COVID-19 and the Economic Importance of In-Person K–12 Schooling

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The extent to which elementary and secondary (K-12) schools should remain open is at the forefront of discussions on long-term pandemic management. In this context, little mention has been made of the immediate importance of K-12 schooling for the rest of the economy. Eliminating in-person schooling reduces the amount of time parents of school-aged children have available to work and therefore reduces income to those workers and the economy as a whole. We discuss two measures of economic importance and how they can be modified to better reflect the vital role played by K-12 education. The first is its size, as captured by the fraction of gross domestic product produced by that sector. The second is its centrality, reflecting how essential the sector is to the network of economic activity. Using data from Canada’s Census of Population and Symmetric Input–Output Tables, we show how accounting for this role dramatically increases the importance of K-12 schooling.

Keywords: COVID-19, K-12 education, in-person schooling, network centrality
Introduction
A report released in Summer 2020 by Toronto’s Hospital for Sick Children, in collaboration with a number of paediatric hospitals in Ontario, advocates for the safe return of children and youth to school. The report emphasizes the importance of school reopening, highlighting the “significant adverse health and welfare consequences for children and youth” (Hospital for Sick Children 2020, 4) stemming from the school closings of March 2020 in response to the coronavirus disease 2019 (COVID-19) pandemic. Those adverse consequences include impediments to students’ educational, social-emotional, and physical development associated with remote learning, compared with in-person school attendance. The switch to home schooling has also had substantial impacts on parents. A recent report by the Royal Society of Canada highlights how it has exacerbated the detrimental effect of the pandemic on the mental health of Canadians (Royal Society of Canada 2020). The report includes the recommendation that provincial and territorial governments should “attempt to keep children in school and carefully weigh the cost/benefit ratio of closing schools in the event of another wave of COVID-19.”

Another important consideration in deciding whether to keep schools open is the economic implications of children not being in school, acting through its impact on parental paid work. This is the focus of this article. Closing schools means that parents either have to take time off paid work or work from home. As many parents have experienced since the onset of the pandemic, this has meant a reduction in the number of hours available to work, reduced productivity while working, or both. This is in addition to the impact that at-home education has had on life at home and parents’ capacity to nurture, support, and mentor their children.

In this context, the elementary and secondary (K–12) school education system fulfils a role that is crucial but seldom discussed: it frees up daytime hours during the work week of parents with school-aged children, allowing them to supply labour to economic activity and earn income. Without in-person K–12 schooling, it would be hard to imagine the modern work environment functioning as it does.

As Canada navigates its second wave of COVID-19, decision makers are increasingly pressed to balance the public health and economic consequences of the pandemic. However, standard measures of the importance of various sectors to the functioning of the overall economy do not account for the role of the K–12 schooling system in enabling parents to work. The risk is that without measures that capture that role, the economic importance of school opening will be underestimated or, possibly, overlooked altogether. Any such omission would also have distributional implications because the impacts of school closings are unequally felt, disproportionately falling on lone parents and mothers in two-parent families and not directly affecting singles or couples without school-aged children at home. Understanding all aspects of the role played by K–12 schooling has correspondingly grown in importance—as potential grounds for viral transmission, as a determinant of the health and well-being of families and children, and as a sector that is crucial to the economy. This is especially true as vaccines become available and policy-makers must prioritize school teachers, and others in the K–12 school system, relative to other individuals and workers in society.

In this article, we describe and implement measures of the importance of the education sector, and in-person K–12 schooling in specific, for economic activity. In the next two sections, we consider the importance of the education sector as conventionally measured in economic statistics and contrast that with what occurs when we explicitly account for its role in freeing up labour time of parents with school-aged children. We consider two distinct measures of a sector’s importance. The first is a measure of centrality: how much the sector is in the functioning of other sectors of the economy. Using either measure, accounting for the fact that in-person K–12 schooling makes it possible for workers in all sectors to go to work dramatically increases the importance of the K–12 sector. This is detailed in the “Results” section, where we also provide measures of GDP loss if in-person schools were to close.

Two Measures of Importance
We begin by discussing the two measures of a sector’s importance that form the basis of our analysis: size and centrality. The many industries that constitute the Canadian economy can be grouped into 20 broadly defined sectors, based on the goods and services they produce. These can be further broken down to capture increasingly narrow sectors of economic activity. This hierarchical structure is formalized by the North American Industry Classification System (NAICS) 2017 (Version 3.0). It identifies broader sectors using two-digit sector codes and provides increasingly fine or disaggregated categories up to six-digit subindustries. We focus on three-digit subsectors—of which there are approximately 100—but present some results at the two-digit level, and sometimes draw on distinctions reflected at the four-digit industry group level.

The first measure of a sector’s importance is its size, as captured by the fraction of Canada’s GDP that is produced by that sector. This information is drawn from Statistics Canada’s National Economic Accounts and corresponds to the sector’s contribution to the nation’s income or “value added.”

The second measure is less familiar and gauges a sector’s essentiality, or centrality, in the supply chain of the economy. Whereas GDP captures the value of final
goods, the measure of centrality also reflects a sector’s intermediary contribution to other parts of the economy. To understand this, note that the economy is a network of activity, where sectors are nodes that produce and trade intermediate output in the process of producing final goods and services. The latter are ultimately destined to final demand and recorded in macroeconomic accounts as expenditures on consumption, investment, net exports, and government spending (and not as part of the network of intermediate good flows). The output of some sectors is used more intensively as intermediate inputs than others. As a result, they are more central to the economic network, because other sectors depend on them. Meanwhile, downstream sectors are at the periphery of the network structure. They use intermediate inputs from other sectors but produce largely for final demand and are less central than others.

