Quantifying the economic impacts of COVID-19 policy responses on Canada's provinces in (almost) real time

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Abstract. We develop a methodology to track and quantify the economic impacts of lockdown and reopening policies by Canadian provinces in response to the COVID-19 pandemic, using data that is available with a relatively short time lag. To do so, we adapt, calibrate and implement a dynamic, seasonally adjusted, input–output model with supply constraints. Our framework allows us to quantify potential scenarios that allow for dynamic complementarities between industries, seasonal fluctuations and changes in demand composition. Taking account of the observed variation in reopening strategies across provinces, we estimate the costs of the policy response in terms of lost hours of employment and production. Among other results, we show how a more aggressive response, even though it imposes higher economic costs in the short run, can lead to lower economic costs in the long run if it means avoiding future waves of lockdowns.

Résumé. Quantification des impacts économiques des politiques associées à la COVID-19 dans les provinces canadiennes en temps réel (ou presque). On développe une méthodologie pour identifier et quantifier les impacts économiques des mesures de confinement et des politiques de déconfinement dans chacune des provinces canadiennes en réponse à la pandémie de la COVID-19 en utilisant des données publiées avec un court décalage. Pour ce faire, on adapte, calibre et implémente un modèle d'entrées-sorties dynamique désaisonnalisé avec des contraintes au niveau de l'offre. Notre modèle nous permet de quantifier des scénarios potentiels qui incorporent les complémentarités dynamiques entre les industries, les fluctuations saisonnières et les changements dans la

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composition de la demande. En prenant en compte les variations observées dans les stratégies de déconfinement de chaque province, on estime les coûts des politiques en ce qui a trait aux pertes d'heures travaillées et de production. Parmi les autres résultats observés, on démontre qu'une réponse plus agressive, quoique plus coûteuse à court terme, peut mener à des coûts économiques moins élevés à long-terme si elle permet d'éviter des vagues de reconfinement.

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> COVID-19 is an unusual macroeconomic shock. It cannot easily be categorized as an aggregate supply or demand shock. Rather, it is a messy combination of disaggregated supply and demand shocks. These shocks propagate through supply chains to create different cyclical conditions in different parts of the economy. Some sectors are tight, constrained by supply constraints and struggling to keep up with demand. Other sectors are slack and shedding workers to reduce excess capacity because of lack of demand.
>
> –Baqaee and Farhi (2020a)

1. Introduction

The World Health Organization named the COVID-19 outbreak a pandemic on March 11, 2020. Over the weeks that followed, federal and provincial governments across Canada took unprecedented steps to slow the rate at which the virus was spreading. Ontario, for example, announced the closure of schools on March 12, the closure of bars, restaurants and recreational facilities on March 17 and the closure of all non-essential workplaces on March 23. By mid-April, it was clear that most locations in Canada had succeeded in "flattening the curve," spreading out the potential duration of the pandemic but ensuring that disease rates at any point in time did not overrun hospital capacity.

At that point, policy-makers started to consider whether and how to relax lockdown restrictions and reopen the economy. Such decisions should account for both the costs of relaxing lockdown restrictions, in terms of COVID-19 illnesses and deaths, as well as the benefits, in terms of effects on employment and GDP and long-run well-being measures. However, while there is real-time data on COVID-19 cases and deaths, data on economic outcomes, such as employment income and GDP by industry and province, and other measures such as test scores assessing student learning are relatively delayed.[1] Furthermore, while well-established epidemiological models were designed to forecast the spread of the disease and mortality during pandemics, most economic models were not designed for pandemics. As such, policy-makers faced clear

1 For example, national estimates of GDP by industry become available from Statistics Canada after a two-month lag and provincial estimates after an even longer period. The lag reflects the gathering of data from the Monthly Survey of Manufacturing and the Survey of Employment, Payrolls and Hours (SEPH).

estimates of the direct benefits of continuing strict lockdown policies[2] but less precise claims about the economic costs of doing so.[3]

The experience with COVID-19 has highlighted the need for economic models that can rapidly help guide regional policy during pandemics or other crises (McCabe et al. 2020). In this paper, we propose one such model that builds on recent research modelling the economic impact of natural disasters. Our model tracks how the pandemic and corresponding lockdown policies have affected regional economic outcomes, such as jobs, hours worked and GDP to date, and provides forecasts projecting these outcomes into the months ahead as the economy recovers from the initial shocks. The model is easily adaptable to account for the specific characteristics of alternative crises and various scenarios that may play out during a downturn and economic recovery process. Finally, the model relies on public data that is collected and released with a relatively short time lag, allowing for frequent updates to provide policy-makers with the most-recent information.

Specifically, we adapt, calibrate and implement a dynamic, seasonally adjusted, input–output model with supply constraints, which allows us to quantify the impact of economy-wide shocks stemming from severe hits to production in a subset of industries, while accounting for dynamic complementarities between industries, seasonal fluctuations and changes in the composition of demand. Taking account of the observed variation in reopening strategies across provinces, we estimate the costs of the policy response in terms of lost hours of employment, jobs and income from production.

Our model builds on recent developments involving dynamic input–output models, developed to assess the economic impacts of natural disasters (e.g., Akhtar and Santos 2013, Hallegatte 2014, Okuyama and Santos 2014, Avelino and Hewings 2019). Specifically, it builds on the generalized dynamic input–output (GDIO) model due to Avelino and Hewings (2019). We adapt this framework to consider month-to-month dynamics in a setting where temporary economic shutdown measures, such as those associated with COVID-19 lockdown policies, may initially constrain production. We refer to this adaptation as the short-term under-capacity dynamic input–output (STUDIO) model.

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2 For example, on April 3, the Government of Ontario projected that the province could see between 3,000 to 15,000 deaths related to COVID-19 given its lockdown restrictions, while the death toll may have been as high as 100,000 without the government restrictions. See `www.cbc.ca/news/canada/toronto/ontario-COVID-projections-1.5519575`.

3 These factors may have contributed to continuation of strict lockdown policies for another month or more following the flattening of the curve, even in communities that reported no new cases during this period. British Columbia did not begin to reopen its economy until May 6, and Ontario did not begin to do so until May 19, starting a months-long process of relaxing lockdown restrictions. Other provinces faced similar delays in reopening.

The STUDIO model captures the interconnection between geographies and industries, which we calibrate using input–output (IO) summary tables, interprovincial and international trade flow data and labour market data from Statistics Canada. We then use the framework to estimate the economic impact of COVID-19 over a 12-month period under alternative forward-looking scenarios about the speed of recovery, government policy and medium- to long-term changes in consumer preferences.

Labour market restrictions during the lockdown are calibrated to replicate observed changes in hours worked and employment for each of the industries using data from the monthly Labour Force Survey (LFS). We use these to compute the immediate impacts on production outcomes. The output of and employment by a given producer depend on both the demand for its goods and services from downstream producers and the supply of inputs available from upstream ones. Consequently, the speed of recovery for a single industry depends on its input–output interactions with others that may continue to be constrained, even if that industry is not. Our model captures these interactions to allow a full assessment of the impacts of each scenario.

Our estimates imply that Canadian provinces jointly experienced a GDP loss of about $165 billion during 2020 because of COVID-19. This represents an 8.4% shortfall in Canadian GDP relative to what was otherwise predicted for that year.[4] These estimates are aggregated from monthly provincial industry-level estimates, which themselves vary considerably.[5] Aggregate hours worked is estimated to have been 9.9% lower than expected in the absence of the pandemic. The implied increase in labour productivity reflected a composition effect resulting from the concentration in hours reductions in relatively low-productivity sectors.

Going forward through 2021, we consider several alternative scenarios that reflect various possible policy measures and changes in demand-side behaviour. Our baseline optimistic scenario starts from the situation reflected in mid-January 2021 and assumes a staged reopening and no further lockdowns after mid-February. A second scenario considers the impacts of a significant and persistent decline in households' marginal propensity to consume through 2021, reflecting a perceived decline in after-tax wealth resulting from burgeoning public sector expenditures. On the policy side, we compare cyclical short-term lockdowns with more persistent, long-term lockdowns similar to that

4 As discussed below, these estimates do not include resource extraction industries.

5 Our analysis only focuses on Canadian provinces and does not include territories. Note that despite their physical size, the economies of the three territories combined (Northwest Territories, Yukon and Nunavut) contribute approximately 0.5% of Canadian GDP.

proposed by Global Canada's COVID Strategic Choices group.[6] We use the model to translate these alternative scenarios into economic cost estimates that can be used to inform decision making.[7] For example, the cost of measures taken today to mitigate the transmission of the virus may be compared with the losses incurred during future lockdowns that result from not taking them. Among other results, our analysis highlights how a more aggressive response that imposes higher economic costs in the short run can be less costly for the economy over time if it enables society to avoid future rounds of lockdown restrictions.

There is already a burgeoning literature that studies, both empirically and theoretically, various aspects of the economic implications of the COVID-19 pandemic, especially in the US. Many of these merge epidemiological and economic modelling to undertake policy analysis for the pandemic.[8] While recognizing there is a greater impact on some sectors of the economy than on others, most papers do not study the resulting dynamic input–output interactions that arise as constraints on different sectors of the economy are tightened and relaxed.

Several papers study these potential interactions in theory. In particular, Guerrieri et al. (2020) show how negative supply shocks can have negative demand spillovers, under the condition that the intersectoral elasticity of substitution is less than the intertemporal one. Baqaee and Farhi (2020a) show that complementarities in the production network can also amplify negative supply shocks, even if the intersectoral and intertemporal elasticities of substitution in consumption are the same.[9] In their analysis of the nonlinear mapping, implied by a generalized IO framework, from changes in hours and household preferences to real GDP, Baqaee and Farhi

6 Analyses we have conducted using this model have been informing policy through the crisis. A series of policy proposals based on an earlier working paper version of this paper, including Cotton et al. (2020, 2021a,b,c), provided the economic projections behind the policy analysis conducted by the Canadian COVID Strategic Choices initiative, as outlined in Agnew et al. (2020) and at `http://www.covidstrategicchoices.ca`, as well as the COVID-19 strategy put forth by the Ontario government (Public Health Ontario 2021).

7 In a working paper version, completed in August 2020, we also considered other likely demand-side changes.

8 Acemoglu et al. (2020), Alvarez et al. (2020), Atkeson (2020a,b), Aum et al. (2020), Azzimonti et al. (2020), Baqaee and Farhi (2020a,b), Baqaee et al. (2020), Berger et al. (2020), Bodenstein et al. (2020), Eichenbaum et al. (2020), Farboodi et al. (2020), Favero et al. (2020), Glover et al. (2020), Guerrieri et al. (2020), Jones et al. (2020), Krueger et al. (2020), Lin and Meissner (2020), Ludvigson et al. (2020), Moser and Yared (2020), Mulligan (2020), Rampini (2020), Rio-Chanona et al. (2020), Stock (2020).

