Sectoral Digital Intensity and GDP Growth After a Large Employment Shock: A Simple Extrapolation Exercise*

Giovanni Gallipoli and Christos A. Makridis †

August 28, 2020

Abstract

We examine the dynamics of GDP following an economy-wide pandemic shock that curtails physical mobility and the ability to perform certain tasks at work. We examine whether greater reliance on digital technologies has the potential to mediate employment and productivity losses. We employ industry-level indices of task-based digital intensity and ability to work from home ("home-shorability"), in conjunction with publicly available data on employment and GDP for Canada, and document that: (i) employment responses after the onset of the shock are milder in digitally-intensive sectors; (ii) conditional on the size of employment changes, GDP responses are less extreme in IT-intensive sectors. We suggest a simple state-dependent algorithm for predicting output dynamics as a function of employment across industries and locations with different digital intensity. In our baseline scenario, aggregate output returns to pre-crisis levels eight quarters after the initial shock onset, although we find significant heterogeneity in recovery patterns across sectors.

Keywords: Output, Digital Intensity, Employment, Canada, Coronavirus, Structural Change

JEL Codes: E32, E66, J21, J23

*We are grateful to Anushka Gupta for excellent research assistance. We also thank Ronit Mukherji for help on an earlier draft of the paper. The views are our own and do not reflect those of any affiliated institutions.

†Giovanni: University of British Columbia, CEPR, HCEO, gallipol@mail.ubc.ca. Christos: Arizona State University, MIT Sloan, christos.a.makridis@gmail.com

1 Introduction

While the pandemic episode of 2020 and the resulting confinement restrictions have led to substantial declines in employment (Bartik et al., 2020; Coibion et al., 2020), the effects have been heterogeneous across sectors (Cajner et al., 2020; Devereux and Lahiri, 2020). These employment declines may have significant consequences for aggregate productivity (Makridis and Hartley, 2020), especially if a permanent rise in unemployment leads to declines in consumer demand (Guerrieri et al., 2020) and permanently scars consumer confidence (Kozlowski et al., 2020).

The primary contribution of this paper is to quantify the anticipated effects of the pandemic on aggregate and sectoral output in Canada. While a full analysis will require time and the collection of detailed data on output and other determinants of social welfare, we suggest a simple strategy for estimating the likely effects on GDP growth across industries and locations. The approach relies on estimates of the elasticity between GDP and employment obtained using publicly available data and, crucially, it allows for heterogeneity across sectors that differ in their occupational concentration of digital tasks (Gallipoli and Makridis, 2018).[1] We exploit variation unique to the 2008-09 financial crisis as the closest and most recent example of a sharp drop in employment, and employ estimates of sectoral elasticities to project output trajectories for the 2020 recessionary episode under various assumptions about the speed of the recovery.

We begin by quantifying the heterogeneous effects of restricted mobility regimes in Canada on employment declines, allowing for variation across sectors. We create an index to measure sectoral "resilience" to social interaction shocks by taking the product of occupational digital task intensity from Gallipoli and Makridis (2018) and home-shorability from Vancouver School of Economics

[1] We use digital intensity and information technology (IT) intensity interchangeably.

(2020). In this way, we provide the first comprehensive evidence that sectors with a higher share of digitally-intensive occupations and home-shorable jobs experienced substantially milder employment declines: a percentage point rise in job resilience is associated with 0.65 percentage point higher employment growth between February and April 2020, suggesting that higher resilience sectors have helped support aggregate economic activity during a period of extreme turbulence.

The second part of the paper examines employment and real GDP growth across sectors to recover an elasticity that is suitable for extrapolating sectoral output. Motivated by the strong correlation between employment growth and our measures of digital intensity, home-shorability, and resilience during the pandemic, we allow elasticities to vary across two broad sectors corresponding to high and low resilience scores. We build on the original insights of Okun (1963), generalizing them to multiple sectors and allowing for heterogeneity in GDP sensitivity to employment changes. Estimates of the elasticities are based on variation that is unique to the 2008-09 financial crisis since that historical event presents the closest analogue to the magnitude of employment declines observed over the course of the pandemic. These estimates are instrumental to obtain a simple, state-dependent rule to infer likely patterns of disaggregated output.

The third part of the paper examines sector-specific recovery durations. We posit that durations of sectoral recoveries are broadly consistent with historical observations following the large employment losses of the 2008/09 recession. Specifically, the path and duration of sectoral employment recoveries back to pre-crisis levels depend on both the size of initial job losses and on the (proportional) rebounds of employment headcounts after the 2008/2009 recession. These assumptions are motivated by the wide availability of data on (i) short-term employment losses (February to April) after the onset of the 2020 shock, and (ii) accurate historical records from the severe recession of the late 2000s. Simplicity and ease of use are key aspects of the approach we suggest. In robustness checks, we experiment with departures from baseline employment scenarios and extrapolate a range of alternative state-dependent outcomes for GDP.

Our procedure allows us to project a path for aggregate GDP under alternative hypothesis about employment recoveries. Having estimated aggregate dynamics, we shift our focus to the evolution of GDP in different industries and locations. We assume that sectoral vulnerabilities to productivity losses due to population confinement depend on the characteristics of the occupations within each industry, namely their digital intensity and home-shorability. We posit that sectoral elasticities are inversely proportional to industry-specific resilience measures and, through a functional form assumption, we relate the prevalence of high-resilience tasks within an industry to that sector's capacity to sustain productivity and output in circumstances of restricted population interaction. This allows us to separately extrapolate GDP growth rates for each two-digit industrial sector as well as examine potential heterogeneity in GDP growth across provinces. We also benchmark our results by comparing preliminary data on disaggregated GDP values in March and April with the estimates produced by our model. Finally, in a different robustness check, we compare our results with similar calculations in which we use an alternative index of sectoral sensitivity to confinement disruptions based on contact intensity (Dingel and Neiman, 2020).

One advantage of this approach is its simplicity: by relying on the interaction of cross-sectional occupational task intensity with measures of digital intensity and home-shorability, we obtain reasonably reliable and sharp real-time estimates of aggregate GDP from employment data.[2] A second advantage of the approach is that forecasts transparently reflect the underlying conjectures about employment dynamics, facilitating hypothetical comparisons. The method relies on assumptions

[2]Using an even simpler approach that proportionally allocates reductions in GDP based on the share of digitally-intensive workers, Makridis and Hartley (2020) found that the aggregate costs of a two month national quarantine came to roughly 10%, matching the 8% figure estimated by the IMF (`https://tinyurl.com/y8hnvs2j`).

about sectoral elasticities of GDP with respect to employment. While the empirical content of this relationship can only be verified as more information becomes available, the functional form assumption itself can be tweaked to improve performance as new data accrue. Lack of initial accuracy is the price one pays to make long-term projections about sectoral GDP and productivity responses with minimal data requirements, but can help policymakers make real-time decisions.

Of course, assuming a path for employment dynamics is a simplification that ignores equilibrium feedbacks working through prices. Nonetheless, to the extent that public health constraints limit the ability of workers to perform tasks on the jobs regardless of prices, positing specific employment paths for recoveries seems a reasonable approximation. As confinement becomes less stringent, one can provide a set of potential paths for the employment and GDP recovery, and assess sectoral differences over short and medium horizons.

We recover GDP-employment elasticities using data from the large recession of 2008/09; this captures possible non-linear responses of GDP following unusually large shifts in worker headcounts. To accommodate uncertainty about hiring intensity, we consider three possible employment recovery scenarios. Our baseline results suggest that Canada might experience an annualized decline in real GDP of 5.4% between February 2020 and February 2021. The decline would be larger (7.8%) in the case of a severe second wave of infections after the Summer of 2020. For the last three quarters of 2020, we estimate a decline in real GDP of about 7.8% under the baseline scenario, and of 8.4% in the case of a severe second wave.[3] In the baseline scenario, we expect that aggregate employment will likely get back to pre-crisis levels by the first quarter of 2022.

Industry-specific heterogeneity in projected growth rates is large: sectors like restaurants and

[3]For comparison, the IMF estimates that Canada's annualized real GDP will decline over the same period by 6.2%, whereas OECD estimates even larger losses at 8.4% in the base case and 9.4% in case of a second wave. A study by Trading Economics suggests an average decline of 4% in the last three quarters of 2020.

hospitality may experience year-on-year drops between 27.6% and 39.9% between February 2020 and February 2021, while industries like Wholesale and Retail Trade would likely only shrink between 5.6% and 8.2% over the same 12-month horizon. The most digitally-intensive sectors—professional, scientific and technical services—may experience even smaller year-on-year output drops between 1.5% and 2.2% and may ultimately expand due to structural change.

2 Data and Measurement

Our primary data on sectoral economic activity comes from publicly available records from Statistics Canada on real gross domestic product (GDP) in chained 2012 prices by industry up until March 2020 and on employment by industry and province up until May 2020.

We refine the task-based index of digital intensity of Gallipoli and Makridis (2018), which is constructed from several sub-indices in the Department of Labor's O*NET database.[4] Since we do not have an analogue of the O*NET for Canada, we cross-walk occupations from their U.S.-based standard occupational classification (SOC) code into the corresponding Canadian code, which operates at a roughly three-digit SOC-level.

In addition, we employ a novel Canada-wide database about occupation-level risk to create a unique score for two-digit industries in a given province using the proportion of workers working from home in each four-digit occupation before the onset of the pandemic.[5] For each province we take an average of this score (weighted by the number of workers in each two-digit industry)

[4]These sub-indices include: knowledge about computers and electronics, activities interacting with computers, programming, systems evaluation skills, quality control analysis, operations analysis, activities with updating and using relevant knowledge, technology design, activities analyzing data and information, activities processing information, knowledge with engineering and technology, activities managing material resources.

[5]The novel database on occupational characteristics was developed at the Vancouver School of Economics (2020) at UBC. We refer to home-shorability measures as HS when convenient. The correlation between homeshorability and Dingel and Neiman (2020) is 0.24.

and we create a measure of home-shorability (HS). A similar method is used to create a HS index for all industries at a national level. Finally, for the purposes of our projections, we combine the digital intensity and HS measures by taking their product within each industry and province. By so doing, we create a merged measure that we call resilience. High resilience signifies a high score for the combination of digital intensity and HS.

Descriptive statistics. We begin with several descriptive statistics for our measures. For each province (and for the whole of Canada), Figure 1 plots the share of workers classified as digitally-intensive as per Gallipoli and Makridis (2018), the share of workers with home-shorable jobs (as per Vancouver School of Economics (2020) "risk tool"), and the share of workers with high resilience. We find a correlation of 0.71 between the digital intensity and HS measures at the provincial level. Interestingly, there is little cross-sectional variation in the digital intensity measures across the major provinces with the average share of high digital intensity jobs in a province around 53%, whereas we see more inter-provincial variation in HS, with the average province-specific HS measure around 7.2%. This suggests that the task-based measure of digital skills is more inclusive, whereas home-shorability narrowly reflects whether a job can be performed at home.

Next, we examine the distribution of these measures across industries. Figure 2 documents variation across two-digit industries in the share of digital workers, ranging from the low of 25% in accommodation and food services to the high of 85% in professional and technical services. There is similar variation when using the HS measure, ranging from accommodation and food services (again) with the lowest at 0.6% to professional and technical services at 11%. Agriculture exhibits an outlying value of 36.8%: this exception exists because many people who work in the agricultural sector both live and work on their farms. The correlation between these two measures