A simple example illustrates this concept. Consider the animal production sector (e.g., poultry farms), which we call Sector A. 3 This sector provides intermediate output to food manufacturing (Sector B; e.g., chicken nugget factories), food and beverage stores (Sector C; e.g., grocery stores), and food services and drinking places (Sector D; e.g., restaurants). Sectors B and C supply to D, and C and D supply to Canadian consumers (as final demand). For simplicity, Sector D supplies only to final demand (i.e., it is not an intermediate producer for other sectors of the economy). Here, Sector A has high centrality because it supplies to all nodes in the supply chain; alternatively, D has low centrality because it is the most downstream, or outermost, node in the production network.

We measure centrality by Bonacich centrality, a concept from graph theory and subsequently introduced to economics (see Bonacich 1987; Carvalho and Tahbaz-Salehi 2019). A sector’s Bonacich centrality is determined by how much of its output is used in the production process of other sectors and how much of those sectors’ outputs are, in turn, used by other sectors, and so on. The derivation of this measure and its theoretical relationship to total expenditure or output shares is detailed in the Appendix. We use Bonacich centrality primarily as a comparative, or ordinal, measure of the importance of nodes in the production network. As such, we report the measure as an index on a 0–100 scale for the sake of exposition, where 100 is the most central three-digit subsector and 0 indicates an entirely non-central subsector.

Both the size and centrality measures are computed using the 2015 Canadian Symmetric Input–Output Tables, compiled by Statistics Canada, for the national economy. The input–output tables provide information on intermediate input usage and total output across subsectors, as well as sectoral labour income and value added. That is, for each three-digit subsector, they detail how much of its production is used as inputs in other subsectors and, conversely, which subsectors it obtains its inputs from.

The size and centrality measures capture different aspects of a subsector’s importance to the economy. For instance, as displayed in Figure 1, the health care and social assistance sector is large in terms of its share of GDP; however, because the vast majority of its output goes toward final demand, it is low in terms of centrality. By contrast, the utilities sector is small in size but highly central because all sectors of the economy use electricity, gas, sewer, and water as inputs.

**Importance of Education**

Educational services is classified both as a two-digit sector (coded 61) and a three-digit subsector (coded 611) in the NAICS; that is, there is no other three-digit subsector in the two-digit education sector. For our analysis, we further distinguish between K–12 schooling (elementary and secondary schools, coded as 611 in the four-digit industry group level) and other schooling services (Codes 6112–6117), such as universities or trade schools, and continue to refer to them as subsectors for expositional convenience. 4

Educational services is not a large subsector of the economy, accounting for less than 6 percent of national GDP (as shown in Figure 1, which we discuss in detail later). This contrasts with the prominence it is given in public policy discourse. Economists believe standard measures of the economic contribution and importance of education, and hence K–12 schooling, are understated. Fundamentally, this is because education generates positive externalities to civil society that are poorly captured in national economic accounts, if at all. Such external or neighbourhood effects are discussed, for example, in Friedman and Friedman (2003, 86):

> A stable and democratic society is impossible without widespread acceptance of some common set of values and without a minimum degree of literacy and knowledge on the part of most citizens. Education contributes to both. In consequence, the gain from the education of a child accrues not only to the child or to his parents but to other members of the society; the education of my child contributes to other people’s welfare by promoting a stable and democratic society.

K–12 education is an investment in externalities to civil society in the distant future. In addition, K–12 education is an investment in human capital that makes workers in all sectors more productive, also in the distant future. Neither impact is captured in contemporaneous national income accounts. Short-term disruptions to schooling as a result of COVID-19 are unlikely to have large impacts on civil society. Whether these disruptions will have serious impacts on human capital accumulation is more uncertain and will almost certainly be the focus of future studies. Because our results do not include these future effects, they should be seen as a...
lower bound on the ultimate effect of school closings on the economy.

At a more immediate level, the K–12 school system provides another essential service: it allows parents and guardians of school-aged children to spend weekday hours as work hours engaged in economic activity in all sectors of the economy. In what follows, we distinguish between workers who have child care obligations that hamper their ability to work (workers needing child care [WNC], defined more precisely later on) from workers whose ability to do paid work is likely unaffected by school closings. Without the K–12 system, the modern work environment would not function as it does. For instance, WNC account for 6.7–23.1 percent of hours worked in Canada, depending on the subsector considered. The loss of in-person schooling effectively reduces labour input available to be supplied in all sectors of the economy.

In addition to the standard measures of importance discussed in the “Two Measures of Importance” section, our goal is to construct extended measures of size and centrality that account for this labour-availing effect. We first construct an alternative measure of size as follows:

1. For each three-digit subsector, we obtain the proportion of employment income that is attributable to WNC from Canada’s 2016 Census of Population. Our focus is on families with children aged 5–17 years, classified into three categories: lone-parent families; two-parent, one-earner families; and two-parent, two-earner families. All lone parents are treated as WNC, and we assume that their ability to work is dependent on in-person K–12 schooling. Conversely, neither parent in two-parent, one-earner families is treated as a WNC; in the case of school closure, we assume home schooling can be done by the non-earning parent. For two-parent, two-earner families, we include one-half of each parent as a WNC in our baseline analysis, and consider alternatives that we describe later.

2. For each three-digit subsector, we know from the input–output tables how much of the subsector’s contribution to GDP is in the form of labour income. We multiply this value by the proportion of employment income in that sector that is attributable to WNC. This gives us the share of the subsector’s contribution to GDP produced by WNC.

3. Finally, we sum these values across subsectors, to obtain the total contribution of WNC to Canada’s GDP. We consider the total size of the K–12 education subsector to be equal to the conventionally measured size of the subsector, plus the size of the WNC sector. In the “Size” section of the Results, we refer to this as the extended K–12 subsector.

This gives a simple estimate of how much of the aggregate economy, specifically its labour income, is dependent on in-person K–12 schooling. In a sense, this is an upper-bound measure because, as we have witnessed during COVID-19, some workers can shift to working from home, educating and caring for their children at the same time, at least in the short run. Even in that case, however, the productivity of WNC is reduced, although perhaps not to zero, as our estimate implies.

