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**News and Uncertainty about COVID-19:
Survey Evidence and Short-Run
Economic Impact**

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**News and Uncertainty about COVID-19:
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We survey households about their expectations of the economic fallout of the COVID-19 pandemic, in real time and at daily frequency. Our baseline question asks about the expected impact on output and inflation over a one-year horizon. Starting on March 10, the median response suggests that the expected output loss is still moderate. This changes over the course of three weeks: At the end of March, the expected loss amounts to some 15 percent. Meanwhile, the pandemic is expected to raise inflation considerably. The uncertainty about these effects is very large. In the second part of the paper we feed the survey data into a New Keynesian business cycle model. Because the economic costs of the pandemic have not fully materialized yet but are nonetheless (a) anticipated and (b) uncertain, private expenditure collapses, thereby amplifying and bringing forward in time the economic costs of the pandemic. The short-run economic impact of the pandemic depends critically on whether monetary policy accommodates the drop in the natural rate of interest or not.

JEL Codes: C83, E43, E52.

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“God gave economists two eyes, one to watch demand, one to watch supply.”

Paul Samuelson (quoted in Davidson et al., 2020).

1 Introduction

The economic fallout of the COVID-19 pandemic is large. Large parts of the economy have been locked down in order to halt the spread of the virus. In the medium term further disruptions are likely because it will take time to restore global value chains and production networks. Some of the damage may never be fully undone. This reduces the productive capacity of the economy—the pandemic represents a genuine supply shock. And yet, in order to understand the short-run economic impact of the pandemic it is essential to account for how aggregate demand adjusts to the shock. For this, in turn, it is necessary to understand how expectations adjust during the crisis triggered by the pandemic.

In this paper we provide new evidence on how households have adjusted their expectations in response to the crisis. Our evidence is unique because our survey is running at high frequency and in real time. Since March 10, we have asked respondents that are representative of the U.S. population about the expected impact of the COVID-19 pandemic on output and inflation over a one-year horizon. Recall that at this point the pandemic had just started to arrive in the U.S. with infections totaling at roughly 1,000. Initially, the median response suggests an expected output loss due to the pandemic of about 2% only. Over time expectations are revised quickly and strongly so. At the end of March the median response regarding the expected output loss amounts to 15%. At the same time, the median response suggests that respondents expect the shock to raise inflation by about 5 percentage points. We also document in detail the extent of uncertainty about these effects.

We show how these expectations play out, as we feed them into a standard New Keynesian business cycle model. Specifically, in our model we study adjustment to a supply shock, namely a reduction in total factor productivity. However, in line with the survey evidence, we assume that the shock is to some extent anticipated. In other words, it is a news shock. Second, to capture the uncertainty about the strength of the shock we consider simultaneously an uncertainty shock. As a result of this shock the range of future realizations of total factor productivity widens. Both shocks are bound to depress private sector expenditures and economic activity falls well before the full consequences of the COVID-19 pandemic materialize. Under these circumstances monetary policy is crucial for the short-run adjustment to shock. We show this as we study alternative scenarios for the conduct of monetary policy.

In the first part of the paper we document the response of household expectations to the COVID-19 outbreak. For this purpose we rely on an online survey that we initiated in March

10. By now we have solicited some 4,000 responses. As stressed above, the expected output loss over the next 12 month that respondents expect as a result of the COVID-19 pandemic amounts to some 15 percent. At the same time, we find that the uncertainty of the overall output effect is large. On the one hand, there is large variation in the point estimates across respondents. On the other hand, we also ask respondents to assign probabilities to alternative outcomes in terms of the output loss due to COVID-19. At the level of individual responses the uncertainty is also large, with a standard deviation of 6 to 7 percentage points.

We also ask households about the expected duration of the COVID-19 outbreak and find that most respondents expect it to last less than 6 month. However, on average households expect the economic consequences of the COVID-19 outbreak to be fairly persistent. Over time, we observe that the distribution over the duration shifts to the center-right. The 3-year ahead output loss is estimated to be close to 1 percent. Households also expect COVID-19 to impact inflation strongly. In the first year the inflation effect is expected to be about 5 percentage points. Here, the uncertainty is also large and the effect is expected to be very persistent. The 3-year ahead inflation prediction is 5 percentage points.

We find complementary evidence from qualitative questions about respondent behavior. For example, we ask respondents about changes in financial planning, the intent of making large purchases or their fear of unemployment. Due to uncertainty regarding the ways the virus can be transmitted, we included a question about avoiding the use of products manufactured in China, where the virus originated. We find that expected GDP loss has no significant effect on reported behavior, but uncertainty matters. In particular, higher uncertainty leads to higher savings and changes in financial planning, and increased fear of unemployment. It also correlates with more spending, likely understood as more spending due to COVID-19 while increasing the avoidance of products from China and storing food and medical supplies. Over time, we observe striking trends. The fractions of respondents reporting changes in financial planning, restraint from large ticket-item purchases and fear of job loss approximately all double. Avoidance of products from China and storing food become more frequent while increased savings slightly decreases.

In the second part of the paper, we use our survey data to quantify the short-run economic impact of the COVID-19 outbreak. In a first step, we quantify the implication of both the expected output loss and the uncertainty thereof for the natural rate of interest within a basic standard asset-pricing framework (Lucas, 1978; Mehra and Prescott, 1985; Barro, 2006). The natural rate is the (real) interest rate that would be observed if prices were completely flexible. Expectations about future output translate into expectations about future consumption and the natural rate adjusts in order to ensure a consumption profile over time in line with the

potential output of the economy. The natural rate drops in response to bad news about the future in order to stimulate today's consumption. This ensures that the good market clears while output is still high. We feed our survey data about the expected output loss due to COVID-19 into the model and compute the implications for the natural rate. In our baseline specification the natural rate drops by about 800 basis points. About one quarter of this effect is due to uncertainty, three quarters are due to the expected average output loss of 6 percent. In the model, this implies a consumption drop of 6 percent, too. To put this into perspective, we note that consumption declined in the U.S. by 16 percent in 1921. This may have been partly a result of "Spanish flu" pandemic in 1918–1920 (Barro and Ursua, 2008; Grammig and Sönksen, 2020), although recent work by (Barro et al., 2020) suggest a rather moderate contribution of the "Spanish flu" of 2.1 percentage points.

Finally, we turn to the implications for monetary policy. For this purpose we rely on the New Keynesian workhorse model and study how the economy adjusts over time to an adverse productivity shock. The key assumption is the productivity shock is anticipated. It is, in other words, a news shock (Schmitt-Groh and Uribe, 2012). On impact productivity is still unchanged, the adverse effects unfold over a couple of months only. It is in this early period that the shock impacts aggregate demand adversely, well ahead of the adverse impact on supply. It is also during that period that monetary policy has key role to stabilize the economy. This becomes clear as we contrast alternative scenarios for monetary policy.

In the first scenario we assume that monetary policy tracks the natural rate perfectly. This involves a sharp cut in the policy rate upon arrival of the news. This cut offsets the increased desire to save and stabilizes the economy at potential. The output gap is closed and inflation remains stable. However, as productivity actually declines output does decline as well. In the second scenario we assume that monetary policy follows a Taylor-type interest rate rule. This rule implies less accommodation in response to the bad news. As a result output declines on impact, the output gap turns negative. Nevertheless we find that the news are inflationary, because future output gaps are expected to be positive and firms set prices in a forward-looking manner. In the third scenario these effects are even stronger because here we assume that monetary policy is unresponsive to the shock during the first four months, say because it is constrained by the zero lower bound or feels it should not respond to the COVID-19 outbreak. Either way, if policy is unresponsive the recessionary impact of the shock is considerably stronger in the short run.

Our paper relates to various strands of research. Binder (2020) also surveys consumers' views about the coronavirus on March 5 and 6, 2020. Her interest is how consumers' views about inflation and unemployment change as they are informed about the Fed's rate cut on

March 3 and its FOMC statement. As far as economic activity is concerned she asks whether there will be more or less unemployment while we ask respondents about the economic costs of COVID-19 in percent of GDP. Jordà et al. (2020) estimate the effect of pandemics on the natural rate of interest on a historical sample. In contrast to us, they focus on the period *after* the pandemic and find a negative effect of close to 2 percentage points two decades after the end of the pandemic.

Earlier model-based work has shown that news shock can be an important source of business cycle fluctuations (Beaudry and Portier, 2006; Barsky and Sims, 2011, 2012). Leduc and Liu (2016) show that uncertain shocks share key features of demand shocks. We also built on contributions which have stressed that the effects of uncertainty shocks get amplified when monetary policy is constrained by the zero lower bound (Fernandez-Villaverde et al., 2015; Basu and Bundick, 2017). Born et al. (2019) estimate the effect of the Brexit vote on the UK economy prior to actual Brexit. They find a significant output drop of about two percent over a two-year period as a result of both adverse news and, to a lesser extent, increased uncertainty. Like us, Guerrieri et al. (2020) and Fornaro and Wolf (2020) stress that the economic fallout from the pandemic may affect supply as well as demand, although through different channels. Lastly, Eichenbaum et al. (2020) model the interaction between economic decisions and epidemic dynamics and study the optimal government policy in the presence of an infection externality.

The remainder of the paper is structured as follows. We introduce our survey in the next section and present results. Section 3 outlines the standard New Keynesian model, while Section 4 presents simulation results. We obtain these as we feed our survey data into the model. A final section offers some conclusions.

2 The Survey

In what follows we first provide some basis information regarding the nature of the survey. We present the main results afterwards.

2.1 Survey Description

We contracted Qualtrics Research Services to provide us with a survey of 3334 nationally representative respondents. We required all respondents to be U.S. residents and have English be their primary language. Respondents were representative by matching several key demographic and socioeconomic characteristics of the U.S. population. In terms of demographics, respondents had to be male or female with 50% probability. Moreover, approximately one third of respondents were targeted to be between 18 and 34, another third between ages 35

and 55, and a final third older than age 55. We also required a distribution across U.S. regions in proportion to population size, drawing 20% of our sample from the Midwest, 20% from the Northeast, 40% from the South and 20% from the West. 66% of the sample were targeted to be non-Hispanic White, 12% non-Hispanic Black, 12% Hispanic and 10% Asian or other.

In terms of the socio-economic make-up, our sample was also representatively collected. In particular, we sampled representatively from the income distribution with a goal of 35% of respondents with a household income of less than 50k, 35% with an income between 50k and 100k, and the remaining 30% with an income above 100k. Half of our respondents had a bachelors degree or above, half some college or less. The survey also includes filters to eliminate respondents who write-in gibberish for at least one response, or who complete the survey in less (more) than five (30) minutes. Table 1 provides a detailed breakdown of our sample. It shows that our sample was approximately representative of the U.S. population according to the sampling criteria.

Table 1: Survey Respondent Characteristics

	pct.		pct.
Age		Race	
18-34	33.09%	non-Hispanic white	68.44%
35-55	35.22%	non-Hispanic black	13.31%
older than 55	31.69%	Hispanic	8.16%
		Asian or other	10.09%
Gender		Household Income	
female	50.00%	less than 50k\$	42.35%
male	49.73%	50k\$ - 100k\$	39.65%
other	0.27%	more than 100k\$	18.00%
Region		Education	
Midwest	20.05%	some college or less	58.01%
Northeast	18.38%	bachelors degree or more	41.99%
South	41.77%		
West	19.81%		
N=3954			

Notes: This table presents data on the characteristics of participants in the survey administered by Qualtrics.

The main questions of the survey are modeled after the Survey of Consumer Expectations (SCE) by the New York Fed. This means we start with some identical questions about income and inflation as in the SCE. For example, to mimic the SCE setup, we use the same language to carefully explain before the actual questions the meaning of probabilities in plain English.

Then, to elicit unconditional expectations for output and inflation over various horizons, we similarly follow the two-pronged approach in the SCE: First, we elicit point estimates. Second, we elicit the probability that respondents assign to a particular outcome, given a range of possible outcomes. In each instance, we use exactly the same questions as a baseline. When we ask for point estimates, we first ask whether respondents expect inflation or deflation (or output increases or decreases). Then we ask what their point estimates are. In the case of eliciting the entire distributions, we bin the support like the SCE into bins of decreases less than -12, -12 to -8, -8 to -4, -4 to -2, -2 to 0, and symmetrically for increase.