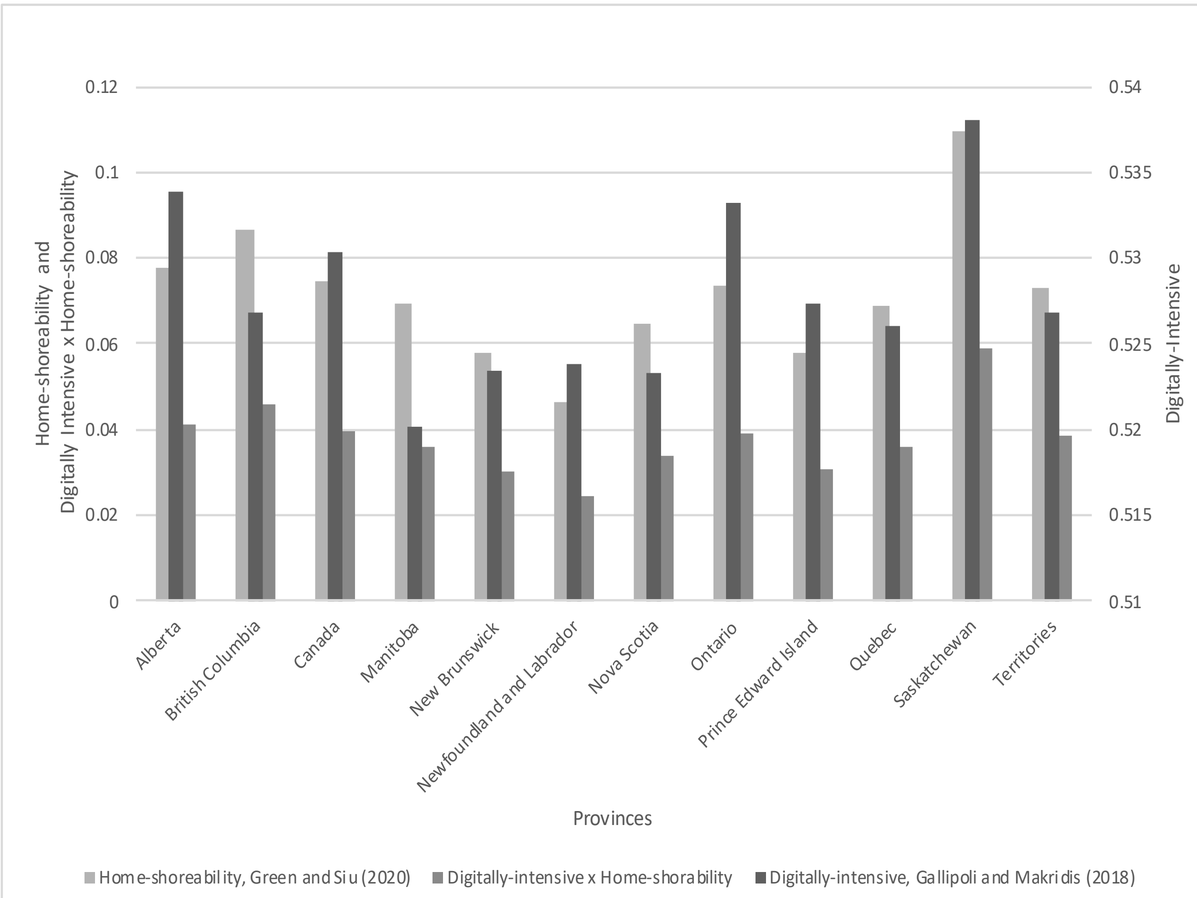


Figure 1: Index for Digitally-intensive and Home-shoreable Employees, by Province

Note.—Sources: StatsCanada, IPUMS Canada, Gallipoli and Makridis (2018), and Vancouver School of Economics (2020) occupation risk tool. The figure plots an index for digitally intensity and home-shorablity of jobs based on occupation and industries measures of Tasks in the United States (for Digital Intensity) and Canada (for Home-shorability). Section A.1 in the appendix describes the process to compute these heterogeneity scores. The third bar plots the province-specific resilience, i.e. the product of the digitally intensive and HS measure for each provinces.

across industries (excluding agriculture) is 0.62.

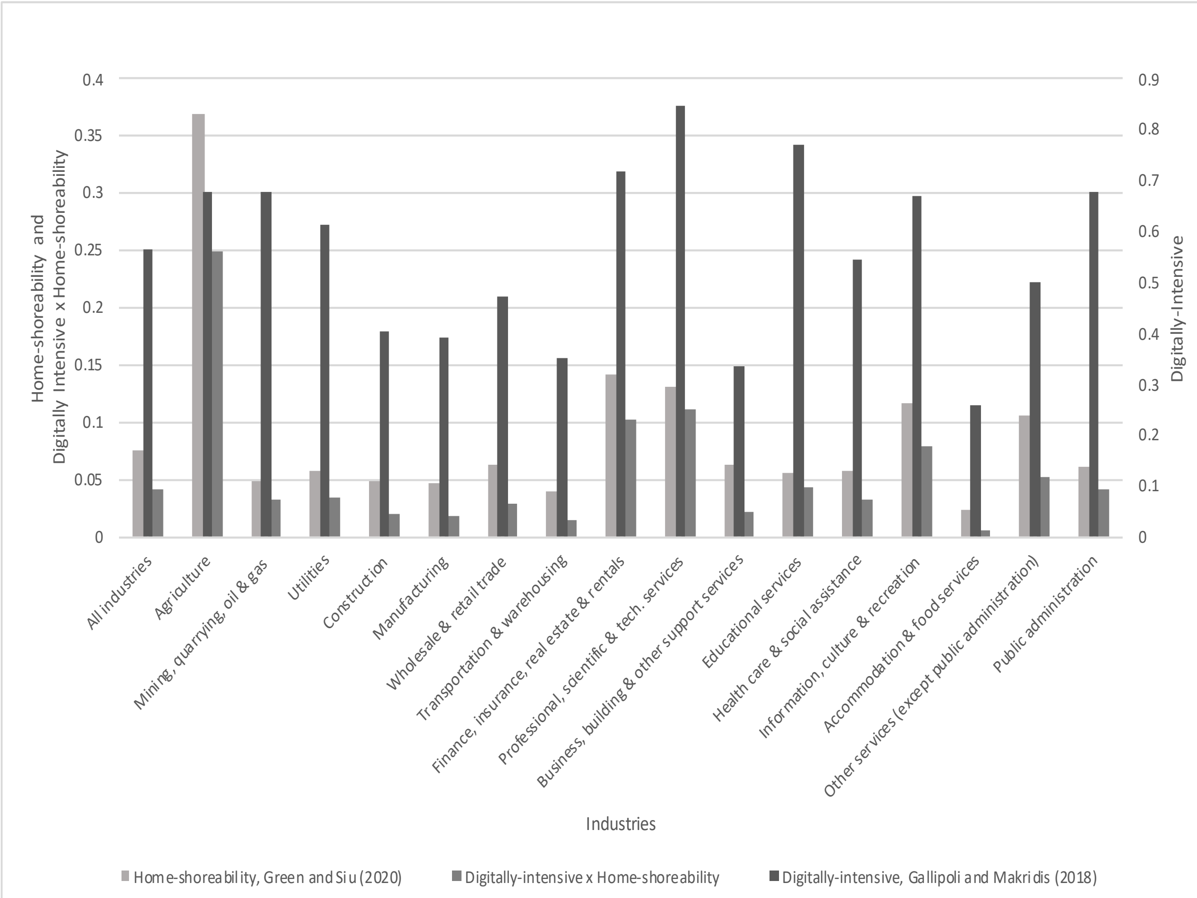


Figure 2: Index for Digitally-intensive and Home-shoreable Employees, by Industry

Note.—Sources: StatsCanada, IPUMS Canada, Gallipoli and Makridis (2018), and Vancouver School of Economics (2020) occupation risk tool. The figure plots an index for digitally intensity and home-shoreablity of jobs based on occupation and industries measures of Tasks in the United States (for Digital Intensity) and Canada (for Home-shorability). Section A.1 in the appendix describes the process to compute these heterogeneity scores. The third bar plots the industry-specific resilience, i.e. the product of the digitally intensive and HS measure for each industry.

3 Tracing Out GDP Recoveries

Modelling output after a period of extreme turbulence is challenging. For the pandemic episode under examination, the challenges are more severe because the turbulence is due to unusual circumstances, such as restrictions on social and economic activities, for which there is little or no precedent in recent history. This difficulty is compounded by our interest in the dynamics of GDP across sectors and locations and the fact that data for employment and output across industries and locations is released with a lag often many months after the initial aggregate estimates become available. These difficulties motivate our effort to develop a simple state-dependent extrapolation approach that can be used with easy-to-access publicly available data.

Given the focus on post-crisis output dynamics, we examine the relationship between output and employment as mediated by a third, intangible factor that changes the sensitivity of different sectors to employment (headcount) losses.

The notion that employment variation can be used to gauge the evolution of output has a long history in economics (e.g. Okun, 1963; Ball et al., 2013). We posit an output function that reflects how the number of workers maps into post-crisis output changes given employment losses and industry-specific resilience. We let y denote output in the post-onset period t and sector i,

$$y_{it} = e_{it}^{\gamma} \times f(e_{it}, z_i) \tag{1}$$

where e_{it} is sectoral employment (headcounts) and $f(e_{it}, z_i)$ is a function capturing differential responses of y to e across industries due to heterogeneity in resilience z_i.[6] For the empirical implementation below, we assume $f(e_{it}, z_i) = z_i^{\zeta \times t} + e_{it}^{\xi \times z_i}$, so that the heterogeneity in z_i is reflected in the post-recovery growth trend and sensitivity to employment levels.

The idea that some sectors might do better than others in terms of employment, GDP, or both, is plausible, given that sectors are heterogeneously exposed to the pandemic restrictions. To the extent that HS and IT intensity can reduce the blow from social distancing measures, one should observe heterogeneous responses across those dimensions and we explore this possibility in

[6]Given our focus on short-term and medium-term recoveries after initial onset, we abstract from physical capital. In the estimation section we consider specifications that include controls for industry-specific capital stocks and find that estimates are not significantly different.

a simple and transparent way.

We proceed in two steps. First, we assume that the sectoral resilience z_i reflects the adoption and penetration of digital and IT technology in production practices. We follow Gallipoli and Makridis (2018) and partition industries into two groups (digitally and non-digitally intensive) based on whether they fall above or below the median share of IT-intensity, as defined by the tasks performed by workers in their occupations. Panel A of Figure 3 provides evidence in support of the hypothesis that higher prevalence of digitally-intensive jobs mitigates the impact of confinement shocks on an industry: a strong positive relationship exists between digital intensity and employment growth between February and April 2020, right after confinement measures became widely adopted across Canadian provinces. Industries with a 10% higher share of IT intensive workers have a 4.1% higher growth rate of employment.

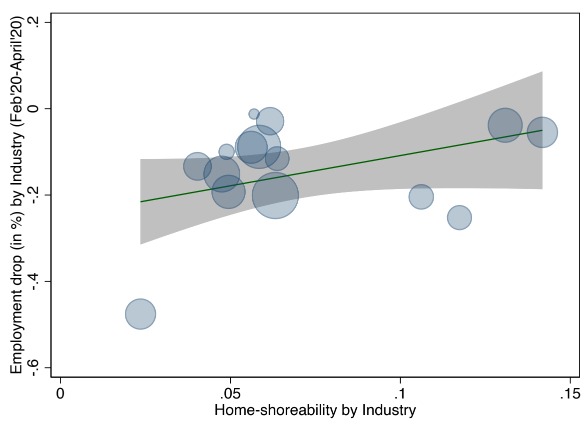
Panels B and C of Figure 3 replicate these patterns using the measures of HS and of overall resilience; the latter is defined as the product of digital intensity and HS. By combining variation about digital intensity and home-shorability, we obtain a more encompassing proxy for gauging the responsiveness of industries to the pandemic shock.

Sectoral elasticities. Are there differences across sectors in the dynamic responses of output to employment after the initial crisis onset? This is a harder question as it requires information about the evolution of headcounts, which is not readily available. For this reason, we estimate a linear approximation for the growth rates of the sectoral output function in Equation 1; this provides a concise description of indystry-specific GDP responses to employment changes. We use different sample intervals between January 2001 and April 2020 at a monthly frequency to establish whether this relationship is significantly different after a large crisis like the recession of

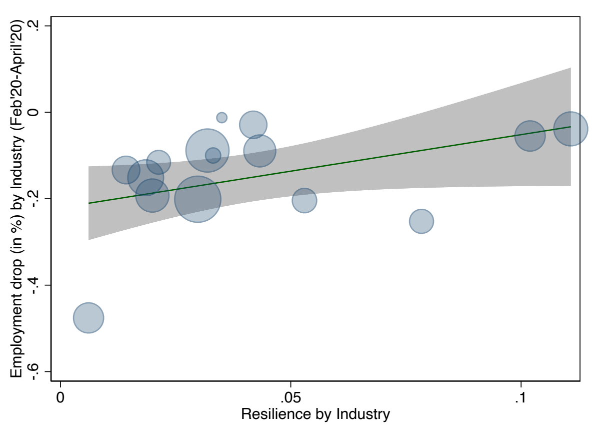
Figure 3: Employment Declines After Onset of the Pandemic Across Sectors

Panel A: Employment Declines & Digital Intensity

Panel B: Employment Declines & Home-shorability



Panel C: Employment Declines & Resilience



Note.—Sources: StatsCanada, IPUMS Canada, Gallipoli and Makridis (2018), Vancouver School of Economics (2020) occupation risk tool. The figures plots employment growth between February and April 2020 within an industry and digital-intensity score, home-shorability and resilience in Panel A, B and C respectively. Since the agriculture industry is an exceptional value in the homeshorability and resilience index, we have excluded it's values from the estimation of the figures in Panel B and C.

2008 and consider regressions of the form:

$$\Delta y_{it} = \gamma \Delta e_{it} + \zeta z_i + \xi(\Delta e_{it} \times z_i) + \epsilon_{it} \tag{2}$$

where Δy_{it} denotes the year-to-year growth rate of (real) GDP in industry i and month-year t, Δe_{it} denotes the year-to-year growth rate of employment for the same industry-period pair, and z denotes a binary indicator for whether the industry is in a relatively more resilient group, that is, above or below median according to a measure of choice. We estimate the latter relationship for two groups (high and low resilience), rather than for each industry, to improve precision; better data quality, and additional sources of variation, would allow for more flexible estimation.

Given the evidence in Figure 8, we expect that $\xi < 0$, meaning that the more digitally intensive sectors should experience less of a decline over the pandemic. We estimate Equation 2 under several specifications: with and without the z interaction, over the extended sample and for the subsample corresponding to the recovery following the 2008-2009 recessionary episode. The latter, restricted subsample is especially informative as it exploits variation unique to GDP-employment changes after a deep and wide economic downturn, shedding light on the way different industries respond, particularly during periods of significant economic turbulence when the elasticity is large.