We also provide an extended measure of centrality for K–12 education. As detailed later, the standard Bonacich centrality of education is small when conventionally measured. This is because education is on the periphery of the network of economic activity. Essentially all of its output is accounted for in final demand, and little if it is used as intermediate input by other sectors in the supply-chain network.

To account for K–12 education’s role in availing the labour of WNC, we consider a conceptual extension to the economy’s input–output structure. We include a new sector of the economy: one that produces or supplies the labour of WNC. As just discussed, we can measure the fraction of each sector’s labour income owing to WNC. Hence, in considering WNC as its own sector, we can measure its production and supply of labour services to all other sectors of the economy. Extending the analysis requires specifying the WNC sector’s use of (or demand for) output from other sectors. In particular, we assume that the final demand for K–12 education is entirely used by the WNC sector as an intermediate input. Using this extended input–output matrix for the economy, we calculate an extended Bonacich centrality measure, with a particular interest in the value for K–12 schooling.

Results

Size

In Figure 1, we show the (standard) contribution of all sectors in the economy, aggregated to the two-digit NAICS level. The total height of each bar measures the two-digit sector’s share of 2015 Canadian GDP, with the smallest sector being management of companies and enterprises at less than 1 percent of national income and the largest being real estate and rental and leasing at almost 13 percent. As conventionally measured, the share of K–12 schools (the four-digit elementary and secondary schools industry) is small, less than 3 percent of GDP. This is indicated as the dotted, light grey (orange, in the electronic version of the article) portion of educational services.

As discussed in the preceding section, this does not account for the role of K–12 schooling in availing the economy of labour from WNC. For each two-digit sector, this contribution is illustrated by the solid, dark grey (blue) portion of the corresponding bar. For example, the health care and social assistance sector accounts for 7.2 percent of Canadian GDP. Of this, 1.0 percentage point (or just less than one-seventh) corresponds to the income
Recall that we compute the total size contribution of K–12 schooling to the economy by envisioning an extended K–12 subsector. To do so, we sum the size of the standard K–12 subsector (direct contribution) and the size of the WNC subsector (indirect contribution). The total earned by our benchmark definition of WNC discussed in the preceding section; the rest is labour income earned by other workers and business owners, capital income, and so forth. When summed across all sectors, WNC account for 8.9 percent of GDP.

Figure 1: Sectoral Contribution to Canadian GDP

Notes: The bars indicate the share of GDP accounted for by various sectors of the economy, aggregated to the two-digit NAICS level. The dotted light grey (orange) bar is the direct contribution of K–12 schooling, and the solid dark grey (blue) bars are the indirect contributions owing to workers needing child care. The extended K–12 bar is the sum of direct and indirect contributions. See text for details. admin = administration; excl = excluding; GDP = gross domestic product; pub = public; mgmt = management; NAICS = North American Industry Classification System; WNC = workers needing child care.

Source: Authors’ calculations.
contribution of the extended K–12 sector is shown by the rightmost bar in Figure 1. The solid, dark grey (blue) portion of the bar presents the indirect contribution of K–12 education, the contribution of WNC summed across all sectors. To arrive at the total, we add to this the direct GDP contribution of K–12 schools. It amounts to 2.5 percent and is represented by the dotted, light grey (orange) portion of the bar for the extended K–12 subsector. Figure 1 also illustrates the adjustment made to the size of the standard education services, to account for the fact that we distinguish between K–12 and other schooling.

Hence, we arrive at an extended contribution of K–12 schools totalling 11.5 percent of GDP. Even though the K–12 system is officially defined as a four-digit industry group in the NAICS, comprehensively measured as done here, it would represent the second largest two-digit sector of the economy, second only to real estate and rental and leasing.

As stated earlier, this is an upper bound on K–12 schooling’s size importance: parents need not completely stop working if their children are home from school. However, its magnitude suggests that even adjusting for working from home, its importance is large. Suppose, for example, that WNC are effectively half as productive when working from home and simultaneously educating their children. Then K–12 schooling amounts to almost 7 percent of GDP—larger than finance and insurance and just smaller than health care and social assistance.

Finally, these estimates are derived from our benchmark definition of WNC that assumes each parent in a two-parent, two-earner family equally shares the duty of home schooling and its associated time away from work. As an alternative definition, we consider the WNC to be the lower-earning parent in such families as measured in the 2016 Census data. This would be the optimal market-production-versus-home-production choice based on comparative advantage if, for example, both parents were equally productive at home schooling. As a point of reference, the male parent is the higher earner in approximately 70 percent of opposite-sex families, and the female parent is the higher earner 30 percent of the time. More important, evidence from the Canadian Labour Force Survey indicates that mothers have borne the disproportionate burden of parenting since March 2020 (see Beauregard et al. 2020; Schirle and Skuterud 2020). Neither of our definitions necessarily reflects how families have shared parenting responsibilities since the start of the pandemic (a critically important issue that is beyond the scope of this article). For our purposes, however, our various measures allow for reasonable bounds on quantifying the importance of in-person K–12 education.

When we define WNC as the lower earners, the WNC subsector accounts for 5.9 percent of GDP, so that the total contribution of K–12 schools is 8.5 percent of GDP. This would make K–12 education the third-largest two-digit sector of the economy, just ahead of public administration and behind manufacturing. To summarize, accounting for its role in freeing up labour time of parents with school-aged children makes in-person K–12 schooling an important part of the economy in terms of size.

**Centrality**

We next consider the importance of K–12 schooling in terms of its centrality in the economy’s network structure. Recall that we express the Bonacich measure as an index on a 0–100 scale, where the most central three-digit subsector is normalized to 100, and an entirely non-central subsector receives a value of zero. After dividing educational services into two distinct nodes (K–12 schooling and all other education), there are 98 measurable subsectors in the Canadian input–output tables. Given this large number of nodes, we present our results in Appendix Table A.1.

