Canadian productivity growth: Stuck in the oil sands

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Abstract. We study the behaviour of Canadian Total Factor Productivity (TFP) growth over the past 60 years. We find that the observed stagnation during the last 20 years is accounted for entirely by the oil sector. Higher oil prices made capital-intensive sources of oil like the oil sands viable to extract on a commercial scale. However, the greater input required per barrel of oil slowed TFP growth. Comparing Canadian TFP growth with that of the United States and Norway reinforces these results. However, our result should not be interpreted to carry any welfare implications.

Résumé. Croissance de la productivité au Canada : Coincée dans les sables bitumineux. Nous étudions le comportement de l'augmentation de la productivité totale des facteurs (PTF) au Canada au cours des 60 dernières années. Nous trouvons que la stagnation observée au cours des 20 dernières années est entièrement imputable au secteur pétrolier. La hausse des prix du pétrole a rendu viables les projets d'extraction pétrolière à forte intensité de capital, comme les sables bitumineux. Toutefois, la hausse de facteurs de production requis par baril de pétrole a ralenti l'augmentation de la PTF. La comparaison de l'augmentation de la PTF canadienne à celle des États-Unis et de la Norvège renforce ces résultats. Cependant, notre résultat ne doit pas être interprété comme ayant des implications sur le bien-être.

JEL classification: E01, O47, O51

1. Introduction

Economists and policy-makers have expressed ongoing concern about the lack of productivity growth in Canada.[1] Conesa and Pujolas (2019) identify the "Canadian productivity stagnation" during the period from 2002 to 2014, where Canadian total factor productivity (TFP) growth was negligible, lagging behind both previous decades in Canada and contemporaneous US TFP growth. Our paper extends the period of Canadian productivity stagnation up to at least 2018 (the last year for which data are available, as detailed

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1 See, for instance, the Fraser Institute's monograph on improving productivity growth in Canada (Douglas et al. 2021); the op-ed in the Financial Post by William Robson, CEO of the C.D. Howe Institute, titled "Faster productivity growth would solve many problems" (Robson 2022); OECD's Canada Economic Snapshot (OECD 2023); Deloitte's Future of Productivity volume (Currie et al. 2021); or Chartered Professional Accountants Canada's "Solution to Canada's plummeting productivity" (Fong 2019), to name a few.

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in appendix A) and demonstrates that the absence of TFP growth during this period, and the divergence of TFP growth with respect to the United States, can be attributed entirely to the oil sector.[2] Increases in oil prices made capital-intensive, lower TFP oil production (such as the oil sands) viable, which in turn reduced aggregate Canadian TFP growth.

In essence, the lack of TFP growth is accounted for entirely by excluding the oil sector from the Canadian national accounts and recalculating TFP accordingly (we refer to this measure as "net-of-oil TFP"). From 2001 to 2018, Canada's TFP grows at 0.06% per year. By contrast, Canada's net-of-oil TFP grows at 0.60% per year, a similar rate to that of the United States (0.47% if oil is included, 0.49% if oil is excluded).[3] It is important to note that TFP does not account for the positive effects of rising oil prices.

To measure TFP, we need data on output (real GDP) and inputs (a measure of the capital stock in the economy as well as total hours worked) and an assumption on how inputs combine to generate output (which we employ through a Cobb–Douglas production function). Then, we calculate TFP as changes in output that cannot be attributed to changes in inputs, as first proposed by Solow (1957). Our methodology is based on the approach in Kehoe and Prescott (2007) and similar to that in Conesa et al. (2007).

We continue our analysis by looking at different Canadian provinces. Namely, we compare Alberta (a large oil-producing province) to Ontario (a large non-oil-producing province).[4] First, we find that Ontario's TFP evolves almost identically regardless of whether oil is included in the calculations (over the period of analysis, TFP and net-of-oil TFP grow at 0.82% per year). Second, we find that Alberta's net-of-oil TFP growth is higher than Ontario's (0.97% per year). However, when oil is included, Alberta's TFP grows at a negative rate during this time period, at −0.20%.

Next, we compare Canadian TFP growth to that of the United States and Norway. We use US data from the Bureau of Economic Analysis and Norwegian data from the Statistisk sentralbyrå (Statistics Norway). Canada, the United States and Norway are the three largest oil producers among developed Western economies. US TFP growth is not significantly affected by excluding the oil sector during the period from 2001 to 2018. We find that the key difference between Canadian and US TFP growth lies in the differential evolution of capital and output by the oil sector. While the Canadian oil sector's share of installed capital almost doubles during the period of analysis (from using 17.1% of all the installed capital in 2001 to 31.4% in 2018), the oil sector's share of Canadian GDP remains fairly constant, and even decreases (5.7% in 2001 to 4.7% in 2018). By contrast, the US oil sector's capital and GDP stay relatively constant and at lower rates throughout (from 2.3% in 2001 to 3.6% in 2018 for capital and from 0.8% in 2001 to 1.1% in 2018 for value added).

2 Throughout the paper, we refer to the industry named "oil and gas extraction," NAICS code 211, as the "oil sector." Similarly, we refer to industry "non-conventional oil and gas extraction," NAICS code 211114, as the "oil sands." Note that this sector was relabelled in the 2017 revision as "oil sands extraction."

3 As shown in Fernald (2015) and Cette et al. (2016), there is a decrease in the TFP growth of many rich economies, including Canada and the United States. To be precise, our work demonstrates that the oil sector can account for the different evolution of TFP between Canada and the United States, but not the overall productivity decrease.

4 For data availability reasons, our provincial-level analysis spans from 1997 to 2018.

Norwegian TFP growth is affected by excluding the oil sector during the period from 2001 to 2018, aligning with Canada. The difference between net-of-oil TFP and TFP growth rates is 0.37% in Norway and 0.54% in Canada (both growth rates are small in Norway, at −0.32% for TFP and 0.05% for net-of-oil TFP). Norwegian results are also driven by the evolution of capital and output by the oil sector. In 2001, 13.9% of capital in Norway is in the oil sector (17.1% in Canada), increasing to 14.2% by 2018 (31.4% in Canada). At the same time, Norway's oil sector accounts for 22.4% of its GDP in 2001 (5.7% in Canada) and decreases to 19.0% in 2018 (4.7% in Canada). We find that the impact of oil on the evolution of Norwegian TFP during the period from 2001 to 2018 tells a similar story to that of Canada. TFP decreases at −0.32% per year in Norway (grows at 0.06% in Canada), whereas net-of-oil TFP grows at 0.05% per year (0.60% in Canada). These results are not surprising when we look at the evolution of capital and output by the oil sector. In 2001, 13.9% of capital in Norway is in the oil sector (17.1% in Canada), increasing to 14.2% by 2018 (31.4% in Canada). At the same time, Norway's oil sector accounts for 22.4% of its GDP in 2001 (5.7% in Canada) and decreases to 19.0% in 2018 (4.7% in Canada).

The surge in capital used by the Canadian oil sector coincides with the early 2000s oil price boom and the commencement of commercial oil sands extraction in 2001.[5] It is noteworthy that the proportion of capital in the oil sands as a percentage of the overall capital in the oil sector has seen a remarkable increase, rising from an average of 5.77% between 1961 and 2000 to an astonishing 30.35% as of 2019.

Last, it is important not to interpret our results as a critique of the oil sector. While the industry confronts a host of challenges, such as carbon emissions, our findings do not necessarily imply any additional negative aspects. Rather, the drop in TFP may be attributed to a combination of increased oil prices and a technology that exhibits decreasing returns to scale. Higher oil prices might encourage the extraction of costlier barrels of oil, which would lead to a lower TFP due to a composition effect. Hence, it is plausible that the Canadian economy is responding optimally by exploiting a resource when its value is high.