Table 1 documents the findings from this exercise. Starting with column 1, we see that a 1pp rise in employment is associated with a 0.33pp rise in GDP over the extended sample period. Given the potential for reverse causality, we instrument for employment growth using two to three month lags following Arellano and Bond (1991); this delivers statistically indistinguishable (and slightly higher) coefficient estimates in column 2. Interestingly, when we restrict the sample to the turbulent 2008-2009 period, estimates of the elasticity are over twice as large: a 1pp rise in

Table 1: Elasticity of GDP Growth to Employment Growth

Dep. var. =	Real GDP Growth					
	(1)	(2)	(3)	(4)	(5)	(6)
Employment Growth	.33***	.37***	.72***	.51***	.49***	.86***
	[.02]	[.03]	[.05]	[.03]	[.04]	[.05]
High Resilience				.01***	.01***	.03***
				[.00]	[.00]	[.00]
× Employment Growth				-.33***	-.23***	-.59***
				[.04]	[.05]	[.09]
R-squared	.12	.11	.40	.15	.14	.56
Sample Size	3488	3440	384	3488	3440	384
Sample	All	All	2008-09	All	All	2008-09
Instrument	No	Yes	No	No	Yes	No

Notes.—Source: Gallipoli and Makridis (2018), Vancouver School of Economics (2020) occupational risk tool and StatsCanada. The table reports the coefficients associated with regressions of industry × month real GDP growth (year-to-year, in chained 2012 prices) on employment growth, interacted with an indicator for whether the sector has high resilience (high IT intensive and home-shorability jobs). The latter exposure is measured using IPUMS Canada 2011 data in conjunction with the digital intensity measure and the home-shorability measure. We instrument the potentially endogenous employment growth with two and three month lagged values of the year-to-year growth rate. Including sectoral measures of capital to this regression does not alter our estimates.

employment is associated with a 0.72pp rise in GDP.

Results are similar when we allow for differences in resilience across sectors. Focusing on column 6, which restricts our sample to the so-called Great Recession period, we see that a 1pp rise in employment is associated with a 0.86pp rise in GDP in low resilience sectors, but with only a 0.27pp rise in GDP in the high resilience sectors. This evidence suggests that job resilience acts as a mediating force that mitigates the impact of employment changes on output during times of economic turbulence. One potential concern with these results is that differences in the capital stock could be correlated with the share of digital workers and with sectoral elasticities. To examine this possibility, we experiment with including capital stocks for different industries as an additional control; estimates are robust to this additional heterogeneity.[7]

[7] Given these findings, and the objective to develop a procedure that can be implemented with minimal data requirements, we do not use these additional specifications. All results are available upon request.

4 Projecting Recovery Paths

4.1 Baseline: "Great Recession" Recovery Path

In the first and baseline case, we assume a linear employment recovery starting in May 2020 and leading back to the level of employment last observed in February 2020. We posit that the duration of the employment rebound is analogous to what was observed after the recession of the late 2000s. Then, it took an average of 21 months for employment in low resilience industries to go back to pre-crisis levels, whereas it took about 30 months in high resilience industries.

Table 2: Year-on-Year Employment Growth Rates, between May 2019 and May 2020

	StatsCanada	Estimated
Low Resilience	-16.6%	-17.9%
High Resilience	-8.4%	-8.4%
All Industries	-13.5%	-14.3%

Note.—Source: Gallipoli and Makridis (2018) and StatsCanada. The table reports the annual (year-on-year) employment growth rates reported between May 2019 and May 2020 by Statistics Canada and the same annual employment growth rates as estimated by our baseline employment recovery scenario.

One way to indirectly validate the assumed duration of employment recoveries is to compare the year-on-year employment growth rates between May 2019 and May 2020 (as measured by Statistics Canada) with the ones implied by a linear recovery path mimicking that of the previous recession. As shown in Table 2, predicted and actual employment drops are close, providing some corroboration for the assumed pace and horizon of the employment recovery. At least initially, it appears that the baseline conjecture about the evolution of headcounts is reasonable.

Next, we use employment changes to project GDP changes consistent with the baseline elasticity estimated in column 6 of Table 1. We normalize output in February 2020 to 1 and plot GDP levels in both low resilience and high resilience industries, as well as for the pooled sample

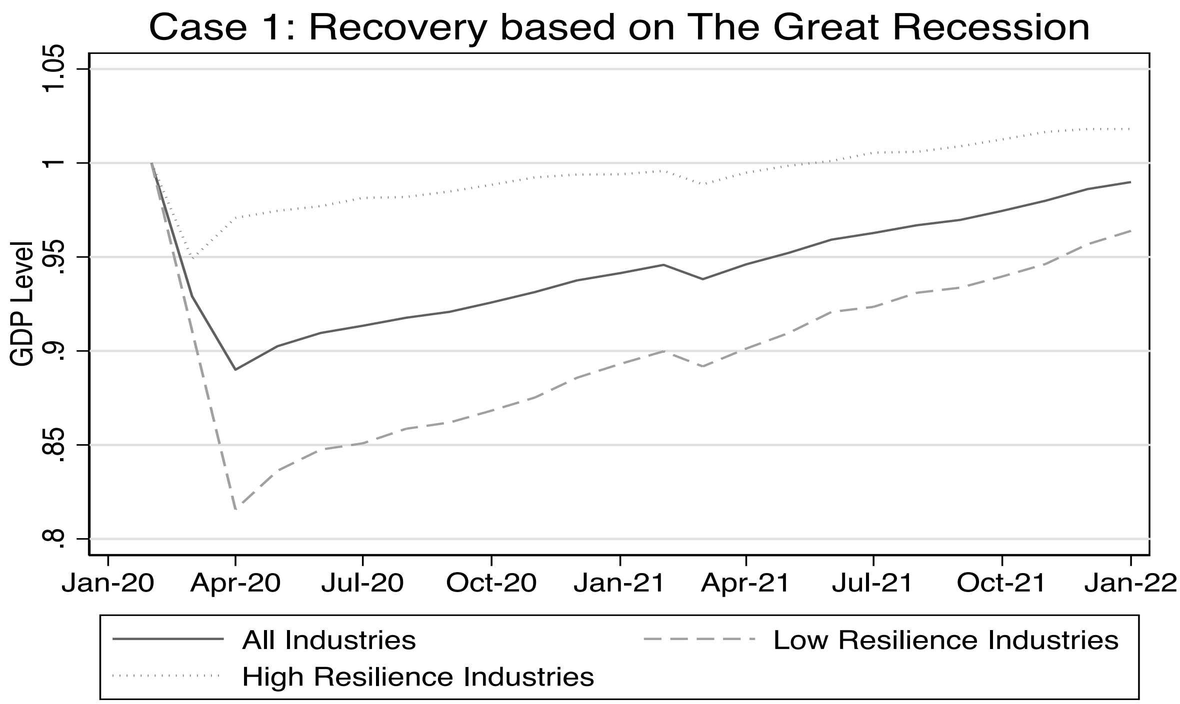


Figure 4: GDP Projection Based on Great Recession, by Resilience

Note.—Source: Gallipoli and Makridis (2018), Vancouver School of Economics (2020) occupational risk tool and StatsCanada. The graph reports GDP levels for low resilience sectors, high resilience sectors and all industries calculated using the values of GDP predicted using our model in equation 2 for a baseline employment recovery. GDP is normalized to one in February 2020. All GDP level estimates are reported in Table 4.

of all industries. Figure 4 highlights that aggregate output likely bottomed out in April 2020, at roughly 89% of its pre-crisis level. The recovery starting in the Summer of 2020 would bring GDP back to its pre-crisis level by the end of the first quarter of 2022. Peak-to-through output losses are likely to be shallower, at around 2.9%, in high resilience industries, as opposed to a loss of roughly 18.4% for low resilience industries. Despite a longer assumed duration of the employment recovery in high resilience sectors (30 months to get back to pre-crisis employment levels, vis-a-vis 21 months in low resilience sectors), the recovery is likely to bring GDP of the high resilience sector back to pre-crisis levels by May 2021. The aggregate GDP, however, would still be 1.4% below the pre-crisis level by the end of 2021.

Year-on-Year Output Growth Rates. An alternative way to summarize the baseline estimates for the post-crisis evolution of GDP is presented in the appendix Figure 13, where we report the yearly GDP growth rates for high and low resilience industries in different quarters. The figure also shows the aggregate annual growth rate, indicating a return to year-on-year growth in the second quarter of 2021. Annual GDP growth rates are expected to increase almost twice as fast in low resilience sectors after the second quarter of 2021, making up for larger initial losses in 2020. The high volatility of the low resilience sector (larger drops and stronger recovery) is consistent with the employment losses shown in Table 2 and with the GDP elasticity estimates in Table 1.

4.2 Faster Employment Rebound: An Optimist's View

March and April 2020 saw large losses in national employment levels, although high resilience industries experienced much smaller proportional employment losses than low resilience industries. As many jurisdictions began easing mandatory confinement of workers, and businesses started to re-open with social distancing measures in place, preliminary estimates suggest that the Canadian economy witnessed a strong month-on-month increase in employment in May 2020, with about 290,000 jobs added to the employment tally. Given this rebound, one might expect that the elimination of strict mobility curbs would go a long way towards bringing back many of the furloughed workers to active employment.[8] That is, one might take the hopeful view that employment would recover faster than it did after the recession of 2008/09.

We next consider an alternative, and optimistic, scenario that assumes an accelerated recovery.

[8] Huang et al. (2020) use high-frequency data from the United States to show that the removal of stay-at-home orders and nonessential business closures were associated with a roughly 20-26% increase in employment and hours worked in retail and hospitality sectors. However, the increase thus far has not been enough to offset the initial decline in labor market conditions.

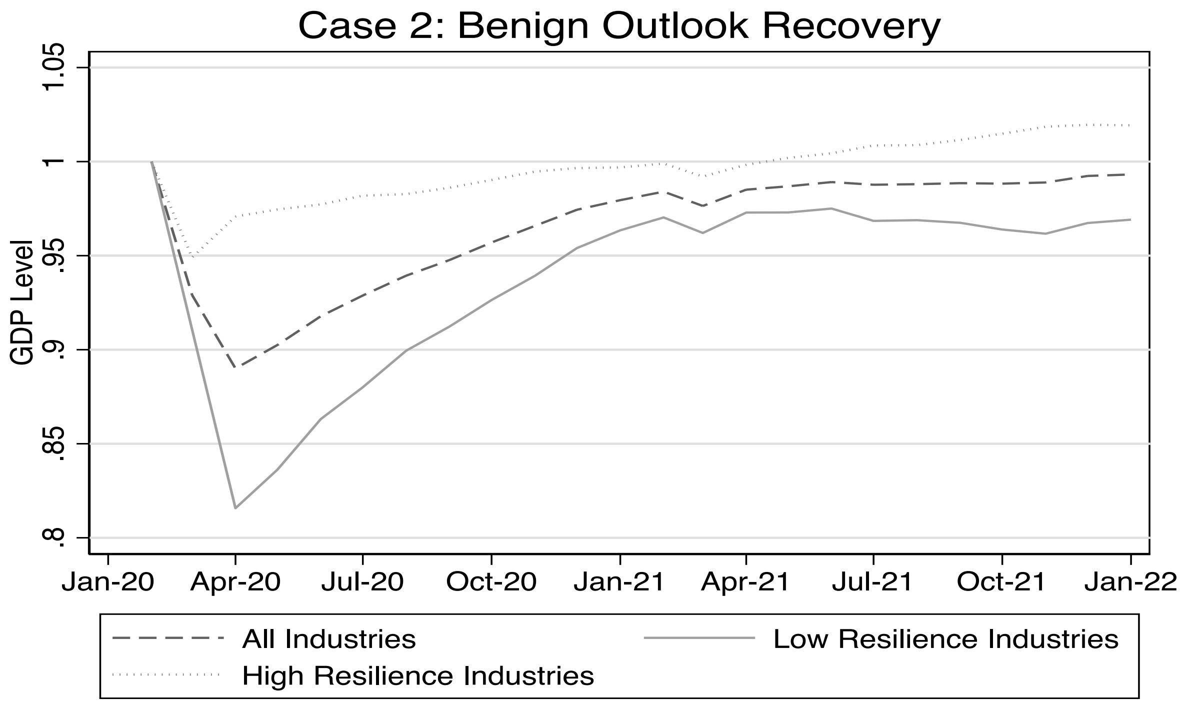


Figure 5: Optimistic GDP Forecast, by Resilience

Note.—Source: Gallipoli and Makridis (2018), Vancouver School of Economics (2020) occupational risk tool and StatsCanada. The graph reports GDP levels for low resilience sectors, high resilience sectors and all industries calculated using the values of GDP predicted using our model in equation 2 for a more optimistic employment recovery. GDP is normalized to one in February 2020. All GDP level estimates are reported in Table 4.

