necessary equipment, increase wages of health workers and new hospital infrastructure. (Page 4 of Staff Report)	including through deferring utility payments for a three-month period, and direct transfers to almost 75 percent of households. (Pages 4 and 5 of Staff Report)	prices. (Pages 8 of Staff Report)
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22. Ethiopia

- Disbursement date: April 30, 2020
- Instrument: Rapid Financing Instrument (RFI)
- Amount disbursed: US\$411 million (SDR 300.7 million), 100 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1ETHEA2020002.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
1.33	2 The IMF highlights government’s increase in health spending 0.55 percent of the GDP, which include the fund of medical supplies, facilities, and to cut trade taxes for medical goods. (Page 6 of Staff Report)	2 The IMF highlights government’s additional spending needs during the remainder of the fiscal year would total \$1.64 billion (1.6 percent of GDP), which include emergency food distribution (US\$635 million, 0.6 percent of GDP), for provision of emergency shelter and non-food items (US\$282 million or 0.3 percent of GDP) and agricultural sector support, nutrition, the protection of vulnerable groups, additional education outlays, logistics, refugee support and site management support. (US\$293 million, 0.3 percent of GDP). (Page 7 of Staff Report)	0

23. Gabon

- Disbursement date: April 9, 2020

- Instrument: Rapid Financing Instrument (RFI)
- Amount disbursed: US\$147 million (SDR 108 million), 50 percent of quota
- Country report link:
<https://www.imf.org/~media/Files/Publications/CR/2020/English/1GABEA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
	3	3	0
2.00	The IMF highlights government's immediate health-related spending of 0.5 percent of GDP. The IMF, for medical equipment and supplies (e.g., ventilators, testing kits, masks, etc.), recommends targeted policies such as the reduction or repeal of any customs duties or reduction in VAT rates. (Page 7 of Staff Report)	The IMF acknowledges the government plan to immediate increase social transfers 0.2 percent of GDP. In addition, the IMF considers that the delay of tax payments is appropriate, but more aggressive or permanent tax policy measures should be avoided. As well, that measures targeting both businesses and households still need to be costed, and their impacts carefully assessed to avoid any 'deadweight' effect and remain temporary. (Page 7 of Staff Report)	

24. Gambia

- Disbursement date: April 15, 2020
- Instrument: Rapid Credit Facility (RCF).
- Amount disbursed: US\$21.3 million (SDR 15.55 million), 25 percent of quota
- Country report link:
<https://www.imf.org/~media/Files/Publications/CR/2020/English/1GMBEA2020002.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
	2	2	2
2.00	The IMF highlights government's increase in health expending for 1.8 percent of GDP. (Page 5 of Staff Report)	The IMF acknowledges the government's social interventions, including distribution of basic foodstuffs to the needy. (Page 5 of Staff Report)	The IMF acknowledges the decrease in fuel subsidies. (Page 6 of Staff Report)

25. Georgia

- Disbursement date: May 1, 2020
- Instrument: Augmentation of Extended Fund Facility (EFF).
- Amount disbursed: US\$375.6 million (SDR 273.6 million), 130 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1GEOEA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
2.33	2	2	3
	The IMF highlights government’s healthcare-related expenditure for Covid-19 (e.g. medical supplies, hospitalization, and quarantine costs), of 0.3 percent of GDP. (Page 7 of Staff Report)	The IMF acknowledges the government’s social interventions, including: support to affected businesses, supporting additional supplies of 10 basic commodities (e.g. rice, wheat, flour, sugar, milk powder, beans), direct transfers for employees in the private sector before Covid-19, direct transfers to families and people with severe disabilities, additional envelope to extend direct transfers to other vulnerable households, subsidies for utility bills. (Page 7 of Staff Report)	The energy reform strategy is one of the required structural reforms under the EFF, which is expected to increase market competition, promote renewable energy, and enhance energy efficiency (Page 63 of Staff Report)

26. Ghana

- Disbursement date: April 13, 2020
- Instrument: Rapid Credit Facility (RCF)
- Amount disbursed: US\$1 billion (SDR 738 million), 100 percent of quota
- Country report link: <https://www.imf.org/~media/Files/Publications/CR/2020/English/1GHAEA2020001.ashx>

IMF Covid Recovery Index	Health Policies	Support to the Vulnerable	Green Recovery
2.00	3	3	0

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	<p>The IMF highlights government's promotion of selected industries (e.g., pharmaceutical sector supplying COVID-19 drugs and equipment). In addition, the Staff recommend further prioritization of health spending. (Pages 7 and 12 of Staff Report)</p>	<p>The IMF acknowledges the government's support of SMEs and employment, and the creation of guarantees and first-loss instruments. In addition, the Staff proposed expansion of targeted relief and support for SMEs, vulnerable households, and informal sector, scaling up of cash transfer programs, and clearance of existing arrears and avoidance of new ones to alleviate cash flow constraints. (Pages 7 and 12 of Staff Report)</p>	<p>No mention.</p>
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Labor market effects of COVID-19 in Sweden and its neighbors: Evidence from novel administrative data¹

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This paper studies the labor market effects of non-pharmaceutical interventions (NPIs) to combat the COVID-19 pandemic. We focus on the Nordic countries which showed one of the highest variations in NPIs despite having similar community spread of COVID-19 at the onset of the pandemic: While Denmark, Finland and Norway imposed strict measures ('lockdowns'), Sweden decided for much lighter restrictions. Empirically, we use novel administrative data on weekly new unemployment and furlough spells from all 56 regions of the Nordic countries to compare the labor market outcomes of Sweden with the ones of its neighbors. Our evidence suggests that the labor markets of all countries were severely hit by the pandemic, although Sweden performed slightly better than its neighbors. Specifically, we find the worsening of the Swedish labor market to occur around 2 to 3 weeks later than in the other Nordic countries, and that its cumulative sum of new unemployment and furlough spells remained significantly lower during the time period of our study (up to week 21 of 2020).

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1 Introduction

The vast majority of countries have implemented strong non-pharmaceutical interventions (NPIs) to slow the spread of COVID-19. While the effectiveness of these policies in terms of health outcomes have been shown in several studies (see, e.g., Conyon, He, and Thomsen, 2020; Flaxman et al., 2020; Glogowsky, Hansen, and Schächtele, 2020; Huber and Langen, 2020; Juranek and Zoutman, 2020), there are important concerns about the potential damage NPIs cause to the economy and labor markets (Andersen et al., 2020; Kong and Prinz, 2020). Specifically, the severe restrictions and social distancing measures many countries have enforced (*'lockdowns'*) are assumed to inflict stark economic pain (Baldwin and Weder di Mauro, 2020; Chetty et al., 2020). Thus, the decision problem governments are facing is often seen as a trade-off between public health and the health of the economy (Lin and Meissner, 2020).

In this paper we use novel high-frequency (weekly) regional unemployment and furlough spells from all four Nordic countries to evaluate the economic effects of NPIs. We employ this data to study the differential labor market effects of one of the most prominent policy variations observed during the COVID-19 pandemic. Sweden departed substantially from its neighbors in the response to the spread of the disease, refraining from closing schools, shutting down businesses or shops. Our estimation strategy draws on this natural experiment in the Nordics, comparing countries which were similarly exposed to the COVID-19 pandemic but responded to it in different ways.