Here, we visually represent the results in two ways. The first is in a simplified, heuristic format displayed in Figure 2. Each bubble or node represents a subsector, with links representing the network structure of the economy. The arrows on those links indicate the direction of intermediate goods and services output flow. The larger the bubble, the greater the subsector’s centrality. Because the number of nodes, \( N = 98 \), is large and the number of potential links in the network, \( N \times (N - 1)/2 \), is even larger, it is not possible to represent all subsectors graphically. Instead, we have selected six nodes, placing the most central one in the centre; network links indicating goods and services flows have been included for those that are quantitatively large. A more detailed representation of Bonacich centrality is presented next, again with complete results documented in Appendix Table A.1.

Figure 2a indicates centrality as conventionally measured. The most central (three-digit) subsector in the Canadian economy is professional, scientific, and technical services (which is also its own sector at the two-digit level), composed of industries that produce, for example, legal, accounting, computer support, and advertising services. Given that these services are used intensively as intermediate inputs by firms in essentially all subsectors, this result is not surprising. The least central subsector is Aboriginal public administration, with a centrality index number of 12.3. K–12 schooling (in light grey [orange in the electronic version of the article]) has a centrality index number of 13.7.

Figure 3 presents the entire distribution of centrality values in the form of a cumulative distribution function. Figure 3a again indicates centrality as conventionally measured. The horizontal axis indicates the Bonacich centrality index between 0 and 100. Each solid, light grey (blue) marker in the figure indicates a subsector. Reading from a marker over to the vertical axis indicates the fraction of subsectors ranked lower in centrality. As in
Figure 2: Heuristic Representation of Centrality in the Canadian Economy: (a) Without a WNC Subsector and (b) With a WNC Subsector

Notes: The size of subsector bubbles represents relative centrality. Professional, scientific, and technical services has (normalized) Bonacich centrality of 100, and the least central subsector, Aboriginal public administration, has centrality of 12.3. The introduction of a WNC subsector increases the centrality of K–12 schooling because WNC is highly central and is highly dependent on K–12 schooling as input. See text for details. WNC = workers needing child care.

Source: Authors’ calculations.

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Figure 3: Distribution of Subsector Centrality in the Canadian Economy: (a) Conventionally Measured Bonacich Centrality and (b) Centrality for Network Structure Extended to Include WNC

Notes: See text for details. mfg = manufacturing; WNC = workers needing child care.

Source: Authors’ calculations.
other advanced economies, the distribution of centrality is fat-tailed, with nearly three-quarters of subsectors having centrality below 25 (relative to professional, scientific, and technical services, with a value of 100) and only eight subsectors with centrality greater than 50 (see, e.g., Acemoglu et al. 2012 and Anufrieva, Goryacheva, and Panchenkob 2016).

K–12 schooling is indicated by the highlighted, dotted (orange) marker. As conventionally measured, K–12 schooling has a centrality index number of 13.7. This makes it the 82nd ranked subsector out of 98, and similar in score to electronics and appliance stores, furniture and related product manufacturing, and personal and laundry services. The low centrality of K–12 schooling is due to the fact that it is a downstream subsector, on the periphery of the production network. It uses intermediate inputs from other sectors, but it produces very little in the way of intermediates itself. Instead, its output is largely “consumed” as final demand.

As discussed, this importance ranking does not account for the role of in-person K–12 schools in availing the economy of the labour time of parents with school-aged children. We model this by assuming the existence of an additional WNC subsector in the network. The WNC subsector is highly central because it provides labour services to all subsectors of the economy; this is the outflow of goods and services from the WNC sector.

Completing the extended input–output analysis requires specifying the WNC subsector’s use of output from all other subsectors. Because this subsector is obviously not listed in the official input–output tables, the inflow of goods and services to WNC must be estimated and taken from final demand. For simplicity, and to minimize deviation from conventional measurement, our benchmark calculation assumes that the WNC subsector uses none of the final demand of other subsectors, except one—it uses in-person K–12 schooling to produce WNC labour services. We assume that the final demand component of K–12 schooling is entirely used by this subsector as an intermediate input.

K–12 schooling is much more important when factoring in its labour-availing role. This is illustrated in Figure 2b and Figure 3b. In our benchmark extension, K–12 education becomes the most central subsector in the economy, taking on an index value of 100. To provide a sense of comparison, professional, scientific, and technical services moves to second (when the fictitious WNC subsector is omitted), with a centrality index number of 66.1.

This uses our benchmark WNC definition, in which one-half of each parent in a two-parent, two-earner family is assigned as WNC. Our alternative definition incorporates the lower-earning parent as part of the WNC subsector. This is presented in the Sensitivity 1 column in Appendix Table A.1. In that case, K–12 schooling remains the most central subsector, but by a smaller margin. Professional, scientific, and technical services remains second, with a centrality value of 94.6.

We provide a final sensitivity analysis (reported in the Sensitivity 2 column of Appendix Table A.1), representing a more substantial departure from the conventional specification of the input-output tables. As we document next, this generates a lower bound on the centrality of K–12 schooling. Here, rather than singling out the labour of WNC, we include two additional subsectors to the analysis, representing all of labour input: WNC and non-WNC. The labour services from both subsectors are outflows to all other subsectors of the economy.

As before, extending the analysis requires specifying labour’s use of output from all other subsectors. That is, we must specify how much Canadian households (both with and without school-aged children) consume from each subsector of the economy in order to provide these labour services. As noted earlier, this is unobservable. Here, we model the inflows from all other subsectors to WNC and non-WNC as being proportional to the WNC and non-WNC shares of aggregate labour income with respect to final demand. Again, the exception is K–12 schooling, where the final demand component of K–12 is entirely used by the WNC subsector as intermediate input (and not at all by non-WNC).

In this specification, K–12 schooling becomes the 13th-ranked subsector in terms of centrality, with an index number of 36.1. This is slightly lower than food manufacturing but higher than petroleum and coal products manufacturing and hospitals. Although less central than in our other extended measures, it is still far above the median and substantially more central than when conventionally measured.