Our objects of interest are inflation and income, measured by GDP, or alternatively, by the “total income of all members of your household (including you).” While GDP is a new variable not included in the SCE, but closer to our modeling interest, we add it as a question with a very similar type of wording to that of household income. We elicit expectations at the 12-month horizon relative to today, and at the three-year horizon in between 2022 and 2023. All of these baseline questions as well as the ones that follow are listed in the Survey Appendix.

Our survey contains a set of questions that is unique to our survey and we use the answers to those questions in our calibration exercises in Section 4 below. These questions aim at extracting the conditional effect of the COVID-19 outbreak on expected point estimates and the entire distributions. We ask questions regarding both output and inflation over one-year and three-year horizons, with the exception of inflation for which we skip the distribution over a three-year horizon, to mitigate respondent cognitive burden.

When we ask about the inflationary impact of COVID-19, we start by asking about the impact on the point estimate first:

Over the next 12 months, do you think that the coronavirus will cause inflation to be higher or lower? Higher/Lower

Depending on the answer (Higher/Lower), we ask respondents to fill in their point estimates according to:

How much [higher/lower] do you expect the rate of to be over the next 12 months because of coronavirus? Please give your best guess.

I expect the rate of inflation to be _____ percentage points [higher/lower] because of coronavirus.

We similarly elicit inflation expectations over a three-year horizon. Next, we elicit the distribution over various inflationary outcomes:

In your view, what would you say is the percent chance that over the next 12 months, coronavirus will cause the rate of inflation to be . . .

and allow respondents to distribute 100 percent over a support that ranges from “Negative, by 12 percent or more ____” to “Positive, by 12 percent or more ____”. The support is binned as described above. To eliminate careless responses, we drop respondents who place all weight in one bin, or two bins with empty bins surrounding them.

When we ask about the output impact of COVID-19, we proceed in an entirely analogous fashion. We start by asking about the impact on the point estimate first:

In your view, within 12 months from today, what will the overall economic impact of the coronavirus be positive or negative? Positive/Negative

Depending on the answer (Positive/Negative), we ask respondents to fill in their point estimates according to:

What do you expect the overall impact of the coronavirus to be over the next 12 months? Please give your best guess.

I expect the overall economic impact of the coronavirus to be [positive/negative] ____ percent of GDP.

As for inflation, we elicit expectations over a three-year horizon, as well. Next, we elicit the distribution over various outcomes for GDP:

What would you say is the percent chance that, over the next 12 months, the overall economic impact in percent of GDP will be . . .

and allow respondents to distribute 100 percent over a support that ranges from “Negative, by 12 percent or more” to “Positive, by 12 percent or more ____.” The support is again binned as described above.

Our survey included a series of complementary questions. These questions do not elicit expectations. However, they cover a wide range of behavioral topics, usually in a yes/no style. These questions include savings and purchasing behavior and plans in response to COVID-19, the expected duration of the pandemic, and whether respondents have hoarded food, and medical supplies in response to COVID-19.

The survey embeds several treatments as we ask either about the effect of COVID-19 on GDP or personal income, and the position of our questions about the effect of COVID-19 can be swapped with the questions about another phenomenon included in the survey, but

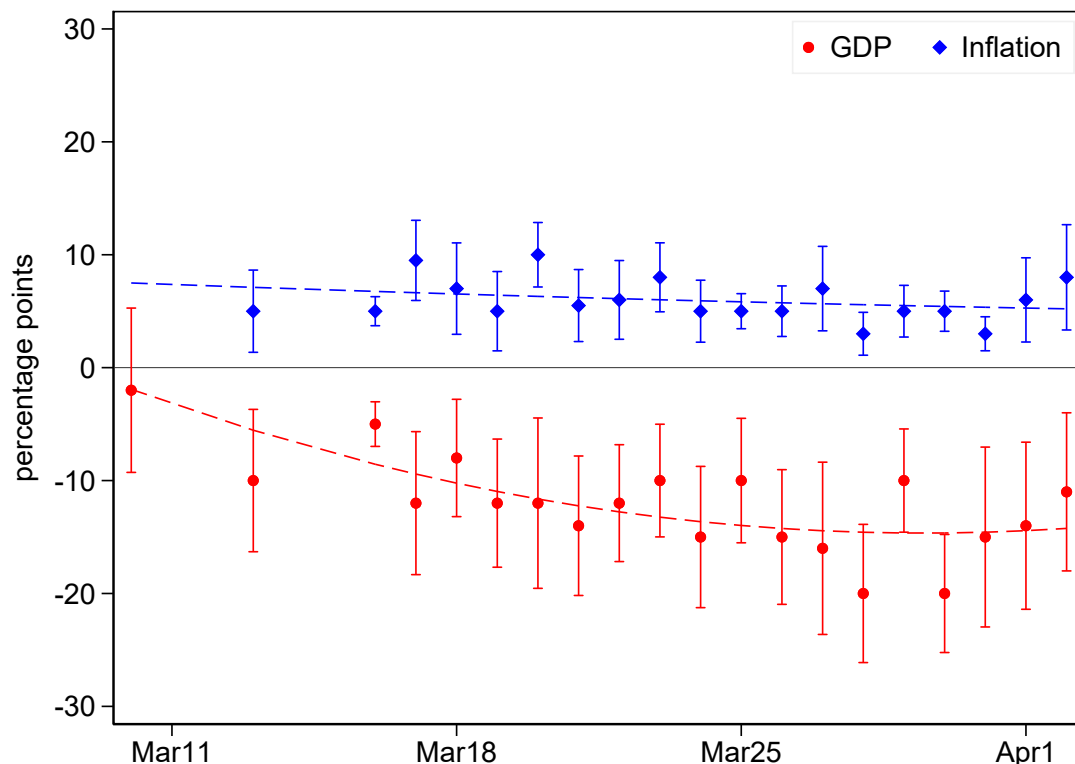


Figure 1: Expected impact of COVID-19 on GDP and Inflation over 12-month period
Notes: Red circles represent median response for output expectations, blue diamonds the median response for inflation expectations. Whiskers represent 95%-confidence interval obtained by bootstrapping. Dashed lines represent second-order polynomial trend. Total number of observations $N=3854$.

not subject of this paper. We report the details of the 4 treatments in the Online Appendix along with further survey details.

2.2 Survey Results: COVID-19 and Expectations

The survey started on March 10, 2020. In what follows we evaluate a first wave of responses based on data up to April 2, 2020. Three findings stand out. First, the COVID-19 outbreak lowered growth expectations and, importantly, our real-time survey documents that U.S. households became gradually aware of the economic fallout from COVID-19 during the second half of March only. Second, households expect the COVID-19 outbreak to be inflationary. Third, the uncertainty about the effects is large, both for output and inflation.

The Coronavirus pandemic had a substantial impact on household expectations for the following year. Figure 1 displays these effects. The red circles represent the median response in the survey for output, the blue diamonds represent the median response for inflation. The

whiskers represent 95% confidence bounds obtained by bootstrapping, while the dashed line represents a second-order polynomial trend. As we emphasize above, the news regarding a possible output loss arrived somewhat gradually. On March 10, the first day of our survey, the median response suggests an output loss of about 2% only. Over time expectations are revised quickly and strongly so. By March 20 the median response regarding the expected output loss is closer to 15% and by end-March, the loss is expected to reach losses near 20%. Towards the end of our sample, there is slight adjustment of expectations towards a smaller output loss.

Table 2 provides detailed statistics on a weekly basis starting with the week of March 8. The left part of Panel A) summarizes the point predictions for GDP. In terms of statistics, we report results for the mean and the median. Before computing the mean we drop, here and in what follows, the 10% most extreme responses, both at the top and at the bottom of the distribution. In panel B of the same table we also summarize the responses for personal household income. Here we find somewhat weaker effects compared to when we ask respondents about GDP, but the effect remains sizable, both in terms of the median and the mean. Figure A.1 in the appendix represents the results for personal household income in the same way as in Figure 1.

Looking again at Figure 1, we note that the median response regarding the expected inflationary impact of the pandemic is more stable over time.¹ There is some fluctuation, but the median respondent expects the COVID-19 pandemic to be inflationary over a 12-month horizon and the effect is expected to be sizeable—in a range between 3 and 7 percentage points. Table 2 again provides detailed statistics for inflation expectations on a weekly basis. The left part of Panel C) summarizes the point predictions of our respondents, both for the mean and the median.

Figure 2 displays the distribution of responses for each of the first four weeks for which the survey has been running.² In Panel A) on the left we show the distribution of responses for the expected impact on GDP, again over a one-year period. In Panel B) on the right we show the distribution of responses for expected inflation for the same period. The distribution of responses is very wide for both variables and in each week. This dispersion underlines the uncertainty of the overall economic impact of the COVID-19 pandemic. Consistent with our results shown in Figure 1 above, we note that the distribution for the expected output effect shifts somewhat to the left from one week to the next. For inflation there is a rightward shift from week 1 to week 2, but this is again reversed in later weeks.

We also analyze the individual forecast distribution of respondents rather than their point

¹Here we lack observations for March 10.

²We drop the 10% most extreme responses.

Table 2: Expected Economic Impact of COVID-19 on one-year horizon

	Reported point prediction					Reported distribution			
	Mean	S.D.	Median	IQR	N	Mean	S.D.	Median	N
A) GDP									
Week									
08.-14.03.2020	-8.16%	25.01pp	-7.00%	25.00pp	89	-3.14%	7.00pp	-3.07%	54
15.-21.03.2020	-13.88%	20.57pp	-10.00%	25.00pp	974	-3.30%	6.99pp	-3.19%	688
22.-28.03.2020	-14.69%	21.42pp	-12.00%	29.00pp	1119	-3.16%	6.72pp	-3.10%	672
29.-02.04.2020	-16.19%	21.84pp	-12.50%	28.00pp	814	-3.15%	6.27pp	-3.14%	439
B) Personal Household Income									
08.-14.03.2020	-0.05%	13.42pp	0.05%	13.00pp	20	-3.15%	6.05pp	-3.15%	12
15.-21.03.2020	-3.59%	6.25pp	-5.00%	10.00pp	54	-2.81%	4.28pp	-2.55%	30
22.-28.03.2020	-4.56%	16.37pp	-4.00%	19.00pp	702	-2.25%	5.92pp	-2.23%	351
29.-02.04.2020	-5.31%	15.78pp	-3.00%	19.00pp	784	-2.12%	6.11pp	-2.02%	410
C) Inflation									
08.-14.03.2020	13.30pp	24.31pp	5.00pp	30.00pp	87	-0.24pp	7.00pp	-1.89pp	53
15.-21.03.2020	11.30pp	17.07pp	6.00pp	19.00pp	1015	-0.10pp	6.99pp	0.02pp	720
22.-28.03.2020	6.83pp	15.74pp	5.00pp	17.00pp	1137	-0.70pp	6.72pp	-0.72pp	631
29.-02.04.2020	7.86pp	16.16pp	5.00pp	17.00pp	815	-0.19pp	6.03pp	-0.54pp	417

Notes: Summary of survey responses about the impact of COVID-19 between March 10 and April 2, 2020. Left panel based on respondents point predictions, right panel based on probabilities respondents attach to a possible outcome. Reported mean and standard deviation are mean over individual distribution means and standard deviations.

predictions. To summarize an individual forecast distribution, we first estimate the best-fitting beta distribution that describes the distribution for each individual. In doing so, we follow the methodology in the SCE exactly (see Appendix C in the SCE methodology). We then compute and summarize the individual distributions on a weekly basis in Table 2. As before, we report results for output expectations, personal household income, and inflation in Panels A) through C). We reported the results for point predictions on the left-hand-side in each panel. The statistics based on the individual forecast distribution are reported on the right.