The Nordic countries represent an ideal laboratory to study the differential impact of NPIs on labor market outcomes. First, the Nordic countries are similar with regard to the general economic environment (e.g., GDP per capita, trade openness), their labor markets, health care sectors and the general institutional background. Second, due to geographical proximity and their economic interrelations these countries experienced similar trajectories of the COVID-19 pandemic: The 100th case of a confirmed infection occurred in Norway on the 4th, in Sweden on the 6th, in Denmark on the 9th and in Finland on the 12th of March. The measures to slow the spread of COVID-19, however, differed substantially between the four countries. Starting in week 11 of 2020, Denmark, Norway and Finland responded with strong NPIs to limit social interaction, while Sweden imposed much lighter restrictions. Table 1 depicts the dates of the introduction of various measures along with an overall government stringency index, developed by Hale et al. (2020). The index shows that Norway and Denmark imposed the toughest restrictions followed by Finland, and the much weaker response of the Swedish government to the pandemic.

The measures had direct implications for many types of economic activity: In Norway, Finland and Denmark, the hospitality industry (such as bars, nightclubs, restaurants or hotels) was largely shut down, personal services (e.g., hair dressers, masseurs or dentists) were closed, shopping centers had to stop operating, and public transport was limited. In contrast, Sweden decided for much less strict measures, with restaurants and bars kept open (under certain proximity restrictions), and private businesses and shops being allowed to operate freely. In fact, Google's COVID-19 Community Mobility Reports show different mobility patterns for Sweden

Table 1: Timing of closures and containment in Nordic countries

Measure	Denmark	Finland	Norway	Sweden
	<i>Day in March 2020</i>			
School Closing	<i>13</i>	<i>16</i>	<i>12</i>	–
Workplace closing	<i>13</i>	<i>16</i>	<i>12</i>	–
Cancel public events	<i>18</i>	<i>12</i>	<i>12</i>	<i>12</i>
Close public transport	–	–	–	–
Restrictions on internal movements	–	28	16	–
International travel controls	11	19	15	19
Stringency index (maximum in week 11–13)	72.2	67.3	75.9	32.4

Notes: Dates in italics indicate that a measure was general in scope. The stringency index is a compound of eight closing measures and is ranged between 0 and 100, where a higher index represents stronger overall restrictions; see Hale et al. (2020).

than for the other three countries, especially in the first weeks after the lockdowns (see Figure 1). We also observe a decline in Sweden. However, it is less pronounced than in the other Nordic countries. That indicates that there are behavioral responses caused by the lockdown measures in addition to the threat of the virus. In other words, the NPIs do constrain the choices of the population.

Despite the very different NPIs imposed to curb the spread of COVID-19 between Sweden and its neighbors, all countries introduced similar government programs to soften the impact of the pandemic on the economy and labor markets. Specifically, Denmark and Sweden almost simultaneously introduced a novel short-time work compensation/furlough program in the mid of March.¹ Both programs guarantee between 75% and 90% of the salary of workers which are currently not needed but kept on payroll of their companies. The salary cap for furloughed workers are similar in both countries (EUR 4,150 vs. 4,000 per month). In a similar vein, Finland made its existing furlough program more generous due to the crisis, with replacement rates varying between 80 and 100% for workers reducing their working hours during the pandemic. Norway also made its existing furlough program more accessible and more generous over the course of the COVID-19 crisis. The only notable difference between the four countries is that Sweden only allowed a part-time reduction in working hours up to 60% (80% after May), whereas the other 3 countries also allow a worker to be furloughed up to a 100%. To account for the degree of working time reduction of the furlough spells, we express the number of furlough spells in full-time equivalents (FTE). Overall, labor market institutions responded in a similar fashion to the crisis across all Nordic countries, with the furlough programs being an especially popular policy (Alstadsæter et al., 2020b; Bennedsen et al., 2020; OECD, 2020). Although program generosity may vary in the details, across all four countries the incentives of affected businesses were large to participate in the respective furlough program.

Since all Nordic countries were similarly exposed to the pandemic but only Sweden refrained

¹In the following, we will use the terms *short-time work compensation* and *furloughs* interchangeably.

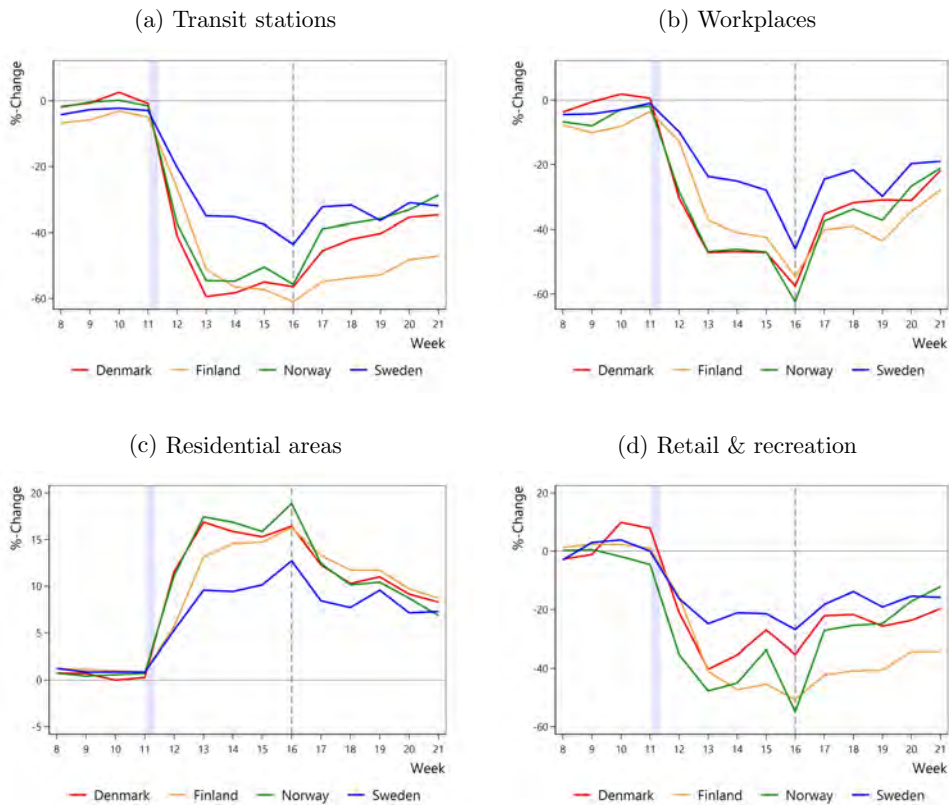


Figure 1: Economic activity in Nordic countries

Notes: The figures show how visits and length of stay at different places changed compared to the median weekly value, using the 5 week period from January 3 to February 6, 2020 as comparison. The blue shaded vertical line indicates the date of the lockdowns from Table 1, which is around March 13 (week 11). The dashed vertical line indicates Easter holidays (week 16). Source: Google LLC “Google COVID-19 Community Mobility Reports.” <https://www.google.com/COVID19/mobility/> [July 15, 2020].

from strict NPIs, a comparison of unemployment and furlough spells between Sweden and the other Nordic countries allows to study the labor market effects of the restrictions. Therefore, we collect novel administrative data on weekly new unemployment and furlough spells from the Nordic countries at the regional level. It is a key strength of our study to not only cover the effect of the crisis on unemployment, but also on the number of people filing for one of the national furlough programs. In our data we find that the number of furloughed workers during the pandemic is significantly larger than the number of workers that became unemployed. Therefore, including furloughed workers is of crucial importance when studying the labor market impact of the pandemic. To our knowledge, we are the first study employing high-frequency data on furlough spells from all Nordic countries.