9 They also show that while complementarities amplify negative supply shocks, they also mitigate negative demand shocks.

(2020b) find that the negative supply and demand shocks associated with COVID-19 are large enough that accounting for non-linearity is quantitatively important.

Here, we focus explicitly on the quantitative *dynamic* input–output interactions between industrial sectors resulting from the lockdown and recovery policies followed by federal and provincial governments in Canada. The intent has been to rapidly provide a usable framework for policy-planning and scenario development. In doing so, we have simplified by abstracting from optimal savings behaviour of households, the direct interactions with epidemiological models and possibilities of input substitution and technological adaptions. In future work, we plan to develop extensions that incorporate these features.

The remainder of this article proceeds as follows. In section 2, we informally describe the key features of our adaptation of the GDIO model, leaving most of the formal details to the appendix. We also detail our parameterization of the model and various scenarios that we consider. In section 3, we provide the main results in each scenario, including the estimated overall losses by province in hours of work and GDP. Section 4 concludes and discusses further work.

2. The model

2.1. The basic framework

Our core model builds on the GDIO model developed by Avelino and Hewings (2019). Input–output (IO) models use regional input–output tables, commonly provided by statistical agencies, to represent the production structure of the economy. Consequently, they emphasize the cross-industry interactions that result from each industry's use of intermediate inputs produced by other industries. The GDIO model is one of a class of dynamic IO models developed to study various kinds of major external shocks such as natural disasters (e.g., hurricanes and earthquakes). The core dynamics of the GDIO model arise from the asynchronicity between the production of intermediate inputs in some sectors and their subsequent use in other sectors and the resulting evolution of inventories of finished goods. This differs from standard "static" IO models, which are typically conceptualized as representing an entire year so that there is no "delay" between input production and use, and inventories are entirely exogenous. An important feature of the GDIO model and other related frameworks is that they allow for the impacts of both supply-side constraints and demand fluctuations and the dynamic interactions between them.

We lay out the formal details of the model in the appendix. The mechanics of the model are essentially driven by managers with limited information trying to match their production with expected demand in a context where prices are not adjusting to clear the market. Managers first determine the feasibility of their production schedules for the period, given the current availability of industrial inputs and labour hours. If the total schedule is not feasible, producers must ration supply to users in excess of any inventories from the previous period. As a result, depending on labour market conditions and household income, final demand might be undersupplied or oversupplied. Managers react to this supply–demand imbalance by adjusting their expectations for the next production cycle and by purchasing the necessary level of inputs. Because this inter-industrial demand may also be undersupplied or oversupplied, after markets clear, managers in each sector determine a feasible production schedule for the upcoming period (Avelino and Hewings 2019).

We refer to our version of the GDIO model as the short-term under-capacity dynamic input–output (STUDIO) model. This reflects our focus on month-to-month dynamics in a situation where lockdown policies may initially constrain production below that which could be produced given the available capital stock. Specifically, we model lockdowns by explicitly imposing labour constraints in the production function. In addition, we allow for endogenous demand-side effects coming from increased unemployment via a simple household expenditure model. Specifically, we assume that total final consumption demand in a given province is given by a time-varying fraction, $\mathbf{\Phi}(t)$, of total current income:

$$C(t) = \mathbf{\Phi}(t)\left(\sum_j w_j(t)H_j(t) + \left(\bar{L}(t) - \sum_j L_j(t)\right)b(t) + \mathbf{\Omega}^o(t)\right), \qquad (1)$$

where $w_j(t)$ denotes the wage per hour in industry j, $H_j(t)$ represents total hours worked, $\bar{L}(t)$ denotes total available labour supply, $L_j(t)$ denotes total labour used by industry j, $b(t)$ denotes transfers received while unemployed and $\mathbf{\Omega}^o(t)$ represent other, non-labour income minus taxes.[10] While we do not model optimal dynamic consumption behaviour, this flexible specification is intended to allow for variation in the propensity to consume out of current income resulting from expected after-tax wealth effects.

Our specification of aggregate consumption behaviour abstracts from heterogeneity in household behaviour. We allow for potential time variation in the aggregate marginal propensity to consume out of disposable income and in the aggregate shares of expenditures on different items (see equation (A11) in the appendix). However, we do not model the dependence of these on individual household incomes or employment status. This reflects a lack of information on the relevant propensities that might come from an empirical household demand system (e.g., Kim et al. 2015). Instead, below we specify

10 All of the variables in the model are province-specific. To save on notation, we do not include a separate index for provinces.

the aggregate implications of these effects in the context of various demand-side scenarios.[11]

The STUDIO model is intended for developing scenarios involving short-term dynamics, especially those associated with labour market restrictions like those imposed by the lockdown.[12] It may not be well suited for studying longer-term dynamics, over several years, because the model does not account for price and wage changes, nor the future impact of capital accumulation or technological change that results from current activities. Oosterhaven and Bouwmeester (2016) argue that the assessment of longer-term regional impacts should be based on a computable general equilibrium (CGE) framework. That said, many applied economists advocate the use of econometric IO models that allow for endogenous coefficient change over time (e.g., Conway 1990, Israilevich et al. 1997, Kim et al. 2015, Heim 2017). IO models have the advantages of rapid implementation, tractability and integration flexibility with external models that may be essential in the context of pandemics. The trade-off is the imposition of more rigid assumptions on substitutability between goods and factors, price changes and functional forms, which make IO more appropriate for short/medium term analysis.[13] In the case of the COVID-19 scenarios considered here, the model economy recovers within several months following the relaxation of lockdown policies and, therefore, we believe a medium-term horizon allows for a reasonable estimation of the main impacts of the pandemic on the economy.

2.2. International and interprovincial trade flows

We treat each province as a small open economy that engages in trade with the rest of the world. In the initial steady state, these trade flows are calibrated to match those implied by Statistics Canada's IO table-consistent interprovincial and international trade data. In our baseline model, during downturns, we allow any shortfalls in required inputs that cannot be produced locally to be imported either from other provinces or other countries. This assumption greatly simplifies the analysis by allowing us to ignore interregional equilibrium conditions and is also consistent with the short-term

11 That said, we estimate that, during the first three quarters of 2020, federal transfers to the unemployed amounted to almost $2 for every $1 in lost labour income. Consequently, the impacts of unemployment on consumption behaviour were likely significantly muted in Canada.

12 Because of its short-term, intra-year nature, we must also allow for seasonal fluctuations (see below).

13 In fact, given the level of aggregation allowed by the provincial supply–use data, substitutability in production between sectors is likely to be limited: most substitution occurs across producers *within* these sectors. Moreover, limited price adjustment may, in part, result from explicit policies to outlaw perceived "price gouging."

assumption that goods and services prices are fixed. While we do incorporate variation in final export demand in an exogenous fashion, we do not account for constraints on imports of final goods and intermediate inputs coming from other provinces or countries.

2.3. Seasonality

As noted above, in considering short-term (intra-year) dynamics, it is important to allow for seasonal variation, which plays a significant role in most industries. Such seasonality is incorporated into the model so that results are reported relative to the seasonal norm that would have been predicted in each month in the absence of the pandemic. We compute this counterfactual, "normal" scenario by first calculating the share of total annual hours worked in industry i attributed each month, averaged over the past five years, $s_i(m)$, $m \in \{1, 2, \dots 12\}$. We then multiply aggregate hours worked in each industry in February 2020 by the ratio of this share in each subsequent month to that in February 2020 to obtain a predicted counterfactual series for aggregate hours.

To compute a similar counterfactual prediction for industry GDP, we combine the implied share of annual GDP attributed to each month with a pre-COVID-19 forecast of GDP in each industry and location for 2020.[14] This approach to adjusting for seasonality cannot fully account for production processes that inherently take place over time according to a seasonal pattern. If GDP is estimated using sales of gross output, the timing may be significantly different from the allocation of hours in production. For example, in the agricultural sector, planting crops might require an increase in hours in May but the associated sales do not occur until after harvest. We discuss further the limitations and conceptual challenges presented by these issues in the conclusion.

2.4. Lockdown and recovery dynamics

Denote the maximum hours expected to be used in production in period t, in the absence of lockdown restrictions, as $\bar{H}_i^*(t)$.[15] Once labour market restrictions are relaxed in sector i, we assume the actual upper bound on total hours evolves according to

$$\bar{H}_i(t) = (1 - e^{-\lambda_i(t-r_i)})\bar{H}_i^*(t) + e^{-\lambda_i(t-r_i)}\bar{H}_i(r_i), \quad \forall t \geq r_i, \tag{2}$$

where r_i denotes the reopening date for sector i and λ_i denotes the maximum rate at which industry i can expand hours of employment once the lockdown is

14 Forecasts come from the Conference Board of Canada's Provincial Outlook Long-Term Economic Forecast for 2020 and 2021.

15 Note that these "normal" hours are time-varying because of seasonal fluctuations in each industry.

lifted. Actual aggregate hours are thus bounded above by this maximum, $H_i(t) \leq \bar{H}_i(t)$. Note that while the upper bound on hours may be binding in some industries, in others available intermediate inputs constrain production. As described below, we also use the experience of the first-wave in 2020 to modify our modelling of the reopening process in future scenarios during 2021.

Although the production side of the model is expressed in terms of aggregate labour hours, the household demand specification requires an estimate of aggregate employment. A complicating feature of the lockdown during 2020 was that different industries responded in different ways in terms of numbers of employees and hours worked per employee. In particular, some cut both while others let employees go while raising the average hours of those remaining. There are several potential models of firms' choices over employment and hours in response to demand fluctuations that one might use to predict future movements. However, it is unlikely that any one of them could capture the myriad of responses in this specific context.

Instead, we specify a reduced-form model of the adjustment in employment in response to changes in aggregate hours given by

$$L_i(t) = L_i^*(t) \left(\frac{H_i(t)}{\bar{H}_i^*(t)} \right)^{\beta_i}, \tag{3}$$

where $L_i^*(t)$ denotes the normal employment that would have been expected in the absence of COVID-19. Here the parameter $\beta_i \in (0,\ 1)$ measures the elasticity of deviations of employment from its expected path with respect to that for total hours worked in industry i. While this reduced form setup is admittedly crude, it captures the spirit of structural employment models featuring adjustment costs and hiring and firing frictions.[16]

2.5. Parameterization

Symmetric provincial IO summary tables, interprovincial and international trade flow data and labour market data (wages and employment) for each province are provided by Statistics Canada.[17] These annual data were used to calibrate the parameters of the model and the specific IO structure of each provincial economy. This core structure consists of 32 "summary" industries for each province.[18] However, because the LFS data is reported at a higher

16 For example, Hamermesh and Pfann (1996), Cooper et al. (2015).

17 Data sources: Statistics Canada tables 15-211-X (Provincial Symmetric Input–Output Tables) and 14-10-0043-01 (Average Usual and Actual Hours Worked in a Reference Week by Type of Work).

