Title:

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

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Abstract:

The extent to which K-12 schools should remain open is at the forefront of discussions on long-term pandemic management. In this context, there has been little mention 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 GDP 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.

1. Introduction

A report released in the summer of 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 (Hospital for Sick Children 2020). The report emphasizes the importance of school reopening, highlighting the "significant adverse health and welfare consequences for children and youth" stemming from the school closings of March 2020 in response to the COVID-19 pandemic. Those adverse consequences include impediments to students' educational, social-emotional, and physical development associated with remote learning, as compared to in-person school attendance.[1] The switch to home schooling has also had substantial impacts on parents. A recent report by the Royal Society of Canada highlights how this 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/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 the current paper. 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 the capacity of parents to nurture, support, and mentor their children.

In this context the K-12 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.[2]

As Canada navigates its second-wave, decision makers are increasingly pressed to balance the public health and economic consequences of the pandemic. But 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 capturing that role, the economic importance of school opening will be underestimated or, possibly, overlooked altogether. Any such omission would also have distributional implications since the impacts of school closings are unequally felt—disproportionately falling on lone parents and mothers in two-parent families, and not directly impacting 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 policymakers must prioritize school teachers, and others in the K-12 school system, relative to other individuals and workers in society.

In this paper, we describe and implement measures of the importance of the education sector, and in-person K-12 schooling specifically, for economic activity. In Sections 2 and 3, 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 *size*: the fraction of national income (GDP) that is attributable to the education sector. The second is a measure of *centrality*: how essential 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 Section 4, where we also provide measures of GDP loss if in-person schools were to close.

2. 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 2-digit sector codes, and provides increasingly

fine/disaggregated categories up to 6-digit subindustries. We focus on 3-digit "subsectors"—of which there are approximately 100—but present some results at the 2-digit level, and sometimes draw on distinctions reflected at the 4-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 the 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 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, since 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 as it supplies to all nodes in the supply-chain; on the other hand, *D* has low centrality as 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/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 3-digit subsector, and 0 indicates the subsector is entirely non-central.

Both the size and centrality measures are computed using the 2015 Canadian Symmetric Input-Output Tables, compiled by Statistics Canada (StatCan) 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 3-digit subsector, it details 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 below, 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, “Utilities” is small in size but highly central because all sectors of the economy use electricity, gas, sewer, and water as inputs.

3. Importance of Education

“Educational services” is classified both as a 2-digit sector (code 61) and a 3-digit subsector (code 611) in the NAICS; that is, there is no other 3-digit subsector in the 2-digit education sector. For our analysis, we further distinguish between K-12 schooling (“Elementary and secondary schools”, coded as 6111 at the 4-digit industry group level) and other schooling services (codes 6112 through 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 below). 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 (1963):

> 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 toward externalities to civil society in the distant future. In addition, K-12 education is an investment toward human capital that makes workers in all sectors more productive, also in the distant future. Neither impacts are captured in contemporaneous national income accounts. Short term disruptions to schooling due to COVID 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. Since 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/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-childcare*, or WNC, hereafter, and defined more precisely below) from workers whose ability to do paid work is likely unaffected by school closings.[5] Without the K-12 system, the modern work environment would not function as it does. For instance, workers-needing-childcare account for 6.7 percent to 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 Section 2, 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:

- For each 3-digit subsector, we obtain the proportion of employment income that is attributable to workers-needing-childcare from Canada's 2016 Census of Population. Our focus is on families with children aged 5 to 17 years old, classified in 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 to be described below.[6] [7]
- For each 3-digit subsector, we know from 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 workers-needing-childcare. This gives us the share of the subsector's contribution to GDP produced by WNC.

- Finally, we sum up these values across subsectors, to obtain the total contribution of workers-needing-childcare 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 Section 4.1, we refer to this as the "Extended K-12" subsector.[8]

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

We also provide an extended measure of centrality for K-12 education. As detailed below, 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, while little of it is used as intermediate input by other sectors in the supply-chain network.