The paper is organized as follows. Section 2 contextualizes our contribution in light of the literature. Section 3 presents the methodology used to measure TFP and highlights that TFP in Canada has remained stagnant since the early 2000s but increases when the oil sector is excluded from the calculations. In section 4, we perform a comparative analysis of TFP between Canada, the United States and Norway. Section 5 offers additional information regarding the Canadian oil sector that is pertinent to understanding the productivity of the sector. Finally, in section 6, we provide further context and propose potential avenues for future research.

2. Literature review

The lack of productivity growth in Canada post-2000 is an ongoing topic of discussion among scholars and policy-makers. This paper builds on Conesa and Pujolas (2019) and other studies that have investigated the sluggish productivity in Canada. For example, Boothe and Roy (2008) review labour and multifactor productivity (MFP) in the Canadian business sector and links weak MFP growth to Canadian firms' lackluster innovation performance. They also note a sharp decline in productivity in the oil and gas sector from 2000 to 2006. Similarly, Alexopoulos and Cohen (2018) find that the slowdown in productivity growth in

5 The offshore oil project Hibernia in Newfoundland and Labrador, which started producing in the late 1990s, also fits this analysis. However, its production is much lower than the oil sands.

TABLE 1
TFP and net-of-oil TFP growth rates

Period	TFP growth	Net-of-oil TFP growth
1961–2018	0.99%	1.21%
1971–1981	0.78%	0.62%
1987–1991	0.75%	1.17%
1991–2001	1.90%	1.79%
2001–2018	0.06%	0.60%

the Canadian business sector since 2000 was due to a decrease in the rate at which Canadian firms adopt new technologies and a lack of innovative activity. Our paper complements these studies by focusing on the connection between TFP and the oil sector, rather than firm-level innovative activity.

Shao and Tang (2021) examine the role of allocative efficiency in driving aggregate labour productivity growth and explore the reasons behind the labour productivity gap between Canada and the United States. The paper identifies capital allocation as the primary factor responsible for the decline in Canadian allocative efficiency. Similarly, Gu (2018) investigates the impact of various measurements of capital on slow productivity growth in Canada and finds that a quarter of Canada's productivity slowdown between 2000 and 2015 is due to the use of capital in the oil and gas sector. Our analysis in section 5 is consistent with these findings: we demonstrate that Canada's capital has been heavily utilized by the oil sector since the late 1990s and that this trend can explain the lack of TFP growth during the same period.

Sharpe (2010) focuses on 12 different industries in Canada and argues that the decline in labour productivity growth in the manufacturing sector is responsible for the entire slowdown in business sector productivity growth between 2000 and 2007. Similarly, Baldwin and Willox (2016) suggest that the low productivity growth in three different industries (including oil extraction) explains the entirety of the slowdown in business sector labour productivity growth from 2000 to 2014. While we recognize the validity of these analyses, in appendix B, we show that, even if one excludes the manufacturing sector (or the agricultural, services or "rest of mining" sectors), the lack of TFP growth persists. Therefore, while all these findings invite further investigations into areas where Canadian productivity growth may be improved, it is striking that the stagnation in aggregate TFP growth can be so singularly attributed to the oil sector.

According to Keay (2009), the resource extraction sector had a positive impact on per capita economic performance in the Canadian economy from 1970 to 2005. Although our paper attributes the recent lack of TFP growth to the oil sector, our growth accounting decomposition with and without the oil sector also reveals that TFP growth was higher during the 1970s and the 1990s thanks to the oil sector (see table 1 for more information). Similarly, Olewiler (2017) suggests that Canada has benefitted from exporting natural resources but notes that failing to account for the environmental externalities of resource extraction raises concerns about the long-term economic benefits.

The notion that the oil sands are expensive and capital-intensive has already been documented in the literature. Heyes et al. (2018) document that a barrel of crude bitumen trades at \$12.77 below the WTI price[6] and that the world oil price for new oil sands projects to be profitable is \$9 higher than other oil extraction projects would be. Leach (2022) shows

6 This is significantly more discounted than Mexican Maya crude (\$6.98 below WTI price).

that, at a minimum, a new oil sands project requires an initial investment of $1 billion and takes up to five years for production to reach full capacity.

One way to evaluate the productivity for oil and gas extraction sectors is to look at the energy return on investment (EROI), a measure that reports the ratio between energy produced per unit of energy used. Gagnon et al. (2009), Hall et al. (2014) and others provide evidence that the EROI for oil and gas extraction at large has been declining. Poisson and Hall (2013) find that, in Canada, conventional oil and gas extraction EROI fell from 20 to 1 to 12 to 1 from the mid-1990s to 2008, while oil sands has fluctuated around a significantly lower average EROI of 4 to 1. Brandt et al. (2013) suggest that, although the EROI of oil sands extraction has improved over time, it remains less efficient than conventional oil production.

Finally, our paper is also related to a long-standing discussion about the Dutch disease (DD) in Canada. The DD phenomenon arises when a sector (in this case, oil) captures factors of production to the extent that it ends up harming the rest of the economy. For instance, Beine et al. (2012) argue that over a third of Canada's manufacturing employment loss in the early 2000s is related to an appreciation of the exchange rate. Boadway et al. (2012) build on those findings to analyze the policy challenges faced by the provincial and federal governments. Papyrakis and Raveh (2014) find that Dutch disease mechanisms are relevant at the regional level for Canada. On the other extreme, Carney (2012) writes about the DD in the following terms: "While the tidiness of the argument is appealing and making commodities the scapegoat is tempting, the diagnosis is overly simplistic and, in the end, wrong." Our paper's findings align with the DD story when it documents that the oil sector has indeed captured an enormous fraction of the overall capital stock in Canada (from 6% in 1961 to over 30% in 2018). However, our findings do not align with DD in that the rest of the economy has not experienced a systematic reduction in importance (approximately, non-oil accounts for 95% of the economy throughout the period). Moreover, our results show that productivity for the Canadian economy without the oil sector continues to grow at levels comparable to those of the United States and Norway, which is not necessarily compatible with what is usually thought of as the DD.

3. Canadian TFP, with and without the oil sector

In this section, we describe our methodology for measuring TFP, which is then used to conduct a growth accounting decomposition of the Canadian economy. We also compare TFP growth rates with and without the oil sector across different time periods. At the end, we also compare TFP growth rates in Alberta and Ontario.

3.1. How to measure TFP

To measure TFP, we assume a standard Cobb−Douglas production function, where GDP (Y_t) is a function of capital (K_t), labour (L_t) and a productivity factor (A_t):[7]

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \tag{1}$$

where α is the parameter that measures the capital intensity of the economy. We obtain data on GDP (Y_t), capital (K_t), labour (L_t) and compensation of employees from Statistics

7 Our results are obtained using series of GDP in constant prices. In appendix C, we recompute the analysis using "output-side real GDP at chained PPPs" from the Penn World Table 10.01 (Feenstra et al. 2015), which is useful "to compare relative productive capacity across countries and over time." Our results are the same regardless of which metric is used.