18 The more detailed national supply–use tables are used by Statistics Canada to estimate monthly industry GDP but only at the national level and with a significant lag.

level, we impose proportional labour market restrictions across the relevant subsectors and report all results aggregated to 16 industries.

The provincial IO tables are based on annual supply–use production data for 2015. While we maintain the same proportional production structure, we artificially "grow" output and final demands in each sector and province in proportion to observed industry GDP growth between 2015 and 2019. Thus, initial industry labour productivity (output per hour worked) in the model reflects that in 2019. The annual input–output matrix is assumed to apply to monthly production, so that seasonal-adjustments come through the impact of changes in hours worked only.[19]

Initial constraints on aggregate hours during past lockdowns were calibrated so that the implied hours worked in each sector closely match those in the monthly LFS for each province.[20] After restrictions start to be relaxed in various sectors, the upper bound on hours follows the recovery dynamics described above. Post-lockdown recovery speeds by sector, λ_i, were calibrated to match the fraction of businesses indicating they would be able to recover within one month according to a recent Statistic Canada business survey.[21] This effectively assumes that recovery rates are independent of the size of businesses within each sector. This estimate by industry is only available on average for Canada and not by province.

"Other income" is set equal to 28% of total employment compensation using figures from the Ontario Ministry of Finance.[22] The monthly income while unemployed is set equal to $b = \$2{,}000$, which is equal to the Canadian Emergency Response Benefit (CERB). Inventory depreciation rates, δ_i, are set equal to 0.99 for all service sectors and 0.01 for all goods-producing sectors. That is, there are basically no inventories of services carried between periods, while goods inventories are assumed to lose little value over a month. We follow Avelino and Hewings (2019) in setting the expectations adjustment parameter to $\sigma = 0.05$. These values are somewhat arbitrary, but the results are not very sensitive to similar alternative values. Finally, we estimated the values of β_i for each industry based on simple monthly log-linear regressions during 2020. We then used these estimates to forecast the relationship between hours and employment for the scenarios considered during 2021.

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19 Avelino (2017) discusses methods for adjusting the IO matrix itself to allow for temporal disaggregation. Unfortunately, Statistics Canada does not provide the seasonally unadjusted provincial industry GDP data on a monthly basis that would be required to apply these methods.

20 Statistics Canada table 14-10-0022-01 (Labour Force Characteristics by Industry, Monthly, Unadjusted for Seasonality).

21 Statistics Canada table 33-10-0244-01 (Length of Time Business Require Before Being Able to Resume Normal Operations Once Social Distancing Measures are Removed, by Business Characteristic).

22 `www.fin.gov.on.ca/en/economy/ecaccts/ecat11.html`.

2.6. Additional data limitations

As noted above, the provincial IO tables restrict the resolution of our data to 32 aggregated goods and service sectors. This has some benefits in that the shares of more aggregated sectors tend to be more stable over time and, relatedly, the degree of input substitutability between these sectors is low. However, it does imply that we do not have enough resolution to trace out the implications of changes in demand for certain narrowly defined items (e.g., toilet paper or mountain bikes) or for supply-chain constraints for particular intermediate inputs. Thus, for example, Manufacturing is a single aggregate sector in our model, and we cannot observe the degree to which labour hours are reallocated across different goods *within* that sector.

The COVID-19 pandemic has undoubtedly been the single dominant factor impacting the Canadian economy during 2020. However, it is not the only major global shock that has occurred. While our counterfactual attempts to adjust for "normal" seasonal movements and growth that was expected prior to the pandemic, it does not control for other such shocks that were not predicted prior to 2020. In particular, a major shock that had a significant impact on several provinces during 2020 was a global oil production glut due to a disagreement on production levels between Russia and Saudi Arabia and the consequent decline in oil prices. Because it is likely that the global lockdowns also contributed significantly to the glut and this price decline, it is unclear how much of the downturn in the oil sector should be attributed to each cause. For this reason, we report our main results below, excluding the resource sector (which includes oil production). The results for all sectors including resources are reported in appendix A2.

3. Results: Estimated losses in 2020

The extent of the impact of the lockdown and timing of reopening for each industry in each province reflects both the observed LFS data and the various recovery plans for each province. While the details and exact timing of these plans varied across provinces, there were many commonalities. For example, most provinces followed a three-stage reopening plan that started sometime in May, and by mid-August, they had all reached the third stage. A few provinces started their first stage prior to the May LFS reference week, whereas most others started later. Some provinces identified more than three phases in their plans, but because they occurred in fairly rapid succession between LFS reference weeks, we have effectively combined some of them. We calibrated the timing and extent of the maximum hours in each industry to generate hours-worked predictions matching reasonably closely those observed in the data.[23]

23 Recovery plan websites for each province are given in appendix A3. Quebec's recovery plan did not explicitly identify any stages, but their actual behaviour follows a pattern similar to that of other provinces, albeit at a different pace.

3.1. Impacts in Ontario

We illustrate the industry-level nature of the estimates during 2020 for Ontario, Canada's largest province economically. Figures 1 and 2, respectively, depict the dynamic evolution of the estimated deviations of GDP and total hours for each sector from their pre-COVID-19 forecast levels.[24]

Proportionally, Accommodation and Food Services was the hardest hit sector. However, in absolute terms, the Wholesale and Retail Trade, the Manufacturing and the Construction sectors emerged as the hardest hit, in terms of both hours and GDP. The impact on total hours in the Finance and Real Estate sector was relatively low, but the resulting impact on GDP in that sector has been much larger and persistent, and its contribution to overall losses was similar to that of Manufacturing.

3.2. Impacts in all provinces

Although we do not have the space here to present similar graphs for all the provinces, there is significant heterogeneity in the industry GDP impacts across them. Appendix table A1 documents the overall contributions of each sector to GDP losses in each province for the whole year and graphs corresponding to figure 1 for each province can be found in the online appendix. For example, the estimated losses in GDP coming from the Finance, the Real Estate and the Construction sectors were the largest in British Columbia, whereas the Construction and the Manufacturing sectors took the biggest GDP hits in Quebec. While many of the losses in April and May were more pronounced in Quebec than in other provinces, the more rapid opening up resulted in less persistence.

Tables 1 and 2, respectively, document the monthly estimated proportional impacts on aggregate GDP and aggregate hours worked for each province during 2020.[25] Figure 3 depicts a "heat map" providing a visualization of the cumulative impacts through 2020. As before, these estimates are relative to the seasonal norm that we estimate would have been expected in the absence of COVID-19. Note first, the impacts on hours worked is generally proportionally greater than that on GDP. The implied increase in labour productivity is really the result of a composition effect: low-value sectors, such as the Accommodation and Food Services sector, experienced much larger percent reductions in hours worked in comparison to high-value sectors, such as Financial Services.

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24 All GDP amounts are measured in 2020 Canadian dollars.

25 Standard provincial name abbreviations are used in all tables. From west to east: BC = British Columbia, AB = Alberta, SK = Saskatchewan, MB = Manitoba, ON = Ontario, QC = Quebec, NB = New Brunswick, NS = Nova Scotia , PE = Prince Edward Island and NL = Newfoundland and Labrador.

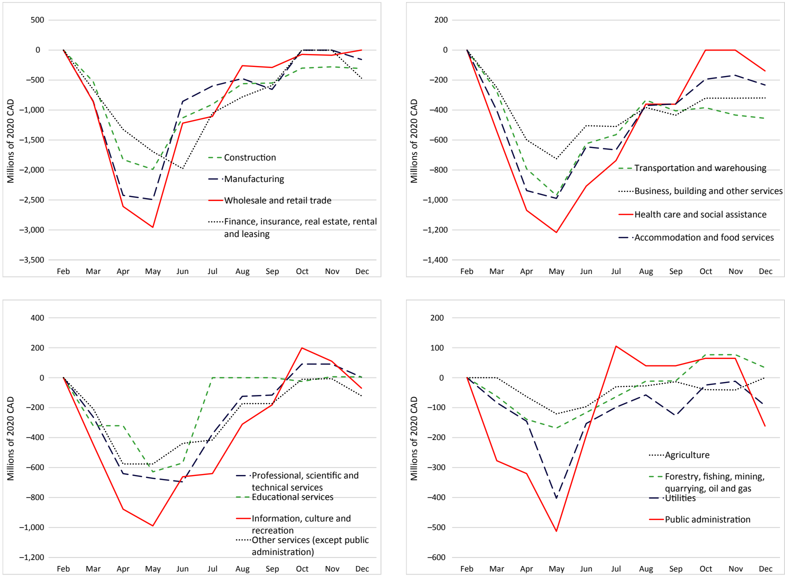

FIGURE 1 Impact on GDP relative to counterfactual by sector in Ontario during 2020. [Color figure can be viewed at `wileyonlinelibrary.com`]

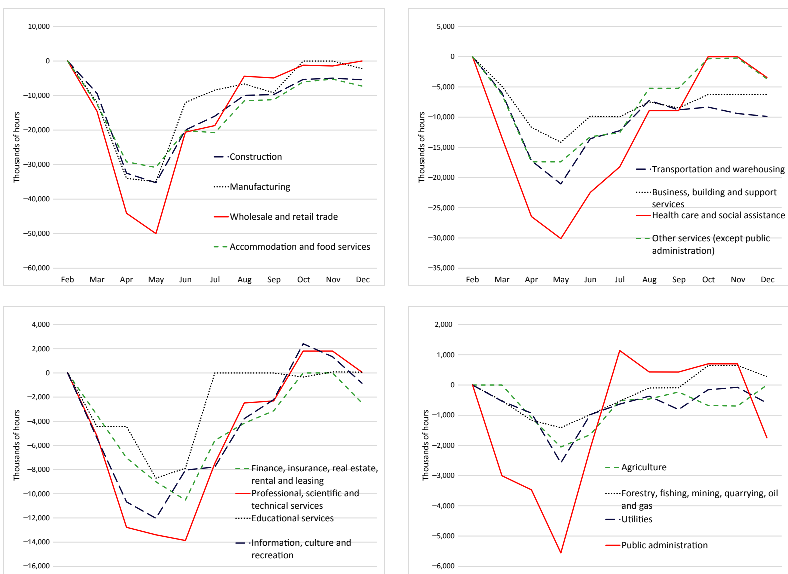

FIGURE 2 Impact on hours relative to counterfactual by sector in Ontario during 2020 (in thousands). [Color figure can be viewed at `wileyonlinelibrary.com`]