To account for its role in availing the labour of workers-needing-childcare, we consider a conceptual extension to the economy's input-output structure. We include a new sector of the economy: one that produces/supplies the labour of WNC.[9] 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/supply of labour services to all other sectors of the economy. Extending the analysis requires specifying the workers-needing-childcare 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.

4. Results

4.1 Size

In Figure 1, we show the (standard) contribution of all sectors in the economy, aggregated to the 2-digit NAICS level. The total height of each bar measures the 2-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 4-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 paper) portion of "Educational services."

[FIGURE 1 GOES ABOUT HERE]
Title: Sectoral Contribution to Canadian GDP

Notes: The bars indicate the share of GDP accounted for by various sectors of the economy, aggregated to the 2-digit NAICS level. The dotted light grey (orange) bar is the direct contribution of K-12 schooling, the solid dark grey (blue) bars are the indirect contributions owing to workers-needing-childcare (WNC). The "Extended K-12" bar is the sum of direct and indirect contributions. Author's calculations. See text for details.

As discussed in Section 3, this does not account for the role of K-12 schooling in availing the economy of labour from workers-needing-childcare. For each 2-digit sector, this contribution is illustrated by the solid, dark grey (blue) portion of the corresponding bar. For example, the "Health care and social service" 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 earned by our benchmark definition of WNC discussed in Section 3; the rest is labour income earned by other workers and business owners, capital income, etc. When summed across all sectors, workers-needing-childcare account for 8.9 percent of GDP.

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 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 4-digit industry group in the NAICS, comprehensively measured as done here, it would represent the second largest 2-digit sector of the economy, second only to “Real estate and rental and leasing.”

As stated above, 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. But its magnitude suggests that even adjusting for working from home, its importance is large. Suppose, for example, that workers-needing-childcare 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 service.”

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-vs-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 while the female parent is the higher earner 30 percent of the time. Importantly, 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 reflect how families have shared parenting responsibilities since the start of the pandemic (a critically important issue that is beyond the scope of this paper). But for our purposes, our various measures allow for reasonable bounds on quantifying the importance of in-person K-12 education.

When we define workers-needing-childcare as the lower earner, 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 2-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.

4.2 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 3-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 table. Given this large number of nodes, we present our results in Appendix Table 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 direction(s) 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×(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/services flows have been included for those that are quantitatively large. A more detailed representation of Bonacich centrality is presented below, again, with complete results documented in Appendix Table 1.

[FIGURE 2 GOES ABOUT HERE. The two panels can be typeset either up/down (above/below each other) or left/right (beside each other); please adjust the references in the paper's text to reflect your choice, for the rest of Subsection 4.2]
Title: Heuristic Representation of Centrality in the Canadian Economy
Notes: Left/Top panel—Professional, scientific and technical services has (normalized) Bonacich centrality of 100. The least central subsector, Aboriginal public administration, has centrality of 12.3. The size of subsector bubbles represents relative centrality. Right/Bottom panel—The introduction of a workers-needing-childcare (WNC) subsector increases the centrality of K-12 schooling. This is because WNC is highly central and is highly dependent on K-12 schooling as input. Author's calculations. See text for details.

The left/top panel indicates centrality as conventionally measured. The most central (3-digit) subsector in the Canadian economy is "Professional, scientific and technical services" (which is also its own sector at the 2-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, or orange in the electronic version of the paper) 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 (CDF). Again, the left/top panel 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 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, for instance, Acemoglu et al. 2012; and Anufrieva, Goryachevaa, and Panchenkob 2016).

[FIGURE 3 GOES ABOUT HERE. The two panels can be typeset either up/down (above/below each other) or left/right (beside each other); please adjust the references in the paper’s text to reflect your choice, for the rest of Subsection 4.2]
Title: Distribution of Subsector Centrality in the Canadian Economy
Notes: Left/Top panel—Conventionally measured Bonacich centrality. Right/Bottom panel—Centrality for network structure extended to include workers-needing-childcare. Author's calculations. See text for details.

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; however, 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 workers-needing-childcare subsector in the network. The WNC subsector is highly central since it provides labour services to *all* subsectors of the economy; this is the “outflow” of goods/services from the workers-needing-childcare sector.