To summarize, the extended measure recognizes the centrality of K–12 schooling as a key intermediate input into a subsector (WNC) that is itself highly central to all others. This indirect effect is what our extended Bonacich centrality measure captures and what the conventional measure misses. Accounting for its role in freeing up the labour time of parents with school-aged children makes in-person K–12 schooling an important part of the economy in terms of centrality.

Closing In-Person K–12 Schools
Our analysis measures the importance of K–12 schooling for the Canadian economy, using data from the 2015 input–output tables and 2016 Census. Our results can also quantify the aggregate implication of suspending K–12 schools, in terms of lost GDP. There are two effects. The first is the direct loss of national income if K–12 schools were to close. As indicated in the “Size” section, this amounts to a loss of 2.5 percent of GDP.10

The second is the indirect, but quantitatively (and conceptually) more important loss stemming from the reduced labour time of WNC. In our baseline definition,
if WNC were unable to work without in-person K–12 schooling, GDP would fall by 8.9 percent. In our more conservative definition (in which the lower earner in two-parent, two-earner families is unable to work), the lost labour productivity of WNC would cost 5.9 percent of GDP.

It is worth noting that the centrality analysis of the “Centrality” section delivers the identical indirect effect, under a particular expression of the counterfactual. The suspension of in-person K–12 schooling generates lost labour productivity of WNC: the productivity of WNC drops to zero without K–12 schools, whereas that of non-WNC is unchanged. Hence, when interpreted as sector-specific labour productivity shocks that are proportional to the sector-specific WNC shares of value added, the loss amounts to either 5.9 percent or 8.9 percent of GDP.13

These effects are large. To provide perspective, real GDP (seasonally adjusted, at an annual rate) fell by an unprecedented 11.5 percent during the second quarter of 2020, as employment declined precipitously (see Baylis et al. 2020; Lemieux et al. 2020). The broad-based return of in-person schooling in Canada since September and the strong rebound in employment and output since then (at the time of writing) is consistent with the importance of in-person K–12 schooling for economic activity.

Conclusion
Public K–12 schooling is a bedrock institution in Canadian society. As the centre of their peer social interactions, schools are integral to the emotional and social development of children and teenagers. K–12 education also plays a key role in socializing engaged and respectful citizens. Moreover, education is critical to the accumulation of human capital that is key to a productive economy.

There is also a more immediate role of K–12 education: it makes it possible for parents of school-aged children to carry out paid work. Our goal in this article is to provide a quantitative assessment of this role. To do so, we augment input-output tables by constructing a hypothetical sector composed of WNC—workers whose ability to work is predicated on having child care for their school-aged children. We calculate how much of national GDP their labour accounts for and the importance of their work to other sectors of the economy.

Our results are striking. Conventionally measured, K–12 schooling accounts for less than 3 percent of total value added. However, when we account for its role in availing the economy of the labour of WNC, its contribution totals 11.5 percent of GDP. In terms of centrality in the supply chain of the economy, the standard measure ranks K–12 schooling 82nd out of 98 three-digit subsectors. Our preferred adjustment suggests that it is in fact the most central sector of the economy, and our lowest estimate places it 13th in rank. Hence, suspending in-person schooling represents not just a loss of output for the economy but a very serious loss of income for the households in which parents are unable to work. Given the aggregate nature of our exercise, we have not investigated the distributional aspects of these results. However, it is clear that the economic costs we consider fall most heavily on women, particularly on lone mothers.

All factors discussed here must be considered when determining whether and in what way to keep schools open as we move through the second and subsequent waves of the COVID-19 pandemic. These factors are also critical in determining the priority of schoolteachers and others in the K–12 system in receiving vaccines as they become available. We contribute to the debate by documenting an aspect of K–12 education that has seldom been discussed—the important part it plays in everyday economic activity.

Notes
1 These concerns have been echoed in provinces across Canada. In its public health guidance for K–12 education issued at the start of the September 2020 school year, the BC Centre for Disease Control similarly stresses the importance of in-person schooling and the “significant hardship” resulting from the suspension of in-person learning in terms of “impaired learning, increased child stress, and decreased connection” (BC Centre for Disease Control 2020, 1). The Association des pédiatres du Québec (2020) has also called attention to the impact of first-wave school closures on children’s well-being and their interaction with existing inequalities in family resources—financial, psychological, and otherwise. These considerations are incorporated in a report prepared on behalf of the Quebec Ministry of Health and Social Services, to support health professionals advising parents on the return of children to the school environment (Québec, Ministry of Health and Social Services 2020). Finally, Haecck and Lefebvre (2020) have estimated that school closures could increase socio-economic inequality in educational outcomes by more than 30 percent.

2 School-aged children cannot easily be left at home alone. For instance, Manitoba and New Brunswick have legislated that children aged younger than 12 years cannot be left unsupervised, and Ontario’s Child and Family Services Act states that a child aged younger than 16 years may not be left unattended “without making provision for his or her supervision and care that is reasonable in the circumstances” (Ontario 1990).

3 Technically, animal production is referred to as a subsector in the NAICS. For now, we refer to subsectors as sectors for short and are more accurate in our reference to NAICS classifications in the “Importance of Education” and “Results” sections.

4 As a point of reference, K–12 schools make up approximately 54 percent of the education sector, with the remainder being trade schools, college, university, and miscellaneous or other educational services.

5 The term WNC is somewhat misleading because it brings to mind child care for pre-school children. We do not take
account of issues related to child care for pre-school age children because our focus is on elementary and secondary schools.

6 We view this assumption, that child care is symmetrically divided in two-parent, two-earner families, as a benchmark; it reflects neither anecdotal nor quantitative evidence on how the pandemic has differentially affected family members (see Qian and Fuller 2020). We provide measures based on an asymmetric definition of WNC in the “Results” section. Workers not needing child care, or non-WNC, include one-half of each parent in two-parent, two-earner families; individuals without school-aged children; and the parent doing paid work in two-parent, one-earner families.