TABLE 1

Impact on GDP relative to counterfactual by province during 2020 (excluding resource industries)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year (%)	Year ($M)
BC	0.0%	−8.5%	−22.8%	−24.3%	−18.4%	−12.8%	−7.5%	−7.2%	−1.6%	−2.5%	−4.0%	−9.2%	−24,673
AB	0.0%	−5.4%	−22.3%	−24.1%	−14.6%	−8.0%	−4.7%	−4.5%	−1.8%	−2.1%	−4.1%	−7.7%	−21,227
SK	0.0%	−2.7%	−18.9%	−22.4%	−15.5%	−5.6%	−1.9%	−2.1%	−0.9%	−2.7%	−4.9%	−6.6%	−4,222
MB	0.0%	−3.1%	−15.8%	−19.1%	−13.8%	−6.9%	−2.7%	−2.8%	0.0%	−1.6%	−4.5%	−5.9%	−3,949
ON	0.0%	−9.2%	−22.5%	−25.1%	−15.3%	−11.3%	−6.3%	−6.4%	−1.6%	−1.7%	−3.7%	−8.6%	−68,682
QC	0.0%	−10.1%	−30.8%	−33.8%	−12.8%	−5.6%	−2.6%	−1.7%	−0.4%	−0.5%	−4.0%	−8.6%	−34,606
NB	0.0%	−6.9%	−19.6%	−20.7%	−11.6%	−5.2%	−3.0%	−2.6%	0.4%	−0.9%	−3.8%	−6.2%	−1,984
NS	0.0%	−8.8%	−20.1%	−24.0%	−19.4%	−11.4%	−6.4%	−6.3%	−4.1%	−3.4%	−6.1%	−9.2%	−3,574
PE	0.0%	−10.1%	−23.9%	−26.4%	−16.5%	−8.7%	−5.6%	−4.1%	−5.5%	−7.8%	−10.6%	−10.0%	−609
NL	0.0%	−8.5%	−28.2%	−30.9%	−14.5%	−7.1%	−4.3%	−4.6%	1.7%	2.9%	0.4%	−7.8%	−1,709
Canada	0.0%	−8.3%	−23.8%	−26.3%	−15.1%	−9.4%	−5.2%	−4.9%	−1.3%	−1.6%	−3.9%	−8.4%	−165,235

TABLE 2

Impact on hours worked relative to counterfactual by province during 2020 (excluding resource industries)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year (%)	Year (1,000s)
BC	0.0%	−9.4%	−25.3%	−26.9%	−19.4%	−14.7%	−8.3%	−7.8%	−3.0%	−3.7%	−5.0%	−10.3%	−392,717
AB	0.0%	−7.4%	−25.8%	−27.6%	−16.5%	−9.9%	−5.6%	−5.4%	−2.8%	−3.4%	−5.6%	−9.2%	−315,765
SK	0.0%	−3.8%	−23.6%	−26.1%	−16.9%	−6.7%	−2.8%	−3.3%	−2.2%	−4.2%	−6.6%	−8.1%	−71,084
MB	0.0%	−4.5%	−20.0%	−23.2%	−15.1%	−7.8%	−3.7%	−3.6%	−0.5%	−2.4%	−5.5%	−7.3%	−73,788
ON	0.0%	−10.8%	−27.1%	−29.5%	−17.6%	−14.2%	−7.6%	−7.8%	−2.5%	−2.6%	−4.4%	−10.3%	−1,194,096
QC	0.0%	−11.6%	−34.6%	−37.3%	−13.6%	−7.7%	−2.9%	−1.7%	−0.9%	−1.3%	−4.5%	−9.8%	−633,068
NB	0.0%	−8.3%	−23.6%	−24.6%	−12.1%	−5.8%	−3.0%	−3.0%	−1.2%	−2.2%	−4.9%	−7.4%	−40,871
NS	0.0%	−10.3%	−24.6%	−28.2%	−19.3%	−13.3%	−8.1%	−8.2%	−6.2%	−5.3%	−7.1%	−10.9%	−77,460
PE	0.0%	−10.3%	−26.3%	−29.1%	−19.2%	−10.5%	−6.7%	−5.7%	−8.2%	−9.6%	−12.9%	−11.6%	−14,678
NL	0.0%	−8.6%	−30.2%	−33.0%	−16.8%	−9.1%	−4.8%	−5.1%	0.2%	−0.3%	−3.2%	−9.3%	−29,818
Canada	0.0%	−9.9%	−27.9%	−30.3%	−16.6%	−11.6%	−6.0%	−5.8%	−2.2%	−2.6%	−4.8%	−9.9%	−2,843,344

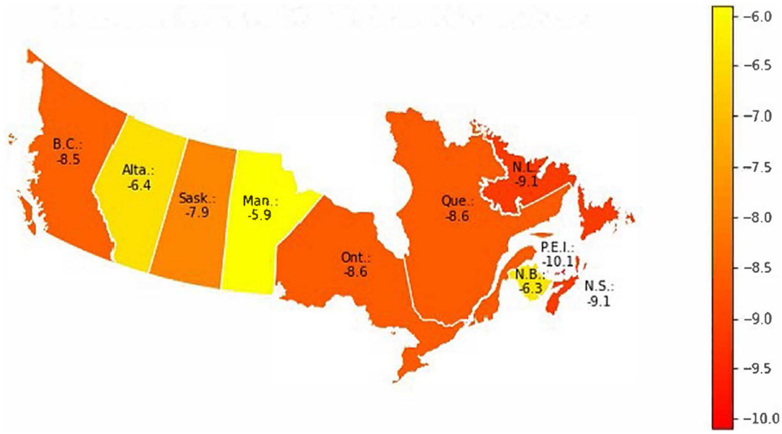

FIGURE 3 Cumulative impacts on GDP (%) by province during 2020. [Color figure can be viewed at `wileyonlinelibrary.com`]

Amongst the larger provinces, Quebec and British Columbia experienced the largest percent loss of GDP over the 12-month period, while Manitoba experienced the least. As can be seen, while the impacts on Quebec are estimated to have been the largest during April and May, its more rapid reopening resulted in much less persistent losses during the summer. Overall, the estimated GDP loss for all the provinces combined during 2020 amounted to just over $165 billion, which was 8.4% of the pre-COVID-19 forecast. When the resource extraction sector is included, the total loss amount to 8.1% (see appendix table A2). Because GDP was forecast to grow at 1.8%, this implies a decline of 6.4% relative to 2019.

4. Results: Projected losses in 2021 under alternative scenarios

In this section, we use the model to consider various alternative scenarios that reflect possible lockdown policy regimes and household behaviour changes through 2021. In each case, we again compare the outcomes to the time paths that were expected in the absence of the COVID-19 pandemic, while holding all other factors constant.[26] We begin by reporting results from a somewhat optimistic baseline scenario that assumes the economy steadily reopens after mid-February 2021, allowing for fairly rapid growth towards the levels that were expected by the end of the year in the absence of the pandemic. We then explore how these projections change under alternative assumptions about

26 As in the previous section, our counterfactual estimates reflect the normal share of hours in each month combined with industry-level GDP forecasts from the Conference Board. We continue to exclude resource industries, but we report results including these in the appendix.

TABLE 3

Impact on GDP relative to counterfactual by province during 2021: Baseline scenario (excluding resource industries)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year (%)	Year ($M)
BC	−3.5%	−2.5%	−5.1%	−4.1%	−4.0%	−3.9%	−3.5%	−2.9%	−2.9%	−2.6%	−2.5%	−2.5%	−3.3%	−9,154
AB	−7.4%	−7.3%	−7.8%	−5.5%	−5.1%	−3.9%	−3.4%	−3.2%	−3.0%	−2.2%	−2.4%	−2.4%	−4.5%	−12,931
SK	−7.0%	−5.9%	−5.5%	−3.2%	−2.6%	−2.8%	−2.7%	−2.7%	−2.5%	−1.9%	−2.0%	−2.1%	−3.4%	−2,276
MB	−6.0%	−4.3%	−5.9%	−4.3%	−4.8%	−4.9%	−4.3%	−4.0%	−3.4%	−2.5%	−2.6%	−2.5%	−4.1%	−2,823
ON	−6.7%	−5.9%	−4.4%	−2.6%	−2.1%	−1.8%	−1.7%	−2.0%	−1.9%	−1.3%	−1.4%	−1.3%	−2.8%	−22,761
QC	−7.0%	−6.7%	−5.3%	−2.5%	−2.0%	−2.1%	−1.9%	−2.1%	−1.9%	−1.5%	−1.5%	−1.5%	−3.0%	−12,223
NB	−5.1%	−4.4%	−4.4%	−2.5%	−2.3%	−2.1%	−2.1%	−2.5%	−2.2%	−1.7%	−1.6%	−1.8%	−2.7%	−900
NS	−5.8%	−2.8%	−3.5%	−2.3%	−1.7%	−1.4%	−1.6%	−1.8%	−1.7%	−1.4%	−1.4%	−1.5%	−2.2%	−918
PE	−10.9%	−8.6%	−6.4%	−2.8%	−3.3%	−1.6%	−1.7%	−1.8%	−1.6%	−1.8%	−1.3%	−1.0%	−3.5%	−225
NL	−4.9%	−5.6%	−3.9%	−2.6%	−2.4%	−1.6%	−2.0%	−2.1%	−1.7%	−1.3%	−1.0%	−1.4%	−2.5%	−567
Canada	−6.4%	−5.7%	−5.2%	−3.3%	−2.9%	−2.6%	−2.3%	−2.4%	−2.3%	−1.7%	−1.8%	−1.7%	−3.2%	−64,779