A drawback of our data is that we observe inflow into unemployment but not outflow from

it. For furloughs, we only observe the outflow for Denmark and Sweden (i.e. we have stock data). However, we think this is of less importance when interested in the short-term effects of the COVID-19 crisis on the labor market. Specifically, during the height of the pandemic there was only little outflow from unemployment, because hiring of new people came to a halt almost completely. This has been documented for the U.S. job market with many of the newly non-employed stopped looking for work during the first weeks after the start of the pandemic in March (Coibion, Gorodnichenko, and Weber, 2020; Forsythe et al., 2020). Furthermore, for Denmark and Sweden we do not observe substantial outflows from the respective furlough program during the time period of our study (see Appendix A.1). Thus, we think our data provides a comprehensive and valid representation of the short-term labor market impact of the COVID-19 crisis.

Empirically, we compare labor market outcomes between Swedish regions and its Nordic neighbors in an event-study framework. Our comparison focuses on the regional number of new weekly unemployment and furlough spells between week 1 and week 21 of 2020 with the corresponding figures in 2019. Week 11 serves as the event date, when the lockdowns of Denmark, Finland and Norway were implemented. To adjust for the general business cycle and seasonal effects we include a set of region-year and country-week fixed effects.

Overall, our result suggest that the labor markets of all Nordic countries were hit hard by the pandemic, as well as by the subsequent NPIs. Starting in week 11 of 2020, we observe a sharp increase in newly unemployment and furlough spells especially for Norway and Denmark, but also for Finland. Sweden shows a similar but less pronounced peak in new unemployment and furlough spells, lagging behind the surge of its neighbors by around 2 to 3 weeks. When using the cumulative (total) number of new weekly unemployment and furlough spells, we again find the labor markets of Denmark and Norway to have suffered the most, followed by Finland and Sweden. Employing weekly regional stock data of furloughs (which is only available for Denmark and Sweden) shows a similar pattern. Specifically, we find a very large increase in Denmark exactly around the time of the lockdown in week 11, and for Sweden a similar but somewhat less strong increase around 2 to 3 weeks thereafter. In sum, the results from the unemployment and furlough data mirror the pattern from the Google mobility data shown in Figure 1: The lockdowns of Norway and Denmark seem to have had the largest impact, followed by Finland and Sweden. Furthermore, even after lifting the lockdown, neither everyday life as recorded in the Google data nor the labor market returned immediately back to normal, but rather recovered only gradually from it.

To quantify the differences in unemployment and furlough spells, we also employ difference-in-differences (DID) regressions. We find the DID coefficient of the cumulative sum of unemployment and furlough spells to be around 1,360 spells higher per 100,000 of population for Denmark in week 21 compared to Sweden. It suggests that Denmark would have accumulated around 30% less unemployment and furlough spells if lighter restrictions similar to Sweden would have been implemented. Our estimates are similar but higher than what Andersen et al. (2020) estimated using bank transaction data from Swedish and Danish bank clients. Specifically, they find a 25%

drop in spending for Sweden versus a 29% drop for Denmark, with the difference of 4 percentage points amounting to a 14% larger drop for Denmark compared to Sweden. Qualitatively, our results are also in line with the recent IMF's *Country Focus* (IMF, 2020), showing that Sweden experienced a small increase in GDP for the first quarter of 2020, contrary to almost all other advanced economies. However, our results seem to contradict findings in Kong and Prinz (2020) who find only small effects of NPIs on UI claims across U.S. states. We believe the Nordic countries provide a setting of (i) more similar exposure (regarding time and space) to the spread of COVID-19, while at the same time having (ii) much larger variation in NPI strictness than most U.S. states. For instance, the 100th confirmed case occurred in New York on the 8th, in New Jersey on the 16th, in West Virginia on the 29th and in Wyoming on the 31st of March. In contrast, the 100th confirmed case in Sweden, Denmark and Norway happened within 5 days. Furthermore, the issuing of NPIs across U.S. states often differed only by a few days or weeks (see Table A.1 of Kong and Prinz (2020)), whereas Sweden had a much lower stringency index throughout the entire pandemic.² However, it is important to note that our analysis ends in week 21, 2020. Thus, our results can only be informative about the short-term effects of the COVID-19 crisis as well as the subsequent lockdowns on the labor market. For instance, our data period is too short to examine whether the recovery in the months after the re-opening occurred slower in Sweden than in the other Nordic countries.

The paper proceeds as follows. The next section introduces the institutional background and in particular the unemployment and furlough programs implemented in the Nordic countries. Section 3 presents the data and provides some descriptive statistics. Section 4 elaborates the empirical specification to identify the impact of NPIs on labor markets and presents the empirical results. Section 5 concludes.

2 Institutional Background

Many countries around the world have created short-term worker programs to avoid large mass-layoffs of workers. In the following, we briefly describe the different programs of the Nordic countries.

2.1 Denmark

Denmark introduced its new short-time work compensation program on March 9th 2020. This new program allows partaking companies to receive a government refund of 75% of the salaries paid to their retained workers. The requirement for a company to be eligible is that it otherwise would have laid off a minimum of 30% of its workforce (Bennedsen et al., 2020). Furloughed workers keep their jobs and salaries but are not allowed to work, meaning that their working

²Unfortunately, the stringency index of Hale et al. (2020) does not exist for U.S. states, but using Google's COVID-19 Community Mobility Reports, for instance, confirms that the differential decline between Sweden and its neighbors in workplace visits was larger than between the 50 U.S. states (see Figure A.2 in the Appendix).

time is reduced by 100%. There is a salary cap on the maximum level of support at 30,000 DKK (around 4,000 EUR) per month for full-time employees (Rothwell and Drie, 2020).³

2.2 Finland

In Finland, there exists no short-time work compensation program as such. However, companies can temporarily layoff employees due to financial or production-related reasons (so called furloughs). This furlough system already existed before but was made more generous and accessible due to COVID-19. A furloughed worker continues to have a valid employment contract with the employer, but the employer stops wage payments temporarily due to the lack of work. Furloughed workers are entitled to the same UI benefits as unemployed workers. All workers, including furloughed workers who work reduced hours (i.e., part-time furloughed), may be entitled to partial UI benefits on top of wage income. Especially the partial UI benefit scheme is generous in Finland, with replacement rates varying between 80 to 100% (Kyyrä, Pesola, and Rissanen, 2017). There is no cap to the (partial) UI benefit in Finland, but the replacement rate declines with the previous (full-time) wage.