7 Note that, to avoid double counting, we first subtract the value of WNC who work in the standard K–12 subsector.

8 This is a now often-used construct in the New Keynesian macroeconomics literature to model wage-setting behaviour; see Erceg, Henderson, and Levin (2000) and Christiano, Eichenbaum, and Evans (2005).

9 This drop in ranking comes from two effects. The first is the inclusion of a portion of all subsectors’ final production as intermediate inflows into the WNC and non-WNC subsectors (and not just the K–12 subsector as an intermediate into WNC). Because the centrality index is a relative measure, this increases the centrality of all other subsectors and decreases the centrality of K–12 schooling. The second effect comes from the inclusion of the non-WNC sector, which is much larger than WNC. Because centrality depends on size and connectedness, this amplifies the first effect.

10 Obviously, if K–12 schools closed and factor input payments (teacher and administrator salaries, capital rental and lease payments) continued to be made, the loss would be significantly less.

11 This is a direct application of Hulten (1978)’s theorem, because our input–output model (as detailed in the Appendix) features Cobb–Douglas production, perfect competition, and efficiency of equilibrium. See also Baqae and Farhi (2019).

12 The choice of the numeraire good is arbitrary and immaterial to the derivation and results.

13 Hence, given Cobb–Douglas production, the elasticity of substitution between labour input of WNC and non-WNC is unity. This differs from the implicit assumption embodied by our extended analysis for sectoral size based on shares of national income; there the elasticity of substitution is assumed to be infinite.

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Appendix

Consider a multi-sector economy with input–output linkages. There are \( J \) sectors of the economy. Sector \( j \) production is Cobb–Douglas and constant returns to scale and is given by

\[
y_j = z_j \ell_j^{1-\eta_j} I_j^{\eta_j}, \quad j \in \{1, 2, \ldots, J\}.
\]  

(1)

Here, \( z_j \) is the productivity of sector \( j \) (which can be a composite of sectoral capital and technology), \( \ell_j \) is sector \( j \) labour input, and \( I_j \) is the sector’s intermediate input. Intermediates are produced by other sectors, giving rise to the network structure of the economy. Specifically,

\[
I_j = \sum_{k=1}^{J} \alpha_{jk} y_k, \quad \sum_{j=1}^{J} \alpha_{jk} = 1.
\]

(2)

Markets are perfectly competitive. The representative firm in sector \( j \) maximizes profit, taking prices \( \{P_k\}_{vk} \) as given:

\[
\max_{\ell_j \{y_{jk}\}_{vk}} p_j z_j \ell_j^{1-\eta_j} I_j^{\eta_j} - \sum_{k=1}^{J} P_k y_{jk} - \omega \ell_j.
\]

Normalizing \( \omega = 1 \), prices are expressed in terms of the numeraire. The first-order condition with respect to sector \( j \)'s intermediate input use of goods from sector \( k \), \( y_{jk} \), can be written as

\[
p_k y_{jk} = \eta_j \alpha_{jk} \ell_j^{1-\eta_j} I_j^{\eta_j} = \eta_j \alpha_{jk} p_j y_j.
\]

(2)

Expressed in units of goods, equilibrium market clearing requires supply equal demand in all sectors \( k \in \{1, 2, \ldots, J\} \):

\[
y_k = \bar{f}_k + \sum_{j=1}^{J} y_{jk},
\]

where demand is composed of both final demand, \( \bar{f}_k \) (e.g., as consumption, investment goods), and intermediate good demand (from all sectors). Multiplying this by \( p_k \) and substituting in Equation (2),

\[
p_k y_k = p_k \bar{f}_k + \sum_{j=1}^{J} \eta_j \alpha_{jk} p_j y_j.
\]

(3)

Note that \( \sum_{j=1}^{J} p_j y_j \) is total output (both final and intermediate good use, expressed in terms of the numeraire). Dividing Equation (3) by this gets

\[
s_k = \bar{f}_k + \sum_{j=1}^{J} \eta_j \alpha_{jk} s_j,
\]

where \( s_j \) is sector \( k \)'s share of total output and \( f_i \) is sector \( k \)'s final good share of total output. Because this holds for all \( k \in \{1, 2, \ldots, J\} \), rewrite this in matrix form:

\[
s = f + As,
\]

(4)

where \( s = (s_1, \ldots, s_J)' \) and \( f = (f_j, \ldots, f_J)' \) are \((J \times 1)\) vectors, and \( A \) is a \((J \times J)\) matrix where the \((j,k)\)th element, \( a_{jk} = \eta_j \alpha_{jk} \), is the expenditure share on sector \( k \)'s production in sector \( j \).

Equation (4) can be rewritten as

\[
s = (I - A)^{-1} f.
\]

(5)

\((I - A)^{-1}\) is known as the economy’s Leontief Inverse matrix and can be expressed as

\[
(I - A)^{-1} = I + A + A^2 + A^3 + \ldots
\]

Hence, the \((j,k)\)th element of the Leontief Inverse matrix measures the importance of sector \( k \) as a direct and indirect intermediate input supplier to sector \( j \) in the economy’s network structure. Let \( 1 \) denote a \((J \times 1)\) vector of ones. Bonacich centrality, \( v \), is given by

\[
v = \frac{1}{J} (I - A)^{-1} 1.
\]

(6)

Hence, \( v \) (also referred to as the influence vector) is \((J \times 1)\), where the \( j \)th element measures the importance of sector \( j \) summed across all sectors of the economy.

Given this, the extension of the centrality analysis discussed in the “Importance of Education” section requires minimum modification. The change is conceptual, and it assumes that the labour input of workers needing child care (WNC) is a distinct factor of production from the labour of those without school-aged children (non-WNC). That is, in the sector \( j \) production function of Equation (1), \( \ell_j \) now denotes labour of non-WNC, and WNC labour becomes its own sector. Correspondingly, the number of sectors increases to \( J + 1 \). Sector \( j \) purchases WNC labour for use as an intermediate input in \( I_j = \prod_{k=1}^{J} \alpha_{jk} y_k \).