We posit comparatively large gains in employment in June and July 2020, similar to those observed in May. After a Summer spike in hiring, we assume that employment keeps growing at a more gentle pace till we get back to pre-crisis levels of employment, and growth, around March 2021 in the non-IT industries and November 2021 in IT intensive industries. As before, differences across industries in the pace of employment reflect the observation that recovery was faster in the non-IT sectors after the recessionary episode of 2008. The recovery duration for employment under this scenario is roughly 60% of that assumed in the baseline case. Figure 5 shows the evolution of normalized GDP, suggesting the economy might get back to pre-crisis output levels by the end of 2021 or the beginning of 2022. Figure 14 reports the annual GDP growth rates for different quarters of the recovery under this alternative scenario. Under this scenario positive year-on-year growth would return much earlier, within the first few months of 2021.

4.3 Delayed Recovery: a Severe 'Second Wave'

The previous two scenarios are based, to a different extent, on benign views of the ability of different jurisdictions to contain the health emergency and allow for a staggered but monotonic return to pre-crisis employment. It is informative to consider the possibility of a second wave of infections in the Fall of 2020, leading to re-emergence of confinements and reduced employment. We assume that strong employment growth in June and July, similar to what was observed in May 2020, will translate into higher infection rates and new restrictions in the Fall of 2020. This would bring about a new tide of employment losses.

However, while new rounds of job losses might stretch out until November 2020, they are unlikely to be of the same magnitude as those suffered in the March-April 2020 period because jurisdictions would be better prepared to handle the health emergency. Starting in December 2020 a new recovery in employment would take hold, qualitatively similar to that of the baseline scenario in terms of duration (that is, taking the same number of months to get to pre-crisis employment as in the post-2008 recovery).

One justification for this scenario stems from the possibility that better therapies, and perhaps a vaccine, will become available between January and March 2021. This would help control the pandemic and set the economy on a path to steady recovery. The GDP levels under this scenario are plotted in Figure 6, which shows a double-dip recession with GDP testing the lowest levels in both Spring and Fall 2020. Aggregate GDP would still be roughly 4% lower than its pre-crisis level by the end of 2021. Annualized (year-on-year) growth rates for different quarters are reported in

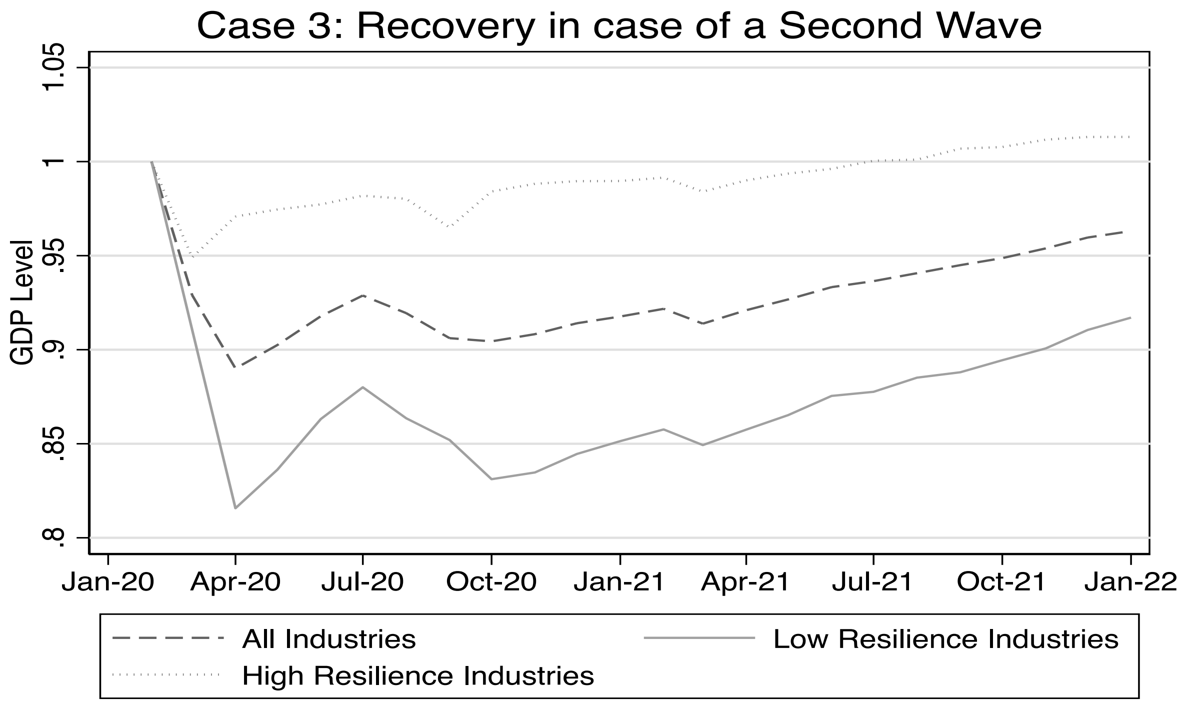


Figure 6: Pessimistic GDP Forecast, by Resilience

Note.—Source: Gallipoli and Makridis (2018), Vancouver School of Economics (2020) occupational risk tool and StatsCanada. The figure reports GDP levels for low resilience sectors, high resilience sectors and all industries calculated using the values of GDP predicted using our model in equation 2 in case the Canadian economy experiences a second wave. GDP is normalized to one in February 2020. All GDP level estimates are reported in Table 4.

Figure 15 and indicate that aggregate annual growth would turn positive in the second quarter of 2021, but would be subdued until the end of 2021.

4.4 Comparing Three Recovery Scenarios

The three scenarios outlined above correspond to alternative employment paths, following the initial onset of the shock. To facilitate comparisons, Figure 7 plots in the same graph the post-onset evolution of (normalized) aggregate GDP in each of the three cases.[9]

Under all scenarios, GDP is likely to shrink by more than ten percentage points at its lowest

[9]Figure 16 in the appendix contrasts predicted GDP levels based on our approach with estimated based on preliminary estimates of employment growth for June and July 2020. All estimates are remarkably close, with our baseline prediction being the most conservative.

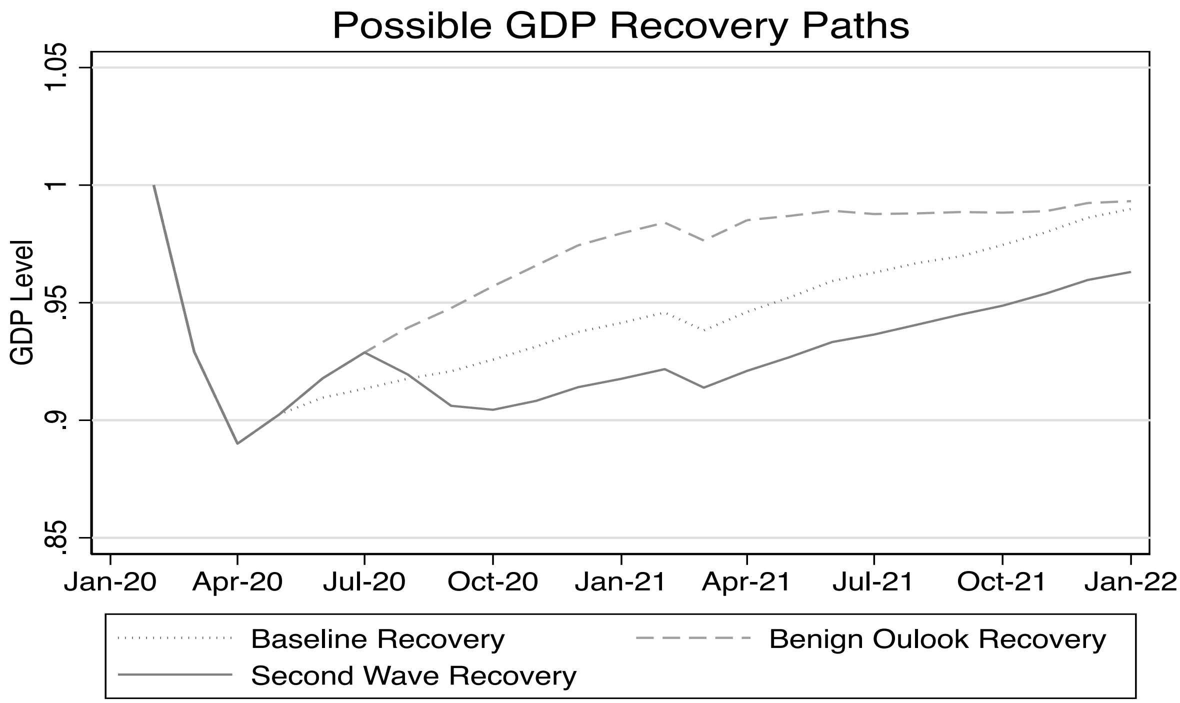


Figure 7: Summary of Possible GDP Paths

Note.—Source: Gallipoli and Makridis (2018), Vancouver School of Economics (2020) occupational risk tool and Statistics Canada. The graph reports aggregate GDP levels calculated using the values of GDP predicted using our model for the three recovery paths we consider. GDP is normalized to one in February 2020. All GDP level estimates are reported in Table 4.

post-onset level. Most of the uncertainty concentrates around the period of early 2021, as outcomes depend on whether a severe second wave of infections occurs. The difference in predicted GDP levels between the delayed and benign views of the recovery in January 2021 is large (6.2 percentage points). This gap shrinks as we approach the end of 2021, as uncertainty is partly resolved.

5 Sectoral and Provincial Heterogeneity in GDP Paths

Data on industry-specific and/or provincial GDP changes is only made available over an extended period of time. Yet, it is often necessary to venture in the risky business of estimating potential patterns of GDP. Our stylized approach can deliver conditional estimates of potential GDP changes across industries after the onset of the shock. To this purpose we use the share of digitally-intensive jobs, compounded by the HS measure, in each industry. This measure is used to proportionally scale real output within each *period* × *industry* unit. For example, an industry with an 80% share of digitally-intensive workers who can be productive at home might be able to sustain a smaller output loss during periods of reduced social interactions than an industry where only 20% of tasks are digitally intensive.

Functional Form Restrictions. To capture the sectoral sensitivity of GDP while preserving aggregation, we calibrate period-specific (month-year) GDP response elasticities ϵ_m relative to baseline values in February 2020. In practice, this allows us to rescale sectoral output to be a fraction of its pre-crisis level under the constraint that, in any given month, aggregate output is taken as given. The calibration exercise can be repeated for every month during the recovery period: each ϵ_m parameter captures GDP changes for period m and can be used to project sectoral output to a specific month during the employment recovery. Sectoral GDP projections depend on industry-specific digital resilience according to:

$$Y_m = \sum_{i=1}^{n} y_{FEB \times i} \left(1 - \frac{\epsilon_m}{r_i}\right) \tag{3}$$

In equation 3, Y_m denotes aggregate GDP in a given month m, $y_{FEB \times i}$ is the baseline GDP of industry i in February 2020 and r_i is the resilience of industry i.

To bring this specification to data, we employ the estimates of monthly aggregate GDP obtained in the previous section, in conjunction with industry-specific real GDP data for February 2020 (as released by Statistics Canada), and resilience measures based on Gallipoli and Makridis

(2018) and the Vancouver School of Economics (2020) occupational risk tool. These are enough to compute a sequence of elasticities ϵ_m, one for each month.

The elasticities can, in turn, be used to calculate the projected GDP for each industry i in a given month m. This is done using equation 4, which spells out each element on the right-hand side summation of equation 3; that is, we denote GDP in industry i and period m as:

$$y_{m \times i} = y_{FEB \times i} \left(1 - \frac{\epsilon_m}{r_i} \right) \tag{4}$$

We follow this procedure for both baseline and delayed recovery scenarios, and measure GDP growth for each industry between February 2020 and February 2021. Implied year-on-year growth rates by industry are reported in Figure 8.

Not surprisingly, industries that rely on consistent social interactions (e.g. accommodation/food services) are likely to suffer much larger output drops, which can exceed 39% year-on-year in the worst case scenario. By the same token, professional and scientific industries and education services are likely to experience much milder drops, around 2.2% and 5.6% respectively in the worst case scenario. This heterogeneity reflects the assumption that digital intensity and home-shorability may mitigate and diffuse the severity of both employment and productivity losses.

GDP Growth Rates by Province. One can follow a similar approach to project GDP growth for different provinces. That is, one can use the relationship in equation 4 under the assumption that index i identifies a location, rather than an industry. The main difference lies in the fact that we do not currently have real GDP data disaggregated by province for February 2020.