TABLE 4

Impact on hours worked relative to counterfactual by province during 2021: Baseline scenario (excluding resource industries)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year (%)	Year (1,000s)
BC	−4.8%	−3.9%	−6.3%	−5.1%	−5.4%	−4.9%	−4.5%	−3.9%	−3.9%	−3.5%	−3.2%	−3.2%	−4.4%	−166,444
AB	−10.3%	−10.1%	−10.1%	−6.8%	−6.3%	−5.1%	−4.6%	−4.2%	−3.9%	−3.1%	−3.4%	−3.4%	−6.0%	−203,864
SK	−8.5%	−7.0%	−6.4%	−3.9%	−3.4%	−3.9%	−3.6%	−3.6%	−3.3%	−2.6%	−2.6%	−2.8%	−4.3%	−37,462
MB	−6.9%	−4.9%	−6.1%	−4.2%	−4.2%	−4.5%	−4.5%	−4.5%	−4.0%	−3.2%	−3.2%	−3.2%	−4.5%	−45,196
ON	−9.4%	−8.5%	−6.7%	−4.1%	−3.3%	−2.8%	−2.7%	−2.9%	−2.8%	−2.1%	−2.3%	−2.2%	−4.1%	−478,984
QC	−9.3%	−9.1%	−7.2%	−3.8%	−3.0%	−3.1%	−3.0%	−3.2%	−3.0%	−2.4%	−2.4%	−2.3%	−4.3%	−280,810
NB	−6.5%	−5.3%	−5.1%	−3.2%	−3.0%	−3.1%	−3.1%	−3.4%	−3.1%	−2.5%	−2.4%	−2.5%	−3.6%	−19,864
NS	−8.2%	−4.9%	−5.9%	−3.6%	−3.1%	−3.0%	−3.1%	−3.3%	−3.1%	−2.8%	−2.5%	−2.5%	−3.8%	−27,138
PE	−12.4%	−8.7%	−5.2%	−3.3%	−3.8%	−3.1%	−2.8%	−2.8%	−2.7%	−2.5%	−1.5%	−1.2%	−4.1%	−5,214
NL	−7.7%	−9.0%	−6.5%	−4.3%	−4.1%	−3.5%	−3.5%	−3.7%	−3.5%	−2.8%	−2.1%	−2.5%	−4.4%	−14,253
Canada	−8.7%	−7.9%	−7.1%	−4.4%	−3.9%	−3.5%	−3.3%	−3.4%	−3.2%	−2.6%	−2.6%	−2.6%	−4.4%	−1,279,227

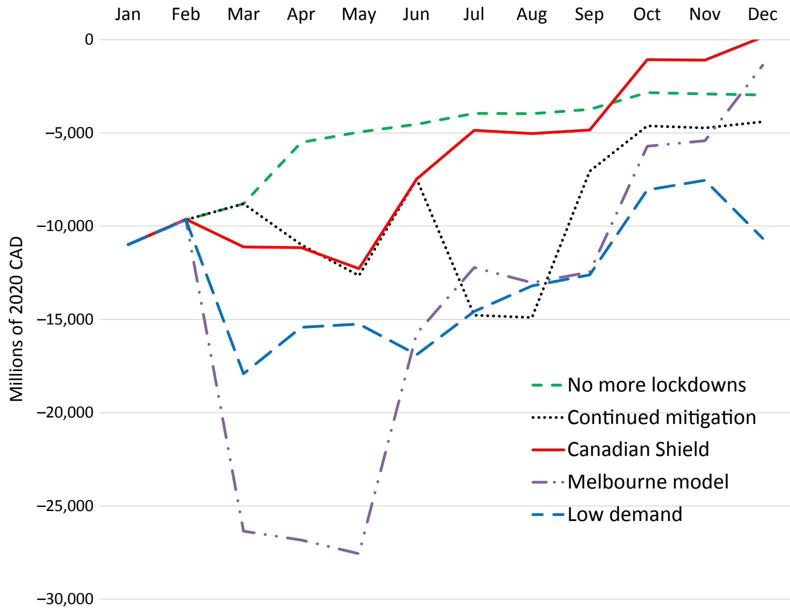

FIGURE 4 Impact on national GDP relative to counterfactual by scenario in 2021 (in millions of CAD). [Color figure can be viewed at wileyonlinelibrary.com]

how COVID-19 may change consumer behaviour and alternative lockdown scenarios.[27]

In all scenarios, we start from the situation observed during January 2021, when all provinces were in relatively restrictive lockdowns in response to a second wave of cases peaking after the holiday period. In most industries and provinces, the economic impact of this lockdown was not as great as those in March and April 2020. This presumably reflects improvements in policymakers' understanding of the spread of the disease and more precise targeting of restrictions, combined with adaptation by the private sector. Figure 4 depicts the forecast time paths of national GDP aggregated across the provinces for each scenario. Tables 5 and 6 provide the projected GDP and hours losses by province for each month during 2021 for each scenario.

4.1. The baseline "no more lockdowns" scenario

We first consider an optimistic scenario in which a further resurgence in COVID-19 cases does not result in additional lockdowns. This possibility could result if vulnerable populations are successfully vaccinated so that

27 In an earlier working paper version completed in August 2020, we considered several other scenarios effecting outcomes during the remainder of that year.

TABLE 5

Impact on GDP relative to counterfactual by province during 2021: Alternative Scenarios (excluding resource industries)

	No more lockdowns		Low demand		Continued mitigation		Canadian Shield		Melbourne model	
Region	%	$Mill	%	$Mill	%	$Mill	%	$Mill	%	$Mill
BC	−3.3	−9,154	−8.7	−23,907	−4.6	−12,681	−3.3	−8,999	−8.2	−22,472
AB	−4.5	−12,931	−8.4	−24,153	−7.4	−21,311	−5.4	−15,704	−8.4	−24,123
SK	−3.4	−2,276	−7.1	−4,778	−6.7	−4,487	−4.8	−3,182	−7.0	−4,674
MB	−4.1	−2,823	−7.9	−5,376	−5.7	−3,858	−4.4	−3,015	−6.6	−4,503
ON	−2.8	−22,761	−7.1	−58,523	−5.1	−41,826	−3.5	−28,848	−7.6	−62,905
QC	−3.0	−12,223	−7.1	−28,712	−5.4	−21,971	−4.1	−16,482	−10.2	−41,441
NB	−2.7	−900	−7.3	−2,407	−4.9	−1,603	−3.3	−1,074	−6.7	−2,216
NS	−2.2	−918	−7.1	−2,894	−3.9	−1,600	−2.5	−1,003	−6.6	−2,707
PE	−3.5	−225	−7.2	−462	−8.2	−525	−5.3	−336	−7.8	−499
NL	−2.5	−567	−6.8	−1,512	−5.1	−1,140	−3.1	−704	−8.1	−1,808
Canada	−3.2	−64,779	−7.5	−152,724	−5.5	−111,002	−3.9	−79,348	−8.2	−167,348

TABLE 6

Impact on hours worked relative to counterfactual by province during 2021: Alternative scenarios (excluding resource industries)

	No more lockdowns		Low demand		Continued mitigation		Canadian Shield		Melbourne model	
Region	%	1,000s	%	1,000s	%	1,000s	%	1,000s	%	1,000s
BC	−4.4	−166,444	−8.5	−324,313	−6.1	−231,283	−4.3	−164,043	−9.4	−355,743
AB	−6.0	−203,864	−8.9	−303,359	−9.9	−337,428	−7.3	−250,642	−10.1	−346,684
SK	−4.3	−37,462	−7.3	−63,769	−7.8	−67,760	−5.6	−49,229	−8.4	−73,665
MB	−4.5	−45,196	−7.5	−76,196	−6.1	−62,163	−4.6	−46,466	−7.8	−79,519
ON	−4.1	−478,984	−7.7	−886,571	−7.2	−828,241	−5.1	−584,248	−9.3	−1,070,226
QC	−4.3	−280,810	−7.8	−501,683	−7.5	−484,882	−5.7	−365,350	−11.2	−721,886
NB	−3.6	−19,864	−7.3	−40,425	−6.1	−33,818	−4.1	−22,721	−7.9	−43,740
NS	−3.8	−27,138	−7.7	−55,083	−6.2	−44,438	−4.1	−28,969	−8.3	−58,815
PE	−4.1	−5,214	−7.0	−8,905	−8.7	−11,109	−5.6	−7,130	−8.6	−10,921
NL	−4.4	−14,253	−8.1	−25,976	−8.2	−26,388	−5.3	−16,965	−9.6	−31,028
Canada	−4.4	−1,279,227	−7.9	−2,286,280	−7.4	−2,127,510	−5.3	−1,535,762	−9.7	−2,792,227

hospitalizations remain low. We assume that starting in February 2021, a staged reopening occurs in a similar fashion to that observed after the first wave. Specifically, in each industry the upper bound on total hours from February to May relative to January 2021 is set equal to that from May to August relative to April 2020. From June 2021, maximum hours in each sector are assumed to adjust according to equation (2). However, export demand from tourism-related industries (Accommodation and Food Services, Transportation and Warehousing, and Arts and Recreation) is assumed to remain 30% lower than was expected in the absence of the pandemic.

Tables 3 and 4 document the implied monthly losses in GDP and hours worked, respectively, by province and for the national economy. Overall, this relatively optimistic scenario implies further losses equal to 3.2% of the pre-COVID-19 GDP forecast in 2021, or almost $65 billion. Note that this implies positive economic growth between 2020 and 2021 equal to 7.9%.[28] Reflecting different starting points in January 2021 and varying sectoral composition, this scenario plays out differently across the provinces. Under these assumptions, Alberta and Manitoba would be the hardest hit overall. Ontario and Quebec would recover relatively quickly from significant losses early in the year, whereas BC's initially lower monthly losses persist, partly reflecting the impact of lost tourism.

4.2. Low demand

Domestic consumer demand in most sectors seem not to have been a constraining factor through 2020.[29] This likely reflects substantial income transfers from the government in the form of CERB and other supports (some of which are also reflected in the model). However, eventually the mounting public sector costs of COVID-19 will need to be paid for. While the extent to which expected future taxes are reflected in current household behaviour remains a matter of debate, it is true that household savings rose substantially in the last quarter of 2020. Although households are not forward-looking in our model, we replicate the possible implications of a decline in expected after-tax wealth by assuming that households' propensity to consume out of current income, $\Phi(t)$, declines by 20% after February 2021 and subsequently recovers only gradually. Other elements of this scenario are the same as the baseline scenario.

This much more pessimistic scenario more than doubles the implied losses during 2021. GDP losses would amount to 7.5% of GDP and a meagre growth

28 Because the counterfactual grows by 2%, the growth rate can be calculated as (1–0.032)*(1.02)/(1–0.085).

29 This conclusion is based on various disparate indicators and survey evidence (e.g., `www.bankofcanada.ca/2021/01/canadian-survey-of-consumer-expectations-fourth-quarter-of-2020/`). Estimates of consumption expenditure by sector are not yet available.

rebound of 2.7% relative to 2020. Moreover, the resulting large losses persist to the end of 2021 and imply further significant losses in subsequent years. This persistent reduction in final demand hurts BC proportionally more than other provinces, reflecting the relative importance of the sectors that were hardest hit.