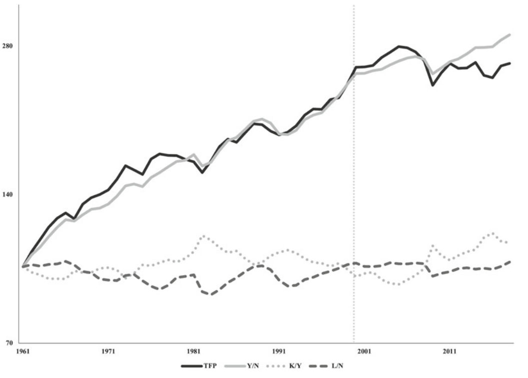

FIGURE 1 Growth accounting decomposition

Canada.[8] Using the compensation of employees data, we can calculate the capital share of income (α) as

$$\alpha = 1 - \frac{1}{T}\sum_t \frac{w_t \times L_t}{Y_t}, \tag{2}$$

where $w_t \times L_t$ is the series of compensation of employees.

With all this information, we can calculate TFP as a residual,

$$A_t = \frac{Y_t}{K_t^{\alpha} L_t^{1-\alpha}}, \tag{3}$$

and decompose GDP per working-age population (N_t, henceforth WAP) as

$$\underbrace{\frac{Y_t}{N_t}}_{\text{GDP per WAP}} = \underbrace{A_t^{\frac{1}{1-\alpha}}}_{\text{TFP}} \times \underbrace{\left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}}}_{\text{Capital}-\text{output ratio}} \times \underbrace{\frac{L_t}{N_t}}_{\text{Hours per WAP}}. \tag{4}$$

3.2. Growth accounting decomposition with and without oil

The growth accounting decomposition of the Canadian economy from 1961 to 2018 is shown in figure 1, where the y-axis is presented in logarithmic scale due to the exponential growth observed in the series for GDP per WAP and TFP.

It is worth noting that, from 1961 to 2001, the Canadian economy followed the typical pattern of developed economies, with almost all growth in GDP per WAP attributed to improvements in TFP. During this period, the capital−output ratio and hours per WAP series remained relatively stable, with minor fluctuations reflecting business cycle movements. Neither variable had a significant impact on the overall growth of GDP per WAP.

Beginning in 2001, the analysis reveals a marked shift in the Canadian economy's productivity trends, labelled as the "Canadian productivity stagnation" by Conesa and Pujolas (2019). Between 2001 and 2018, the TFP series exhibits little to no growth, fluctuating around a horizontal line and yielding an annualized growth rate of a mere 0.06%.

In the next phase of our analysis, we eliminate all components of the oil sector from our TFP calculation. We perform the same analysis but substitute $\mathrm{Y}_\mathrm{t}^\mathrm{NO}, \mathrm{K}_\mathrm{t}^\mathrm{NO}, \mathrm{L}_\mathrm{t}^\mathrm{NO}$ in place of Y_t, K_t, L_t, respectively, where X_t^{NO} is defined as X_t minus X_t^{Oil} for X being Y, K or L and

8 See appendix A for details.

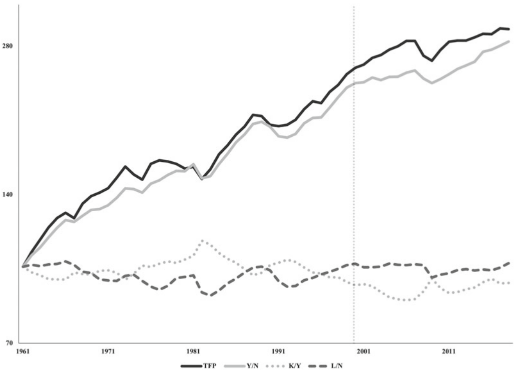

FIGURE 2 Net-of-oil growth accounting decomposition

"NO" indicates net of oil. To ensure consistency in our analysis, we revise α^{NO} to exclude oil sector labour payments from the economy.[9] We present the results of the net-of-oil TFP growth accounting decomposition exercise in figure 2.

After removing the oil sector components from the analysis, our results indicate that the economy did not display stagnant TFP post-2001. On the contrary, TFP increased at an annualized rate of 0.60% between 2001 and 2018. These findings align with Canada's historical TFP growth rate.[10]

Table 1 presents the annualized growth rates of TFP for different periods, comparing the economy with and without the oil sector. TFP has grown at 0.99% per year for the period considered, from 1961 to 2018. When the oil sector is excluded, this figure increases to 1.21%. This difference in growth rates, however, is not consistent throughout the period. Net-of-oil TFP rises faster than overall TFP during the 1980s but not during the 1970s or the 1990s. Most importantly, while the annual TFP growth rate when the oil sector is included is a meagre 0.06% since 2001, the growth rate increases to 0.60% during that time period when we exclude the oil sector from the analysis. This figure is more in line with other growth rates presented in the table, like the net-of-oil TFP growth rate in the 1970s and the TFP growth in the 1970s and 1980s.

3.3. Alberta vs. Ontario

The impact of the oil extraction sector varies across different Canadian provinces. Alberta, which accounts for 17.26% of Canadian GDP,[11] stands out for having a significant portion

9 We provide an exact description of how the net-of-oil series are calculated at the end of appendix A. Moreover, we find that using the same α value as in the previous net-of-oil TFP analysis (figure 1) has no impact on the results, as shown in figure D1 in appendix D. Likewise, we find that using the exact evolution in the labour share (using a time-varying α) does not affect our results either (figures 21(a) and 21(b) also in appendix D).

10 We find that removing any sector other than oil from the Canadian economy is inconsequential for the evolution of TFP. The result of these exercises can be seen in figures B1, B2, B3 and B4 in appendix B.

11 All the percentages in this paragraph are calculated based on the average from 1997 to 2018, which represents the available provincial–sectoral data time frame. Refer to appendix A for details regarding the data sets used in this analysis.

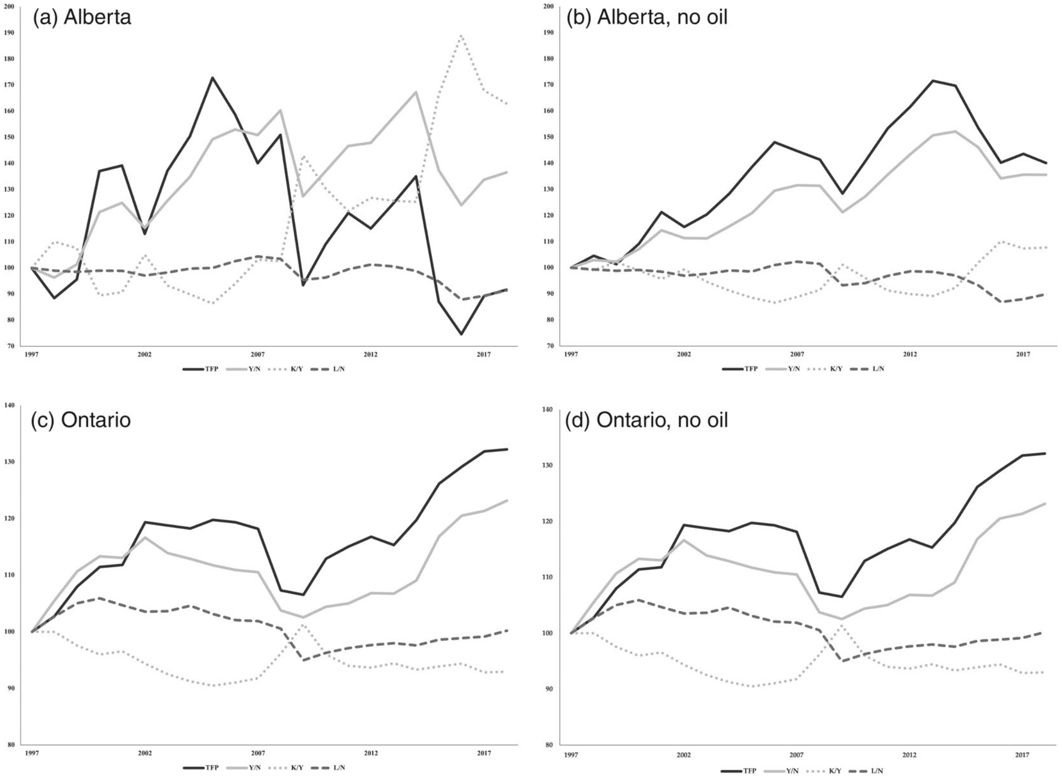

FIGURE 3 Provincial growth accounting decompositions

of its GDP derived from the oil sector (24.27%). In contrast, Ontario, which accounts for 38.94% of Canadian GDP, has only a minimal fraction of its GDP attributed to the oil sector (0.02%). The significance of these two provinces in the overall economy, along with the substantial contrast in the oil sector's importance within their respective economies, make them excellent candidates for studying the oil sector's impact on TFP.