Hence, we must recover the February baseline GDP values by calculating the GDP contribution

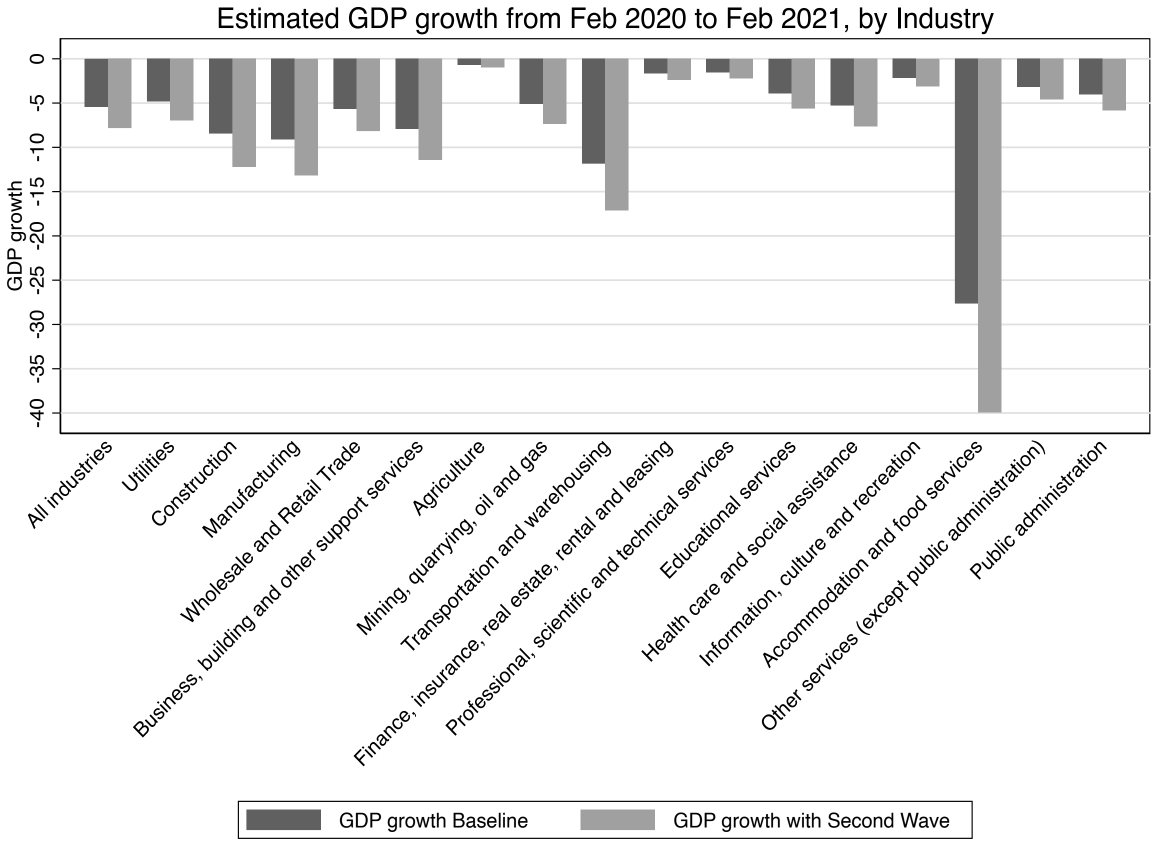


Figure 8: Expected GDP Growth in 2020 Using Occupational Resilience Measures, by Industry

Note.—Sources: StatsCanada, IPUMS Canada. Based on author's calculations of resilience using Gallipoli and Makridis (2018)'s IT intensity index and Vancouver School of Economics (2020) index of home-shoreability, we estimate GDP values with Equation 2. We then use the process explained in Section 5 to estimate GDP by Industry for 2020 and report GDP growth from Feb 2020 to Feb 2021. Table 6 provides estimated GDP growth values for each of Industry.

of each province in February 2020. To do this we use the most recent GDP share data released by StatsCan for the year 2019. We then estimate unique, month-specific values of the elasticity of GDP for each province, based on province-specific resilience measures (the same measures we reported in Table 1). We also impose an adding-up constraint so that provincial GDP values sum up to the aggregate GDP in each month. Figure 9 documents the results of this exercise under our baseline and delayed growth scenarios.

While digital intensity does not markedly vary across provinces, the resilience measure does. Year-on-year GDP drops between February 2020 and February 2021 appear to be highest for

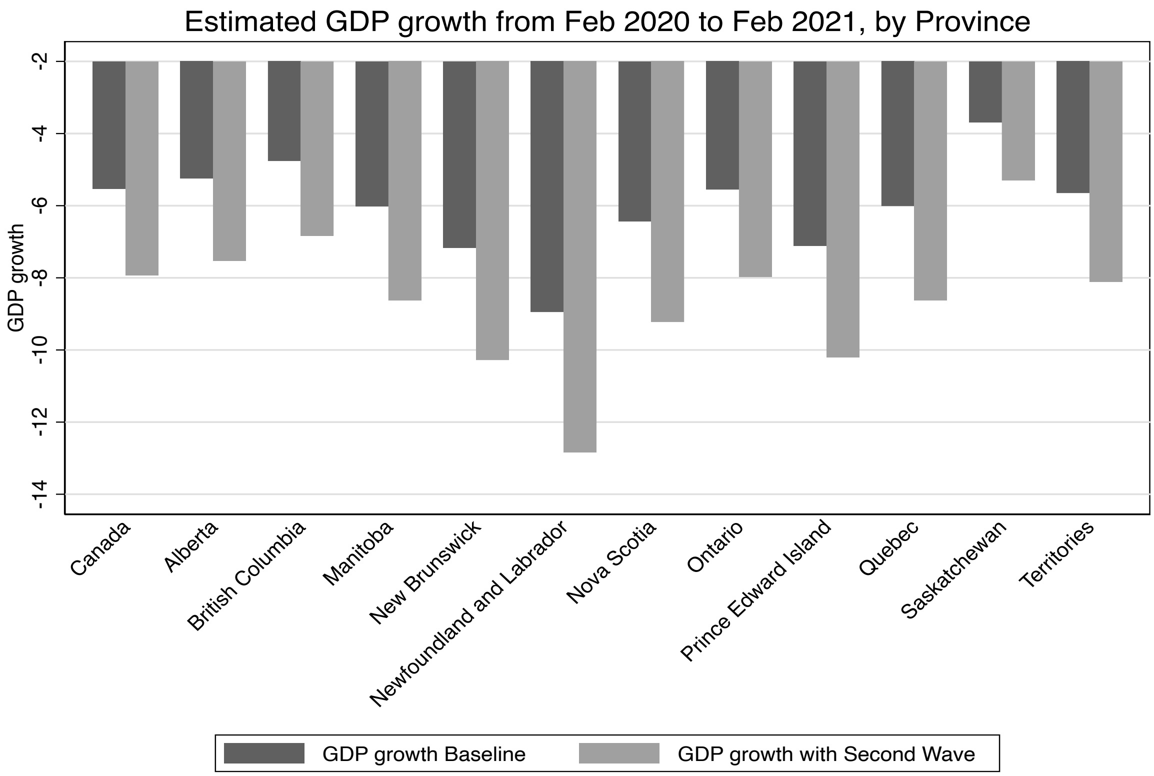


Figure 9: Expected GDP Growth in 2020 Using Occupational Resilience Measures, by Province

Note.—Sources: StatsCanada, IPUMS Canada. Based on author's calculations of resilience using Gallipoli and Makridis (2018)'s IT intensity index and Vancouver School of Economics (2020)'s home-shoreability, we estimate GDP values with equation 2. We then use the process explained in Section 5 to estimate GDP by Province for 2020 and report GDP growth from Feb 2020 to Feb 2021. Table 7 provides estimated GDP growth values for each jurisdiction.

Newfoundland and Labrador with 8.9% and 12.8% and smallest for Saskatchewan with 3.7% and 5.3% in the baseline and delayed scenario respectively. BC and Saskatchewan are instead projected to have shallower recessions. It is important to recognize that the real loss in each province will depend on their ability to restrain the spread of infection. The effectiveness of social distancing and mitigation activities, and measures aimed at reducing infection, will ultimately determine where they end up. Realized (ex-post) differences in provincial growth rates are likely to be more dispersed since they will reflect heterogeneity in the severity of local infections. Nonetheless, our estimates indicate the presence of significant ex-ante heterogeneity in provincial growth rates.

6 Extensions and Robustness

6.1 A Validation Exercise

A simple validation exercise is helpful to assess how reasonable the results in Section 5 are. We employ preliminary GDP estimates by industry, released by Statistics Canada for April 2020, and compare them to cross-industry GDP variation estimated using our approach. Figure 10 shows predicted and realized GDP drops, by industry, between February and April 2020; while the model slightly under-predicts GDP drops, overall cross-industry variation is accurately captured.

6.2 Contact Intensity and Industry Heterogeneity

So far, we have focused on heterogeneity in resilience, reflecting sectoral differences in IT tasks intensity and home-shorability of jobs. Yet, other sources of heterogeneity across industries may affect their behaviour during a pandemic event. For example, some attention has been devoted to measures of industry-specific contact intensity (see Dingel and Neiman, 2020). The latter indirectly capture the adaptability of sectors to work-from-home arrangements by measuring the need for human contact when performing job tasks. Unsurprisingly, these measures are positively correlated with both digital intensity and home-shorability: the correlation between the contact intensity measures of Dingel and Neiman (2020) and the home-shorability measures of the Vancouver School of Economics (2020) is 0.24; the correlation between contact intensity and our measure of resilience is slightly higher, at 0.37.

Given its distinct focus and popularity, Dingel and Neiman's contact intensity is a suitable can-

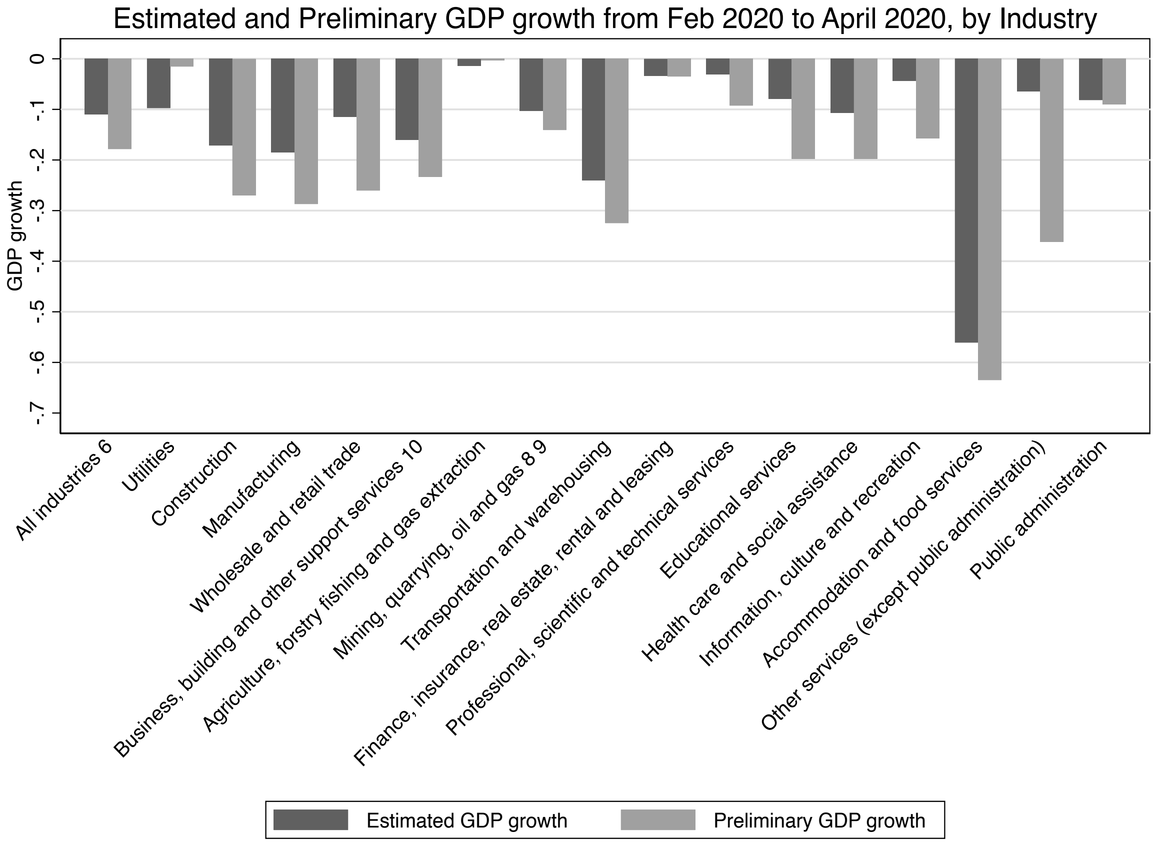


Figure 10: Model estimates vs preliminary data on GDP growth released by Statistics Canada (changes between Feb 2020 and April 2020, by Industry)

Note.—Sources: StatsCanada, IPUMS Canada. Based on author's calculations of resilience using Gallipoli and Makridis (2018)'s IT intensity index and Vancouver School of Economics (2020) occupational risk tool's home-shorability, GDP values are estimated according to equation 2. We use the procedure outlined in Section 5 to estimate GDP by Industry for April 2020. We then calculate the growth rate from February 2020 to April 2020, and report both the estimated values and the preliminary GDP growth data released by StatsCan.

didate for simple robustness exercises that illustrate how one can easily adapt our state dependent extrapolation algorithm to explore alternative sources of sectoral heterogeneity. To this purpose, we classify industries into high and low contact intensity groups (above and below median) and re-estimate the GDP-employment elasticities under this alternative characterization of sectoral heterogeneity. The estimates, presented in column (6) of Table 3, can then be used to project GDP growth by industry and location.