4.3. Continued mitigation

A significant risk, currently highlighted by many epidemiologists, is that as current restrictions are relaxed, case rates and hospitalizations will again rise. Indeed many observers are currently forecasting that the more highly transmissible "variants of concern" will result in more rapid exponential growth before vaccines are widely available in Canada. To capture these ongoing surges associated with third and possibly fourth waves, we consider a scenario involving cyclical quarterly lockdown restrictions like those imposed in January 2021. We assume these are re-imposed in April and July, followed by staged reopenings in the interim months (as in the baseline scenario). The idea of this scenario is to reflect an "on-again, off-again" lockdown policy regime in which the disease is not fully brought under control until the fall of 2021.

As can be seen from figure 4, this scenario induces a cyclical pattern in hours and production and results in significantly lower economic activity throughout the year compared to the baseline. The worsening losses during the summer months to a large extent reflect the greater economic activity that would normally occur then. Overall, this scenario implies losses equal to 5.5% of 2021 GDP, or about $111 billion. The implied economic growth between 2020 and 2021 would be 5.3%.

4.4. Melbourne model

Several jurisdictions in other countries have taken a much more aggressive stance to combating COVID-19 than most Canadian provinces. In particular, the Australian state of Victoria is well known for its tough two-month lockdown during 2020 that brought locally transmitted case rates down essentially to zero. In this scenario, we introduce a more restrictive lockdown in every province during March and April 2021 that reduces maximum hours worked in each industry by two thirds of the reduction in April 2020.[30] Assuming that these restrictions are successful in largely eliminating local transmission, we assume that they can then be removed in a staged fashion after May 2021. Demand shocks to tourism-related industries are also assumed to ease at the end of the reopening process.

While the economic growth following reopening is the greatest for this scenario, the losses imposed by such a tough two-month lockdown would be sufficiently high that they would more than offset the gains at the end of 2021.

30 While this may seem somewhat arbitrary, the main point is that particularly tough restrictions would be necessary to reduce transmissions to zero.

Overall, the GDP losses imposed by the Melbourne model during 2021 would be very similar to the losses that we estimate occurred in 2020. The impact on Quebec would be particularly severe under this scenario, reflecting the relatively harsh restrictions that would be imposed during the summer months.

4.5. Canadian Shield

While not as stringent as the Melbourne model, the "Atlantic bubble" regime adopted by Canada's four Atlantic provinces (New Brunswick, Nova Scotia, PEI and Newfoundland and Labrador) was initially very effective in maintaining case rates reasonably low. The "Canadian Shield" scenario proposed by the COVID Strategic Choices Group posits that maintaining the lockdown for a longer period of time at the beginning of 2021 will eliminate the need for further lockdown restrictions for the remainder of 2021.[31] We assume that the level of restrictions on hours worked that were in place in January 2021 are extended through April 2021. After this extended period of lockdown, the gradual reopening process is implemented, as in the baseline. As in the Melbourne model, it is assumed that with declining case rates, demand shocks to tourism-related industries are eased at the end of the reopening process.

As can be seen, while this scenario would incur greater short-term losses than the Continued Mitigation scenario during March, it more than makes up for them later in the year to the extent that the early year lockdown measures lead to a near-zero rate of COVID-19 as predicted by the Strategic Choices Group (Agnew et al. 2020) and eliminate the need for additional rounds of lockdowns. The main reason for this is that it avoids many of the losses incurred by greater restrictions during the summer months, when economic activity would normally be relatively high in highly affected industries (e.g., Retail Trade and Accommodation and Food Services). Overall, this scenario would result in GDP losses amounting to just under $80 billion, or 3.9%.

5. Concluding remarks

Our objective in this paper has been to develop and assess a framework to estimate the current and possible future impacts of the COVID-19 pandemic on Canadian provinces, using data that is available with a relatively short time lag. Such a framework can help guide policy when policy-makers need to weigh very costly trade-offs while responding quickly in times of crisis. The framework needs to be flexible enough to allow the consideration of multiple alternative scenarios in a context of low and evolving information regarding the distribution of possibilities. To this end, we have adapted a dynamic input–output model with labour supply constraints, endogenous consumption

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31 See Agnew et al. (2020), Global Canada (2020) as well as `www.covidstrategicchoices.ca`. See also Otto et al. (2021) for an updated version of the epidemiological modelling that shaped these scenarios.

behaviour and seasonal variation. The flexibility of the model to forecast regional economic outcomes over alternative recovery scenarios makes it a useful tool for policy-makers considering different recovery policies.

There are, of course, several limitations to our approach and numerous challenges remain. As noted previously, inherent issues of time disaggregation generate a number of questions for some sectors. We have effectively treated all seasonal variations as being driven by available labour hours, whereas some clearly arise from the demand side, and the production function itself likely varies within the year (see Avelino 2017). A related issue arises in the measurement of industry GDP on a monthly basis inferred via estimates of gross output vs. hours or employment. In their national estimates of monthly GDP, Statistics Canada uses a combination of estimates from different sources (e.g., gross output or sales from the Monthly Survey of Manufacturing and person hours or employment from the Survey of Payroll Employment and Hours). In some sectors, the approach used likely makes little difference, but in others the timing may matter. For example, aggregating to the national level, our estimates of GDP growth for the Manufacturing and the Accommodation and Food Services sectors are very similar to those of Statistics Canada. For agriculture, however, the timing of production in our model is likely rather different from the timing of sales in the data.[32]

The production relationships in the model are quite simple and assume strong complementarity. As noted earlier, however, at the relatively high level of aggregation allowed by the data, substitutability between sectors in production is likely quite limited, even in the long run. Most important substitution of inputs likely occurs between producers *within* these sectors. Note that, even within sectors, the pandemic has revealed significant limitations on substitution of inputs across users, partly because of fragmentation and "just-in-time" production systems.[33] A natural extension, which we plan to consider in further work, would be to allow for a nested production structure that allows for such substitution amongst intermediate producers within sectors and in different locations. A significant challenge to implementing such a generalization is the parameterization of the various elasticities of substitution that would arise.

Several other features of the model, that have been treated in a reduced-form fashion here, could arguably be based on more appealing microfoundations. In doing so, formulating the choices of households and managers in a forward-looking fashion could enhance the framework's usefulness, especially for normative considerations. However, due to the large number a state variables necessitated by the IO structure, there are significant computational challenges in such an undertaking.

32 Nevertheless, the implied contractions in overall national GDP during the first three quarters of 2020 were very close to those estimated by Statistics Canada.

33 We thank a referee for this insight.

Finally, in this paper, we have not integrated any epidemiological features into the model. However, the likelihood and nature of future restrictions will depend on interactions between economic activity and disease transmission rates. Recently, Baqaee et al. (2020) have developed a framework in which age-specific transmission rates reflect the impact of economic activity across industrial sectors in the US economy. However, their model assumes a high degree of substitutability across sectors and does not make implicit the dynamic input–output structure of the economy. As they note, "complementarities in consumption and in production can amplify real GDP losses, relative to what we have reported, by somewhere between 10% and 40%." In related work, we are working on combining state-of-the art epidemiological modelling with the STUDIO model to develop an integrated framework.

Appendix A: Model details

This appendix lays out a variant of the generalized dynamic input–output (GDIO) model of Avelino and Hewings (2019), which we refer to as the short-term under-capacity dynamic input–output (STUDIO) model. The fact that the economy is operating below capacity in the short term implies that the capital stock available to each sector is assumed not to be a constraint on production. However, the hours available for use in production in sector j, $H_j(t)$, is assumed to be subject to a time-varying upper bound, $\bar{H}_j(t)$.[34] During normal times, this upper bound reflects the available labour supply to each industry at each point of time. During a lockdown, it reflects policy decisions and health restrictions and during a reopening it reflects the capacities of industries to expand while ensuring the health and safety of its workers.

A1. Allocation of current production

The maximum potential output that can be produced at time t by sector j is given by the Leontief production function

$$\bar{Q}_j(t) = \min\left[\frac{\bar{z}_{1j}(t)}{A_{1j}},\ \frac{\bar{z}_{2j}(t)}{A_{2j}},\ \ldots,\ \frac{\bar{z}_{Nj}(t)}{A_{Nj}},\ \frac{\bar{H}_j(t)}{A_{Hj}}\right], \tag{A1}$$

where $\bar{z}_{ij}(t)$ denotes the quantity of inputs produced by sector i in the previous period that are available for use in sector j, A_{ij} is the unit input requirement of input i in sector j and A_{Hj} is the unit input requirement for labour hours. The *actual* output produced by sector j is the lesser of $\bar{Q}_j(t)$ and a *scheduled* output level that was determined in the previous period, net of any inventories of intermediate inputs that were unused from the previous period:

34 Such a constraint on factors of production distinguishes the model from standard static IO models and imply that multiplier effects are limited, as in a CGE model.

$$X_j^A(t) = \min\left[\bar{Q}_j(t),\quad X_j^S(t) - I_j^I(t-1)\right] \tag{A2}$$

The stock of materials and supplies produced by sector i for use in sector j that remain unused at the end of period t is given by

$$\Phi_{ij}(t) = \max\left[\bar{z}_{ij}(t) - A_{ij}X_j^A(t),\ 0\right]. \tag{A3}$$

Because prices are assumed fixed in the short run, rationing is required whenever the actual output produced at t falls below that previously scheduled. Here, we assume a uniform rationing rule such that all users of output produced by sector i receive the same fraction of the output produced:

$$r_i(t) = X_i^A(t)/X_i^S(t) \tag{A4}$$

Total hours actually worked in sector i is given by

$$H_i(t) = A_{Hi}X_i^A(t). \tag{A5}$$

Total final demand for goods and services from industry i is then given by

$$Y_i^T(t) = Y_i^C(t) + Y_i^X(t) + Y_i^O(t), \tag{A6}$$

where $Y_i^C(t)$ denotes final consumption demand, $Y_i^X(t)$ denotes final export demand and $Y_i^O(t)$ denotes other final demand (investment expenditures and government consumption). Final consumption demand is given by a potentially time-varying share, $s_i(t)$, of overall consumption:

$$Y_i^C(t) = s_i(t)C(t) \tag{A7}$$

The actual vector of final demand supplied locally is the lesser of total final demand and the fraction of scheduled final demand that is produced plus any inventories of final goods carried over from the previous period:

$$Y_i^A(t) = \min\left[Y_i^T(t),\ Y_i^S(t) \times r_i(t) + I_i^F(t-1)\right] \tag{A8}$$