2.3 Norway

Similar to Finland, Norway already had a short-time work and unemployment program in place prior to the pandemic. Originally, a furloughed employee reduced working hours by at least 50%, with the state paying 62.4% of the lost income, up to approximately 31,000 NOK (around EUR 2,900) per month for a full-time unemployed. The government strengthened the program with effect on March 20 by granting 100% pay, capped at 31,000 NOK per month, for the first 20 days. From day 21 on, the part of the income below 25,000 (around 2,300) is replaced at 80%, whereas the coverage remains unchanged for the other parts of the income (Alstadsæter et al., 2020a). Furthermore, the minimum required reduction in working hours decreased to 40%.

2.4 Sweden

Sweden, similar to Denmark, created a novel short-time work compensation program coming into effect on March 16th 2020 (Hensvik and Nordström Skans, 2020). The new program can be used when companies are faced with temporary financial or production challenges as a consequence of the COVID-19 pandemic. The most important distinction between Sweden's program, and that of its Nordic neighbors is that a company's employees can reduce their working hours only up to a maximum of 60% (up to 80% after 1st of May) while the government provides financial support in the form of a short-time work allowance. In our analysis we deal with this difference, by comparing full-time equivalent (FTE) furlough spells (see section 3.2 for more detail). The

³<https://danishbusinessauthority.dk/assistance-businesses-denmark-during-corona-virus-diseaseCOVID-19> [July 15, 2020]

financial support reduces an employer's costs for personnel by around 50% (70% after 1st of May), while workers will retain almost 90% of their original pay (KPMG, 2020). The salary cap for financial support is 44,000 SEK (around 4,150 EUR) per month.⁴

3 Data

3.1 Data Sources

During the pandemic, the administrations of the Nordic countries started to produce weekly reports on the new number of individuals being laid-off or put on furlough. Most of the reports they issued during these weeks focused on inflow into unemployment and furlough. Thus, we have access to high-frequency weekly inflow data on the new number of unemployment as well as furlough spells for all regions of Denmark, Norway, Finland, and Sweden for the years 2019 and 2020.⁵ In addition, for Sweden and Denmark we also have data on the stock number of people currently on furlough, which allows us to also examine outflows from the respective furlough program.

For Denmark, we received data on the weekly number of new unemployed through Statistics Denmark. We received furlough data from *Erhvervsstyrelsen*, the Danish Business Authority which manages the program. For Sweden, we received data on the weekly number of new unemployed through the national employment agency. Furlough data was collected through *Tillväxtverket*, the government agency managing the furloughs. For both Denmark and Sweden, the furlough programs were newly introduced due to the Corona crisis, which means that no prior data exists (in Sweden, the first data on furloughs is from week 12, for Denmark from week 11). In our data we replace the missing observations for Sweden and Denmark prior to week 12 and in 2019 with zeroes, consistent with the fact that the program did not exist. For Finland, we downloaded the data from the *Helsinki Graduate School of Economics* webpage. Helsinki GSE created a special webpage collecting and analysing data around the COVID-19 pandemic.⁶ The Norwegian data we received from NAV, the Norwegian Labour and Welfare Administration. The furlough programs of both Finland and Norway existed prior to the pandemic, which gives us data on the weekly number of new furlough spells also for 2019.

3.2 Calculating Full-time Equivalents for Furloughs

As it has been described above, the institutional arrangements regarding part-time/partial furloughs differ between the four countries. For instance, in Denmark every person being furloughed is on full-time furlough, meaning that working time is reduced by 100%. In contrast, a furloughed person in Sweden continues to work partially, since working hours can only be reduced

⁴<https://tillvaxtverket.se/english/short-time-work-allowance.html> [July 15, 2020]

⁵Statistics Denmark provides the regional weekly numbers before 2020 as the average from the years 2015-2019 only.

⁶<https://www.helsinkiigse.fi/korona-data/> [July 15, 2020]

by a maximum of 60% (up to 80% after 1st of May). In Finland and Norway, both part-time (i.e., a partial reduction in working hours) and full-time furlough (100% reduction) is possible. Since the working time reduction of a furlough spell indicates how severely a labor market has been hit by the crisis, we want to take this into consideration. Specifically, to account for the different intensities of the furlough spells and to make them more comparable, we will express the number of furloughs as full-time equivalents (FTE). To do so, we first need information on the number of part-time as well as of full-time furlough spells. Second, we have to find a way to account for the average degree of the hours reduction the part-time furloughed are taking (which we do not have in the data).

Receiving the number of partial furlough spells is relatively straightforward. For Denmark, the share of part-time furloughs is zero, since everyone on the furlough program needs to reduce working time by a 100%. In Sweden, only part-time furloughs are possible, which means that everyone in our furlough data is part-time furloughed. For Norway, we have weekly information on the number of part-time as well as of full-time furlough spells, but only on the national level. We use this share of part-time furlough spells on the national level as a proxy to calculate the number of part-time furloughs on the regional level. For Finland, we only received data on the number of full-time furlough spells. However, a government report on the Finnish furlough program from May 2020 finds that only around 15% of all furloughs are actually part-time (Elinkeinoministeriö, 2020). Thus, for Finland we will use the 15% stated in the report to infer the part-time share for all Finnish regions.

In a second step, we need to take into account the degree of the hours reduction the part-time furloughed are taking in order to calculate the corresponding FTE. This data does not exist for any of the countries, neither on the individual nor aggregate level. Therefore, we decided to use the maximum possible reduction of working time possible in Sweden (60% before 1st of May, 80% thereafter), and use this degree of hours reduction also for the part-time furloughed in the other countries to calculate the FTE. The vast majority of furlough spells of the other three countries are actually full-time, namely 72% for Norway, 85% in Finland, and 100% in Denmark. Thus, the assumption about the working time reduction of the part-time furloughed do not matter greatly for these three countries, since most furlough spells are full-time. In the Appendix A.3 we present robustness checks where we change the assumed working time reduction for the partially furloughed. Overall, we receive qualitatively similar results.⁷

3.3 Descriptive Statistics

The main variables of interest in our study are the weekly new unemployment and furlough spells, both measured on the regional level. All our dependent variables are measured in FTEs as explained above, and we normalize them by the population of the respective region and

⁷An alternative way would be to *not* calculate FTEs but use the unadjusted absolute number of furlough spells recorded in the raw data. This would treat every furloughed employee the same, irrespective of whether the person is full-time furloughed or not. Given that in Sweden no full-time furloughs exist, this approach would overestimate the actual extent of working time reduction in Sweden and bias our results downwards.

year. Table 2 shows the average number of weekly new unemployment, furlough as well as the cumulative sum of weekly new unemployment and furlough spells for the weeks 11 to 21 and the years 2019 and 2020, respectively.