In Figure 11 we plot estimates of year-on-year GDP growth between February 2020 and Febru-

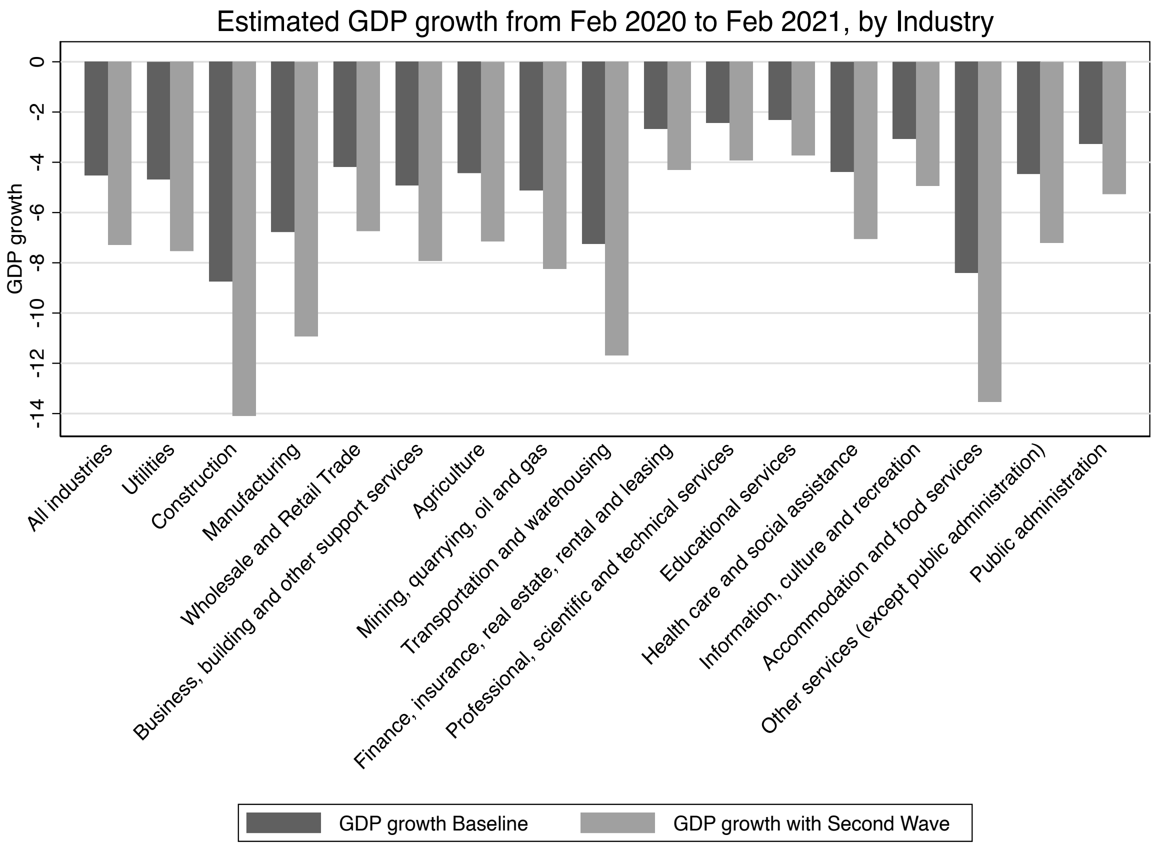


Figure 11: Expected GDP Growth in 2020 following Dingel and Neimann (2020), by Industry

Note.—Sources: StatsCanada, IPUMS Canada. Based on author's calculations using Dingel and Neiman (2020)'s work from home index to estimate GDP values with equation 2. We then use the process explained in Section 5 to estimate GDP by Industry for 2020 and report GDP growth from Feb 2020 to Feb 2021. Table 8 provides estimated GDP growth values for each of these Industries.

ary 2021 based on Dingel and Neiman's contact intensity. The average magnitude of industry-specific GDP drops is similar to our benchmark results; perhaps more interestingly, relative differences in industry-specific growth rates are also similar to those reported in the benchmark analysis, suggesting that the simple state-dependent algorithm is fairly robust to using alternative measures to capture sectoral heterogeneity in jobs' resilience during the pandemic event.

In Figure 12 we also show projections of year-on-year growth rates for different provinces using the Dingel and Neimann contact intensity measures. We estimate less heterogeneity across locations than we do across industries. In fact, there is clearly less variation across provincial GDP

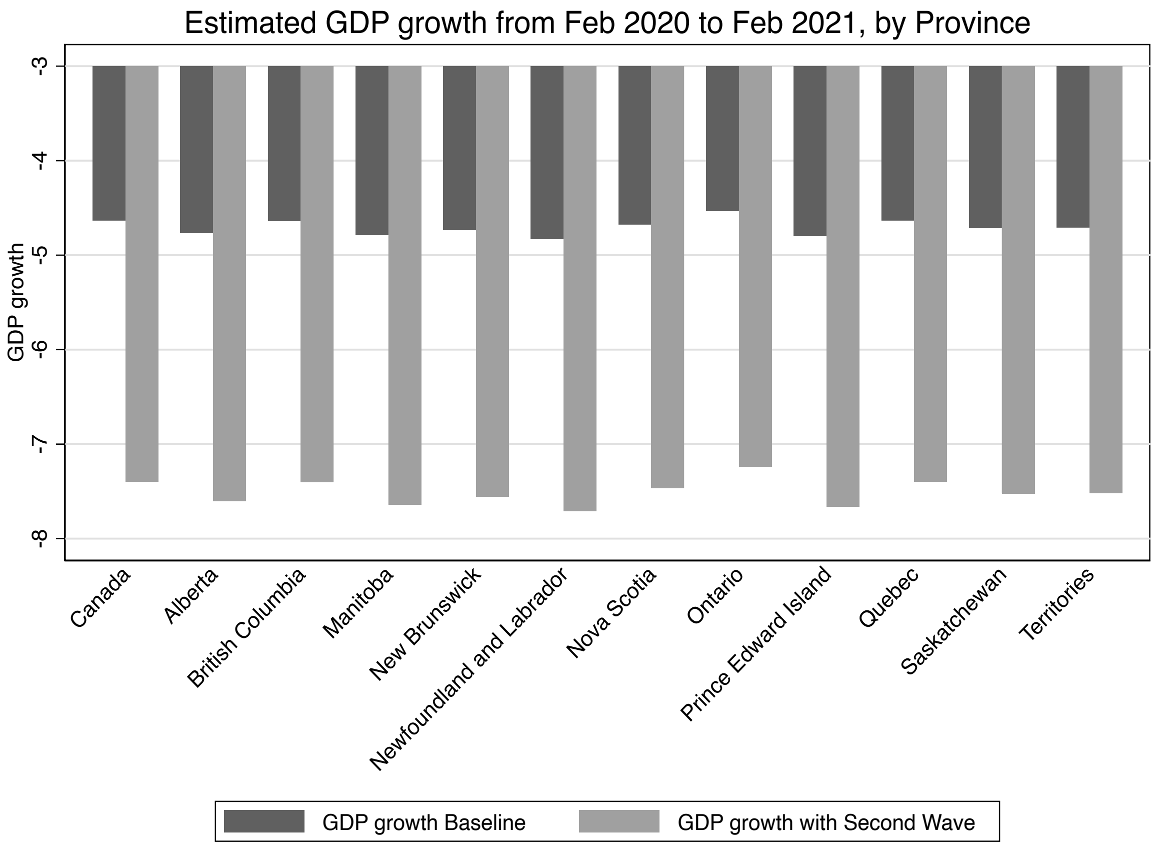


Figure 12: Expected GDP Growth in 2020 following Dingel and Neimann (2020), by Province

Note.—Sources: StatsCanada, IPUMS Canada. Based on author's calculations using Dingel and Neiman (2020)'s work from home index to estimate GDP values with equation 2. We then use the process explained in Section 5 to estimate GDP by Province for 2020 and report GDP growth from Feb 2020 to Feb 2021. Table 9 provides estimated GDP growth values for each of Province. We were not able to calculate exact growth rates for each Territory as StatsCan doesn't provide specific data required to make these estimations.

growth rates than in our baseline analysis, where we use a richer resilience measure. Realized provincial growth rates will likely be very different from each other in reality, as they will reflect the local severity of the infection spread.

The key message of this robustness exercise is that, given the simplicity of the state-dependent approach used to project growth rates, one could combine several alternative measures of industry heterogeneity to generate a richer set of estimates. The easy scalability of the extrapolation approach is in fact one of its main advantages.

Table 3: Elasticity of GDP Growth to Employment Growth

Dep. var. =	Real GDP Growth					
	(1)	(2)	(3)	(4)	(5)	(6)
Employment Growth	.33***	.37***	.72***	.39***	.40***	.81***
	[.02]	[.03]	[.05]	[.03]	[.03]	[.04]
High Contact Intensity				.01***	.01***	.04***
				[.00]	[.00]	[.00]
× Employment Growth				-.17***	-.07	-.56***
				[.04]	[.06]	[.10]
Constant	.02***	.02***	-.01***	.01***	.01***	-.02***
	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]
R-squared	.12	.11	.40	.13	.13	.58
Sample Size	3488	3440	384	3488	3440	384
Sample	All	All	2008-09	All	All	2008-09
Instrument	No	Yes	No	No	Yes	No

Notes.—Source: Gallipoli and Makridis (2018), Dingel and Neiman (2020) and StatsCanada. The table reports the coefficients associated with regressions of industry × month real GDP growth (year-to-year, in chained 2012 prices) on employment growth, interacted with an indicator for whether the sector has high exposure to information technology-intensive (IT-intensive) jobs. The latter exposure is measured using IPUMS Canada 2011 data in conjunction with the Gallipoli and Makridis (2018) IT-intensity measure. We instrument the potentially endogenous employment growth with two and three month lagged values of the year-to-year growth rate.

7 Conclusion

When a wide-reaching shock hits the economy, there is invariably some urgency to come up with estimates about its likely impact. The 2020 pandemic event has generated much speculation about its implications for aggregate and sectoral growth. Using readily available data on sectoral output and employment during the large recession of 2008/09, we develop a state-dependent procedure to quantify the magnitude of likely GDP declines in Canada, and document how these declines might vary across industries with different occupational concentration of digital tasks. Building on the classic work of Okun (1963), our procedure has minimal implementation and data requirements, and can be easily scaled to include multiple measures of industry and geographic heterogeneity.

We present evidence that sectors with greater digital intensities and home-shorability are less exposed to the confinement shocks observed during a pandemic. We estimate the degree of heterogeneity in sectoral elasticities of real GDP to employment growth, and employ these estimates to extrapolate bounds for GDP growth over the months following the onset of the shock: a percentage point rise in the resilience of workers is associated with 0.65 percentage point higher employment growth between February and April 2020.

We consider three alternative paths for GDP and employment. Under the baseline view, the economy is likely to shrink by over 10% during the Spring of 2020, and then gradually recover to resume year-on-year positive growth by the Spring of 2021. However, the pre-crisis GDP level is unlikely to be reached before the second quarter of 2022. These aggregate patterns hide significant differences across sectors: in low resilience sectors year-on-year GDP drops are predicted to be roughly five times as large relative to high resilience industries. Under a more benign scenario, employment recovers faster than in the previous recessionary episode, with aggregate GDP returning to pre-crisis levels by the end of 2021. Finally, we consider a double-dip recession scenario, associated to renewed confinement measures due to a second wave of infections. In this case aggregate GDP would still be 4 percentage points below pre-crisis level by the beginning of 2022. While time will tell how (in-)accurate these forecasts are, they provide a data-driven and transparent way to gauge the impact of the large pandemic shock on aggregate and sectoral output. The analysis highlights the importance of differences in occupational task intensities, specifically related to the digital economy, in mediating employment and output declines. Projected GDP growth rates vary significantly across industries, with a handful of them shouldering most of the output losses following the initial onset of the shock. Future research might explore how organizations in different sectors have adapted to the changes over the course of the recovery and how sustained increases in layoffs in certain sectors translate into lower future GDP.

References

Arellano, M. and Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies*, 58(2):277–297.

Ball, L. M., Leigh, D., and Loungani, P. (2013). Okun's law: fit at fifty? Technical report, National Bureau of Economic Research.

Bartik, A. W., Betrand, M., Lin, F., Rothstein, J., and Unrath, M. (2020). Labor market impacts of COVID-19 on hourly workers in small- and medium- size businesses: Four facts from HomeBase data. *Chicago Booth Rustandy Center, Working Paper*.

Cajner, T., Crane, L., Decker, R. A., Grigsby, J., Hamins-Puertolas, A., Hurst, E., Kurz, C., and Yildirmaz, A. (2020). The U.S. labor market during the beginning of the pandemic recession. *BFI working paper*.

Coibion, O., Gorodnichenko, Y., and Weber, M. (2020). Labor markets during the COVID-19 crisis: A preliminary view. *NBER working paper*.

Devereux, M. and Lahiri, A. (2020). Pandemics Through the Lens of Occupations.