By and large, we obtain similar results. Two remarks are noteworthy, however. First, the mean expectation implied by the individual forecast distribution is negative for inflation, rather than positive as in case of the point prediction. This inconsistency disappears when we drop those respondents which report a point prediction with a sign different from the sign of the mean implied by their individual forecast distribution. Second, the mean expected output

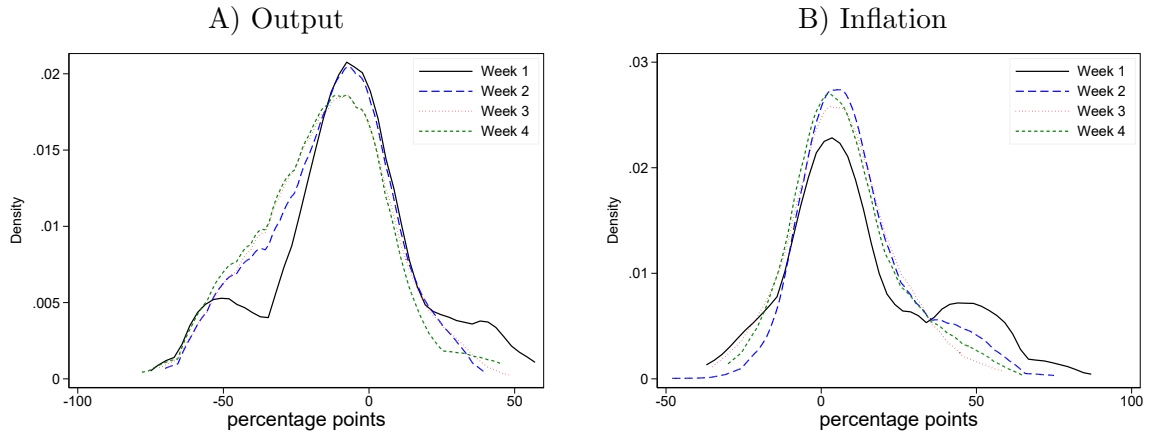


Figure 2: Distribution of output and inflation expectations

Notes: Panel A) shows weekly distribution of expected output impact of COVID-19, Panel B) shows distributions for expected inflation impact. We disregard the 10% most extreme responses. Total number of observations $N=3854$.

loss implied by the mean of the individual forecast distribution is not increasing over time, in contrast to the point prediction for the output loss. This discrepancy can be explained by the fact that we have provided all the respondents in our sample with the same grid of possible output realizations. We find that over time, the share of respondents which attach a lot of weight to the largest possible output loss has been increasing over time, see figure A.5. This shift suggests clear consistency but we cannot quantitatively confirm it.

Importantly, however, the individual forecast distribution allows us to measure the extent of uncertainty about the about the economic impact of the COVID-19 pandemic. Arguably the individual forecast distribution provides a better measure of uncertainty than the variation of the point predictions in the cross section. For this reason, we aggregate the individual forecast distributions on a bin-by-bin basis. Results are shown for each week in Figure A.3 in the appendix. Next we estimate the best-fitting beta distribution on the aggregate distribution and show results in Figure A.4 in the appendix. The result is quite comparable to the distribution of point predictions across respondents shown in Figure 2. Two points in particular are noteworthy. First, the distribution spans a wide range of possible outcomes and the mass associated with extrem outcomes is large, even though the support in Figure A.4 is somewhat narrower. Second, the extent of uncertainty does not change much from week to week.

We also ask respondents to look farther into the future to get a sense of the expected duration of the COVID-19 pandemic. Figure 3 shows the weekly distribution of responses once we ask participants how long they expect the “coronavirus outbreak” to last. Most

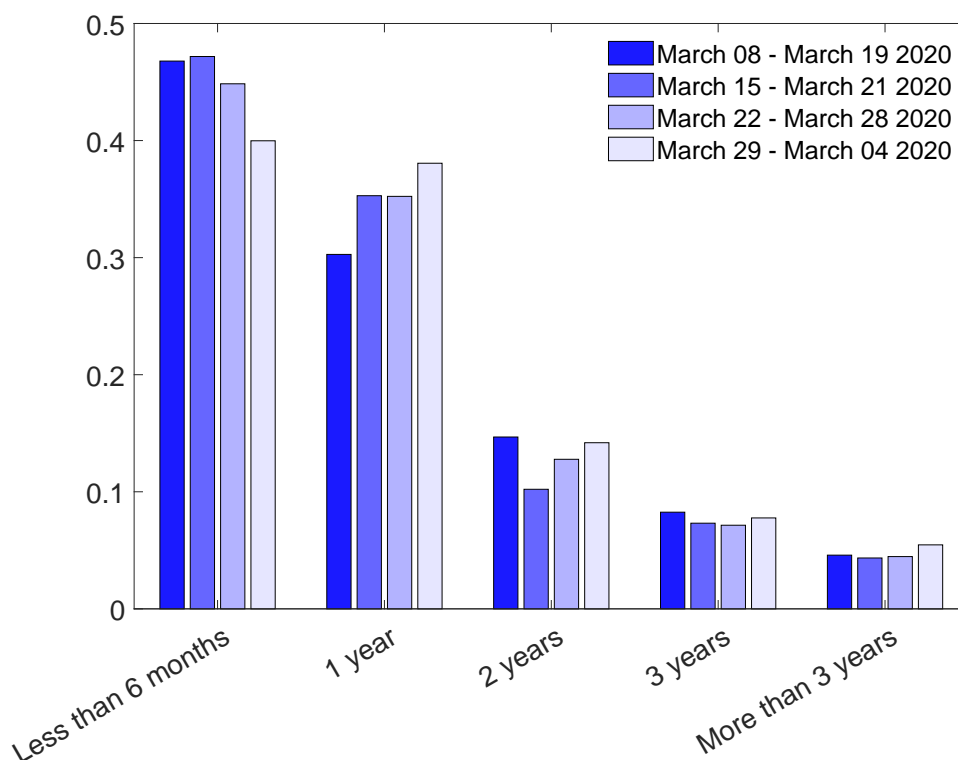


Figure 3: Expected Duration of Covid-19

Notes: Survey participants expectations on the duration of Covid-19. $N = 3954$.

respondents believe that the duration is shorter than 6 months. About 35% of respondents expect a one-year duration, 11% a two-year duration and a non-zero mass is on 3 years, or more than 3 years. Note, however, that over the course of the survey mass has shifted from “less than six months” to “1 year” and about equally to “2 year” categories.

Against this background, we turn to the responses regarding the expected impact of the COVID-19 outbreak in the period between March 2022 and March 2023. We show results in Figure 4, in Panel A) on the left for output, in Panel B) on the right for inflation. In each panel we compare for each day the median response for the 12-month period following March 2020 to the median response for the period following March 2022. The difference are quite stark. In Panel A) the responses for output suggest that respondents expect output to have recovered in 2023. The responses for inflation, shown in Panel B), in contrast suggest that respondents expect inflation to be high for an extended period. We show the results for the expected changes in personal household income in Figure A.2 in the appendix. It displays a similar pattern as Panel A) in Figure 4 for output.

As explained above, we also include a number of behavioral questions in the survey. Table

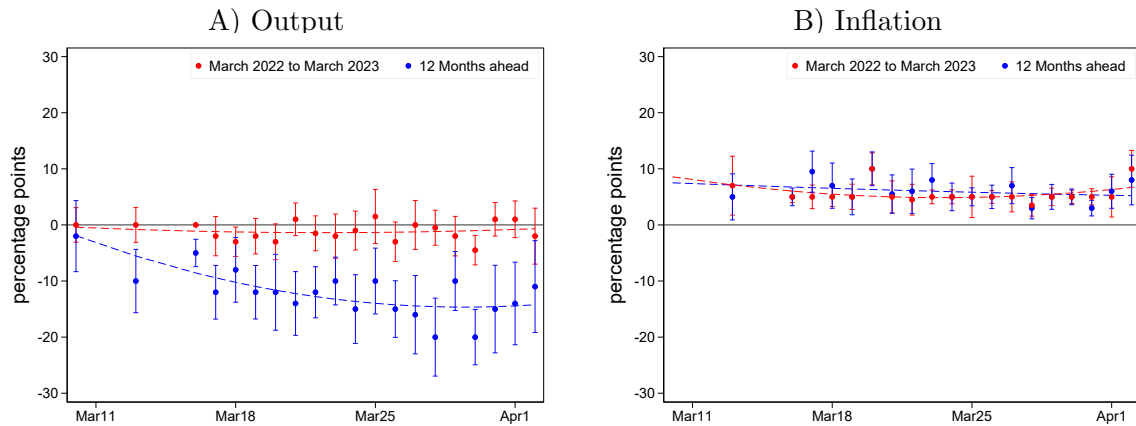


Figure 4: Expected impact of COVID-19: over 12 month vs 3 years period
Notes: Panel A) shows output expectations, Panel B) inflation expectations; 3-year period is period between March 2022 and March 2023. Total number of observations $N=3854$.

3 shows the questions and summarizes the answers. In Panel A) we focus on the questions about savings and expenditures. 40% of respondents spend a larger fraction of their income in response to the COVID-19 pandemic, 70% have refrained from planned larger purchases, 61% report that their financial planning has changed, and 38% have increased their personal savings. In Panel B) we focus on additional aspects of economic behavior related to the COVID-19 pandemic. Due to uncertainty regarding the ways the virus can be transmitted, we included a question about avoiding the use of products manufactured in China, where the virus originated. In particular, 45% of respondents report that they started to store larger quantities of medical supplies at home. 58% have started to store larger quantities of food supplies at home. 54% report avoiding products from China, and 44% fear they may lose their job due to the economic consequences of COVID-19.

When we analyze these behavioral responses over time, we find several, even strong time trends. Figure 5 illustrates these results. A substantially larger fraction of respondents reports changing their financial planning over time in response to COVID-19, growing from 30% to 60% (Panel Q2). The fraction intending no larger purchases (Panel Q3) increases from 40% to 80% while the fraction afraid of a job loss goes up from 25% to 45% (Panel Q5). We also see increases in the fractions increasing spending, storing food and avoiding products from China over time. There is a slight downwards trend in the fraction increasing savings due to COVID-19. We observe no clear trend in the fraction storing medical supplies.

We also assess whether expectations about the output loss caused by the COVID-19 pandemic as well as the associated economic uncertainty can account for the behavioral responses we record in the survey. For this purpose, we run a number of probit regressions

Table 3: Questions with qualitative answers

Question	Share of positive answers
Q1: <i>“Have you increased your personal savings due to the outbreak of the coronavirus?”</i>	38%
Q2: <i>“Has your financial planning changed due to the outbreak of the coronavirus?”</i>	61%
Q3: <i>“Have you refrained from planned larger purchases due to the outbreak of the coronavirus?”</i>	70%
Q4: <i>“Do you spend a larger fraction of your income due to the outbreak of the coronavirus?”</i>	40%
Q5: <i>“Due to the economic consequences of the coronavirus, do you fear you may lose your job?”</i>	44%
Q6: <i>“Since the outbreak of coronavirus, do you try to avoid products from China?”</i>	54%
Q7: <i>“Since the outbreak of the coronavirus, have you started to store larger quantities of food supplies at home than before?”</i>	58%
Q8: <i>“Since the outbreak of the coronavirus, have you started to store larger quantities of medical supplies at home than before?”</i>	45%

Description: Table gives questions asked in survey to learn on behavioural adjustment of respondents due to COVID-19. Each question can only be answered with “Yes” or “No”. Mean gives the fraction of survey respondents answering with “Yes”.

relating in each of several specifications the response to a behavioral question to individual characteristics such as demographics and socioeconomic status. In addition, and this is our main interest, we include the expectation of the GDP loss (over a one-year horizon) in the regression as well as the standard deviation of the best-fitting beta distribution given the individual probabilities assigned to different GDP losses (over a one-year horizon). The latter is our measure of the uncertainty of the expected GDP loss as reported by the individual respondent.

We find several economically meaningful results, as Table 4 illustrates. We find that the expected GDP loss has no significant effect on the reported behavior, but uncertainty matters. We find in particular, that higher uncertainty leads to higher savings and changes in financial planning. It also induces respondents to spend more. This may seem at odds with the fact that it also leads to higher savings. Note, however, that we ask respondents whether they increased spending because of the coronavirus. So, most likely, this question is understood as capturing expenditures related to the coronavirus. Consistent with this interpretation, we also find that the answer to this question is also positively correlated with the answer to the question about whether respondents store larger quantities of medical and food supplies.