Completing the extended input-output analysis requires specifying the WNC subsector’s use of output from all other subsectors. Since this subsector is obviously not listed in the official input-output table, the “inflow” of goods/services to workers-needing-childcare 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 the right/bottom panels of Figure 2 and Figure 3. 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 a worker-needing-childcare. Our alternative definition incorporates the lower-earning parent as part of the WNC subsector. This is presented in the column labelled “Sensitivity 1” in Appendix Table 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 rightmost column of Appendix Table 1), representing a more substantial departure from the conventional specification of input-output tables. As we document below, this generates a lower bound on the centrality of K-12 schooling. Here, rather than singling out the labour of workers-needing-childcare, 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 school-aged children and without) consume from each subsector of the economy,

in order to provide these labour services. As noted above, 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.[10] This is slightly lower than “Food manufacturing.” but higher than “Petroleum and coal products manufacturing” and “Hospitals.” While 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 (workers-needing-childcare) 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.

4.3 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 Subsection 4.1, this amounts to a loss of 2.5 percent of GDP.[11]

The second is the *indirect*, but quantitatively (and conceptually) more important loss stemming from the reduced labour time of workers-needing-childcare. 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 were 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 Subsection 4.2 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 workers-needing-childcare: the productivity of WNC drops to zero without K-12 schools, while 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.[12]

These effects are large. To provide perspective, real GDP (seasonally adjusted, at an annual rate) fell by an unprecedented 11.5 percent during 2020Q2, 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.

5. Conclusion

Public K-12 schooling is a bedrock institution in Canadian society. Schools are integral to the emotional and social development of children and teenagers, as the centre of their peer social interactions. K-12 education also plays a key role in socializing engaged and respectful citizens. Furthermore, 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 paper is to provide a quantitative assessment of this role. To do so, we augment input-output tables by constructing a hypothetical sector composed of workers-needing-childcare—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 3-digit subsectors. Our preferred adjustment suggests it is in fact the most central sector of the economy, and our lowest estimate places it in 13th 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 where 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, and 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 school teachers 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.

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 given by:

$$y_j = z_j \ell_j^{1-\eta_j} I_j^{\eta_j}, \quad j \in \{1,2,\dots,J\}. \tag{1}$$

Here, z_j is the productivity of sector j (which can be a composite of sectoral capital and technology), ℓ_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:

$$I_j = \prod_{k=1}^{J} y_{jk}^{\alpha_{jk}}, \quad \sum_{k=1}^{J} \alpha_{jk} = 1.$$

Markets are perfectly competitive. The representative firm in sector j maximizes profit, taking prices $\{p_k\}_{\forall k}$ as given:

$$\max_{\ell_j, \{y_{jk}\}_{\forall k}} p_j z_j \ell_j^{1-\eta_j} I_j^{\eta_j} - \sum_{k=1}^{J} p_k y_{jk} - \omega \ell_j.$$

Normalizing $\omega = 1$, prices are expressed in units of the numeraire (in this case, labour).[13] The first order condition with respect to sector j's intermediate input use of goods from sector k, y_{jk}, can be written as:

$$p_k y_{jk} = \eta_j \alpha_{jk} p_j z_j \ell_j^{1-\eta_j} I_j^{\eta_j} = \eta_j \alpha_{jk} p_j y_j. \quad (2)$$

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

$$y_k = \tilde{f}_k + \sum_{j=1}^{J} y_{jk},$$

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

$$p_k y_k = p_k \tilde{f}_k + \sum_{j=1}^{J} \eta_j \alpha_{jk} p_j y_j. \quad (3)$$