Figure 3(a) illustrates the growth accounting decomposition for Alberta when the oil sector is included, while figure 3(b) displays the growth accounting decomposition for Alberta when the oil sector is excluded. Correspondingly, figures 3(c) and 3(d) depict the equivalent growth accounting decompositions for Ontario.

Analyzing the figures indicates a shared behaviour between Alberta's growth accounting decomposition figures without the oil sector and Ontario's figures (whether considering the oil sector or not because the two are almost indistinguishable). Despite encountering several ups and downs, particularly notable during the Great Recession period, the figures present variations of the canonical growth accounting exercise figure of developed economies: two relatively flat at lines (the capital–output ratio and the hours per WAP) and two lines that move in parallel with an upward trend (TFP and GDP per WAP).

The figure that notably stands out is Alberta's growth accounting decomposition with the oil sector. Initially, there is a remarkable surge in TFP from 1997 to the early 2000s, followed by a sharp decline that erases all the gained productivity by 2018. Interestingly, GDP per WAP decouples from the TFP trajectory, continues to rise (albeit with some fluctuations along the way), and the increase aligns with the significant upswing in the capital-to-output ratio starting in the mid-2000s.

FIGURE 4 TFP and net-of-oil TFP, Canada and United States

Overall, the four pictures reinforce the story that Canadian productivity sluggishness since the turn of the century is driven largely by the oil sector. Next, we show that a comparison of Canada with the United States and Norway reinforces this result.

4. International comparisons

In this section, we compare Canada with the United States, a standard benchmark, and with Norway, a small open economy with a large oil sector. These three countries are the three largest oil producers among rich Western economies.

4.1. Canada and the United States

We explore whether the lack of TFP growth driven by the oil sector, which was observed in Canada post-2000, also occurs in the United States. Specifically, we investigate the evolution of TFP and net-of-oil TFP in the United States and compare them with their Canadian counterparts. We find that, unlike for Canada, excluding the oil sector has no significant effect on measured aggregate TFP growth in the United States.

We use the same approach as in our analysis of Canada, using data on capital, value added, hours worked and labour compensation from the Bureau of Economic Analysis in the United States.[12]

Figure 4(a) displays the TFP and net-of-oil TFP evolution for Canada and the United States from 1961 to 2018, normalized to 100 in 1961.[13] As expected, all series increase with some fluctuations, and the US curve is smoother. Nevertheless, until 2000, both Canadian TFP series followed similar trends. The primary contrast between the two Canadian series emerges after this year.

To gain insights into the evolution of TFP post-2000, we narrow our focus in figure 4(b), normalizing the series to 100 in 2001. The figure highlights a clear trend: while all the TFP series for Canada and the United States have business cycles, only Canada's TFP series displays stagnant growth post-2001. In contrast, the TFP series for the United States and the net-of-oil TFP series for both countries exhibit strikingly similar growth patterns. They

12 See appendix A for details.

13 While Canadian TFP has grown faster than the US TFP during this period, it is still the case that Canadian output per person is lower.

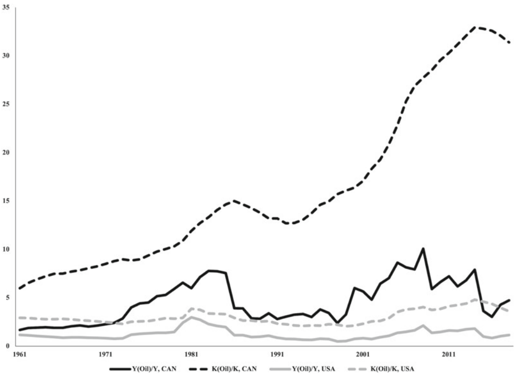

Figure 5 Importance of oil, Canada and United States

all experience fluctuations but grow consistently throughout the period, indicating that the lack of TFP growth in Canada is a unique phenomenon, linked to the oil sector.

We consider figure 4(b) to be a clear representation of the key message conveyed in this paper. If measured without the oil sector, Canada's TFP growth would have been similar to that of the United States and there would not have been a "Canadian productivity stagnation." Except for the oil sector, Canada has been on par with the United States in terms of TFP growth.

Figure 5 illustrates the trend in the ratio of capital invested in the oil sector compared with the total capital in the Canadian economy (dashed black line) and the ratio of value added contributed by the oil sector as a fraction of the total value added in Canada (solid black line). Respectively, the lines for the United States are plotted in grey.

For Canada during the period of analysis, the oil sector's share of value added hovers around a trend of about 5%, while the proportion of capital allocated to the oil sector has increased from 6% to 31%. This growth is observed mostly after 2001, suggesting that the oil sector is using a relatively greater amount of input to produce relatively the same amount of output. Because the oil sector has low labour requirements, the divergence between the growth of capital and value added mechanically accounts for the lower TFP.

For the United States, on the other hand, the oil sector's share of value added remains around 1% and the proportion of capital allocated to the oil sector remains at around 3%. The relative constant percentages for the importance of the oil sector in the US explains why TFP behaves similarly to net-of-oil TFP.

4.2. Canada and Norway

Norway's oil production accounts for 20% of its GDP.[14] At the same time, Norway is a small open, very rich economy. The importance of the oil sector together with its developed economy makes it an excellent candidate to compare with Canada. We find that, even though the Norwegian economy has fared better than the Canadian one in the last half a century, the evolution of TFP and the net-of-oil TFP of both countries exhibits a remarkably similar story during the last two decades. To conduct our analysis, we again use the same analysis of Canada, using the relevant data for Norway from the Statistisk sentralbyrå.[15]

14 To keep the comparison figures the same with the previous section, this average is also from 1997 to 2018.

15 See appendix A for details.

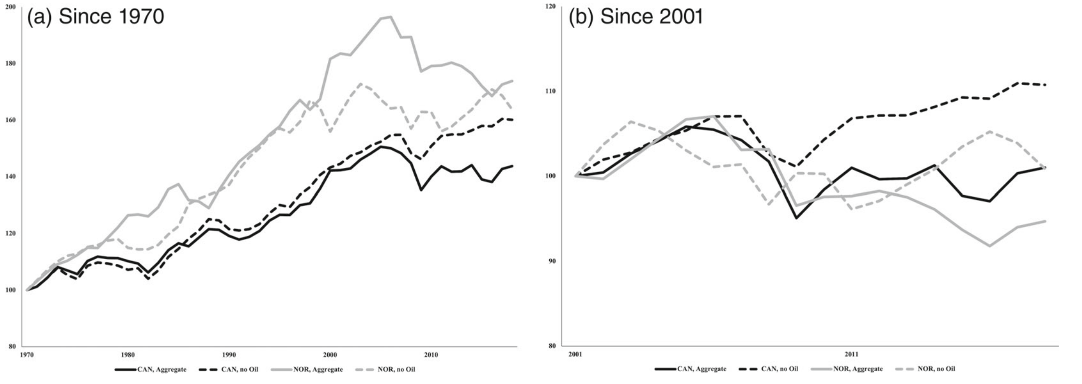

Figure 6 TFP and net-of-oil TFP, Canada and Norway

Figure 6(a) displays the TFP and net-of-oil TFP evolution for Canada and Norway from 1970 to 2018, normalized to 100 in 1970.[16] As expected, all series increase with some fluctuations, and the Canadian curve is smoother. Until the 2000s, Norwegian TFP grows faster than Canadian TFP. The pattern that emerges from 1970 to 2000 is that of two similar lines for Norway (in grey, substantially higher) and two similar lines for Canada (in black, substantially lower). Since 2000, however, we note that TFP growth in both countries is stagnant.