Table 4: Probit Estimation Results on Behavioral Questions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Savings Increased	Financial Plans Changed	No Large Purchases	Spend More	Fear Un- employment	Avoid Products from China	Store Food	Store Medical
Expectation on GDP	0.000222 (1.16)	0.00000443 (0.12)	0.00000465 (0.19)	0.000134 (0.68)	0.0000381 (0.18)	0.0000138 (0.06)	0.000902 (1.30)	0.0000639 (0.30)
Uncertainty	0.0268*** (3.39)	0.0269*** (3.37)	0.00765 (0.96)	0.0409*** (5.30)	0.0292*** (3.76)	0.0441*** (5.77)	0.0303*** (3.86)	0.0406*** (5.21)
Age	-0.0159*** (-7.45)	-0.0130*** (-6.29)	0.0000461 (0.27)	-0.00795*** (-3.87)	-0.0223*** (-10.47)	-0.0000396 (-0.48)	-0.00804*** (-3.92)	-0.0100*** (-4.87)
Male	0.380*** (5.85)	0.162* (2.49)	0.0475 (0.72)	0.0292 (0.46)	0.0259 (0.40)	0.0631 (1.01)	0.191** (2.96)	0.258*** (4.03)
Less than Bachelor	-0.268*** (-3.73)	-0.347*** (-4.81)	-0.214** (-2.91)	-0.315*** (-4.46)	-0.294*** (-4.11)	0.0234 (0.34)	-0.237*** (-3.33)	-0.250*** (-3.53)
Low Income	-0.646*** (-6.60)	-0.336*** (-3.33)	-0.212* (-2.08)	-0.307** (-3.23)	-0.257** (-2.67)	-0.549*** (-5.74)	-0.456*** (-4.55)	-0.572*** (-5.84)
Middle Income	-0.553*** (-6.16)	-0.334*** (-3.53)	-0.186* (-1.97)	-0.391*** (-4.48)	-0.153 (-1.74)	-0.375*** (-4.25)	-0.342*** (-3.65)	-0.648*** (-7.15)
White non-Hispanic	-0.215 (-1.50)	0.0503 (0.34)	-0.242 (-1.55)	-0.0941 (-0.67)	-0.0702 (-0.50)	0.152 (1.10)	-0.428** (-2.69)	-0.385** (-2.62)
Constant	0.945*** (5.03)	1.130*** (5.85)	1.017*** (5.53)	0.427* (2.31)	1.072*** (5.77)	0.0849 (0.52)	1.263*** (6.31)	0.978*** (5.16)
Observations	1853	1853	1853	1853	1853	1853	1853	1853

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: Results of a probit model estimation for each of the behavioral questions towards adjustment to COVID-19. We use age, education, ethnicity, income and gender as demographic control variables. Individual standard deviations obtained from the beta distribution of individual survey participants responses on the COVID-19 impact on GDP used as a measure for personal uncertainty. Expectations on GDP are the individual mean of the beta distribution.

We find that people who are more uncertain about the GDP loss caused by the COVID-19 pandemic tend to store more medical supplies and food. Lastly, we also note that they tend to avoid products from China.

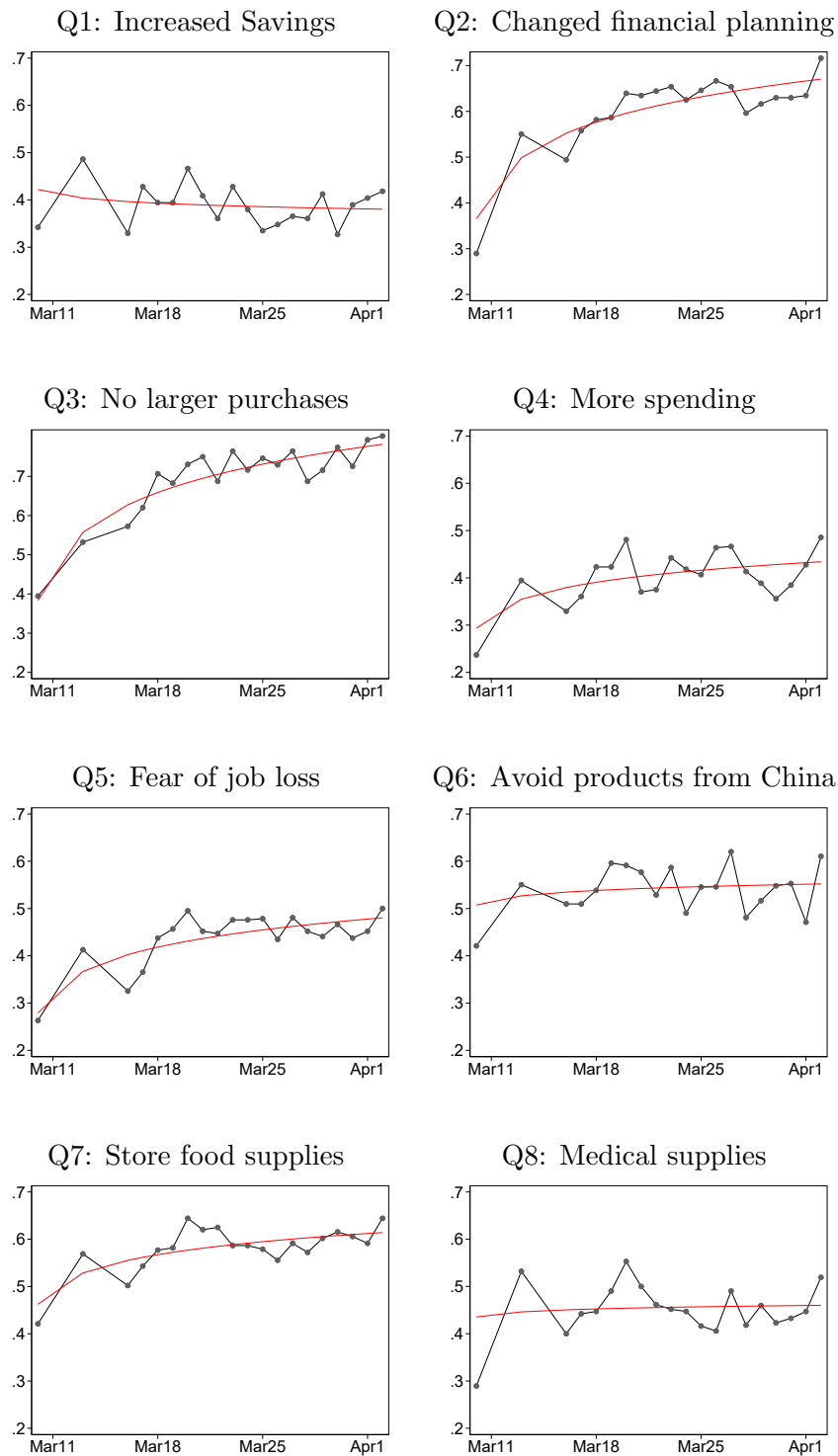


Figure 5: Reported behavioural adjustment over time

Notes: Time Series development of the behavioural adjustment questions. Lines give the fraction of respondents answering the particular question with “Yes” on a given date in the survey.

3 The model

In order to assess the short-run macroeconomic impact of the Covid-19 outbreak we feed private sector expectations as solicited in the survey into a standard New Keynesian model. In fact, for this purpose we rely on the textbook version. In what follows we provide a compact exposition following chapter 3 of (Galí, 2015). Readers familiar with the model, we directly move to Section 4 where we report results.

A representative **household** in country has preferences over private consumption, C_t^i , public and labor, N_t^i , given by

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma} - 1}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right) \quad (1)$$

In the expression above E_0 is the expectation operator, $\beta \in (0, 1)$ is the discount factor, σ is the degree of relative risk aversion, and φ is the inverse of the Frisch elasticity of labor supply. Aggregate consumption is a bundle of varieties $C_t(i)$ with $i \in [0, 1]$:

$$C_t \equiv \left[\int_0^1 C_t(i)^{1-\frac{1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}}. \quad (2)$$

In the expression above $\epsilon > 1$ is the elasticity of substitution across varieties. The household chooses consumption in order to maximize (1), (2) and a flow budget constraint:

$$\int_0^1 P_t(i) C_t(i) di + Q_t B_t \leq B_{t-1} + W_t N_t + D_t, \quad (3)$$

as well as a solvency constraint. Here $P_t(i)$ is the price index of good i , B_t is a nominally riskless discount bond which trades at price Q_t , W_t are wages and D_t is the household's dividend income.

The households supplies labor and saves via the riskless bond in order to satisfy the following optimality conditions

$$\frac{W_t}{P_t} = C_t^\sigma N_t^\varphi \quad (4)$$

$$Q_t = \beta E_t \left\{ \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right\} \quad (5)$$

The optimal intertemporal allocation of consumption expenditures implies the demand function for a generic good i :

$$C_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\epsilon} C_t \quad (6)$$

where $P_t \equiv \left[\int_0^1 P_t(i)^{1-\epsilon} di \right]^{\frac{1}{1-\epsilon}}$ is the consumption price index.

There is a continuum of **firms**, indexed by $i \in [0, 1]$; each firm produces a differentiated good operating under monopolistic competition. The production function of a generic firm i is given by

$$Y_t(i) = A_t N_t(i)^{1-\alpha},$$

where $Y_t(i)$ is the firm's output, $N_t(i)$ is labor employed by firm i , A_t is productivity. It is common across firms and determined exogenously. $\alpha \in [0, 1)$ is a parameter.

Firms are constrained in their ability to adjust prices. In each period a fraction $\theta \in [0, 1]$ is unable to adjust its price. Under this assumption the price level evolves as follows:

$$P_t = [\theta(P_{t-1})^{1-\epsilon} + (1-\theta)(P_t^*)^{1-\epsilon}]^{\frac{1}{1-\epsilon}}, \quad (7)$$

where P_t^* is the optimal price set by firms that are randomly selected to be able to adjust their price. Since they face an identical decision problem, they chose the same price. Specifically, P_t^* solves

$$\max \sum_{k=0}^{\infty} \theta^k E_t \{ Q_{t,t+k} [P_t^* Y_{t+k|t} - C_{t+k}(Y_{t+k|t})] \},$$

where $Y_{t+k|t} = \left(\frac{P_t^*}{P_{t+k}}\right)^{-\epsilon} C_{t+k}$ is demand in period $t+k$, given prices set in period t and $Q_{t,t+k} \equiv \beta^k \left(\frac{C_{t+k}}{C_t}\right)^{-\sigma} \left(\frac{P_t}{P_{t+k}}\right)$. Here this assumption is that firms are ready to produce any amount demanded at the posted prices. The optimal price satisfies:

$$\sum_{t=0}^{\infty} \theta^k E_t \{ Q_{t,t+k} Y_{t+k|t} (P_t^* - \mathcal{M} \Psi_{t+k|t}) \} = 0,$$

where $\Psi_{t+k|t} = C'_{t+k}(Y_{t+k|t})$ denotes marginal costs and $\mathcal{M} \equiv \frac{\epsilon}{\epsilon-1}$ is the markup in steady state.

If prices are completely flexible ($\theta = 0$), the optimal price implies a constant markup over marginal costs:

$$P_t^* = \mathcal{M} \Psi_{t|t}.$$

Market clearing requires for each variety i :

$$Y_t(i) = C_t(i).$$

Further, defining aggregate output $Y_t \equiv \left(\int_0^1 Y_t(i)^{1-\frac{1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}$, we also have

$$Y_t = C_t. \quad (8)$$

Further, labor market clearing implies

$$N_t = \int_0^1 N_t(i) di = \left(\frac{Y_t}{A_t}\right)^{\frac{1}{1-\alpha}} \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\frac{\epsilon}{1-\alpha}} di.$$

The riskless bond is zero net supply.

Monetary policy can undo the effect of price rigidities by making sure that inflation is zero at all times

$$\frac{P_t}{P_{t-1}} = 0. \tag{9}$$

In order to implement price stability it may adjust the short term nominal interest rate, $R_t = Q_t^{-1}$, that is, the inverse of the price of the discount bound. Assuming that this is feasible at all times (say, because the zero lower bound does not constrain short term rates), we can rewrite the Euler equation (5) as follows

$$\frac{1}{R_t^n} = \beta E_t \left\{ \left(\frac{Y_{t+1}}{Y_t} \right)^{-\sigma} \right\}. \tag{10}$$

Here we use equations (8) and (9) and add a superscript n to the short term interest rate since it is the natural rate of interest, that is, the interest that would be observed if prices were completely flexible.

4 Results

The responses to our survey show that starting on March 13 the expected economic loss due to the corona outbreak increased sharply, basically from an average value of zero to an average value of about 5 percent, across respondents. Likewise, the uncertainty increased markedly as well, both if measured by the cross-sectional variation in the responses as well as by the level of individual responses. We now feed these data into the model. We proceed in two steps. First, we compute the response of the natural rate to the shift in expectations triggered by the corona outbreak. Here we take respondents' answers about the output loss at face value and remain agnostic about the specifics of transmission mechanism. Second, we develop a specific shock scenario and trace out the adjustment dynamics for alternative assumptions about monetary policy.