If there are no constraints on trade, any shortfall in final demand is imported:

$$M_i^F(t) = Y_i^T(t) - Y_i^A(t) \tag{A9}$$

The stock of inventories of finished goods for final demand that will be carried over to the subsequent period are given by the excess supply of output for final demand:

$$I_i^F(t) = (1-\delta_i)\max\left[r_i(t)\,Y_i^S(t) - Y_i^A(t) + I_i^F(t-1),\ 0\right] \tag{A10}$$

A2. Production planning and purchasing of inputs for next period

Managers are assumed to form an expectation of the final demand for each sector i in the next period. We assume this is given by revising up or down the current total final demand by an amount proportional to the current shortfall in final demand:

$$Y_i^E(t+1) = Y_i^T(t) + \sigma\big(Y_i^T(t) - Y_i^A(t)\big) \tag{A11}$$

Managers must then form an estimate of how much output will be required to meet this expected final demand for next period plus the vector of inputs required for the period after that. This calculation is simplified by assuming that the output estimate is equal to the estimate that would be necessary to produce the expected final demand vector in steady state. This is given by applying the Leontief inverse to the vector of expected final demands over and above any inventories of final goods carried forward:

$$\mathbf{X}^R(t+1) = (\mathbf{I} - \mathbf{A})^{-1}\big(\mathbf{Y}^E(t+1) - \mathbf{I}^F(t)\big) \tag{A12}$$

Taking account of labour supply constraints, the constrained required output of good j going forward is

$$X_j^R(t+1) = \min\left[\mathbf{X}_j^R(t+1),\quad \frac{\bar{H}_j(t)}{A_{Hj}}\right]. \tag{A13}$$

This vector of required output implies a matrix of intermediate input requirements that will be needed over and above any materials and supplies carried forward from the current period:

$$z_{ij}^R(t+1) = \max\left[A_{ij}X_j^R(t+1) - \Phi_{ij}(t),\ 0\right] \tag{A14}$$

The matrix of inputs actually purchased locally for use in the next period is then given by the lesser of that required and the rationed fraction of the levels scheduled previously plus any inventories of finished intermediates carried over:

$$z_{ij}^A(t+1) = \min\left[z_{ij}^R(t+1),\quad z_{ij}^S(t) \times r_i(t) + I_i^I(t-1) \times d_{ij}(t)\right] \tag{A15}$$

Here, d_{ij} represents an inventory distribution scheme needed to allocate inventories of good i to production of good j. We assume that inventories are allocated only to sectors in which there is an excess input requirement, in proportion to the allocation of scheduled output. That is,

$$d_{ij}(t) = \frac{\chi_{ij} \times z_{ij}^S(t) \times r_i(t)}{\sum_j \chi_{ij} \times z_{ij}^S(t) \times r_i(t)}, \tag{A16}$$

where

$$\chi_{ij} = \begin{cases} 1, & \text{if } z_{ij}^R(t+1) > z_{ij}^S(t) \times r_i(t) \\ 0, & \text{otherwise} \end{cases}. \tag{A17}$$

In this small open economy, it is assumed that any difference between the required inputs and those that can be produced locally will be imported:

$$M_{ij}^I(t+1) = z_{ij}^R(t+1) - z_{ij}^A(t+1) \tag{A18}$$

Inventories of finished goods for intermediate demand carried into the next period are given by

$$I_i^I(t) = (1-\delta_i)\max\left[\sum_j z_{ij}^S(t)r_i(t) + I_i^I(t-1) - \sum_j z_{ij}^A(t+1),\ \ 0\right], \tag{A19}$$

where δ_i denotes the depreciation rate of inventories in sector i. The total available quantity of inputs produced in sector i that are available for use in sector j next period is then given by

$$\bar{z}_{ij}(t+1) = z_{ij}^A(t+1) + M_{ij}^I(t+1) + \Phi_{ij}(t). \tag{A20}$$

The scheduled output for the next period is

$$X_j^S(t+1) = \min\left[\frac{\bar{z}_{1j}(t+1)}{A_{1j}},\ \frac{\bar{z}_{2j}(t+1)}{A_{2j}},\ \ldots,\ \frac{\bar{z}_{Nj}(t+1)}{A_{Nj}},\ \frac{\bar{H}_j(t)}{A_{Hj}}\right] \tag{A21}$$

and the scheduled inputs to be produced locally are

$$z_{ij}^S(t+1) = RPC_{ij} \times A_{ij} \times X_j^S(t+1), \tag{A22}$$

where RPC_{ij} denotes the regional purchase coefficient for input i in the production of good j. The scheduled final demand vector for next period is then

$$Y_i^S(t+1) = \min\left[Y_i^E(t+1),\ \ X_i^S(t+1) - \sum_j z_{ij}^S(t+1) + I_i^F(t)\right]. \tag{A23}$$

Appendix B: Additional results tables

Table A1 documents the contribution of each sector to the overall percent decline in GDP for each province. The sectors are listed in order of the size of their contributions to the loss for the whole country. These contributions are computed as the product of the percent loss of each sector multiplied by its share of overall GDP (excluding resource industries) divided by the total percent GDP loss for each province. Similarly, table A2 shows the contribution of each sector to the overall percent decline in hours worked.

TABLE A1

Sectoral contribution to percent GDP lost by province during 2020 (excluding resource industries)

Sector	BC	AB	SK	MB	ON	QC	NB	NS	PE	NL	Canada
Finance, Insurance, Real Estate, Rental	24.3%	8.1%	6.8%	3.2%	12.4%	12.5%	11.7%	15.3%	21.7%	11.0%	13.4%
Wholesale and Retail Trade	14.9%	13.6%	12.5%	16.8%	13.8%	10.2%	8.3%	11.2%	13.5%	10.7%	13.1%
Construction	16.7%	9.4%	10.7%	9.5%	12.2%	14.8%	11.0%	10.4%	6.6%	25.3%	13.0%
Manufacturing	0.6%	14.4%	11.3%	13.3%	12.4%	14.2%	13.6%	13.4%	10.2%	4.7%	11.2%
Accommodation and Food Services	7.7%	10.4%	9.0%	7.6%	7.2%	7.3%	6.0%	7.9%	9.2%	6.9%	7.8%
Information, Culture and Recreation	7.8%	5.8%	8.7%	8.9%	5.6%	7.8%	8.9%	8.1%	3.7%	4.4%	6.7%
Transportation and Warehousing	6.8%	4.8%	3.5%	8.1%	7.6%	6.4%	3.6%	4.3%	1.1%	8.0%	6.7%
Health Care and Social Assistance	6.3%	6.4%	4.1%	11.9%	7.8%	4.3%	6.9%	8.6%	9.5%	5.1%	6.6%
Business, Building and Support Services	4.2%	3.3%	1.8%	1.7%	6.4%	3.1%	7.6%	2.4%	5.4%	1.4%	4.6%
Educational Services	2.9%	4.7%	13.8%	3.3%	2.7%	8.0%	9.5%	3.9%	4.3%	8.4%	4.6%
Other Services (except Public Admin.)	4.6%	5.8%	1.5%	1.6%	3.9%	4.6%	6.6%	1.7%	4.7%	5.5%	4.3%
Professional, Scientific and Technical Services	1.0%	5.5%	2.6%	1.1%	3.9%	2.7%	−1.4%	0.6%	2.2%	0.7%	3.2%
Public Administration	0.8%	2.3%	3.1%	0.7%	1.7%	2.1%	−1.3%	10.3%	4.9%	4.8%	1.9%
Utilities	−0.4%	2.4%	2.1%	8.5%	1.7%	1.5%	5.9%	0.6%	−2.3%	1.3%	1.6%
Agriculture	1.7%	3.0%	8.6%	3.8%	0.6%	0.5%	3.2%	1.1%	5.3%	1.8%	1.4%

TABLE A2

Sectoral contribution to percent hours lost by province during 2020 (excluding resource industries)

Sector	BC	AB	SK	MB	ON	QC	NB	NS	PE	NL	Canada
Wholesale and Retail Trade	22.1%	15.9%	12.4%	17.2%	13.4%	11.1%	9.8%	14.2%	17.2%	13.4%	14.4%
Accommodation and Food Services	14.4%	19.1%	18.6%	16.4%	13.0%	13.1%	11.7%	18.7%	15.8%	17.6%	14.3%
Construction	17.2%	9.3%	8.1%	9.3%	12.5%	15.3%	10.9%	13.2%	8.8%	15.4%	13.2%
Health Care and Social Assistance	9.2%	9.2%	5.2%	15.3%	11.1%	5.6%	8.9%	10.5%	10.3%	6.6%	9.3%
Manufacturing	0.6%	8.8%	6.4%	11.1%	10.0%	11.8%	11.3%	13.4%	7.6%	4.1%	9.0%
Transportation and Warehousing	5.4%	4.4%	2.3%	7.5%	9.6%	8.4%	3.3%	4.7%	1.0%	8.6%	7.7%
Other Services (except Public Admin.)	8.4%	10.2%	2.8%	2.7%	6.8%	7.6%	12.7%	2.4%	8.5%	11.3%	7.4%
Information, Culture and Recreation	7.5%	4.8%	9.8%	6.7%	4.0%	7.2%	7.8%	6.7%	2.1%	2.7%	5.6%
Business, Building and Support Services	5.3%	2.8%	2.6%	2.5%	7.2%	3.7%	8.2%	4.0%	4.3%	2.1%	5.3%
Educational Services	3.1%	5.7%	16.2%	3.2%	2.2%	7.4%	9.4%	3.2%	3.1%	6.5%	4.4%
Professional, Scientific and Technical Services	1.2%	6.7%	3.8%	1.2%	4.5%	3.3%	−1.7%	0.7%	4.6%	0.7%	3.7%
Finance, Insurance, Real Estate, Rental	5.9%	1.7%	1.5%	0.7%	3.8%	3.6%	2.3%	2.8%	3.8%	1.6%	3.6%
Agriculture	1.5%	3.7%	5.7%	3.2%	0.6%	0.4%	3.9%	1.5%	8.4%	4.5%	1.4%
Public Administration	0.6%	1.5%	2.2%	0.4%	1.0%	1.4%	−0.7%	4.9%	3.4%	2.9%	1.2%
Utilities	−0.1%	1.5%	0.6%	2.8%	0.6%	0.2%	1.6%	0.2%	−0.1%	0.4%	0.6%

Tables A3 to A6 correspond to tables 1 to 4 but for all sectors, including resource industries.