Figure 6(b) displays the TFP and net-of-oil TFP evolution for Canada and Norway from 2001 to 2018. Both countries have a sluggish evolution in their overall TFP (solid lines) with Norwegian TFP decreasing by 0.32% (grey line) and Canadian TFP showing a slight increase of 0.06% (black line). Notably, net-of-oil TFP exhibits more favourable outcomes (dotted lines). Norwegian net-of-oil TFP remains relatively stable, with a modest increase of 0.05% (dotted grey line), while Canadian net-of-oil TFP experiences increases of 0.60% (dotted black line). In summary, excluding the oil sector results in an annual growth rate that is 0.37% higher in Norway and 0.54% higher in Canada. The primary factor behind this outcome is the allocation of capital.

Figure 7 reproduces figure 5 but changing the United States for Norway, depicting the evolution of the ratio of capital invested in the oil sector compared with the total capital (dashed grey line) and the ratio of value added contributed by the oil sector as a fraction of the total value added in Norway (solid grey line).

In the context of Norway, the oil sector's contribution to value added experiences a notable growth until the mid-2000s, followed by a consistent decline leading up to 2018. During this period, there is an increase in the allocation of capital to the oil sector, albeit with a slight decrease towards the end of the period. From 2001 to 2018, the importance of the oil sector in terms of value added diminishes, while its importance in capital allocation sees a modest rise. In the case of Canada, the oil sector's share of value added remains relatively stable, with occasional fluctuations. However, the proportion of capital allocated to the oil sector sees a significant increase, particularly during the late 1990s and early 2000s. Over the period from 2001 to 2018, the importance of the oil sector in value added remains fairly constant, while its importance in capital allocation increases substantially.

16 Canadian TFP has grown slower than Norway's during this period, and Canadian output per person is lower than its Norwegian counterpart.

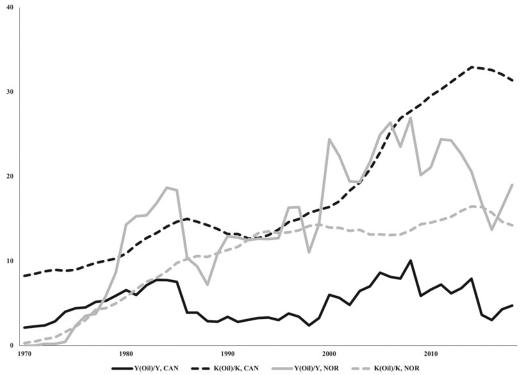

Figure 7 Importance of oil, Canada and Norway

In both instances, the observed trend is characterized by a decline or stagnation in value added (the numerator in TFP), while capital (which appears in the denominator of TFP) increases. Consequently, the oil sector plays a crucial role in explaining the lower growth rate of TFP compared with net-of-oil TFP in both Norway and Canada.

5. More details about the Canadian oil sector

In this section, we show first that TFP in the Canadian oil sector is a rarity compared with the other sectors of the economy. Then, we propose two potential explanations for the observed fall in TFP: a composition effect and a misallocation of factors effect. While the evidence we provide aligns well with the former, our evidence does not allow us to confirm or deny the latter. Last, we explain why it is unlikely that Canadian data alone will suffice to disentangle the question of misallocation.

5.1. Canadian oil sector TFP: A rarity

In figure 8(a), we document a significant difference in the evolution of TFP between the oil sector and the rest of the economy. While TFP for the overall economy grows, TFP for the oil sector experiences a secular decline. Thus, the oil sector in Canada stands out as a distinctive sector with unique characteristics.

To further support this perspective, figure 8(b) illustrates the trends of TFP in the oil sector as well as in the agriculture, manufacturing and services sectors. The volatile, declining pattern of TFP in the oil sector is not observed in any of the other sectors. On the contrary, other sectors' TFP grows in tandem with the overall economy's TFP over the entire period.

5.2. A composition effect

Oil TFP may be falling due to a composition effect. For the sake of argument, assume that the oil sector has two subsectors. The traditional oil subsector is highly productive and operates at capacity; the oil sands subsector has low productivity and decreasing returns to scale. If the world oil price increases, the traditional oil subsector cannot expand its production; however, the oil sands subsector will expand its output using more factors of production, even if the marginal unit produced will be increasingly unproductive. As a result, the effect of a price increase will decrease sectoral TFP.

The assumptions about productivity in the two subsectors is consistent with the heavy discount on a barrel of crude bitumen as well as the massive costs of starting an oil sands

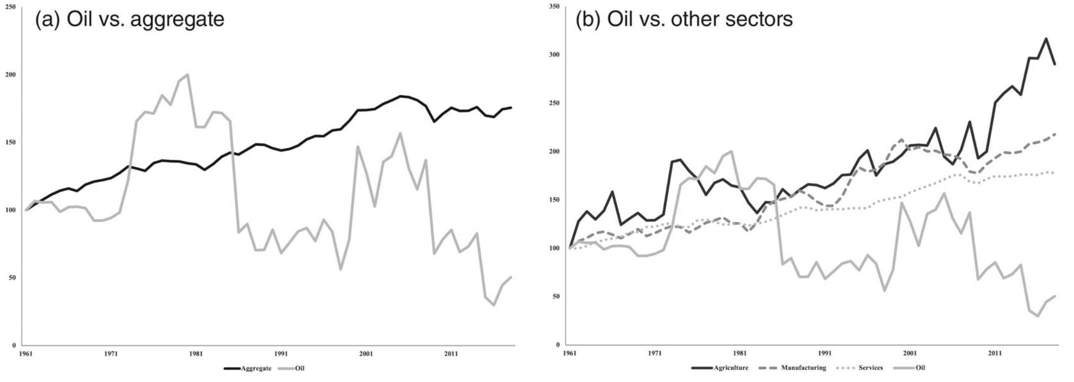

Figure 8 TFP: Oil vs. rest of the economy

Figure 9 Oil sands capital and WTI price

project, as noted in Heyes et al. (2018) and Leach (2022). When the oil price boom occurred, it became profitable to invest heavily in the sector. As capital owed in, the sectoral productivity mechanically fell as resources were allocated to the less-productive type of oil.

In figure 9(a), we plot the percentage of capital and investment allocated to the oil sands as a fraction of the total capital and investment in the oil sector. The proportion of capital in the oil sands ranged from 5% to 8% between 1961 and 2001, but it surged to about 30% afterwards. Similarly, the proportion of investment in the oil sands, which ranged at similar values between until the mid-1990s albeit more erratically, reached a peak of 44% post-2001.