4.1 The response of the natural rate

We now quantify the response of the natural rate to Covid-19 news and uncertainty, as measured in our survey. The exercise is straightforward: we evaluate the Euler equation (10) on the basis of the survey responses regarding the potential output loss in the 12 month from March 2020 until February 2021. This exercise is inspired by Barro (2006) who uses the basic asset pricing model to explore the effect of expectations about rare disasters on the equity premium as well as on interest rates.

Response of natural rate

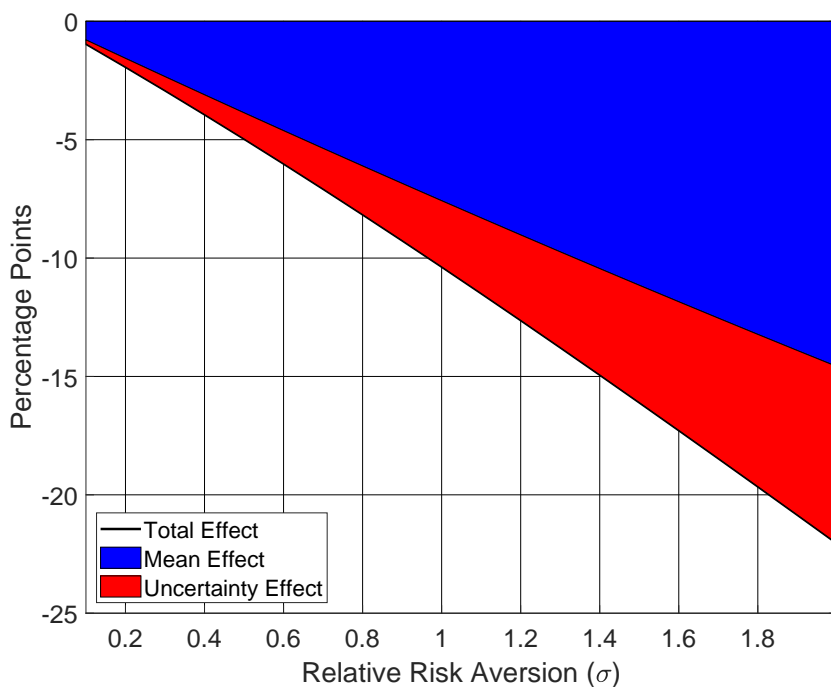


Figure 6: Effect of participants' beliefs (point expectations) about the output loss due to Covid-19 on the natural rate of interest. Computation based on equation (10) and the survey responses. Horizontal axis: alternative values for coefficient of relative risk aversion σ .

Equation (10) also shows that both the expected change in output matters as well as the uncertainty about this change. In our analysis we compute the total effect which includes both the shift in the mean expectations as well as the uncertainty. To quantify the contribution of the latter to the total effect, we also compute the response of the natural rate to a the average expected output loss.

Figure 6 shows the results. The vertical axis measures response of the natural rate in basis points, the horizontal axis measures alternative values for the coefficient of relative risk aversion (σ). The larger the coefficient, the stronger the response of the natural rate. For $\sigma = 1$, we find that the natural rate drops by some 900 basis points. For larger values the drop amounts to more than 2000 basis points. Such larger values are certainly not unheard of. Barro (2006), for instances, uses a value of 4 in his baseline parameterization. In any case, there can be no doubt that the effect on the natural rate is large. The contribution of the mean effect dominates the contribution of uncertainty, but the latter also becomes increasingly important as the coefficient of relative risk aversion goes up.

4.2 Macroeconomic adjustment and monetary policy

Next we use the model to study the dynamic adjustment to the shock, using alternative assumptions for monetary policy. We will show in particular, how the adjustment of output and inflation to the shock depends on how closely monetary policy tracks the natural rate. For this purpose, we simulate the model after assigning parameter values. We assume that a period in the model corresponds to one month. We try to choose parameters that are as uncontroversial as possible. For the time-discount factor we set $\beta = 0.9993$. At the annual frequency, this implies a steady-state real rate of interest of 0.8 percent annualized, in line with the latest (pre-COVID-19) estimates using the Laubach and Williams (2003) methodology.³ We set $\alpha = 1/4$. The own-price elasticity of demand is set to $\epsilon = 11$, a conventional value implying a markup of 10 percent. As for price-stickiness, we choose a monthly price stickiness of $\theta = 0.8^{(1/3)}$. It implies that prices are adjusted rarely, mirroring industrialized economies' inflation experience in the years following the financial crisis. At the same time, it allows for an inflation response that resembles the expected response in the survey. See, for example, the discussion in Corsetti et al. (2013) for the rationale for choosing a rather flat Phillips curve. We choose $\varphi = 1$, implying a Frisch elasticity of labor supply of one, at the upper end of values used in the literature, and in line with an extensive-margin view of the hours worked in the model. Moreover, we set $\sigma = 0.5$ a baseline that is conservative as far as the response of the natural rate is concerned. Last, we assume a steady-state inflation target of 1 percent annualized, so as to mimic the Fed's leeway for cutting interest rates prior to the March 2020 rate cuts.

The shock scenario

In line with the arguments put forward above we assume that the exogenous driving force is an adverse productivity shock with a substantial news component. Specifically, we assume that productivity follows an AR(2) process

$$\log(A_t/A) = \rho_1 \log(A_{t-1}/A) + \rho_2 \log(A_{t-2}/A) + u_t^A, \quad (11)$$

with $\rho_1 = \rho + \gamma$, and $\rho_2 = -\gamma\rho$. Parameters γ and ρ both are $\in (0, 1)$ to ensure stationarity. Here ρ governs the persistence of the AR(2) process after the trough and α governs the propagation to the trough. Our experiment is to feed into the model a sequence of negative and anticipated productivity shocks. We assume that in March (period 0 of our simulations) households learn that $u_t^A = -0.5$ in April, May, June, July, and August 2020. That is, there are negative 0.5 percent innovations to productivity in each of these months. This is a ju-

³Available at <https://www.newyorkfed.org/research/policy/rstar>.

dicious choice. Our goal, then is to use the survey evidence as targets for the TFP process. Toward this end, what we wish to match is an expected fall in average economic activity by 6.5 percent over the course of the first 12 months after the shock. Next to this, we aim for a shock that is persistent so that output is still 2 percent below steady state over the period from month 22 to month 33 after the shock (mimicking the period 2022–2023 for which we ask respondents to provide forecasts in the survey, see 3 above), with the peak effect a little over six months after the news breaks. This leads us to choose $\rho = 0.85$ and $\gamma = 0.9$.

Monetary policy baseline

The simulations require us to parameterize the monetary policy rule. We assume that the central bank follows a standard Taylor rule of the following form

$$i_t = \phi_\pi \pi_t + \phi_y (y_t - y_t^n). \quad (12)$$

We parameterize this as follows: a mild response to inflation $\phi_\pi = 1.2$ and a strong response to the output gap $\phi_y = 1/12$. Note that the model runs on a monthly frequency, so that $\phi_y = 1/12$ is a response as in Taylor-1999. This parametrization in part follows our perception that monetary policy is unlikely to put stronger weight on inflation after a shock that is as severe as the COVID-19 pandemic. Throughout, monetary policy is constrained by a lower bound, which we set at zero nominal interest rates.

Simulation results - baseline policy

We conduct the simulations under perfect foresight with the news about future TFP breaking in period 0. That is, under the assumption that in period 0 households learn about the sequence of shocks. We also use the linearized New Keynesian model for this exercise. In other words, the simulations capture the natural rate effect discussed above but not yet the additional uncertainty effect. Furthermore, it should be noted that this is a setting with a representative household. That is, the model implicitly assumes that insurance contracts exist (or are mimicked by the government) such that there is no idiosyncratic risk.

Figure 7 shows the responses in the baseline under the Taylor rule (12). It focuses on the short run adjustment over the 12 months following the shock. In each panel, the horizontal axis measures time in months, while the vertical axis measures the deviation from the steady state value. Shown are the response in the benchmark (black solid lines). The figure also shows two alternatives. One without the lower bound constraint blue dashed lines, and one if the central bank would not lower interest rates but otherwise follow the Taylor rule (red dash-dotted lines). The shocks, the natural level output, and the natural rate of interest are common to all three scenarios. We discuss these first.

The time path of the exogenous productivity process (11) is shown in the left panel of the second row. Productivity falls gradually, to a trough of -6 percent by the end of the year. Thereafter it gradually recovers (most of the recovery phase is not shown). In line with the analysis in the previous section, the natural rate of interest (third row, right panel) sharply falls in the earlier stages of the crisis; by 3.5 percentage points (annualized) on impact, and continues to fall subsequently, before it starts to recover 5 months after the shock. Averaged over a year this amounts to a fall of the natural rate of interest by 3.5 percent on impact (third row, left panel). Potential output (first row, right panel) tracks the exogenous productivity process. What this implies is that the natural level of output would barely fall on impact.

The other panels show the evolution of the actual economy. We start with the baseline scenario (Taylor rule and ZLB, black solid line). On impact, the monetary policy rate falls by 1.8 percent, to the lower bound (middle row, center panel, black solid line). Still, the policy rate fails to mimic the fall in the natural rate. The cut is not sharp enough, though, to stabilize output in the initial phase (top row, left panel, black solid line). Rational expectations and a limited monetary response in the face of a strong drop in the natural rate mean that the adverse effect of the COVID-19 pandemic is moved forward in time. Output falls by 4.5 percent on impact and output losses average 6 percent over the course of the first 12 months. As a consequence, there is a large negative output gap (top row, center panel). Still, inflation rises on impact. In the context of the model, this is so because eventually, as the shock unfolds, monetary policy turns accommodative (the output gap turns positive, output exceeds potential). Price-setters subject to nominal rigidities anticipate the associated rise in marginal production costs and raise prices early on. The actual long-term real rate of interest (plotted here is a 10 year real rate, bottom row, center panel) increases on impact and more so over time, reflecting the path of future short-term rates.

Figure 7 also illustrates the effect that monetary constraints have on the simulation results. The figure shows two alternative scenarios. In one, there is no lower bound. This is shown as a blue dashed line. The real rate falls by more (see bottom panel, center), so output falls less on impact. Still, under the Taylor rule output falls. In the other alternative that Figure 7, initially there is no monetary accommodation, because policy rates cannot fall or policy makers do not choose to cut rates. This is shown as a dash-dotted red line. If monetary policy no longer accommodates the TFP shock, output considerably more on impact (top row, left panel, dash-dotted red lines).