Table 2: Descriptive statistics

Variable	Denmark	Finland	Norway	Sweden
Number of observations (regions)	210 (5)	779 (19)	462 (11)	882 (21)
Population (1,000)				
Mean	1,162.88	291.00	486.17	493.88
Min.	589.76	29.88	241.24	59.64
Max.	1,846.02	1,708.43	1,241.12	2,409.46
<i>New weekly unemployment spells (mean of regions)^{a)}</i>				
2019	116.41	162.36	39.80	59.50
2020	186.92	167.31	95.94	115.58
<i>New weekly furlough spells (mean of regions)^{a)}</i>				
2019	–	19.56	7.73	–
2020	341.62	359.32	530.52	232.08
<i>Cumulative unemployment and furlough spells^{a)}</i>				
2020	6,272.38	6,314.31	7,136.35	4,604.45

Notes: ^{a)}Only weeks 11 to 21, all numbers per 100,000 population.

As we can see in the table, from 2019 to 2020 the average weekly number of new unemployment spells increased by about 3% in Finland, by more than 50% in Denmark and more than doubled in Norway and Sweden. More dramatic is the growth in furlough spells, shown in the bottom lines of Table 2. Two things are worth noting: First, we see how important it is to also obtain data on furlough spells when studying labor markets during the COVID-19 crisis: The average number of new weekly furlough spells are around 2 to 6 times higher than the average number of new weekly unemployment spells. Second, it becomes already evident from this table that the labor markets of all Nordic countries were severely hit by the COVID-19 pandemic.

Table 2 also shows the average size and population of the regions used in our study. We observe 5 Danish regions in our sample, with an average population size of 1.2 Million people. The other Nordic countries include more regions (19 in Finland, 11 in Norway and 21 in Sweden) with lower population size (around 300 Tsd. in Finland, and about 500 Tsd. in Norway and Sweden).

4 Empirical Analysis

4.1 Specification and Identification of Labor Market Effects

Our data is structured as a panel with a country-region (cr) cross section and a year-week (jw) time dimension. Hence, the observational unit is at the cr, jw -level. Our main outcome variables (y) are (i) weekly new unemployment spells, (ii) the weekly new unemployment plus furlough spells, and (iii) the cumulative sum of these spells over time. Our regression model is given by

$$y_{cr,jw} = \eta_{r,j} + \alpha_{c,w} + \beta_{c,w}D_{j=2020} + \varepsilon_{cr,jw}, \quad (1)$$

where $y_{cr,jw}$ denotes the respective outcome for region r of country c in week w of year j . $\eta_{r,j}$ are region-year-fixed effects, $\alpha_{c,w}$ denote country-week fixed effects controlling for seasonal fluctuations in the respective outcome, and $D_{j=2020}$ is a dummy which equals 1 if the year is 2020, and zero else. The main coefficient of interest is $\beta_{c,w}$ which measures deviations in the respective outcome in week w in 2020 compared to the same week w in year 2019.⁸ Week 10 serves as the baseline, i.e., $\beta_{c,10}$ is normalized to 0. Standard errors are clustered on the country-region level.

4.2 Results

Figure 2 present the results from estimating equation (1). Panel *a* uses the weekly new unemployment spells as outcome variable, whereas Panel *b* is based on the weekly new unemployment plus furlough spells. Note that the figures use different scales, since the number of furlough spells is so much larger than the number of unemployment spells in all four countries. A couple of things are notable when looking at the two figures. First, the coefficients for the periods prior to the lockdown in week 11 are quantitatively small, move basically in parallel, and do not exhibit a trend. This confirms that during the first weeks of 2020 the labor markets of the four countries were on similar trajectories once accounting for region-year and country-week fixed effects. This parallel trend changes abruptly in the week of the lockdown (week 11), when the number of new unemployment spells increases tremendously in Denmark, Finland and Norway. Sweden lags behind this development of its neighbors by a few weeks, with the peak number of new unemployment spells being in week 14. Overall, panel *a* of Figure 2 shows that the pandemic dwarfs other regional and seasonal specific labor market fluctuations.

When studying weekly new unemployment plus furlough spells together (panel *b* of Figure 2), a similar but more dramatic picture emerges. Again, and in line with Bennedsen et al. (2020) as well as Alstadsæter et al. (2020b), we find the increase to be sudden and sharp for Denmark and especially for Norway. In Sweden and Finland, the labor market worsens more gradually, with the peak number of weekly new unemployment plus furlough spells being in week 14. In sum, we find that the two strict lockdowns of Denmark and Norway had an immediate and strong

⁸For Denmark, we do not have data from 2019 only but the average from the years 2015-2019.

effect on their national labor markets. The somewhat less strict and later lockdown of Finland (see Table 1) delayed the worsening of the labor market by around 2 weeks. Interestingly, also the Swedish labor market seems to have been hit hard by the escalating pandemic, but with a slightly better performance compared to its neighbors.

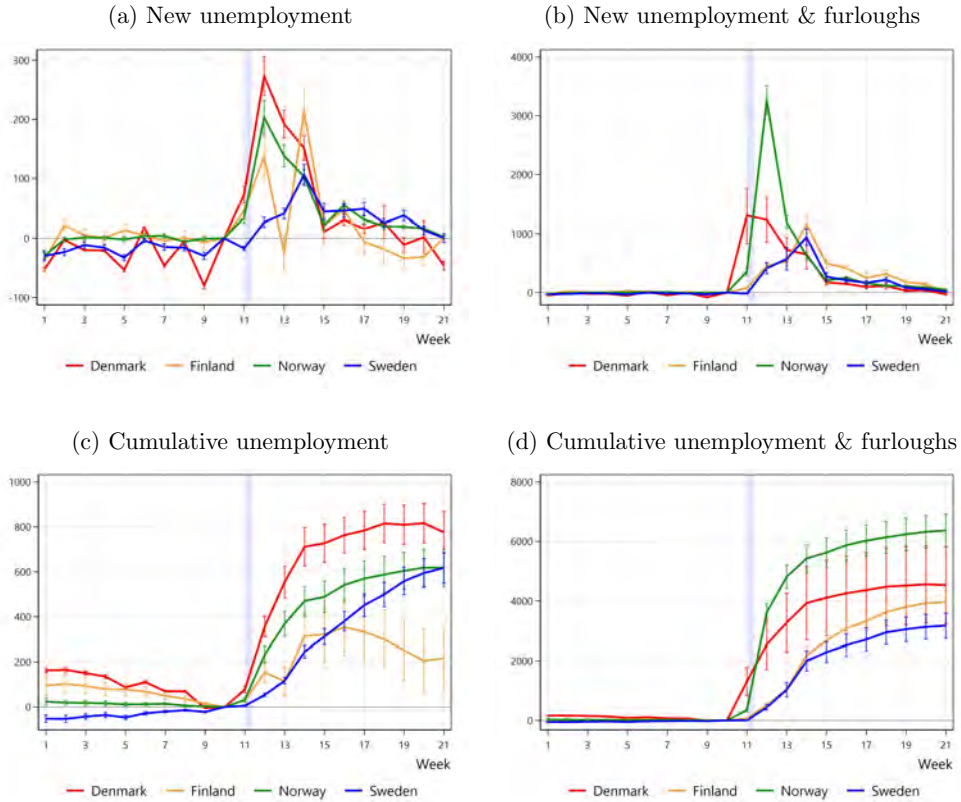


Figure 2: Seasonally and regionally adjusted unemployment/furloughs per 100,000

Notes: The figure shows the event-study coefficients estimated from equation (1), including 95%-confidence intervals (standard errors clustered on the country-region level). The blue shaded vertical line indicates the week of the lockdowns in Denmark, Finland and Norway (week 11). Panel *a* employs new weekly unemployment spells, panel *b* new weekly unemployment plus furlough spells, panel *c* cumulative unemployment spells, and panel *d* cumulative unemployment plus furlough spells as the respective outcome (all per 100,000 population).