The increase of capital allocated to the oil sands is consistent with two occurrences: the technological advancement allowing for the opening of the first commercial steam-assisted gravity drainage (SAGD) project at Foster Creek in 1996 and the potential profitability of exploitation.[17] Figure 9(b) plots the evolution of the oil price, measured as the West Texas Intermediate. It was roughly \$20 per barrel in the 1990s but surged to approximately \$100 per barrel by 2007 and has since fluctuated but at significantly higher prices than before 2001.

17 More details on the history of the oil sands and technology used can also be found in the 2008 report prepared for the US Congress (Humphries 2008).

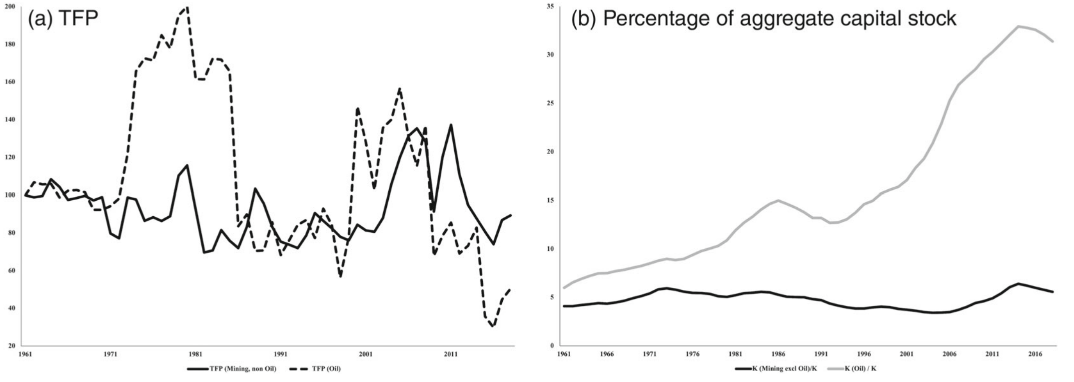

Figure 10 TFP and capital, oil and other mining

5.3. Capital reallocation

Another possibility regarding the fall in oil sector TFP is that there has been a surge in resource misallocation.[18] Given the rapid growth in the percentage of the aggregate capital stock installed in the oil sector, it is worth asking whether this came at the expense of more-productive sectors.

The oil sector is a particularly capital-intensive sector, with a labour share of 0.11. To be able to show that there is an increase in misallocation, we would have to demonstrate that in the absence of the oil price boom, capital would have been installed in more-productive sectors. However, no other sector is as capital-intensive as the oil sector, making it difficult to establish an appropriate counterfactual. It is also not obvious that aggregate investment in the capital stock would have been comparable had the oil price boom never occurred.

The closest comparable sector to look at is mining excluding oil and gas (NAICS code 212). In figure 10(a), we show that in the rest of the mining sector, TFP is relatively flat. It spikes during the 2000s commodity boom (as does oil). However, figure 10(b) shows that share of the aggregate capital stock in the rest of the mining sector has historically been below oil and remains fairly constant during the period when the oil sector's share explodes. Hence, it does not seem that capital flowed in that direction.

Alternatively, it is worth investigating whether misallocation happens as capital is removed from the manufacturing sector into the oil sector: figure 11 shows that the decrease in the former coincides with an increase in the latter. Before we dig into the details, it is worth noting that the decline in capital allocated to the manufacturing sector is consistent with the canonical pattern of structural transformation during this time period (see, for instance, Herrendorf et al. 2013). The overall fall in capital installed in manufacturing can be seen in Canada (it fell from 16.97% in 2001 to 8.06% in 2018) but also, even if less dramatically, in the United States (from 10.37% in 2001 to 8.54% in 2018).

The data from Statistics Canada split capital into engineering construction (EC), intellectual property products (IPP) and machinery and equipment (ME). Figures 12(a) and 12(b) plot the evolution of each type of capital as a percentage of the oil sector's and the manufacturing sector's total capital stock. The first thing to note is that the oil sector's

18 The literature on misallocation, started by Restuccia and Rogerson (2008) and Guner et al. (2008) and covered in Restuccia and Rogerson (2017), shows how capital misallocation can have large impacts on aggregate productivity.

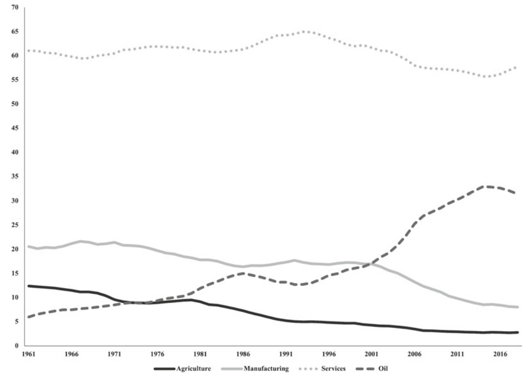

Figure 11 Percentage of aggregate capital stock by sector

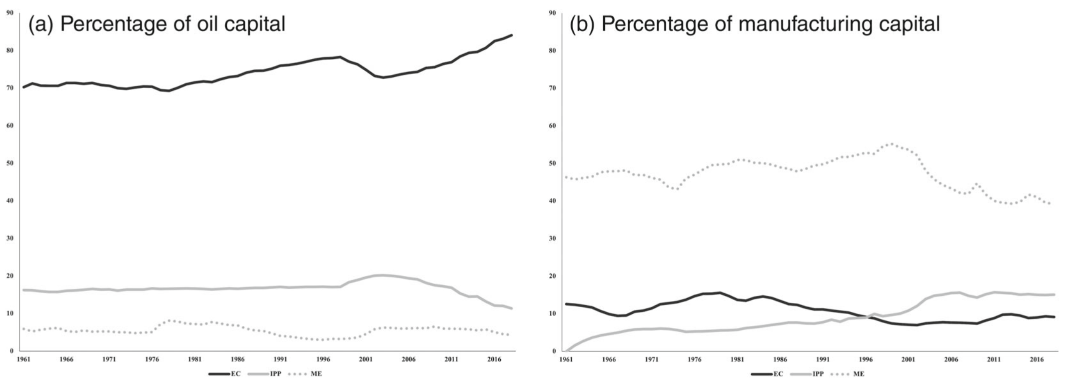

Figure 12 Capital composition, oil and manufacturing

capital stock is dominated by EC, and this importance grows during the oil price boom. By comparison, EC in the manufacturing sector is small and stays relatively constant during that time period. On the other hand, the capital stock in the manufacturing sector consists largely of ME, which falls during the capital boom in the oil sector. However, the ME in the oil sector stays relatively flat.

These findings indicate that each sector is reliant on a different type of capital and that the type of capital that grows in importance in the oil sector during the boom is different than the type of capital that falls in the manufacturing sector during that same period.

Still, the comparison we make may be masking more substantive patterns because the denominator in the two figures is different—the aggregate capital in each sector. In the three panels of figure 13, we plot the evolution of the different types of capital split between manufacturing and oil sector and the latter further divided into oil sands and traditional oil.

Figure 13(a) shows that EC is largely used in the oil sector, initially only in the traditional sector, and it spikes in the oil sands after the 2000s. During this time period, the percentage of EC in the manufacturing sector is very small throughout. Hence, it is unlikely that there is a movement of capital between the two sectors.

Figure 13(b) shows that IPP was installed mostly in the oil sector in the 1960s. In the early 1970s, it then stabilized at around 41% in oil and 31% in manufacturing. Since then, we can observe a secular increase in oil to about 44% and a secular decrease in manufacturing to about 12%. The decrease in manufacturing is more pronounced after 2001.