That is, even though the only shocks are shocks to productive capacity (“supply side shocks”), monetary accommodation is essential early on. This way, the central bank prevents the sharp drop in the natural rate of interest and subsequent reversal to translate into out-

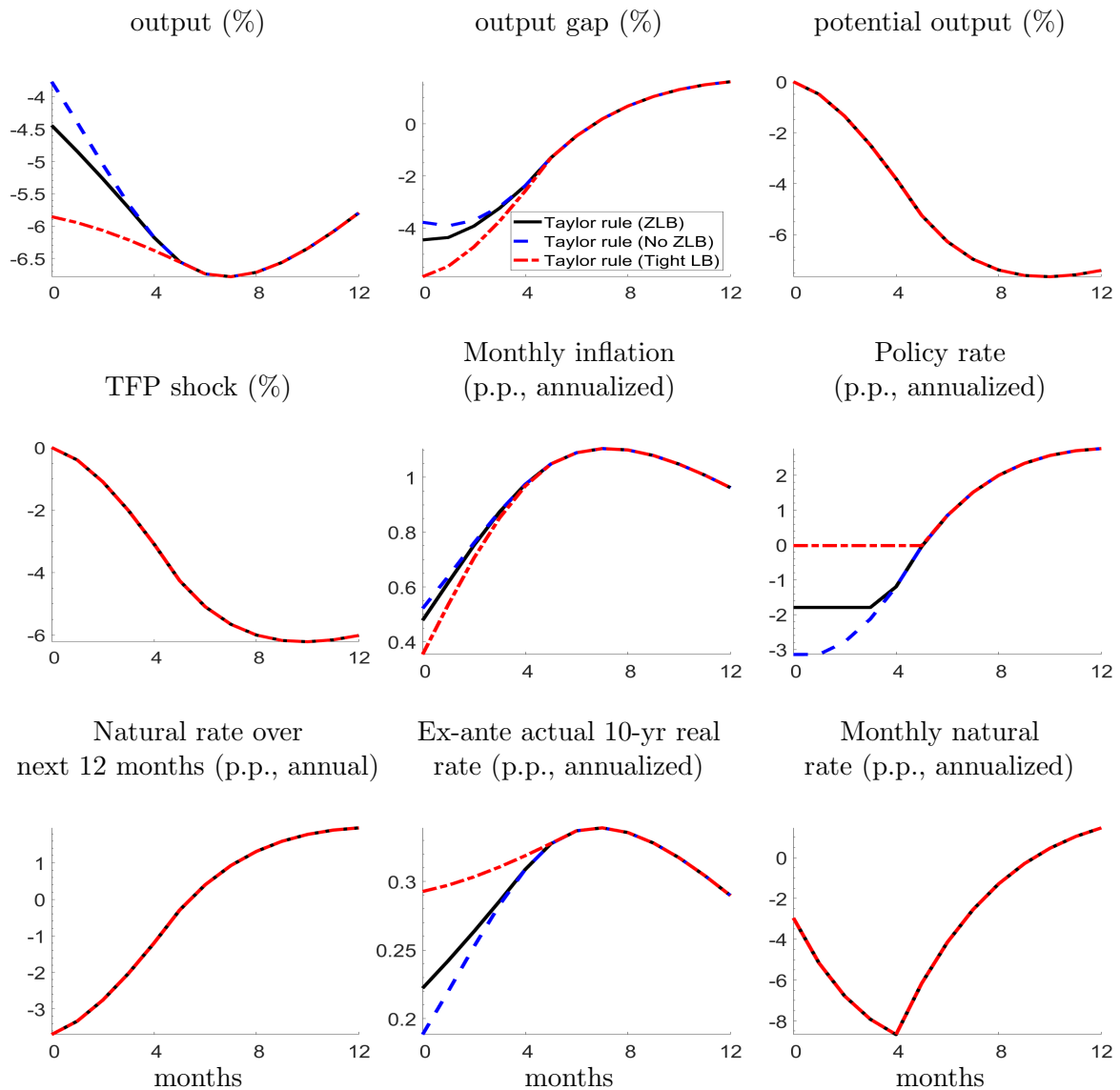


Figure 7: Response to negative productivity shock. Shown are responses under the Taylor rule. Black solid line: ZLB allows for 1.8 percent interest could on impact. Blue dashed line: response of the economy absent the lower bound. Red dashed-dotted line: response of the economy if interest cuts would not be possible.

sized effects on demand at a time when potential output has not yet fallen.

Simulation results - alternative policy assumptions

Figure 8 provides simulations under different policy assumptions. These serve to highlight that insufficient stimulus early can have notable costs. And they serve to highlight that monetary policy distributes the losses in productive capacity to output and inflation.

The black solid line in Figure 8 provides a natural benchmark for the exercise, namely,

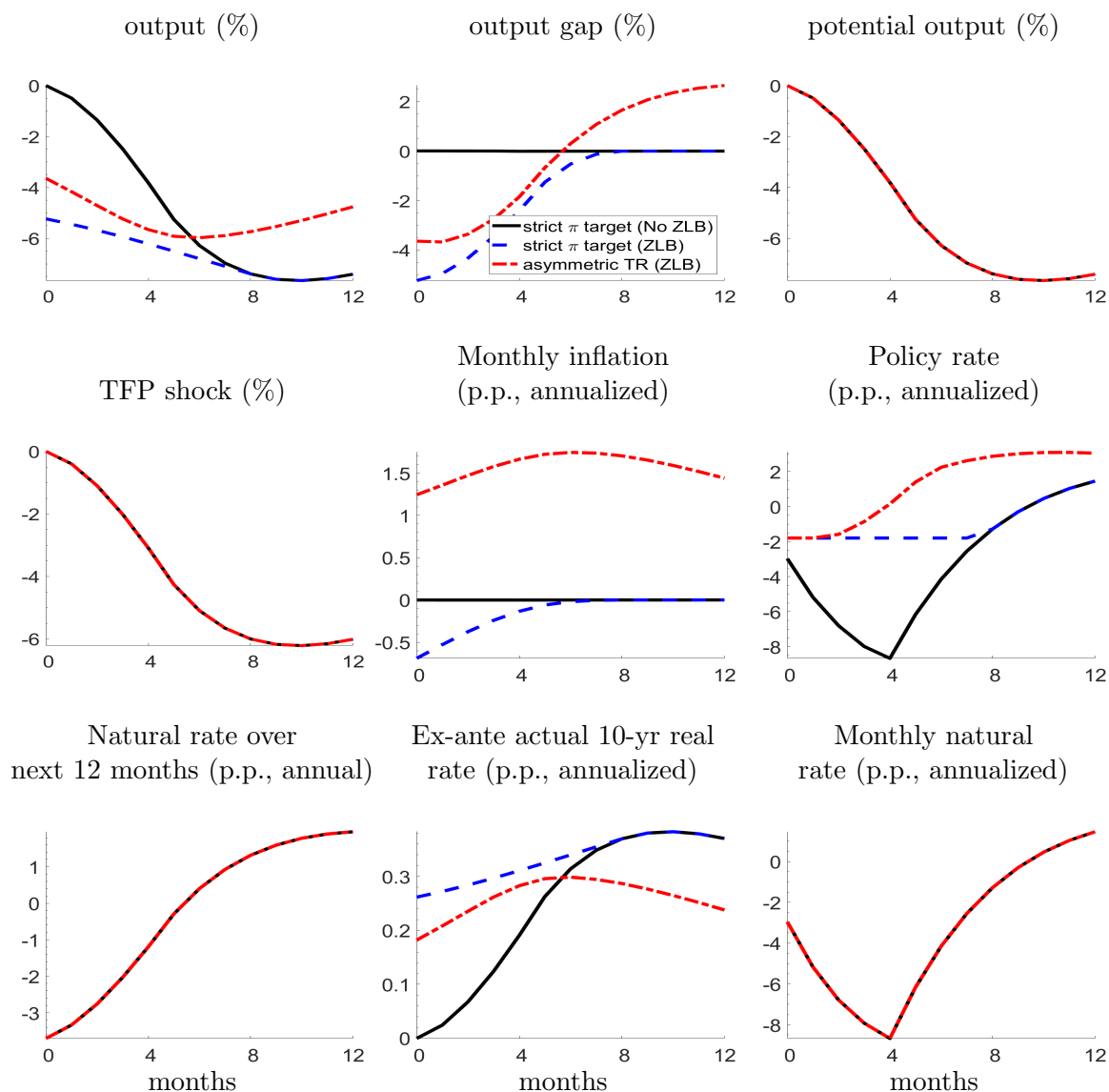


Figure 8: Response to negative productivity shock. Shown are responses for different policy rules under the ZLB. Black solid line: response of the economy with strict inflation targeting, and absent the ZLB (the flex-price allocation). Blue dashed line: strict inflation targeting, but with ZLB in place. Red dashed-dotted line: response of the economy with asymmetric Taylor rule.

that of strict inflation targeting. In baseline New Keynesian model shown here, strict inflation targeting would be the optimal monetary policy to follow, if there are no constraints on monetary policy. This perfectly stabilizes inflation and implements the flex-price (natural) allocation. The response of the nominal rate (center row, right panel), therefore, is identical to the response of the natural rate (bottom row, right panel), and output falls along with potential. What is noteworthy is the size of the interest cuts in the first few months that

would be needed to stabilize activity at the natural level. The necessary cuts would be well below those allowed for by the lower bound (still center row, right panel).

By the nature of the shock that we simulate, the productive capacity of the economy eventually is adversely affected. Absent the ZLB, the central bank can let output follow potential. With the ZLB, however, the central bank cannot follow that policy. Next, we implement the policy of strict inflation targeting through a large parameter ϕ_π in the Taylor rule but leave the lower bound in place. Results are shown as dashed lines in Figure 8. The figure shows that a policy of strict inflation targeting that is subject to implementability restrictions imposed by the lower bound, reduces output by more in the initial periods than under the Taylor rule (compare the blue dashed line here to the solid line of Figure 7, top row, left panel each). This scenario also illustrates that monetary policy shapes the effect of the shock on inflation. Instead of the baseline's inflation, disinflation would result (center row, center panel).

The Taylor rule in Figure 7 was tight early on (relative to the natural rate), but accommodative later. If the central bank continues to provide monetary stimulus to support aggregate demand, eventually demand surpasses potential output. In the baseline, Figure 7, this is what happens about half a year after the news of the impact of COVID-19 is realized and explains the inflationary pressures. To highlight this point more clearly, the current Figure 8 shows results under another, more alternative policy (as a red dash-dotted line). We assume that the central bank follows an asymmetric Taylor rule of the following form

$$i_t = \phi_\pi \pi_t + \phi_y (y_t - y_t^n) I(y_t - y_t^n < 0) + \phi_y / 2 (y_t - y_t^n) I(y_t - y_t^n > 0).$$

This parametrization assumes that policy will not tighten as rapidly when the output gap turns positive (output exceeds potential) on the recovery path. That is, the policy is more accommodative later on than the baseline Taylor rule. This is inflationary (red dash-dotted line, center row, center panel of Figure 8), but serves to stabilize output in the face of the shock, in spite of the lower bound. The center panel in the bottom row shows that this has notable implications for long-term interest rates.

Yield curves

Figure 9 plots the model-implied change in yield curves for different policies against the changes witnessed in the data. In the left panel we show the yield curve at the beginning of March 2020 (blue dashed line) and the yield curve at the end of our sample (March 23: red solid line). We observe that the yield curve shifts downward at the short end, but much less so at the long end. Our model predictions align well with this observation: In the right panel

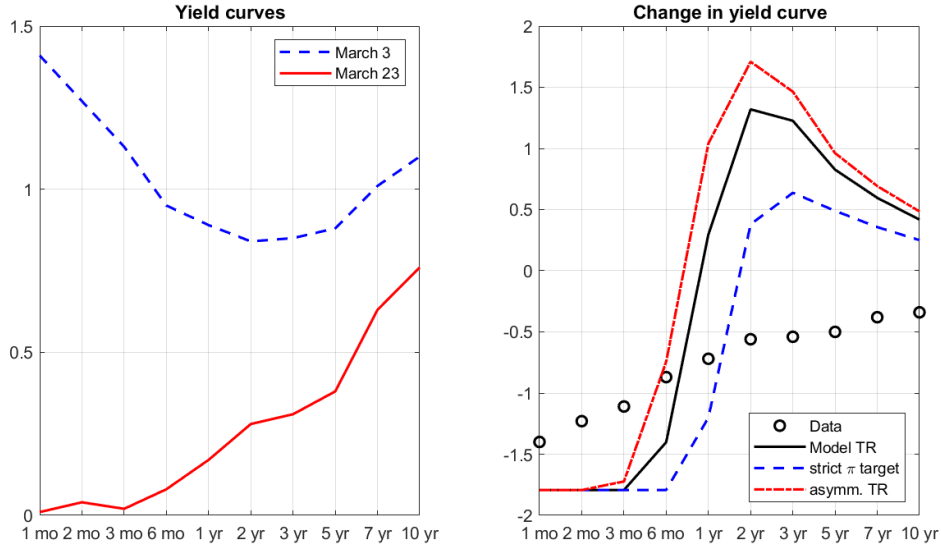


Figure 9: Yield curve. Left panel: financial market implied yield curves on March 3 and March 23 across different maturities ranging from 1 month to 10 years. Right panel: change in yield curves observed in the data (black circles) against effects on the yield curve implied by our simulations. Black solid line: the Taylor baseline shown in Figure 7. Blue dashed line: yield curve effects under strict inflation targeting. Red dash-dotted line: effects under the asymmetric Taylor rule. The latter two are the scenarios shown in Figure 8.

of the figure we compare the shift of the yield curve in the data (black circles) to the model prediction.