The differential timing in the surge of the weekly new numbers may mask some differences in the total sum of unemployment and furlough spells across the four countries. Therefore, we also employ the cumulative sum of new unemployment and furlough spells as dependent variables. Panel *c* displays the regression coefficients when using cumulative new unemployment, and panel *d* when employing cumulative new unemployment plus furloughs as the respective outcome. When looking at the combined measure (panel *d*), we again find that the labor markets of Denmark and Norway seem to have suffered the most. This mirrors what we have already

observed in the mobility data shown in Figure 1: The lockdowns of Norway and Denmark seem to have had the largest impact, followed by Finland and Sweden.

In order to estimate the differences between Sweden and its neighbors more directly, we employ an event-study difference-in-differences (DID) analysis in which Sweden serves as the control group and where treatment takes place in week 11:⁹

$$y_{cr,jw} = \eta_{r,j} + \alpha_{c,w} + \gamma_{jw} + \beta_{c,w}D_{w \geq 11} + \varepsilon_{cr,jw}, \tag{2}$$

where γ_{jw} denote week-year fixed effects. In this model, $\beta_{c,w}$ denotes the DID between country c and Sweden (the omitted category) between week w and week 10.

Results are reported in Figure 3 where we focus on the cumulative sum of the weekly unemployment and furlough spells as outcome variable. We see that after week 10, Denmark as well as Norway see a strong spike in the cumulative sum of unemployment and furlough spells relative to Sweden. After week 13, the coefficients for both Denmark and Norway decline gradually, but remain significantly larger compared to Sweden up to week 21. Finland tracks the Swedish development much closer, and the increase in the cumulative sum of unemployment and furlough spells is insignificant for some coefficients.

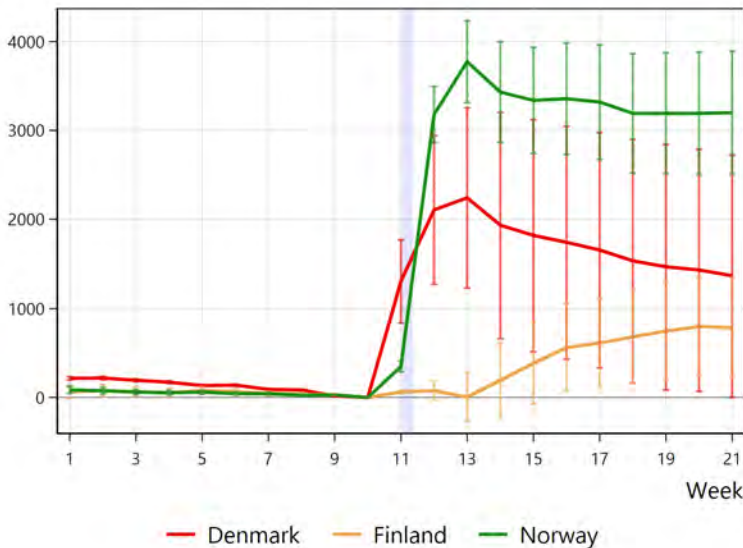


Figure 3: Seasonally and regionally adjusted cumulative unemployment + furloughs per 100,000

Notes: The figure shows the the leads and lags estimated from equation (2), including 95%-confidence intervals (standard errors clustered on the country-region level). The outcome variable is the cumulative sum of unemployment plus furlough spells per 100,000 population. The blue shaded vertical line indicates the week of the lockdowns in Denmark, Finland and Norway (week 11).

⁹A table with conventional DID estimates can be found in the Appendix, see Section A.2.

In order to quantify the effects, we use the estimated coefficient of week 21 from our DID estimation (equation (2)) and compare it to the overall level of the same outcome variable in the same week once seasonal and regional effects are controlled for. Specifically, we use the DID coefficient for Denmark in week 21, which is ca. 1,360 per 100,000 population (depicted in Figure 3, as well as in Table A. 1 in the Appendix). The overall level of the cumulative sum of the weekly new unemployment plus furlough spells for Denmark is around 4,200 in week 21, once corrected for seasonal and regional differences (see Panel *d* of Figure 2). Thus, following the Swedish model of no strict lockdown, Denmark would have accumulated 30% less unemployment plus furlough spells up to calendar week 21. For Norway and Finland, the estimated difference regarding the cumulative sum of the weekly unemployment and furlough spells compared to Sweden in week 21 is ca. 50% and 25%, respectively.

The estimate for Denmark appears to be in the same ballpark but somewhat higher than what Andersen et al. (2020) find using bank transaction data from Swedish and Danish bank clients. Specifically, they find a 25% drop in spending for Sweden versus a 29% drop for Denmark, and interpret the difference as the causal effect of the lockdown. This difference points to a differential impact of the lockdown of about 14%, based on the drop of activity in Denmark ($\approx 4/29$).¹⁰

5 Conclusion

This paper studies the labor market effects of non-pharmaceutical interventions (NPIs) to combat the COVID-19 pandemic. We focus on the Nordic countries which showed one of the highest variations in NPIs despite having similar exposure to the spread of COVID-19 at the onset of the pandemic. Empirically, we use novel data on weekly new unemployment and furlough spells from all 56 regions of the Nordic countries to compare the labor market outcomes of Sweden with the ones of its neighbors.

We find that the labor markets of all four countries were severely hit by the pandemic, with Sweden performing slightly better than its neighbors. Specifically, we find the worsening of the Swedish labor market to occur with a time lag of 2 to 3 weeks compared with its neighbors, and that its cumulative sum of new unemployment and furlough spells remains significantly lower up to week 21 of 2020.

Juranek and Zoutman (2020) show that the lockdown in Denmark and Norway was successful in terms of reducing the pressure on the health care system and mortality. However, our study indicates that the lockdown comes at a cost in terms of labor market performance, at least in the short run. Whether the benefits outweigh the costs depend in part on ethical judgment which is beyond the scope of this paper.

It is important to note that our study only focuses on the 10 weeks after the the initial lockdown

¹⁰For Finland and Norway, we don't know of any other study estimating the economic effect of the NPIs with which our estimates could be compared with.

in the beginning of March. Thus, we cannot make statements regarding the mid- or long-term recovery once the lockdown is lifted and the spread of COVID-19 was under better control. For instance, it might be the case that countries with a stricter lockdown are able to recover faster once the economy opens up again (Correia, Luck, and Verner, 2020). Unfortunately, we do not have sufficient data to examine this claim. However, we can say that up to calendar week 21, labor markets across all Nordic countries were severely affected, with the largest negative effects for Norway and Denmark. Finland and Sweden performed somewhat better, which mirrors the pattern in Google's mobility data.