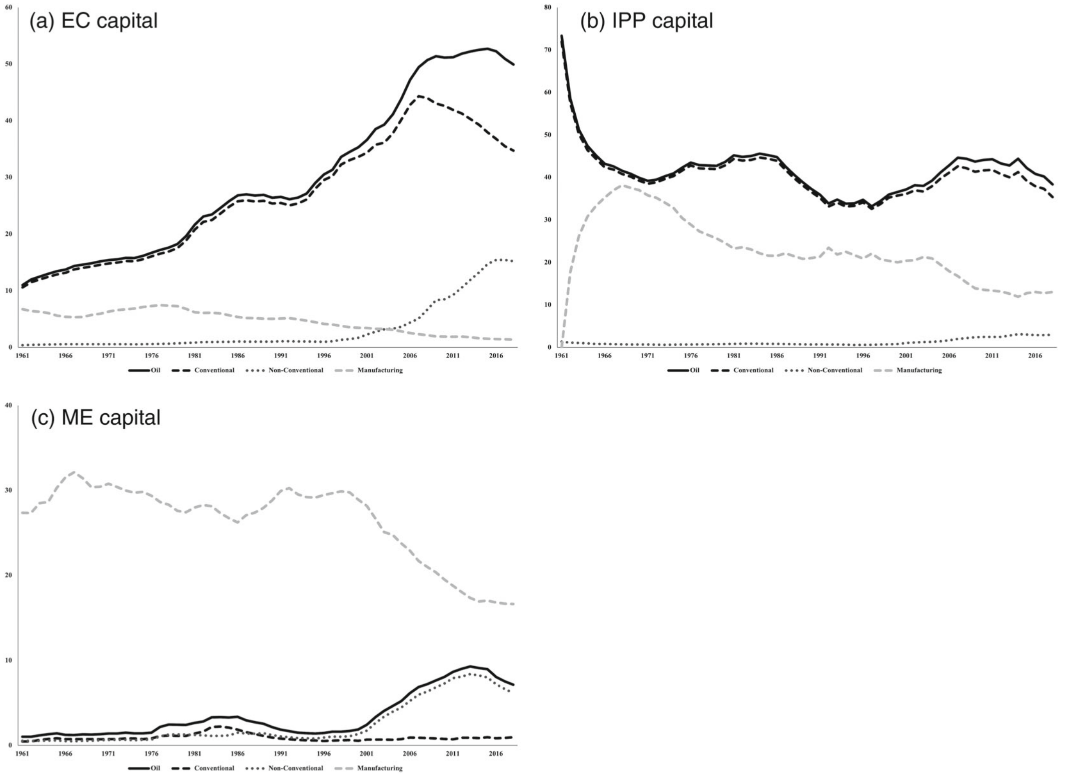

Figure 13 Capital types in oil and manufacturing

Last, figure 13(c) shows that ME increases dramatically in the oil sector after 2001 (from 2% to 7%), and it falls substantially in the manufacturing sector during the same time period (from 28% to 17%). The increase in the oil sector is caused largely by the increase in the oil sands.

The picture that emerges from comparing the types of capital installed in the manufacturing sector with those installed in the oil sector is that capital (especially IPP and, more prominently, ME) could have been reallocated from the manufacturing sector to the oil sector—and notably, to the oil sands.

That being said, the potential evidence of factor reallocation does not necessarily mean that there is misallocation. It could well be that the units of capital in the oil sands became less productive than when they were installed in manufacturing—or the other way around. To be able to disentangle this question, we need more disaggregated data at the firm and probably also household (owner) level. In the absence of more disaggregated data, we cannot conclusively state that the growth in the capital stock allocated to the oil sector comes at the expense of more-productive activities in the manufacturing (or any other non-oil) sector. It could well be that the capital was installed to take advantage of high oil prices and would not have otherwise been used. Our aggregate analysis cannot provide conclusive evidence either way.

6. Concluding remarks

Our research shows that the oil sector is the primary reason for the lack of TFP growth in Canada (and Norway) and that it does not generate a similar lack of TFP growth in the United States. Hence, our result concludes that the difference in productivity growth between Canada and the United States can be attributed entirely to the oil sector.

While we believe that our result sheds light on the underlying cause of differential evolution of productivity between the two countries, it should be used with caution: we find that the oil sector can explain, in an accounting sense, the lack of Canadian TFP growth. Our findings do not, however, make a judgement on the desirability of this result nor get into the debate surrounding an industry that confronts a host of challenges, such as carbon emissions.

Namely, it is perfectly plausible that the Canadian economy is responding optimally by exploiting a resource when its value is very high. Whether this represents the best course of action is a question that requires further exploration. Consequently, we defer the answer to this crucial issue to future research.

We view the question of whether the explosion in the oil sector capital stock constitutes a case of resource misallocation as an important one and worthy of future research. It would be valuable to know whether capital moved from more-productive sectors like manufacturing in response to changes in oil prices or if the observed trend is a result of an investment boom that was directed to more profitable uses of capital. To properly answer this question, one will likely require firm-level data.

Similarly, because our data span only until 2018, our work is silent about the well-documented post-COVID productivity decline.[19] Still, there has been a surge in oil prices that may be behind part of the sluggish behaviour of Canadian productivity. Understanding how oil prices have interacted with the post-COVID productivity decline is another promising area of future research.

Appendices

A. Data details

In this appendix, we describe the data sources we use to compute all the figures in our paper (sections 3, 4 and 5). Note that all the references to tables in this section are to online tables obtained from Statistics Canada, the Bureau of Economic Analysis and Statistisk sentralbyrå (Statistics Norway). Specifically, we examine the sectoral information for all business sectors of the economy that report capital stock, hours worked and value added.

We use online tables 36-10-0217-01, 36-10-0208-01 and 36-10-0096-01 from Statistics Canada for aggregate GDP, hours worked and compensation. The latter refers to row "business sector" in online table 36-10-0208-01, which consists of the entire economy net of public administration, non-profit institutions and the rental value of owner-occupied dwellings. Capital ($K_{i,t}$) in each sector i for each year t is constructed using data (in current prices) on investment ($I_{i,t}$), geometric depreciation ($\delta_{i,t}K_{i,t}$) and geometric end-year net stock ($K_{i,t+1}$) so that, in year t and sector i,

$$K_{i,t} = K_{i,t+1} + \delta_{i,t}K_{i,t} - I_{i,t}. \tag{A1}$$

The capital series is then deflated using the deflator for each year implied by the aggregate value added in current and 2012 prices. The aggregate capital series is constructed by subtracting the government sector and non-profits from the investment, depreciation and end-year net stock of Total Industries.

19 See Tombe (2023) for a recent description of this decline.

The Canadian provincial-level data are also taken from Statistics Canada online tables 36-10-0211-01 (aggregate GDP, hours worked and compensation), 36-10-0402-01 (oil sector GDP), 36-10-0489-01 (hours worked and compensation in the oil sector) and 36-10-0096-01 (capital).

The data for the United States are produced analogously using online data from the Bureau of Economic Analysis (BEA). Using online tables on value added by industry, we obtain value added for each industry in current prices and compute value added in 2012 prices using the tables for chain-type price indexes for value added by industry. We combine the values from the current tables for the years 1997 to 2018 with the historic tables that cover 1961 to 1997. Where discrepancies for the year 1997 exist, we use the values from the current tables. Using the current price and 2012 price values for value added, we compute the aggregate deflator, which is then used to produce real valued estimates for value added in each industry.

For capital, we combine online tables 3.1ESI, 3.4ESI and 3.7ESI on net-stock, depreciation and investment of private fixed assets by industry, respectively, in the same way described above. We then deflate the value of the capital stock using the aggregate deflator for value added.