5 Conclusion

The short-run economic impact of the COVID-19 pandemic depends on what people expect its overall effect to be, and how much uncertainty there is about it. To measure household expectations and the extent of uncertainty about the economic impact of the COVID-19 pandemic, we run a survey of household expectations in the U.S, starting in March 10, 2020. This is a relatively early date as far as the spread of the virus in the U.S. is concerned. On that day the number of infections exceed just 1,000 cases but the pandemic had been raging in China for months.

Initially, that is, on March 10, we find that the average expected output loss is basically zero. However, as we ask about the expected output loss 3 days later, the average amounts to 5.8 percent. The responses in the following days are similar, although there is slight trend towards a larger expected loss in the days up to March 20. In this sense our survey captures the arrival of news about the economic fallout caused by COVID-19, as far as U.S. households

are concerned. Moreover, and this our second main finding, the responses show a high degree of variation across respondents. Similarly, once we ask respondents to assign probabilities to specific outcomes, the standard-deviation at the level of the individual responses is also large. This testifies to the uncertainty about the economic costs the COVID-19 pandemic.

In the second part of the paper, we use the expectations data from the survey to infer the economic consequences in the short run. We feed the distribution of expected output losses into a standard asset-pricing equation and quantify the implications for the natural rate of interest. This exercise is relatively general to the extent that we are not required to make any assumptions beyond this asset-equation to compute the response of the natural rate to the COVID-19 induced expectations and uncertainty about the change of output in the 12 months following March 2020. We find that the natural rate declines by several percentage points suggesting that monetary accommodation is warranted.

This is noteworthy not least in light of the experience during the 2007–2008 financial crisis. During that period, the Fed lowered short-term interest rates by about 500 basis points, starting in the second half of 2007. Rates were cut all the way to zero by the end of 2008. Clearly today's environment is different. Interest rates already were very low before the COVID-19 outbreak. For this reason, it likely is harder for central banks to accommodate the drop in the natural rate. As discussed in the introduction, the Fed lowered interest rates on March 3 and 15 by 150 basis points in two unscheduled FOMC meetings. Markets did not calm down afterward. Our survey evidence and the theory-based considerations above provide a clear narrative why that was. In this reading, the Fed's rate cuts helped, but they overlapped with the timing of the arrival of bad news and a notable rise in uncertainty.

Finally, we explore more systematically the role of monetary policy for the adjustment dynamics in the short run. For this purpose we rely on the conventional New Keynesian model which we calibrate to monthly frequency. We feed a shock process into the model which lowers potential output, but its peak effect is delayed by a couple of months. In the short-run, that is, prior to the peak effect monetary policy is key. If it is able to track the natural rate, it can stabilize the economy at its potential level. If instead monetary policy is unable or unwilling to lower policy rates, the actual output falls strongly and much more than potential output. This drop is a demand-driven recession which in turn is caused by bad news about medium-term potential output. Hence, we find that monetary policy is key in the short run. We also note, however, that monetary policy cannot offset the effect of the shock on potential output in the medium run.

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A Appendix

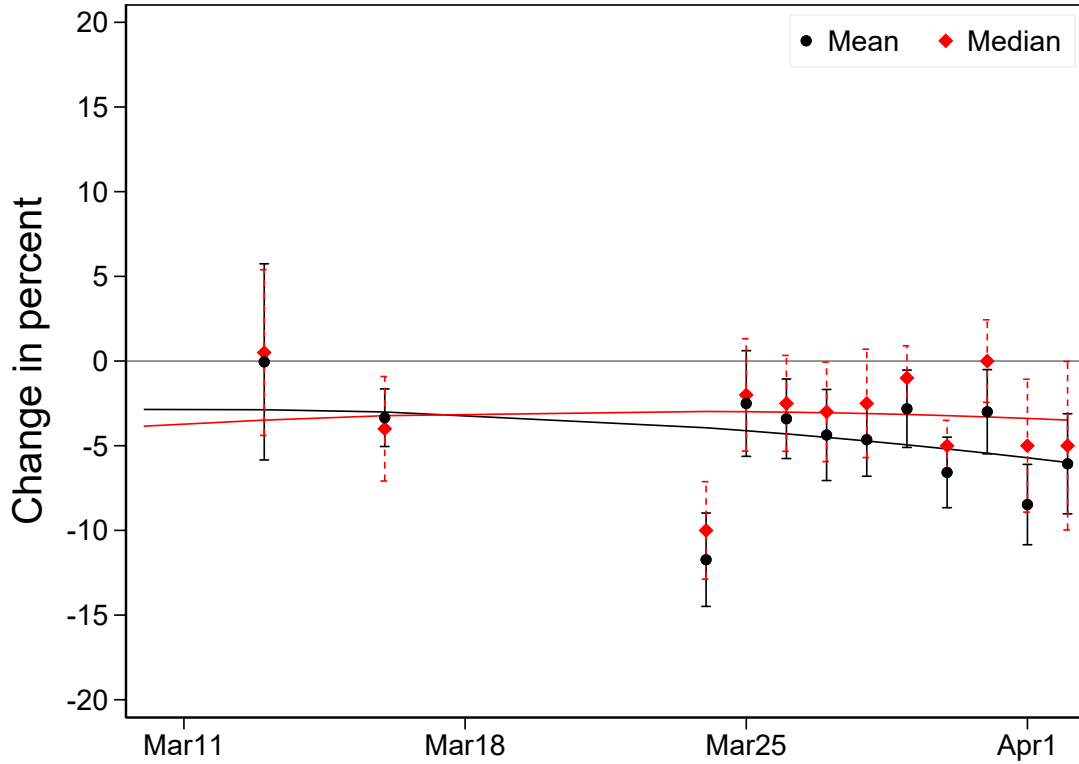


Figure A.1: Expected change in Personal Household Income (PHI) due to COVID-19
Notes: Figure shows expectations on PHI for the next 12 months due to COVID-19 over time. Black dots give means, red diamonds medians of the daily distribution of responses (N=1560). Whiskers represent the 95% confidence interval of the mean (black, solid) and median (red, dashed) obtained via bootstrapping. The solid lines represents a second-order polynomial trend for mean (black) and median (red).

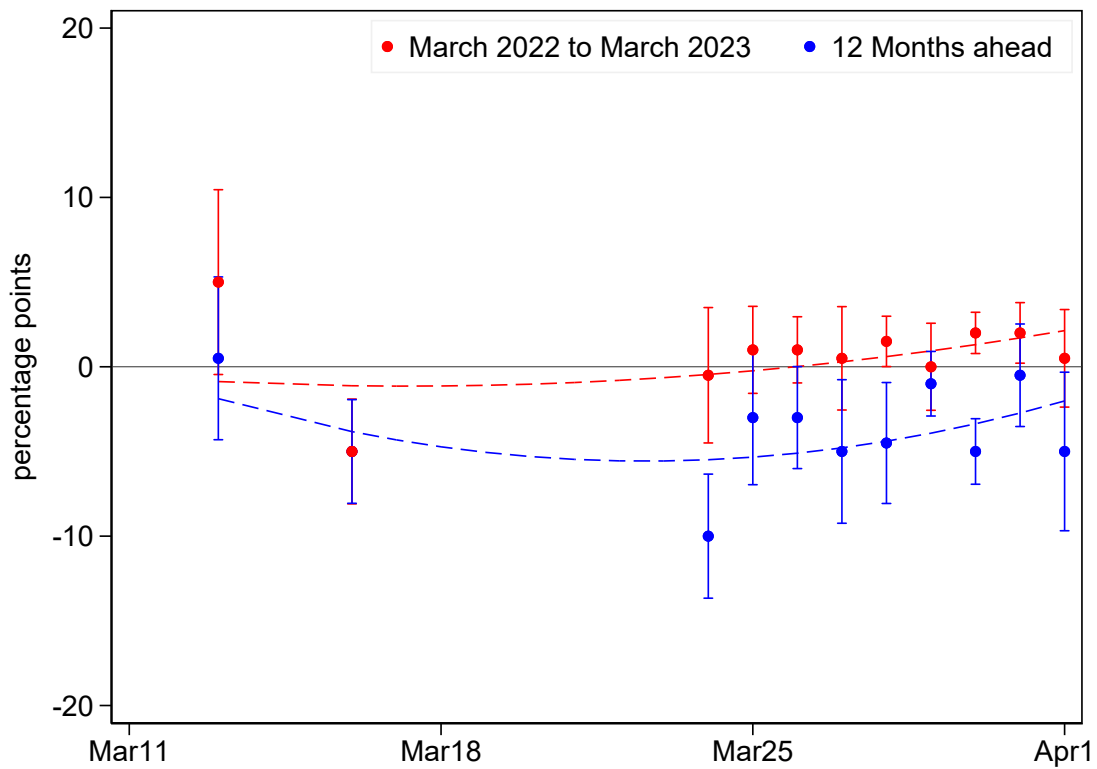


Figure A.2: Expected impact on Personal Household Income (PHI) of COVID-19: over 12 month vs 3 years period
 Notes: 3-year period is period between March 2022 and March 2023. Total number of observations: N=2083.

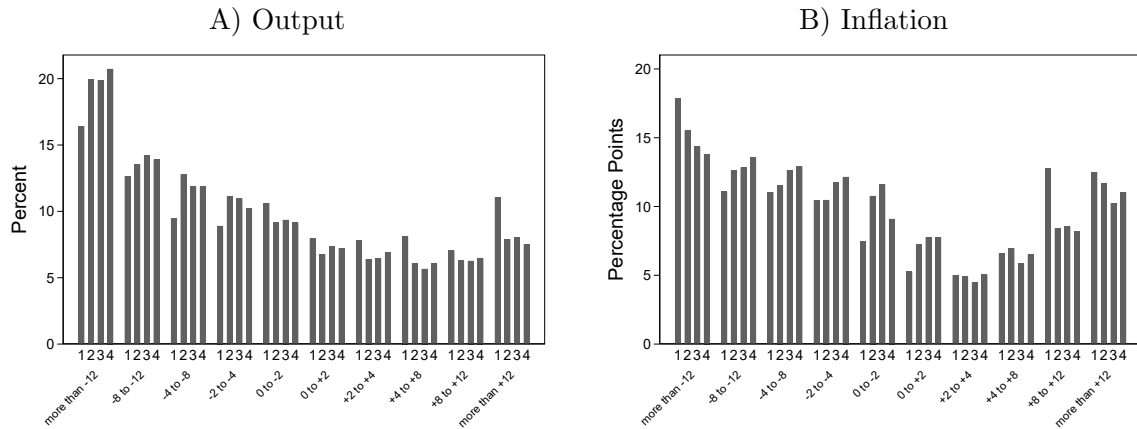


Figure A.3: Expected GDP change due to COVID-19 over 12 month period (Distribution)
 Notes: Average probability given by survey participants per bin for GDP (Panel A) and inflationary (Panel B) expectations due to COVID-19, by week. Numbers below bars give week. Respondents who indicate 100% into a single bin as well as those whose responses do not sum up to 100% across all bins are excluded. Responses per week: $N_{W1} = 65$, $N_{W2} = 820$, $N_{W3} = 805$, $N_{W4} = 539$.

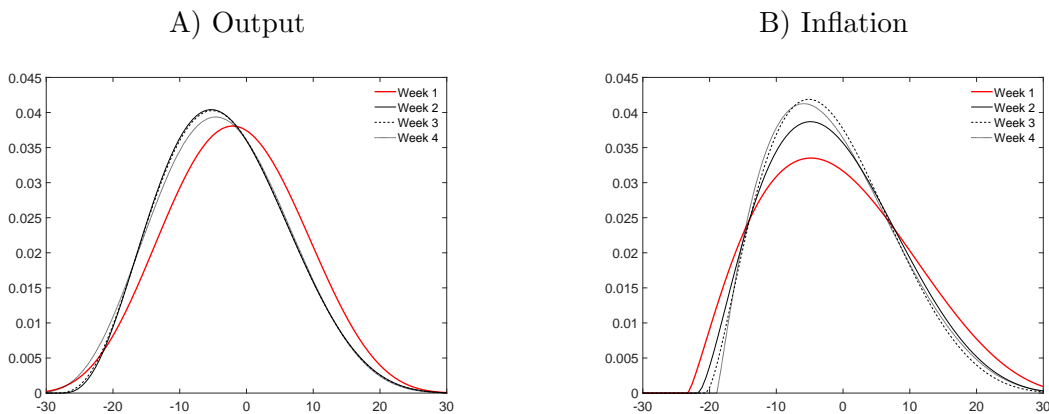


Figure A.4: Estimated beta distribution of expectatios due to COVID-19
 Notes: Panel A) Output expectations. Panel B) Inflationary expectations. Weekly estimated beta distribution on average response of survey participants on GDP and inflationary impact of COVID-19. Average probabilities per bin per week as displayed in figure A.3 used to estimate the best fitng beta distribution.