Let the WNC sector be denoted as sector \( w \). Hence, empirically, \( a_{jw} = \eta_j \alpha_{jw} \) is sector \( j \)'s expenditure share of labour income payments to WNC workers, in the extended model’s \((J \times J)\) matrix of Equation (4).

Implementation also requires specifying how sector \( w \)'s output (WNC labour) is produced. As with all other sectors, we assume a Cobb–Douglas functional form:

\[
y_{w} = z_{w} \ell_{w}^{1-\eta_{w}} I_{w}, \quad I_{w} = \sum_{k=1}^{J} \alpha_{wk} y_{wk}.
\]

(6)

In our benchmark specification, we assume that the \( a_{wk} = 0 \) for all \( k \) except for the K–12 sector, which takes a value of 1. In the specification for our sensitivity analysis, \( a_{wk} > 0 \) for all \( k \), with values corresponding to sectoral inflows being proportional to the WNC share of aggregate labour income with respect to final demand; again, the exception is K–12 schooling, where the final demand component of K–12 is entirely used by the WNC sector.

Finally, it is worth reiterating that the analysis in the “Results” section centers on the Bonacich centrality of...
schooling is an important input into WNC, a sector that is itself highly central to all other sectors.

### Table A.1: Subsector Centrality in the Canadian Economy

| NAICS three-digit subsector                                      | Conventional | Extended | Sensitivity 1 | Sensitivity 2 |
|-----------------------------------------------------------------|--------------|----------|---------------|---------------|
| Elementary and secondary schools                                | 13.6         | 100.0    | 100.0         | 36.1          |
| Professional, scientific, and technical services                | 100.0        | 66.1     | 94.6          | 79.4          |
| Administrative and support services                             | 68.5         | 46.3     | 65.8          | 42.0          |
| Chemical manufacturing                                          | 70.0         | 45.7     | 65.7          | 40.5          |
| Primary metal manufacturing                                    | 56.8         | 37.0     | 53.2          | 37.8          |
| Oil and gas extraction                                          | 55.8         | 36.7     | 52.6          | 45.8          |
| Petroleum and coal products manufacturing                      | 54.6         | 35.9     | 51.5          | 33.5          |
| Credit intermediation and related activities                    | 52.6         | 34.2     | 49.2          | 46.8          |
| Transportation equipment manufacturing                         | 50.3         | 32.7     | 47.1          | 53.1          |
| Real estate                                                     | 46.4         | 30.4     | 43.7          | 100.0         |
| Truck transportation                                            | 44.7         | 29.1     | 41.8          | 28.8          |
| Insurance carriers and related activities                       | 40.4         | 26.2     | 37.8          | 29.1          |
| Support activities for transportation                           | 38.3         | 24.9     | 35.8          | 19.9          |
| Mining and quarrying (except oil and gas)                       | 37.8         | 24.5     | 35.3          | 22.8          |
| Fabricated metal product manufacturing                         | 37.3         | 24.5     | 35.2          | 25.0          |
| Heavy and civil engineering construction                        | 35.0         | 24.1     | 34.0          | 60.7          |
| Computer and electronic product manufacturing                  | 36.8         | 24.1     | 34.6          | 19.6          |
| Utilities                                                       | 36.2         | 24.1     | 34.3          | 26.2          |
| Machinery manufacturing                                         | 36.6         | 24.0     | 34.4          | 21.0          |
| Plastics and rubber products manufacturing                      | 36.8         | 23.9     | 34.4          | 20.1          |
| Food manufacturing                                              | 35.0         | 22.6     | 32.6          | 38.3          |
| Telecommunications                                              | 30.8         | 20.1     | 28.9          | 25.5          |
| Management of companies and enterprises                         | 29.9         | 19.4     | 27.9          | 15.1          |
| Funds and other financial vehicles                              | 29.3         | 19.0     | 27.3          | 24.2          |
| Paper manufacturing                                             | 28.6         | 18.7     | 26.9          | 16.0          |
| Motion picture and sound recording industries                   | 28.5         | 18.5     | 26.6          | 10.7          |
| Rental and leasing services                                     | 25.4         | 16.5     | 23.8          | 12.7          |
| Machinery, equipment, and supplies merchant wholesalers          | 25.0         | 16.3     | 23.5          | 17.9          |
| Electrical equipment, appliance, and component manufacturing    | 24.7         | 16.3     | 23.3          | 12.7          |
| Farms                                                          | 24.8         | 16.0     | 23.1          | 18.3          |
| Repair and maintenance                                          | 24.0         | 15.9     | 22.7          | 13.5          |
| Food services and drinking places                               | 24.0         | 15.6     | 22.4          | 26.4          |
| Publishing industries (except Internet)                        | 22.4         | 15.4     | 21.8          | 11.6          |
| Animal production                                               | 23.2         | 15.0     | 21.6          | 14.9          |
| Lessors of non-financial intangible assets (except copyrighted works) | 22.4   | 14.5     | 20.9          | 9.9           |
| Printing and related support activities                         | 21.4         | 14.3     | 20.4          | 8.7           |
| Air transportation                                              | 21.9         | 14.3     | 20.5          | 12.7          |
| Miscellaneous merchant wholesalers                               | 21.7         | 14.1     | 20.3          | 11.8          |
| Local, municipal, and regional public administration            | 20.7         | 14.0     | 19.9          | 30.0          |
| Support activities for mining and oil and gas extraction        | 21.4         | 14.0     | 20.1          | 13.3          |
| Wood product manufacturing                                      | 21.4         | 13.8     | 19.9          | 14.4          |
| Non-metallic mineral product manufacturing                      | 20.8         | 13.5     | 19.4          | 11.7          |
| Miscellaneous manufacturing                                     | 20.8         | 13.5     | 19.4          | 9.6           |
| Personal and household goods merchant wholesalers               | 20.1         | 13.1     | 18.9          | 13.6          |