Overall, most forecasts agree that Sweden with its large trade exposition will also face a severe recession this year, but it is too early to say whether its distinct strategy will prolong the recession or aid the recovery. Future research should aim to estimate the longer-term labor market impact of COVID-19, of the different lockdown policies, as well as the subsequent re-openings.

References

- Alstadsæter, Annette, Julie Brun Bjørkheim, Wojciech Kopczuk, and Andreas Økland (2020a). "Norwegian and US policies alleviate business vulnerability due to the Covid-19 shock equally well". *Unpublished Working Paper*.
- Alstadsæter, Annette, Bernt Bratsberg, Gaute Eielsen, Wojciech Kopczuk, Simen Markussen, Oddbjørn Raaum, and Knut Røed (2020b). "The first weeks of the coronavirus crisis: Who got hit, when and why? Evidence from Norway". *Covid Economics* 15, 63–87.
- Andersen, Asger, Emil Hansen, Niels Johannesen, and Adam Sheridan (2020). "Pandemic, shutdown and consumer spending: Lessons from Scandinavian policy responses to COVID-19". *arXiv:2005.04630*.
- Baldwin, Richard and Beatrice Weder di Mauro (2020). *Mitigating the COVID Economic Crisis: Act Fast and Do Whatever It Takes*. London: CEPR Press.
- Bennedsen, Morten, Birthe Larsen, Ian Schmutte, and Daniela Scur (2020). "Preserving job matches during the COVID-19 pandemic: Firm-level evidence on the role of government aid". *Covid Economics* 27, 1–21.
- Chetty, Raj, John N. Friedman, Nathaniel Hendren, Michael Stepner, and The Opportunity Insights Team (2020). "How did covid-19 and stabilization policies affect spending and employment? A new real-time economic tracker based on private sector data". *NBER Working Paper* No. 27431.
- Coibion, Olivier, Yuriy Gorodnichenko, and Michael Weber (2020). "Labor markets during the COVID-19 crisis: A preliminary view". *Covid Economics* 21, 40–58.

- Canyon, Martin J., Lerong He, and Steen Thomsen (2020). “Lockdowns and COVID-19 deaths in Scandinavia”. *Covid Economics* 26, 17–42.
- Correia, Sergio, Stephan Luck, and Emil Verner (2020). “Pandemics depress the economy, public health interventions do not: Evidence from the 1918 flu”. *Unpublished Working Paper*.
- Elinkeinoministeriö (2020). “Työllisyyskatsaus”. *Toukokuu 2020*.
- Flaxman, Seth, Swapnil Mishra, Axel Gandy, H. Juliette T. Unwin, Thomas A. Mellan, Helen Coupland, Charles Whittaker, Harrison Zhu, Tresnia Berah, Jeffrey W. Eaton, Mélodie Monod, Imperial College COVID-19 Response Team, Azra C. Ghani, Christl A. Donnelly, Steven M. Riley, Michaela A.C. Vollmer, Neil M. Ferguson, Lucy C. Okell, and Samir Bhatt (2020). “Estimating the effects of non-pharmaceutical interventions on COVID-19 in Europe”. *Nature* 583, 1–8.
- Forsythe, Eliza, Lisa B. Kahn, Fabian Lange, and David Wiczer (2020). “Labor Demand in the time of COVID-19: Evidence from vacancy postings and UI claims”. *Journal of Public Economics*, forthcoming.
- Glogowsky, Ulrich, Emanuel Hansen, and Simeon Schächtele (2020). “How effective are social distancing policies? Evidence on the fight against COVID-19 from Germany”. *CESifo Working Paper* No. 8361.
- Hale, Thomas, Anna Petherick, Toby Phillips, and Samuel Webster (2020). “Variation in government responses to COVID-19”. *Blavatnik School of Government Working Paper* No. 2020/031.
- Hensvik, Lena and Oskar Nordström Skans (2020). *IZA COVID-19 Crisis Response Monitoring: Sweden*. Bonn: Institute of Labor Economics.
- Huber, Martin and Henrika Langen (2020). “The impact of response measures on COVID-19-related hospitalization and death rates in Germany and Switzerland”. *arXiv:2005.11278v3*.
- IMF (2020). “Sweden: Will COVID-19 Economics be Different?” *IMF Country Focus*, <https://www.imf.org/en/News/Articles/2020/06/01/na060120-sweden-will-covid-19-economics-be-different> [July 17, 2020].
- Juranek, Steffen and Floris Zoutman (2020). “The effect of social distancing measures on intensive care occupancy: Evidence on COVID-19 in Scandinavia”. *CESifo Working Paper* No. 8262.
- Kong, Edward and Daniel Prinz (2020). “The impact of shutdown policies on unemployment during a pandemic”. *Covid Economics* 17, 24–46.
- KPMG (2020). “Short-Time Work in Selected Countries”. *KPMG Global Legal Services*.

- Kyyrä, Tomi, Hanna Pesola, and Aarne Rissanen (2017). “Unemployment insurance in Finland: A Review of recent changes and empirical evidence on behavioral responses”. *VATT Research Report* No. 184.
- Lin, Peter Zhixian and Christopher M. Meissner (2020). “Health vs. wealth? Public health policies and the economy during Covid-19”. *NBER Working Paper* No. 27099.
- OECD (2020). “Country Policy Tracker: Employment and Social Measures”. *OECD Country Policy Tracker*.
- Rothwell, Jonathan and Hannah Drie (2020). “The effect of COVID-19 and disease suppression policies on labor markets: A preliminary analysis of the data”. *Brookings COVID-19 Memos*, <https://www.brookings.edu/research/the-effect-of-covid-19-and-disease-suppression-policies-on-labor-markets-a-preliminary-analysis-of-the-data/> [July 15, 2020].

A Appendix

A.1 Stock of Furloughs

As described in Section 3, we only have data on the stock of furloughs for Sweden and Denmark. This stock data is useful for two reasons: First, it enables us to check whether our results based on weekly new unemployment and furlough spells (inflow only) would turn out differently if stock data would be used. Second, it helps us assess whether unemployment or furloughs drop considerably once a lockdown is lifted. If this would be the case, then using our measure of the cumulative sum of new unemployment and furlough spells (as, e.g., in Figure 2) would mask such a development.

As mentioned above, we have stock data on the weekly number of total furloughs only available for Denmark and Sweden. Thus, we run our regression based on equation (1) with the stock of furloughs as dependent variable only for these two countries. Figure A.1 shows that the stock of furloughs plateau out at around week 15 for Denmark and week 18 for Sweden respectively. However, a considerable decrease in the stock number of furlough spells can not be observed in either of the two countries. Thus, Figure A.1 suggests that for the time period of our study, using the cumulative sum of new unemployment and furlough spells (which we have access to for all four countries) seems sufficient to analyze the labor market effects during the height of the COVID-19 crisis.