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:

$$s_k = f_k + \sum_{j=1}^{J} \eta_j \alpha_{jk} s_j,$$

where s_k is sector k's share of total output, and f_k is sector k's final good share of total output. Since this holds for all $k \in \{1,2,\dots,J\}$, rewrite this in matrix form:

$$\boldsymbol{s} = \boldsymbol{f} + A\boldsymbol{s}, \tag{4}$$

where $s = (s_1, \dots, s_J)'$ and $f = (f_1, \dots, f_J)'$ 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:

$$\boldsymbol{s} = (\mathbb{I} - A)^{-1}\boldsymbol{f}. \tag{5}$$

$(\mathbb{I} - A)^{-1}$ is known as the economy's "Leontief Inverse" matrix and can be expressed as:

$$(\mathbb{I} - A)^{-1} = \mathbb{I} + A + A^2 + A^3 + \cdots$$

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:

$$\boldsymbol{v} = \frac{1}{J}(\mathbb{I} - A)^{-1}\mathbf{1}. \tag{6}$$

Hence, $\boldsymbol{v}$ (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 Section 3 requires minimum modification. The change is conceptual, and assumes that the labour input of workers-needing-childcare (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), ℓ_j now denotes labour of non-WNC, while WNC labour becomes its own sector.[14] Correspondingly, the number of sectors increases to $\tilde{J} = J + 1$. Sector j purchases WNC labour for use as an intermediate input in $I_j = \prod_{k=1}^{\tilde{J}} y_{jk}^{\alpha_{jk}}$. Let the WNC sector be denoted as sector w. Hence empirically, $a_{jw} = \eta_j \alpha_{jw}$ is sector j's expenditure share on labour income payments to WNC workers, in the extended model's $(\tilde{J} \times \tilde{J})$ A 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:

$$y_w = z_w \ell_w^{1-\eta_w} I_w^{\eta_w}, \quad I_w = \sum_{k=1}^{\tilde{J}} y_{wk}^{\alpha_{wk}}.$$

In our benchmark specification, we assume that the $\alpha_{wk} = 0$ for all k except for the K-12 sector, which takes a value of 1. In the specification for our sensitivity analysis, $\alpha_{wk} > 0$ 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 of Section 4 centers on the Bonacich centrality of the K-12 schooling sector, and not on the centrality of the WNC sector. However, as noted, the measured centrality of K-12 schools depends on that of WNC, since K-12 schooling is an important input into WNC, a sector that is itself highly central to all other sectors.

[APPENDIX TABLE 1 GOES ABOUT HERE]

Title: Subsector Centrality in the Canadian Economy

Notes: Normalized Bonacich centrality for various subsectors of the economy at to the 3-digit NAICS level. Author's calculations. See text for details.

Endnotes

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[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 (BCCDC) similarly stresses the importance of in-person schooling, and the "significant hardship" from the suspension of in-person learning—in terms of "impaired learning, increased child stress, and decreased connection" (BC Centre for Disease Control 2020). The Association of Pediatricians of Québec has also called attention to the impact of first-wave school closures on children's well-being, and its interaction with existing inequalities in family resources—financial, psychological, and otherwise (most recently accessed 11 January 2021, at https://pediatres.ca/covid-19/). These considerations are incorporated in a report prepared on behalf of the Québec 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, Haeck and Lefebvre (2020) have estimated that school closures could increase socioeconomic 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 younger than 12 years of age cannot be left unsupervised, and Ontario's Child and Family Services Act states that a child under the age of 16 may not be left unattended "without making provision for his or her supervision and care that is reasonable in the circumstances."

[3] Technically, animal production is referred to as a "subsector" in the NAICS. For now, we will refer to subsectors as sectors for short, and will be more accurate in our reference to NAICS classifications in Sections 3 and 4.

[4] As a point of reference, K-12 schools comprise approximately 54 percent of the education sector, with the remainder being trade schools, college, university, and miscellaneous/other educational services.

[5] The term workers-needing-childcare is somewhat misleading since it brings to mind childcare for pre-school children. We do not take account of issues related to childcare for pre-school age children since 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 Section 4.

[7] Hence, workers-*not*-needing-childcare, 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.

[8] Note that we first subtract the value of workers-needing-childcare who work in the standard K-12 subsector, to avoid double counting.

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

[10] 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). Since 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. Since centrality depends on size and connectedness, this amplifies the first effect.

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

[12] This is a direct application of Hulten (1978)'s theorem, since our input-output model (as detailed in the Appendix) features Cobb-Douglas production, perfect competition, and efficiency of equilibrium. See also Baqaee and Fahri 2019.

[13] The choice of the numeraire good is arbitrary and immaterial to the derivation and results.

[14] 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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