Appendix C: Recovery plans by province

British Columbia (BC): http://www2.gov.bc.ca/gov/content/safety/emergency-preparedness-response-recovery/COVID-19-provincial-support/bc-restart-plan

Alberta (AB): http://www.alberta.ca/alberta-relaunch-strategy.aspx

Saskatchewan (SK): http://www.saskatchewan.ca/government/health-care-administration-and-provider-resources/treatment-procedures-and-guidelines/emerging-public-health-issues/2019-novel-coronavirus/re-open-saskatchewan-plan

Manitoba (MB): http://www.gov.mb.ca/COVID19/restoring/approach.html

Ontario (ON): http://www.ontario.ca/page/framework-reopening-our-province

Quebec (QC): http://www.quebec.ca/en/health/health-issues/a-z/2019-coronavirus/gradual-resumption-activities-COVID19-related

New Brunswick (NB): http://www2.gnb.ca/content/gnb/en/corporate/promo/COVID-19/recovery.html

Nova Scotia (NS): http://www.novascotia.ca/coronavirus/restriction-updates

Prince Edward Island (PE): http://www.princeedwardisland.ca/en/topic/renew-pei-together

Newfoundland and Labrador (NL): http://www.gov.nl.ca/COVID-19/alert-system

TABLE A3

Impact on GDP relative to counterfactual by province during 2020 (all industries)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year (%)	Year ($Mill)
BC	0.0%	−8.0%	−21.6%	−23.1%	−17.5%	−12.0%	−7.0%	−6.5%	−1.1%	−1.7%	−3.4%	−8.5%	−24,267
AB	0.0%	−3.9%	−19.3%	−20.8%	−13.4%	−6.0%	−3.4%	−3.5%	−2.0%	−1.5%	−3.0%	−6.4%	−24,723
SK	0.0%	−5.8%	−23.5%	−26.0%	−20.4%	−9.4%	−2.1%	−3.3%	0.8%	−1.2%	−3.6%	−7.9%	−7,083
MB	0.0%	−3.3%	−16.5%	−19.6%	−13.4%	−6.2%	−2.2%	−2.2%	−0.2%	−1.8%	−4.6%	−5.9%	−4,050
ON	0.0%	−9.2%	−22.4%	−25.1%	−15.3%	−11.3%	−6.3%	−6.3%	−1.4%	−1.5%	−3.6%	−8.6%	−69,068
QC	0.0%	−10.1%	−30.9%	−34.0%	−12.9%	−5.5%	−2.6%	−1.7%	−0.3%	−0.5%	−4.2%	−8.6%	−35,612
NB	0.0%	−6.9%	−19.6%	−20.7%	−12.0%	−4.9%	−2.9%	−2.8%	−0.1%	−1.2%	−4.0%	−6.3%	−2,062
NS	0.0%	−8.7%	−19.8%	−23.9%	−19.4%	−10.9%	−6.3%	−6.2%	−4.1%	−3.5%	−6.0%	−9.1%	−3,633
PE	0.0%	−10.2%	−24.1%	−26.8%	−17.7%	−8.6%	−5.5%	−4.2%	−5.4%	−7.7%	−10.5%	−10.1%	−624
NL	0.0%	−11.1%	−31.1%	−36.9%	−13.9%	−6.7%	−5.1%	−2.8%	0.1%	0.7%	−1.6%	−9.1%	−3,189
Canada	0.0%	−7.9%	−23.3%	−25.8%	−15.0%	−8.9%	−4.8%	−4.6%	−1.2%	−1.3%	−3.7%	−8.1%	−174,310

TABLE A4

Impact on hours worked relative to counterfactual by province during 2020 (all industries)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year (%)	Year (1,000s)
BC	0.0%	−9.3%	−24.9%	−26.5%	−19.1%	−14.4%	−8.1%	−7.6%	−2.8%	−3.4%	−4.8%	−10.1%	−391,040
AB	0.0%	−6.8%	−24.7%	−26.4%	−16.0%	−9.2%	−5.2%	−5.1%	−2.8%	−3.1%	−5.2%	−8.8%	−325,075
SK	0.0%	−4.2%	−24.1%	−26.5%	−17.7%	−7.2%	−2.7%	−3.5%	−1.8%	−3.9%	−6.3%	−8.3%	−75,912
MB	0.0%	−4.5%	−20.1%	−23.4%	−15.0%	−7.6%	−3.6%	−3.5%	−0.5%	−2.4%	−5.5%	−7.3%	−74,214
ON	0.0%	−10.8%	−27.0%	−29.5%	−17.6%	−14.2%	−7.5%	−7.8%	−2.4%	−2.5%	−4.3%	−10.3%	−1,197,330
QC	0.0%	−11.6%	−34.6%	−37.4%	−13.6%	−7.6%	−2.9%	−1.7%	−0.9%	−1.3%	−4.6%	−9.8%	−640,136
NB	0.0%	−8.2%	−23.5%	−24.5%	−12.7%	−5.5%	−2.8%	−3.2%	−1.7%	−2.5%	−5.0%	−7.5%	−42,613
NS	0.0%	−10.2%	−24.2%	−28.0%	−19.3%	−12.8%	−7.9%	−8.1%	−6.2%	−5.3%	−7.0%	−10.8%	−78,427
PE	0.0%	−10.3%	−26.7%	−29.7%	−20.8%	−10.3%	−6.5%	−5.7%	−8.0%	−9.5%	−12.8%	−11.7%	−15,168
NL	0.0%	−9.1%	−30.6%	−33.9%	−16.5%	−8.9%	−4.9%	−4.7%	0.0%	−0.5%	−3.3%	−9.4%	−32,429
Canada	0.0%	−9.8%	−27.7%	−30.1%	−16.6%	−11.4%	−5.9%	−5.7%	−2.2%	−2.5%	−4.8%	−9.8%	−2,872,345

TABLE A5

Impact on GDP relative to counterfactual by province during 2021: Baseline scenario (all industries)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year (%)	Year ($M)
BC	−3.3%	−2.3%	−4.8%	−3.9%	−3.8%	−3.7%	−3.3%	−2.8%	−2.7%	−2.5%	−2.4%	−2.3%	−3.3%	−9,154
AB	−5.3%	−5.2%	−5.6%	−4.2%	−4.0%	−3.1%	−2.5%	−2.3%	−2.2%	−1.6%	−1.7%	−1.8%	−4.5%	−12,931
SK	−5.8%	−5.1%	−4.6%	−3.1%	−2.6%	−2.5%	−2.1%	−2.2%	−1.9%	−1.4%	−1.4%	−1.5%	−3.4%	−2,276
MB	−6.2%	−4.7%	−5.9%	−4.2%	−4.7%	−4.8%	−4.2%	−3.9%	−3.4%	−2.4%	−2.5%	−2.4%	−4.1%	−2,823
ON	−6.7%	−5.9%	−4.4%	−2.6%	−2.1%	−1.8%	−1.6%	−2.0%	−1.9%	−1.2%	−1.3%	−1.3%	−2.8%	−22,761
QC	−7.1%	−6.9%	−5.2%	−2.5%	−1.9%	−2.1%	−1.8%	−2.0%	−1.8%	−1.5%	−1.5%	−1.5%	−3.0%	−12,223
NB	−5.6%	−4.8%	−4.3%	−2.4%	−2.2%	−2.0%	−2.1%	−2.4%	−2.2%	−1.7%	−1.6%	−1.7%	−2.7%	−900
NS	−5.8%	−2.7%	−3.4%	−2.3%	−1.7%	−1.4%	−1.6%	−1.7%	−1.7%	−1.4%	−1.3%	−1.5%	−2.2%	−918
PE	−11.0%	−8.6%	−6.4%	−2.8%	−3.3%	−1.6%	−1.7%	−1.7%	−1.5%	−1.7%	−1.3%	−1.0%	−3.5%	−225
NL	−8.4%	−8.7%	−2.3%	−1.5%	−2.5%	−0.8%	−1.2%	−1.3%	−1.1%	−0.8%	−0.6%	−0.9%	−2.5%	−567
Canada	−6.4%	−5.7%	−5.2%	−3.3%	−2.9%	−2.6%	−2.3%	−2.4%	−2.3%	−1.7%	−1.8%	−1.7%	−3.2%	−64,779

TABLE A6

Impact on hours worked relative to counterfactual by province during 2021: Baseline scenario (all industries)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year (%)	Year (1,000s)
BC	−4.8%	−3.9%	−6.3%	−5.1%	−5.4%	−4.9%	−4.5%	−3.9%	−3.9%	−3.5%	−3.2%	−3.2%	−4.4%	−166,444
AB	−10.3%	−10.1%	−10.1%	−6.8%	−6.3%	−5.1%	−4.6%	−4.2%	−3.9%	−3.1%	−3.4%	−3.4%	−6.0%	−203,864
SK	−8.5%	−7.0%	−6.4%	−3.9%	−3.4%	−3.9%	−3.6%	−3.6%	−3.3%	−2.6%	−2.6%	−2.8%	−4.3%	−37,462
MB	−6.9%	−4.9%	−6.1%	−4.2%	−4.2%	−4.5%	−4.5%	−4.5%	−4.0%	−3.2%	−3.2%	−3.2%	−4.5%	−45,196
ON	−9.4%	−8.5%	−6.7%	−4.1%	−3.3%	−2.8%	−2.7%	−2.9%	−2.8%	−2.1%	−2.3%	−2.2%	−4.1%	−478,984
QC	−9.3%	−9.1%	−7.2%	−3.8%	−3.0%	−3.1%	−3.0%	−3.2%	−3.0%	−2.4%	−2.4%	−2.3%	−4.3%	−280,810
NB	−6.5%	−5.3%	−5.1%	−3.2%	−3.0%	−3.1%	−3.1%	−3.4%	−3.1%	−2.5%	−2.4%	−2.5%	−3.6%	−19,864
NS	−8.2%	−4.9%	−5.9%	−3.6%	−3.1%	−3.0%	−3.1%	−3.3%	−3.1%	−2.8%	−2.5%	−2.5%	−3.8%	−27,138
PE	−12.4%	−8.7%	−5.2%	−3.3%	−3.8%	−3.1%	−2.8%	−2.8%	−2.7%	−2.5%	−1.5%	−1.2%	−4.1%	−5,214
NL	−7.7%	−9.0%	−6.5%	−4.3%	−4.1%	−3.5%	−3.5%	−3.7%	−3.5%	−2.8%	−2.1%	−2.5%	−4.4%	−14,253
Canada	−8.7%	−7.9%	−7.1%	−4.4%	−3.9%	−3.5%	−3.3%	−3.4%	−3.2%	−2.6%	−2.6%	−2.6%	−4.4%	−1,279,227

Supporting information

Supplementary material accompanies this article.

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