A.2 Difference-in-Difference results

In this section we summarize results from our difference-in-differences (DID) analysis. Column (1) of Table A. 1 uses weekly new unemployment spells, and column (2) uses weekly new unemployment plus furlough spells as the respective outcome. The coefficients shown in the first two columns are based on a conventional DID, estimating one post-treatment effect that represents the average effect over all post-lockdown weeks. We find that over the entire treatment period of week 11 to 21, Denmark has on average 149 (per 100,000 population) more new unemployment plus furlough spells per week compared to Sweden. Finland has roughly 78 more new unemployment plus furlough spells per week and 100,000 inhabitants than Sweden, and Norway around 300.

Column (3) of Table A. 1 uses the cumulative sum of new unemployment plus furlough spells as outcome variable. Column (3) is based on Equation (2), but we only display the coefficient estimated for week 21. This coefficient corresponds exactly with what is depicted for week 21 in Figure 3, which is also the coefficient we use in the main text to quantify our results. We find that up to week 21, all three other Nordic countries have a significantly higher cumulative sum of new unemployment plus furlough spells compared to Sweden.

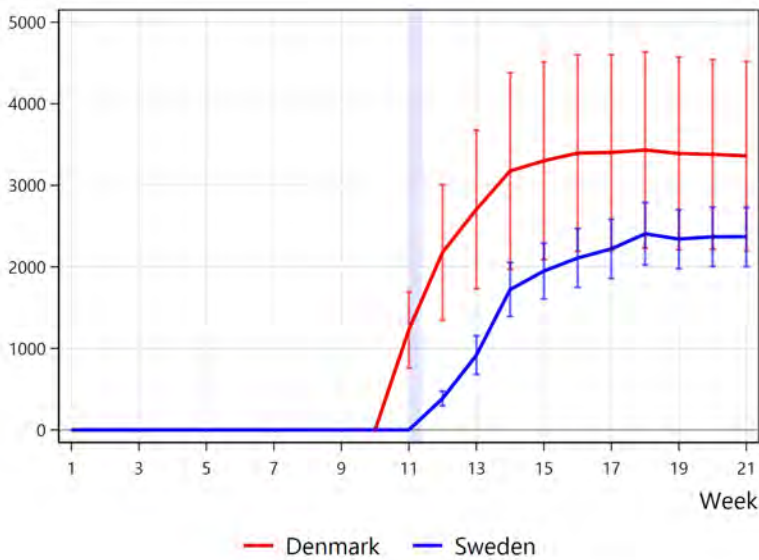


Figure A.1: Seasonally and regionally adjusted stock number of furloughs per 100,000

Notes: The figure shows the event-study coefficients estimated from equation (1), using the cumulative stock of furloughs rather than inflows (all per 100,000 population). The whiskers indicate the 95%-confidence intervals (standard errors clustered on the country-region level). The blue shaded vertical line indicates the week of the lockdowns in Denmark (week 11).

Table A. 1: Difference-in-Difference results

DID-comparison	UE	UE & FU	UE & FU Week 21
Denmark # Sweden	39.878*** (5.758)	149.420** (61.486)	1,363.665* (680.952)
Finland # Sweden	-21.392** (8.675)	77.725*** (26.859)	784.544** (277.302)
Norway # Sweden	10.098* (5.178)	301.985*** (30.955)	3,198.487*** (346.753)
Observations	2,333	2,333	2,333

Notes: Column (1) uses weekly new unemployment spells, column (2) weekly new unemployment plus furlough spells, and column (3) the cumulative sum of new unemployment and furlough spells as the respective outcome variable. Column (3) only shows the coefficient for week 21. All estimates per 100,000 population. ***, ** and * indicates significance at the 1%-,5%- and 10%-level. Standard errors are clustered on the country-region level.

A.3 Sensitivity due to changes in FTE calculation

As mentioned in Section 3.2, we want to alternate the assumed degree of working time reduction of the part-time furloughed when calculating the FTEs in order to check sensitivity. In our baseline results above we assumed that part-time furlough spells reduce their working time by the maximum possible reduction in Sweden (60% before 1st of May, 80% thereafter). As a sensitivity check, we now assume that the part-time furloughs reduce their working-time only by 50%. Again, we apply this to all part-time furloughs in our data.

Table A. 2 replicates Table A. 1. We see that all estimated coefficients remain statistically significant, but increase in size. This increase in the size of the coefficients is most likely driven by the larger share of part-time furloughs in Sweden (where all furloughs are part-time) compared to the other countries. Overall, we receive qualitatively similar results compared to our preferred estimates shown in Table A. 1.

Table A. 2: DID results when part-time furloughs reduce working time by 50%

DID-comparison	UE	UE & FU (FTE)	UE & FU (FTE) Week 21
Denmark # Sweden	39.878*** (5.758)	190.089*** (60.672)	1,811.019*** (671.806)
Finland # Sweden	-21.392** (8.675)	114.414*** (24.600)	1,169.030*** (252.396)
Norway # Sweden	10.098* (5.178)	322.852*** (28.632)	3,429.082*** (320.800)
Observations	2,333	2,333	2,333

Notes: Column (1) uses weekly new unemployment spells, column (2) weekly new unemployment plus furlough spells, and column (3) the cumulative sum of new unemployment and furlough spells as the respective outcome variable. Column (3) only shows the coefficient for week 21. All estimates per 100,000 population. ***, ** and * indicates significance at the 1%-,5%- and 10%-level. Standard errors are clustered on the country-region level.

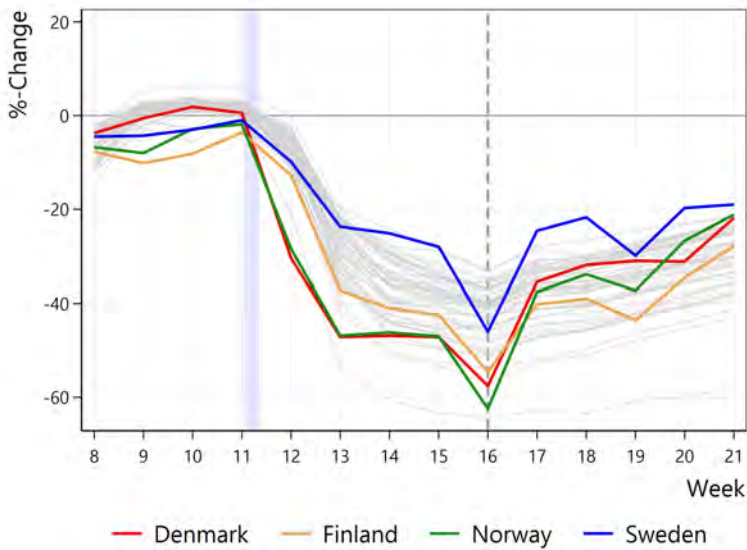


Figure A.2: Workplace visits in the Nordic countries and all U.S. states

Notes: The figure shows how workplace visits changed compared to the median weekly value, using the 5 week period from January 3 to February 6, 2020 as comparison. The U.S. states are shown in shades of light-grey colors. The blue shaded vertical line indicates the date of the lockdowns in Denmark, Finland and Norway from Table 1, which is around March 13 (week 11). The dashed vertical line indicates Easter holidays (week 16). Source: Google LLC “Google COVID-19 Community Mobility Reports.” <https://www.google.com/COVID19/mobility/> [July 15, 2020].