Dingel, J. I. and Neiman, B. (2020). How many jobs can be done at home. *Journal of Public Economics*.

Gallipoli, G. and Makridis, C. (2018). Structural Transformation and the Rise of Information Technology. *Journal of Monetary Economics*, 97:91–110.

Guerrieri, V., Lorenzoni, G., Straub, L., and Werning, I. (2020). Macroeconomic implications of COVID-19: Can negative supply shocks cause demand shortages. *Working paper.*

Huang, A., Makridis, C. A., Baker, M., Medeiros, M., and Guo, Z. (2020). Understanding the Impact of COVID-19 Intervention Policies on the Labor Market of the Hospitality and Retail Industries. *SSRN working paper.*

Kozlowski, J., Veldkamp, L., and Venkateswaran, V. (2020). Scarring body and mind: The long-term belief-scarring effects of COVID-19. *Working paper.*

Makridis, C. A. and Hartley, J. (2020). The cost of COVID-19: A rough estimate of the 2020 GDP impact. *Mercatus Center, Policy Brief Special Edition.*

Okun, A. M. (1963). *Potential GNP: its measurement and significance.* Yale University, Cowles Foundation for Research in Economics New Haven.

Vancouver School of Economics, V. (2020). Measures of occupational heterogeneity. In *VSE COVID Risk/Reward Assessment Tool.*

A Online Appendix: Procedures, Tables and Figures

A.1 Procedures to Compute Heterogeneity Scores

IT Intensity scores for Industries (Figure 2) There is a binary value for high and low it intensity (1 and 0) given according to the z-itscores for 3-digit SOC levels. We merge this with the cleaned IPUMS file and collapse the binary values by industry. This gives us a unique score for each industry. This score is plotted in Figure 2.

IT intensity score for provinces (Figure 1) We use employment data of Provinces by Industry from 2019 and merge it with the unique industry score calculated above. We calculate the product of this industry IT score and number of people in the industry in that province (*ind_prov_highit_occ*). We then find the sum of *ind_prov_highit_occ* for each province and divide it by the number of working people in that province. This gives us a unique value for each province which is the province-specific IT intensity plotted in Figure 1.

Home-shorability score for Industries for Canada (Figure 2) We have the number of people (*n_workers*) in a 4-digit occupation and the proportion of people working from home (*wfh*) in that occupation throughout Canada. We collapse the number of people working in 4-digit occupations by 2-digit industries (called *n_total*) to find the number of people in an industry. We find the share of people from an occupation working in an industry (*share_occ_ind*) by dividing *n_workers* by *n_total*. We then find the product of the *wfh* and *share_occ_ind* and collapse it by industry. This gives us a unique score for each industry for Canada, reported in (Figure 2).

Home-shorability score for Provinces (Figure 1) Using the same procedure defined above, we can calculate a unique score for each industry in a given province. We then calculate the share of workers from an industry in a particular province ($share\_ind\_prov$) by dividing the number of workers in an industry with the number of workers in that province. Then we find the product of the unique industry score and share of workers in that industry in the province and call it $score\_share\_prov$. When we collapse this, we get a unique number for the given province. This can be repeated for each province to find the score which is then reported in (Figure 1).

Resilience (Figure 1 and 2) It is the product of the IT intensity score and home-shorability score for each province and industry.

A.2 Tables and Figures

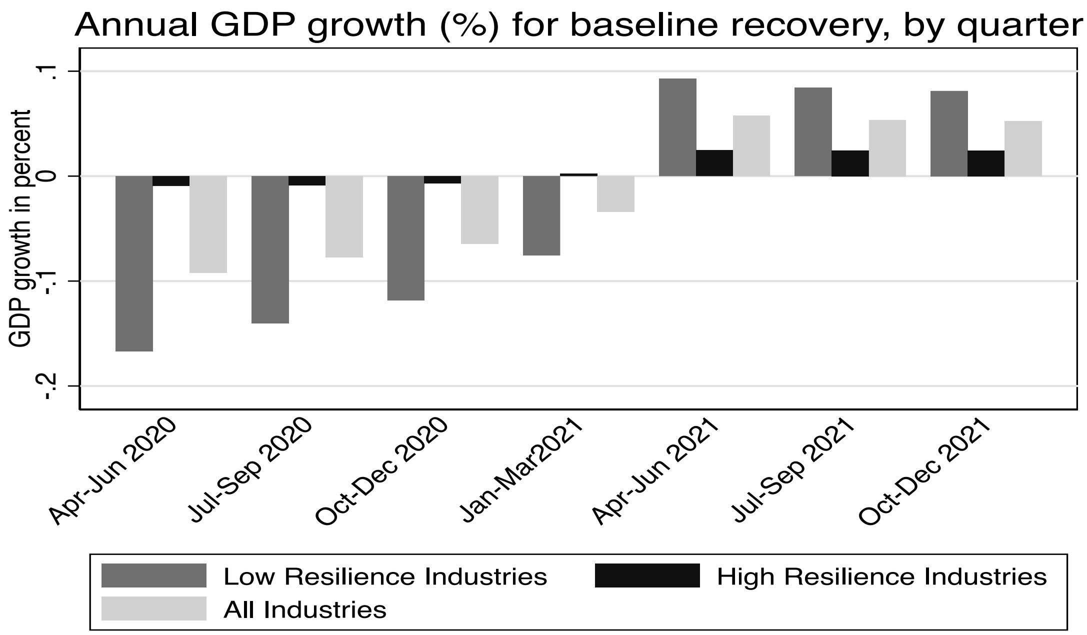


Figure 13: Quarterly GDP Growth rates for Baseline Scenario

Note.— Source: Gallipoli and Makridis (2018), Vancouver School of Economics (2020) occupational risk tool and StatsCanada. GDP growth for each quarter is defined as the average of the annual growth rate estimated for each month of the quarter for the baseline scenario. The annualized GDP growth rates from February 2020 to January 2022 are reported in Table 5.

Table 4: GDP Levels (Feb 2020 normalized to one)

	Baseline			Optimistic			Second wave		
	Aggregate	Low Resilience	High Resilience	Aggregate	Low Resilience	High Resilience	Aggregate	Low Resilience	High Resilience
Feb-20	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mar-20	0.929	0.911	0.949	0.929	0.911	0.949	0.929	0.911	0.949
Apr-20	0.890	0.816	0.971	0.890	0.816	0.971	0.890	0.816	0.971
May-20	0.903	0.836	0.975	0.903	0.836	0.975	0.903	0.836	0.975
Jun-20	0.910	0.848	0.977	0.918	0.863	0.977	0.918	0.863	0.977
Jul-20	0.913	0.851	0.981	0.929	0.880	0.982	0.929	0.880	0.982
Aug-20	0.918	0.859	0.982	0.939	0.899	0.983	0.919	0.864	0.980
Sep-20	0.921	0.862	0.985	0.948	0.912	0.986	0.906	0.852	0.965
Oct-20	0.926	0.868	0.988	0.957	0.926	0.990	0.904	0.831	0.984
Nov-20	0.931	0.875	0.992	0.966	0.939	0.995	0.908	0.835	0.988
Dec-20	0.938	0.886	0.994	0.974	0.954	0.997	0.914	0.845	0.990
Jan-21	0.941	0.893	0.994	0.980	0.963	0.997	0.918	0.851	0.990
Feb-21	0.946	0.900	0.996	0.984	0.970	0.999	0.922	0.858	0.991
Mar-21	0.938	0.892	0.989	0.976	0.962	0.992	0.914	0.849	0.984
Apr-21	0.946	0.901	0.995	0.985	0.973	0.998	0.921	0.858	0.990
May-21	0.952	0.909	0.999	0.987	0.973	1.002	0.927	0.865	0.994
Jun-21	0.959	0.921	1.001	0.989	0.975	1.004	0.933	0.875	0.996
Jul-21	0.963	0.923	1.005	0.988	0.968	1.009	0.936	0.878	1.000
Aug-21	0.967	0.931	1.006	0.988	0.969	1.009	0.941	0.885	1.001
Sep-21	0.970	0.934	1.009	0.989	0.967	1.011	0.945	0.888	1.007
Oct-21	0.975	0.940	1.013	0.988	0.964	1.015	0.949	0.894	1.008
Nov-21	0.980	0.946	1.017	0.989	0.962	1.019	0.954	0.901	1.012
Dec-21	0.986	0.957	1.018	0.992	0.967	1.020	0.960	0.910	1.013
Jan-22	0.990	0.964	1.018	0.993	0.969	1.019	0.963	0.917	1.013

Note.—Source: Gallipoli and Makridis (2018), Vancouver School of Economics (2020) occupational risk tool and StatsCanada. This table gives us the levels of GDP for a month when compared with the level of GDP of February 2020 (which is considered to be 1). We have three different scenarios- baseline, optimistic and second wave. Each scenario has the GDP level reported for aggregate GDP, GDP of low resilience industries and GDP of high resilience industries. We use equation 2 to estimate annual GDP growths given an assumed path of employment growth for each scenario. This GDP growth rate is then used to calculate GDP values which is further used to estimate GDP levels as presented in this table. Throughout all three scenarios, we only observe an unexpected drop in employment levels in March and April 2020. This gives us a sudden drop in the employment and GDP levels for March 2021 as they depend upon the employment levels in March 2020. To overcome this challenge of our model, we calculate the employment growth rate of March 2021 with respect to the average employment level of March and April 2020 i.e. ((employment in March'21- average of employment in March'20 and April'20)/(average of employment in March'20 and April'20)). This employment growth rate is then used as per the model to compute GDP growth rate and levels.

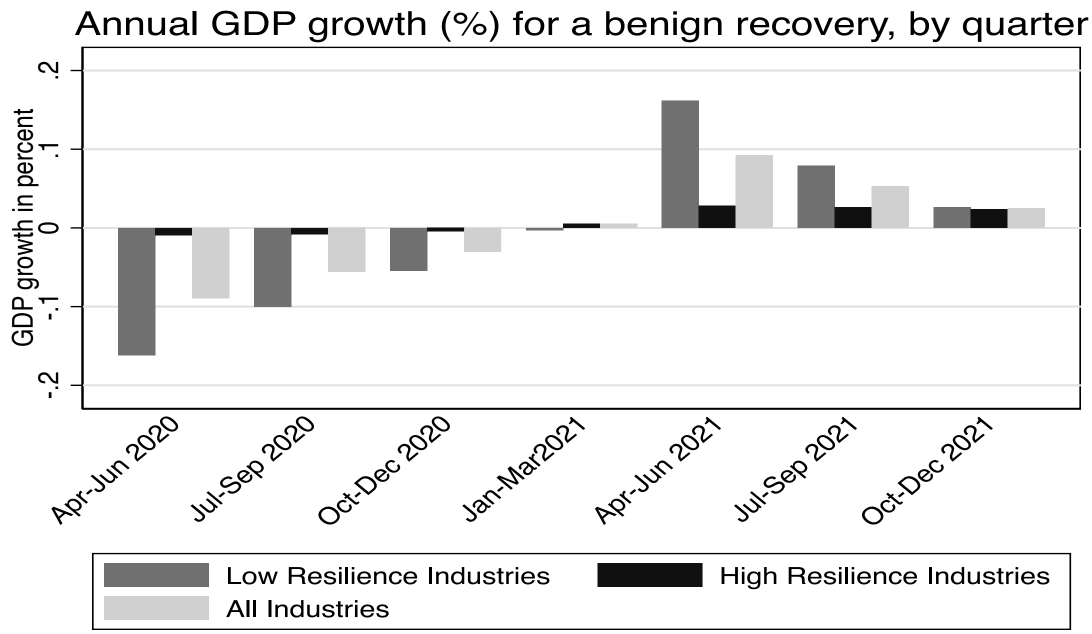


Figure 14: Quarterly GDP Growth rates for the benign outlook

Note.— Source: Gallipoli and Makridis (2018), Vancouver School of Economics (2020) occupational risk tool and StatsCanada. GDP growth for each quarter is defined as the average of the annual growth rate estimated for each month of the quarter for a benign outlook. The annualized GDP growth rates from February 2020 to January 2022 are reported in Table 5