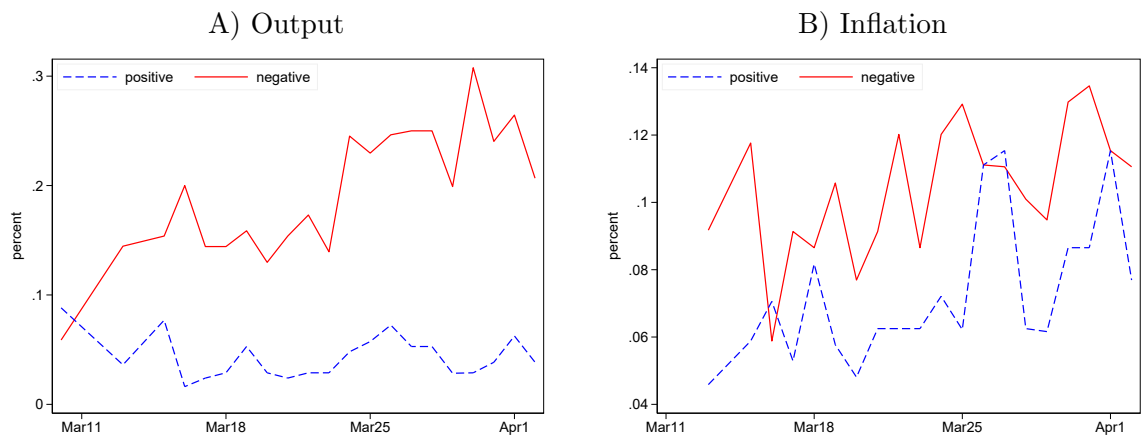


Figure A.5: Extreme Bins in distribution of forecast

Notes: Fraction of survey respondents choosing the most positive (blue, dashed line) or most negative (red, solid line) bin regarding the COVID-19 GDP (Panel A) and inflationary (Panel B) impact with certainty (giving “100%” as an answer to the respective bin).

Table 5: Expected Inflationary Impact of COVID-19 - Non Contradicting Respondents

Inflation Week	Reported point prediction					Reported distribution			
	Mean	S.D.	Median	IQR	N	Mean	S.D.	Median	N
08.-14.03.2020	13.30pp	24.31pp	5.00pp	30.00pp	87	0.04pp	6.55pp	0.11pp	26
15.-21.03.2020	11.30pp	17.07pp	6.00pp	19.00pp	1015	1.48pp	6.47pp	1.57pp	428
22.-28.03.2020	6.83pp	15.74pp	5.00pp	17.00pp	1137	0.70pp	6.34pp	0.66pp	375
29.-02.04.2020	7.86pp	16.16pp	5.00pp	17.00pp	815	1.00pp	6.00pp	1.01pp	268

Notes: Summary of survey responses about the impact of COVID-19 on Inflation between 10.03.2020 and 02.04.2020. Left panel based on respondents point predictions, right panel based on probabilities respondents attach to a possible outcome. Only survey responses where mean of reported point prediction and reported distribution are not contradictory in their sign. Reported mean, median and standard deviation are mean over individual distribution means, medians and standard deviations.

B Survey Appendix

B.1 Survey Overview

The survey was administered on the Qualtrics Research Core Platform, and Qualtrics Research Services recruited participants to provide responses. Survey data spans the time from March 10 to March 31 2020. Participants were asked for their expectations and behavior regarding COVID-19 as well as climate change which we do not use and therefore not reported in this study. Respondents were assigned to different treatment groups:

We conducted our survey in three waves: Ia, Ib and II. Wave Ia was conducted on March 10. Consecutively, wave Ib was conducted from March 13 to March 16, with some of the questions changed in their layout. Wave II took place daily between March 17 to March 31. For wave II, none of the questions were changed from wave Ib, but some additional questions - not used and therefore not reported in this paper - were added on the end of the survey. Note that in this section, questions will be reported as asked in wave Ib and II - differences to Ia will be reported in footnotes.

B.2 Sample

Invitations went out to residents of the U.S. Respondents were pre-screened for residence-status, English language fluency, and age. All respondents who failed to meet the screening criteria were discontinued from the survey. Only respondents who confirmed residence in the U.S., who professed English language fluency, and who reported to be of ages above or 18,

were brought on to the survey proper. Upon meetings these criteria, we screened responses by removing any participants who took less than five minutes to complete the survey or had at least one gibberish response (e.g., *sd - \$rt2*).

B.3 Treatments

Survey Participants were assigned to different treatment groups. For wave Ia and Ib, aside for the baseline group, there were treatments for a U.N. Scenario on Climate change as well as a group asked the questions on COVID-19 before questions on climate change. We do not find any significant differences regarding the answers on the economic Impact of COVID-19. For wave Ib, there was additionally one group asked questions of COVID-19 impact on personal household income instead of climate change.

For wave II, we proceeded only with the baseline specification of questions, but added three different treatment groups regarding the FOMC's decision on nominal interest rates from March 15. We again find that results do not differ for each treatment from the baseline significantly.

B.4 COVID-19 Effect on GDP

In order to learn on respondents' expectation on the economic impact of COVID-19 we use the following set of questions. Note that we first ask about participants' point estimates on the change of GDP due to COVID-19 and then additionally collect data on the individual distribution of expectations. By this approach, we can gain insights into individual uncertainty.

Survey participants are shown the following introductory text:

Since January 2020 the coronavirus (COVID19) is spreading with human infections around the world. Besides causing human suffering, this might also affect economic activity. We now want to know your personal expectations on this topic. Of course, no one can know the future. These questions have no right or wrong answers - we are interested in your views and opinions.

We then start with questions on the GDP change due to COVID-19 for the 12 months horizon:

In your view, within 12 months from today, will the overall economic impact of the coronavirus be positive or negative? This would include direct effects and indirect effects.

O Positive

O Negative

Dependent on the answer given on the previous question, the participant is shown the next question:

What do you expect the overall economic impact of the coronavirus to be over the next 12 months? Please give your best guess.

*I expect the overall economic impact of the coronavirus to be **positive/ negative** _____ percent of GDP.*

We choose to ask on point estimates in this twofold manner in order to avoid issues about the correct sign of the numerical answer, i.e. that respondents intend to answer -3% but just give 3 into the answer field.

We then proceed by asking about the individual distribution of expectations:

In your view, within 12 months from today, what will be the overall economic impact of the coronavirus?

*What would you say is the percent chance that, over the next 12 months, the overall economic impact in percent of GDP will be . . .*⁴

Negative, by 12 percent or more _____

Negative, by 8 to 12 percent _____

Negative, by 4 to 8 percent _____

Negative, by 2 to 4 percent _____

Negative, by 0 to 2 percent _____

Positive, by 0 to 2 percent _____

Positive, by 2 to 4 percent _____

Positive, by 4 to 8 percent _____

Positive, by 8 to 12 percent _____

Positive, by 12 percent or more _____

A pair of questions on the GDP change due to COVID-19 for the 12 months horizon between March 2022 and March 2023 concludes this section:

In your view, over the 12-month period between March 2022 and March 2023, will be the overall economic impact of the coronavirus be positive or negative? This would include direct effects and indirect effects.

O Positive

⁴For survey wave Ia, the answer bins have been sorted inversely, starting with “Positive, by 12 percent or more” to “Negative, by 12 percent or more”.

O Negative

What do you expect the overall economic impact of the coronavirus to be over the 12-month period between March 2022 and March 2023? Please give your best guess.

*I expect the overall economic impact of the coronavirus to be **positive/ negative** _____ percent of GDP.*

B.5 COVID-19 Effect on Personal Household Income

Over the next 12 months, do you think that the coronavirus will cause the total income of all members of your household (including you), after taxes and deductions increase to be higher or lower?

O Higher

O Lower

How much higher do you expect total income of all members of your household to be over the next 12 months because of coronavirus? Please give your best guess.

*I expect total income of all members of my household to be _____ percent **higher/ lower** because of coronavirus.*

In your view, what would you say is the percent chance that over the next 12 months, the coronavirus will cause total income of all members of your household (including you), after taxes and deductions, to be . . .

Lower, by 12 percent or more _____

Lower, by 8 to 12 percent _____

Lower, by 4 to 8 percent _____

Lower, by 2 to 4 percent _____

Lower, by 0 to 2 percent _____

Higher, by 0 to 2 percent _____

Higher, by 2 to 4 percent _____

Higher, by 4 to 8 percent _____

Higher, by 8 to 12 percent _____

Higher, by 12 percent or more _____

How much higher do you expect total income of all members of your household to be over the 12-month period between March 2022 and March 2023 because of coronavirus? Please give your best guess.

O Higher

O Lower

How much lower do you expect total income of all members of your household to be over the 12-month period between March 2022 and March 2023 because of coronavirus? Please give your best guess.

*I expect total income of all members of my household to be _____ percent **higher/ lower** because of coronavirus.*

In survey wave Ia) there were no corresponding questions asked.

B.6 COVID-19 Effect on Inflation

The next few questions are about inflation. Over the next 12 months do you think that the coronavirus will cause inflation to be higher or lower?

O Higher

O Lower

How much higher do you expect the rate of inflation to be over the next 12 months because of coronavirus? Please give your best guess.

*I expect the rate of inflation to be _____ percentage points **higher/ lower** because of coronavirus.*

In your view, what would you say is the percent chance that, over the next 12 months, the coronavirus will cause the rate of inflation to be . . .

lower by 12 percentage points or more _____

lower by between 8 percentage points and 12 percentage points _____

lower by between 4 percentage points and 8 percentage points _____

lower by between 2 percentage points and 4 percentage points _____

lower by between 0 percentage points and 2 percentage points _____

higher by between 0 percentage points and 2 percentage points _____

higher by between 2 percentage points and 4 percentage points _____

higher by between 4 percentage points and 8 percentage points _____

higher by between 8 percentage points and 12 percentage points _____

higher by 12 percentage points or more _____

Over the 12-month period between March 2022 and March 2023 do you think that the coronavirus will cause inflation to be higher or lower?

O Higher

O Lower

How much higher do you expect the rate of inflation to be over the 12-month period between March 2022 and March 2023 because of coronavirus? Please give your best guess.

*I expect the rate of inflation to be _____ percentage points **higher/ lower** because of coronavirus.*

In survey wave Ia) there were no corresponding questions asked.

B.7 Behavioral Adjustment Questions and Duration of COVID-19

We used the following set of eight questions - each to be answered with yes or no - to check for possible adjustments in respondents behaviour due to the COVID-19 pandemic.

Have you increased your personal savings due to the outbreak of the coronavirus?

O Yes

O No

Have you increased your personal savings due to the outbreak of the coronavirus?

O Yes

O No

Has your financial planning changed due to the outbreak of the coronavirus?

O Yes

O No

Have you refrained from planned larger purchases due to the outbreak of the coronavirus?

O Yes

O No

Have you increased your personal savings due to the outbreak of the coronavirus?

O Yes

O No

Do you spend a larger fraction of your income due to the outbreak of the coronavirus?

O Yes

O No

Due to the economic consequences of the coronavirus, do you fear you may lose your job?

O Yes

O No

Since the outbreak of coronavirus, do you try to avoid products from China?

O Yes

O No

Since the outbreak of the coronavirus, have you started to store larger quantities of food supplies at home than before?

O Yes

O No

Since the outbreak of the coronavirus, have you started to store larger quantities of medical supplies at home than before?

O Yes

O No

We also asked respondents about their perception on how long the pandemic will last.

How many years do you think the coronavirus outbreak will last? ⁵

O Less than 6 months

O 1 year

O 2 years

O 3 years

O More than 3 years

⁵Survey wave Ia did ask this question without the first possibility “Less than 6 months” but therefore the second as “1 year or less”. Due to the different design of answer possibilities, we do not use data from Ia for figure 3, since the short run duration seems to be important for respondents.

B.8 Demographics

To check for demographics and to make the survey representative, we checked for certain demographic characteristics. These include age, gender, ethnicity, state of residence, the highest educational level, personal income, and the personal savings rate.