(Continued)
Table A.1: Continued

| NAICS three-digit subsector | Conventional | Extended | Sensitivity 1 | Sensitivity 2 |
|-----------------------------|--------------|----------|---------------|---------------|
| Textile and textile product mills | 20.3         | 13.1     | 18.9          | 6.9           |
| Forestry and logging        | 19.9         | 12.8     | 18.5          | 8.4           |
| Waste management and remediation services | 19.4         | 12.8     | 18.3          | 8.5           |
| Building material and supplies merchant wholesalers | 19.6         | 12.8     | 18.4          | 11.9          |
| Couriers and messengers     | 19.5         | 12.6     | 18.2          | 8.1           |
| Performing arts, spectator sports, and related industries | 19.1         | 12.4     | 17.8          | 7.8           |
| Accommodation services      | 18.9         | 12.3     | 17.7          | 10.9          |
| Broadcasting (except Internet) | 18.6        | 12.0     | 17.3          | 7.4           |
| Rail transportation         | 18.4         | 11.9     | 17.2          | 9.2           |
| Ambulatory health care services | 18.5        | 11.9     | 17.2          | 23.0          |
| Motor vehicle and parts dealers | 17.4        | 11.3     | 16.3          | 11.5          |
| Motor vehicle and motor vehicle parts and accessories merchant wholesalers | 17.5 | 11.3 | 16.3 | 10.2 |
| Beverage and tobacco product manufacturing | 17.4 | 11.2 | 16.2 | 9.1 |
| Pipeline transportation     | 16.9         | 11.0     | 15.8          | 8.1           |
| Scenic and sightseeing transportation | 13.3 | 10.9 | 14.6 | 5.1 |
| Water transportation        | 16.8         | 10.8     | 15.6          | 6.1           |
| Other information services | 16.3         | 10.5     | 15.2          | 5.4           |
| Provincial and territorial public administration | 16.2 | 10.5 | 15.1 | 39.7 |
| Support activities for agriculture and forestry | 16.2 | 10.5 | 15.1 | 5.3 |
| Food, beverage, and tobacco merchant wholesalers | 16.0 | 10.3 | 14.9 | 10.6 |
| Federal government public administration | 15.7 | 10.1 | 14.6 | 26.1 |
| Building material and garden equipment and supplies dealers | 15.6 | 10.1 | 14.6 | 7.7 |
| Religious, grant-making, civic, and professional and similar organizations | 15.5 | 10.1 | 14.5 | 11.7 |
| Petroleum and petroleum product merchant wholesalers | 15.5 | 10.0 | 14.5 | 6.3 |
| Educational services except K–12 | 15.5 | 10.0 | 14.4 | 22.1 |
| Warehousing and storage     | 15.5         | 10.0     | 14.4          | 5.5           |
| Data processing, hosting, and related services | 15.4 | 9.9 | 14.3 | 5.5 |
| Specialty trade contractors | 15.3         | 9.9      | 14.3          | 5.5           |
| Postal service              | 15.0         | 9.7      | 14.0          | 5.5           |
| Food and beverage stores    | 14.8         | 9.5      | 13.8          | 12.5          |
| General merchandise stores  | 14.7         | 9.5      | 13.7          | 8.8           |
| Business-to-business electronic markets and agents and brokers | 14.5 | 9.4 | 13.5 | 5.3 |
| Hospitals                   | 14.5         | 9.4      | 13.5          | 32.2          |
| Gasoline stations           | 14.4         | 9.3      | 13.4          | 6.7           |
| Clothing and leather and allied product manufacturing | 14.2 | 9.3 | 13.3 | 4.7 |
| Amusement, gambling, and recreation industries | 14.2 | 9.2 | 13.2 | 8.4 |
| Health and personal care stores | 14.1 | 9.1 | 13.1 | 8.9 |
| Transit and ground passenger transportation | 13.7 | 9.0 | 12.9 | 5.8 |
| Personal and laundry services | 13.9 | 9.0 | 12.9 | 8.2 |
| Furniture and related product manufacturing | 13.6 | 8.8 | 12.7 | 7.1 |
| Clothing and clothing accessories stores | 13.5 | 8.7 | 12.5 | 8.6 |
| Electronics and appliance stores | 13.4 | 8.7 | 12.5 | 5.2 |
| Non-store retailers         | 13.3         | 8.6      | 12.4          | 5.3           |
| Miscellaneous store retailers | 13.3       | 8.6      | 12.4          | 5.4           |
| Furniture and home furnishings stores | 13.3 | 8.5 | 12.3 | 5.9 |
| Social assistance           | 13.2         | 8.5      | 12.3          | 8.1           |
| Farm product merchant wholesalers | 13.1       | 8.4      | 12.2          | 4.7           |

(Continued)
Table A.1: Continued

| NAICS three-digit subsector                      | Conventional | Extended | Sensitivity 1 | Sensitivity 2 |
|------------------------------------------------|--------------|----------|----------------|---------------|
| Fishing, hunting, and trapping                  | 12.9         | 8.3      | 12.0           | 4.4           |
| Sporting goods, hobby, book, and music stores   | 12.9         | 8.3      | 12.0           | 4.9           |
| Nursing and residential care facilities         | 12.7         | 8.2      | 11.8           | 10.3          |
| Heritage institutions                           | 12.5         | 8.1      | 11.6           | 4.1           |
| Monetary authorities—central bank               | 12.4         | 7.9      | 11.5           | 3.5           |
| Construction of buildings                       | 12.3         | 7.9      | 11.4           | 49.8          |
| Aboriginal public administration                | 12.3         | 7.9      | 11.4           | 5.4           |

Notes: Normalized Bonacich centrality for various subsectors of the economy at the 3-digit NAICS level. See text for details. NAICS = North American Industry Classification System.
Source: Authors’ calculations.