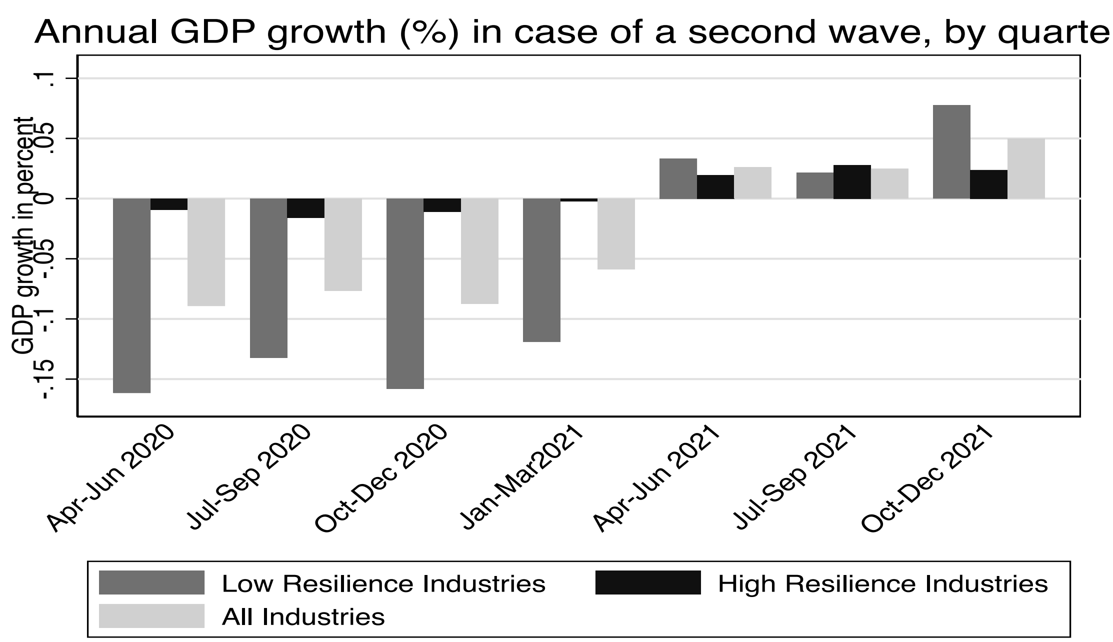


Figure 15: Quarterly GDP Growth rates in case of a Second Wave

Note.— Source: Gallipoli and Makridis (2018), Vancouver School of Economics (2020) occupational risk tool and StatsCanada. GDP growth for each quarter is defined as the average of the annual growth rate estimated for each month of the quarter in case Canada experiences a second wave. The annualized GDP growth rates from February 2020 to January 2022 are reported in Table 5

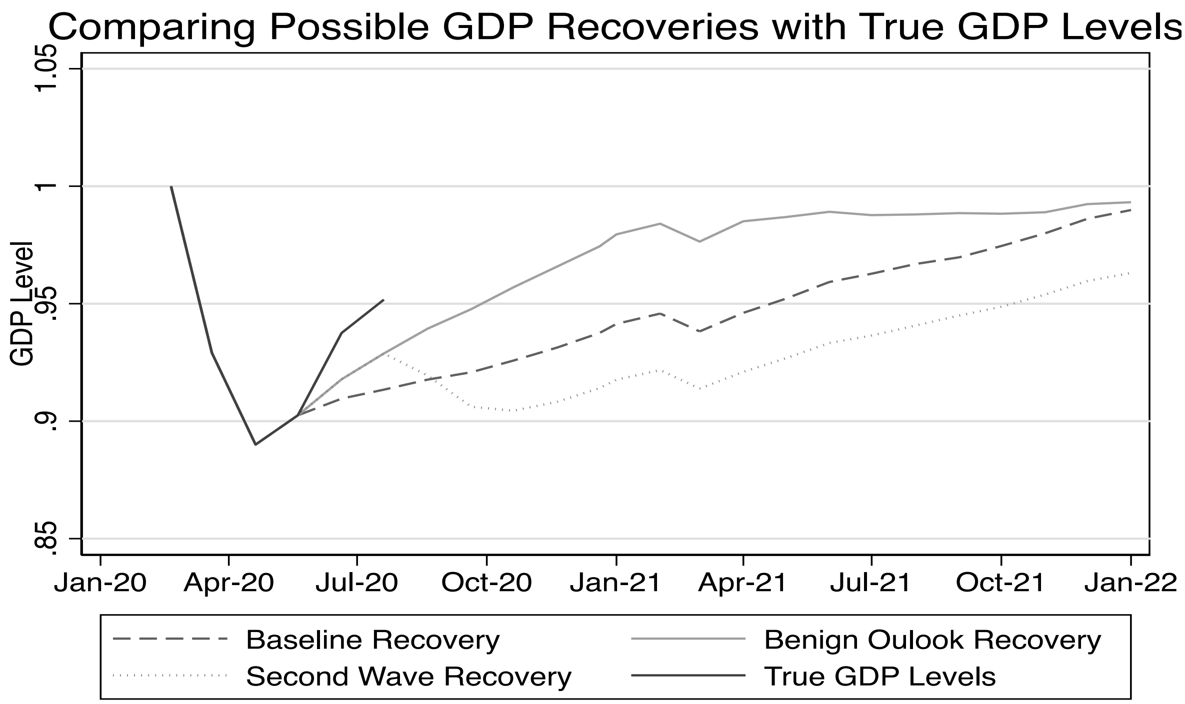


Figure 16: Comparing Possible GDP Recoveries with True GDP Levels

Note.—Source: Gallipoli and Makridis (2018), Vancouver School of Economics (2020) occupational risk tool and StatsCanada. The graph reports the aggregate GDP levels calculated using our model in equation 2 for all three recovery paths discussed above. GDP is normalized to one in February 2020. This graph also reports the levels of GDP that our model implies when we instead use preliminary estimates of employment for June and July 2020.

Table 5: Annualized GDP Growth Rates (percentages)

	Baseline			Optimistic			Second wave		
	Aggregate	Low Resilience	High Resilience	Aggregate	Low Resilience	High Resilience	Aggregate	Low Resilience	High Resilience
Feb-20	2.21	1.93	2.52	2.21	1.93	2.52	2.21	1.93	2.52
Mar-20	-5.74	-6.17	0.59	-5.74	-6.17	0.59	-5.74	-6.17	0.59
Apr-20	-10.07	-18.27	-0.98	-10.07	-18.27	-0.98	-10.07	-18.27	-0.98
May-20	-9.01	-16.32	-0.94	-9.01	-16.32	-0.94	-9.01	-16.32	-0.94
Jun-20	-8.55	-15.47	-0.91	-7.73	-13.91	-0.89	-7.73	-13.91	-0.89
Jul-20	-8.04	-14.63	-0.83	-6.49	-11.71	-0.78	-6.49	-11.71	-0.78
Aug-20	-7.75	-13.94	-0.97	-5.57	-9.84	-0.89	-7.57	-13.44	-1.14
Sep-20	-7.46	-13.51	-0.85	-4.76	-8.46	-0.72	-8.93	-14.51	-2.85
Oct-20	-6.95	-12.58	-0.85	-3.82	-6.73	-0.67	-9.10	-16.32	-1.28
Nov-20	-6.38	-11.69	-0.66	-2.92	-5.23	-0.42	-8.71	-15.78	-1.07
Dec-20	-6.07	-11.17	-0.55	-2.38	-4.32	-0.28	-8.43	-15.30	-0.97
Jan-21	-5.76	-10.60	-0.48	-1.94	-3.56	-0.19	-8.14	-14.78	-0.91
Feb-21	-5.42	-10.02	-0.42	-1.60	-2.97	-0.10	-7.83	-14.24	-0.85
Mar-21	0.98	-2.08	1.58	5.10	5.64	1.93	-1.64	-6.74	1.11
Apr-21	6.30	10.49	2.47	10.68	19.27	2.83	3.48	5.12	1.98
May-21	5.50	8.75	2.46	9.35	16.35	2.82	2.69	3.46	1.96
Jun-21	5.46	8.64	2.46	7.77	12.96	2.78	1.68	1.42	1.93
Jul-21	5.40	8.53	2.45	6.34	10.05	2.72	0.82	-0.27	1.89
Aug-21	5.36	8.43	2.45	5.18	7.71	2.65	2.31	2.50	2.12
Sep-21	5.31	8.32	2.44	4.31	6.04	2.57	4.28	4.23	4.34
Oct-21	5.26	8.22	2.44	3.27	4.04	2.48	4.89	7.61	2.40
Nov-21	5.22	8.12	2.44	2.39	2.38	2.40	5.02	7.90	2.38
Dec-21	5.18	8.02	2.43	1.84	1.40	2.31	4.99	7.81	2.37
Jan-22	5.15	7.93	2.43	1.40	0.59	2.25	4.95	7.71	2.37

Note.—Source: Gallipoli and Makridis (2018), Vancouver School of Economics (2020) occupational risk tool and StatsCanada. This table shows the annualized growth rate as calculated by our model in equation 2 in percentage. Annualized growth rate refers to the rate of growth between a month from year to year. This has been reported for all three scenarios for aggregate GDP, low resilience industries and high resilience industries.

Table 6: Expected GDP Growth (%) in 2020 following Gallipoli and Makridis (2018), by Industry

Industries	GDP Growth (Baseline)	GDP Growth (Delayed)
All industries	-5.42	-7.83
Agriculture	-0.68	-0.98
Mining, quarrying, oil and gas	-5.09	-7.34
Utilities	-4.81	-6.95
Construction	-8.45	-12.20
Manufacturing	-9.11	-13.15
Wholesale and Retail Trade	-5.65	-8.17
Transportation and warehousing	-11.85	-17.11
Finance, insurance, real estate, rental and leasing	-1.65	-2.39
Professional, scientific and technical services	-1.52	-2.20
Business, building and other support services	-7.91	-11.42
Educational services	-3.89	-5.62
Health care and social assistance	-5.28	-7.63
Information, culture and recreation	-2.15	-3.11
Accommodation and food services	-27.64	-39.92
Other services (except public administration)	-3.18	-4.59
Public administration	-4.03	-5.81

Note.—Sources: StatsCanada, IPUMS Canada. Based on author's calculations of resilience using Gallipoli and Makridis (2018)'s IT intensity index and Vancouver School of Economics (2020) occupational risk tool's home-shoreability, we then use the estimates of GDP values calculated in section 4 in the baseline and delayed scenario to follow the process explained in Section 5 to estimate GDP by Industry for 2020 and report GDP growth from Feb 2020 to Feb 2021 in this table.

Table 7: Expected GDP Growth (%) in 2020 following Gallipoli and Makridis (2018), by Province

Provinces	GDP Growth (Baseline)	GDP Growth (Delayed)
Canada	-5.526	-7.930
Newfoundland and Labrador	-8.949	-12.842
Prince Edward Island	-7.111	-10.205
Nova Scotia	-6.429	-9.226
New Brunswick	-7.164	-10.280
Quebec	-6.010	-8.624
Ontario	-5.553	-7.969
Manitoba	-6.013	-8.630
Saskatchewan	-3.690	-5.296
Alberta	-5.247	-7.529
British Columbia	-4.762	-6.834
Territories	-5.650	-8.108

Note.—Sources: StatsCanada, IPUMS Canada. Based on author's calculations of resilience using Gallipoli and Makridis (2018)'s IT intensity index and Vancouver School of Economics (2020) occupational risk tool's home-shoreability, we then use the estimates of GDP values calculated in section 4 in the baseline and delayed scenario to follow the process explained in Section 5 to estimate GDP by Province for 2020 and report GDP growth from Feb 2020 to Feb 2021 in this table. We were not able to calculate exact growth rates for each Territory as StatsCan doesn't provide specific data required to make these estimations.

Table 8: Expected GDP Growth (%) in 2020 following Dingel and Neimann (2020), by Industry

Industries	GDP Growth (Baseline)	GDP Growth (Delayed)
All industries	-4.52	-7.29
Agriculture	-4.43	-7.14
Mining, quarrying, oil and gas	-5.11	-8.24
Utilities	-4.68	-7.54
Construction	-8.75	-14.10
Manufacturing	-6.78	-10.92
Wholesale and Retail Trade	-4.18	-6.74
Transportation and warehousing	-7.25	-11.69
Finance, insurance, real estate, rental and leasing	-2.67	-4.30
Professional, scientific and technical services	-2.43	-3.92
Business, building and other support services	-4.92	-7.93
Educational services	-2.31	-3.72
Health care and social assistance	-4.38	-7.05
Information, culture and recreation	-3.06	-4.93
Accommodation and food services	-8.40	-13.54
Other services (except public administration)	-4.47	-7.20
Public administration	-3.27	-5.27

Note.—Sources: StatsCanada, IPUMS Canada. Based on author's calculations using Dingel and Neiman (2020)'s Work from home index, we estimate GDP values for a baseline and delayed scenario with equation 2 and elasticities in column ($7^{\dagger}$) of Table 3. We then use the process explained in Section 5 to estimate GDP by Industry for 2020 and report GDP growth from Feb 2020 to Feb 2021 in this table.

Table 9: Expected GDP Growth (%) in 2020 following Dingel and Neimann (2020), by Province

Provinces	GDP Growth (Baseline)	GDP Growth (Delayed)
Canada	-4.632	-7.396
Newfoundland and Labrador	-4.828	-7.709
Prince Edward Island	-4.798	-7.660
Nova Scotia	-4.676	-7.466
New Brunswick	-4.733	-7.557
Quebec	-4.634	-7.399
Ontario	-4.533	-7.237
Manitoba	-4.785	-7.640
Saskatchewan	-4.711	-7.522
Alberta	-4.763	-7.605
British Columbia	-4.636	-7.402
Territories	-4.708	-7.517

Note.—Sources: StatsCanada, IPUMS Canada. Based on author's calculations using Dingel and Neiman (2020)'s Work from home index, we estimate GDP values for a baseline and delayed scenario with equation 2 and elasticities in column ($7^{\dagger}$) of Table 3. We then use the process explained in Section 5 to estimate GDP by Province for 2020 and report GDP growth from Feb 2020 to Feb 2021 in this table.