For hours worked, we use online tables 6.9B, 6.9C and 6.9D. Due to discrepancies between online tables 6.9C and 6.9D, we use the data for 1998 to 2018 from online table 6.9D and for 1987 to 1997 from online table 6.9C. The tables lack data for hours worked in oil and gas extraction. To get around this, we compute average hours worked in mining by dividing total hours worked in mining by the number of full-time and part-time employees in mining (from online tables 6.4B, 6.4C and 6.4D) and then multiply this value by the number of full-time and part-time employees in oil and gas extraction:

$$Hours_{oil} = Hours_{mining} \times \frac{Employees_{oil}}{Employees_{mining}}. \tag{A2}$$

Similar to hours worked, the values for 1998 to 2018 come from online table 6.4D. Finally, for compensation, we use online tables 6.2B, 6.2C and 6.2D in the same way.

The data used for Norway come from the Annual National Accounts. Data on value added are taken from online table 9 (value added by kind of main activity at basic values). Data on employee compensation come from online table 13 (compensation of employees by kind of main activity), and hours worked are taken from online table 15 (total hours worked by kind of main activity, employees and self-employed). The capital stock is taken from online table 37 (fixed assets by kind of main activity). Data on value added, the capital stock and employee compensation are reported in current prices. They are then converted into real terms using the GDP deflator taken from the OECD. From each table, the aggregate series refers to the “total industry” row and the oil sector series refers to the “oil and gas extraction” row.

The parameters of the production function and TFP for all three countries are computed as described in section 3. Data on working age population in each country are taken from the OECD.

For each country, the net-of-oil aggregates are constructed by taking the aggregate values for value added, the capital stock, hours worked and employee compensation and subtracting the corresponding values from the oil sector. For monetary values (GDP and capital), we take aggregate variable in current prices and subtract the corresponding variable in oil extraction in current prices. This value is then deflated using the aggregate GDP deflator to obtain the net-of-oil variables in real terms. Net-of-oil hours worked is obtained by subtracting hours worked in the oil sector from aggregate hours worked. We then recompute the labour share and TFP using the net-of-oil values instead of the aggregate values.

B. Alternative exclusions in growth accounting decompositions exercise

This appendix section presents alternative growth accounting decompositions that differ from those in the main text. Specifically, we demonstrate that the correction of the TFP series that arises when we exclude the oil sector does not occur when we exclude other sectors such as agriculture, manufacturing, services or mining other than oil. To illustrate this point, in figure B1, we remove the agriculture sector and observe that TFP remains stagnant during the 2000s. Thus, we can conclude that the agriculture sector alone cannot account for the lack of TFP growth during this period.

In figure B2, we conduct a similar analysis, but this time we exclude the manufacturing sector. As before, we arrive at the same outcome, namely, that TFP remains stagnant during the 2000s even after removing the manufacturing sector from consideration.

In figure B3, we repeat the same analysis by excluding the services sector. Although we reach the same conclusion that removing this sector alone cannot explain the stagnant TFP, we obtain a much more volatile depiction. This is due to the fact that the services sector constitutes a significant proportion of GDP, resulting in greater measurement error when it is excluded from the analysis. Additionally, the declining hours per WAP line can be attributed to structural transformation, where the services sector has grown significantly during this period. Removing it from consideration causes the total number of hours worked in the economy to fall mechanically.

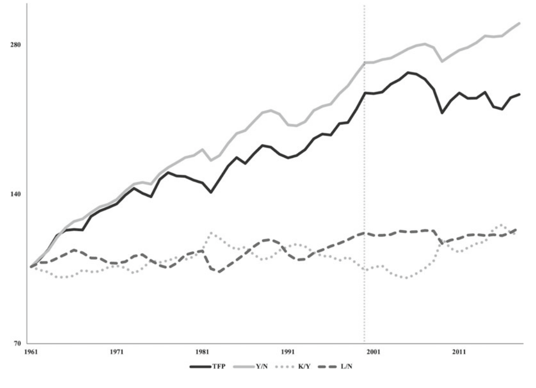

Figure B1 Robustness: Net of agriculture

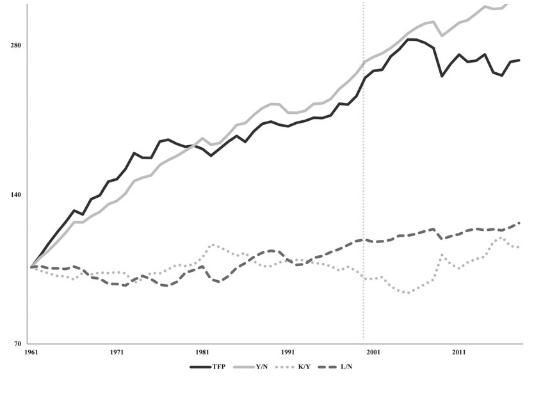

Figure B2 Robustness: Net of manufacturing

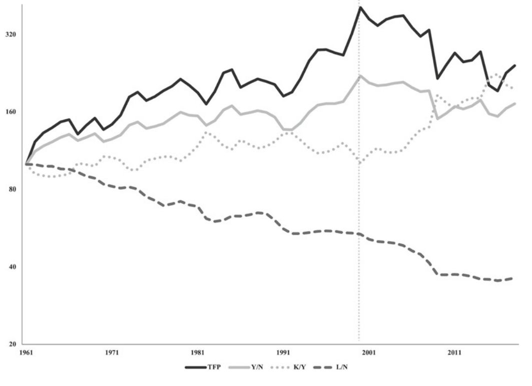

Figure B3 Robustness: Net of services

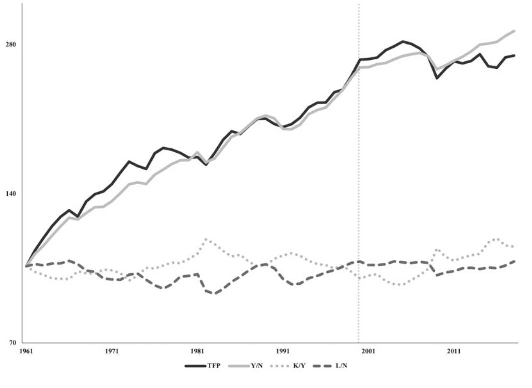

Figure B4 Robustness: Net of other mining

Finally, figure B4 demonstrates that the remaining mining sector, apart from oil, is also not accountable for the stagnant TFP.

C. Adjusting for PPP in growth accounting decompositions exercise

In our analysis comparing Canada to the United States, we do not adjust for exchange rate fluctuations. It is well established that oil prices greatly affected Canadian exchange rates, particularly during the commodity boom in the 2000s. To verify the robustness of our results, we repeat the decomposition using the Penn World Table (Feenstra et al. 2015) values for Canadian and American Real GDP, respectively. In particular, we use "output-side real GDP at chained PPPs," which allows us to "compare relative productive capacity across countries and over time." We then recompute the aggregate GDP deflator by taking the ratio between aggregate GDP in current prices and the PWT values and deflating all the monetary variables accordingly.

As figures C1(a) and C1(b) show, adjusting for PPP does not meaningfully impact the results of the aggregate growth decomposition for Canada. When oil is included, the lack of TFP growth in the 2000s persists.

In figures C2(a) and C2(b), we repeat the comparison of the evolution of TFP growth between Canada and the United States using these PPP adjusted measures.

While the overall trend post-2010 of net-of-oil TFP growth is more subdued when accounting for PPP, the main result is strengthened. When we remove oil from the growth

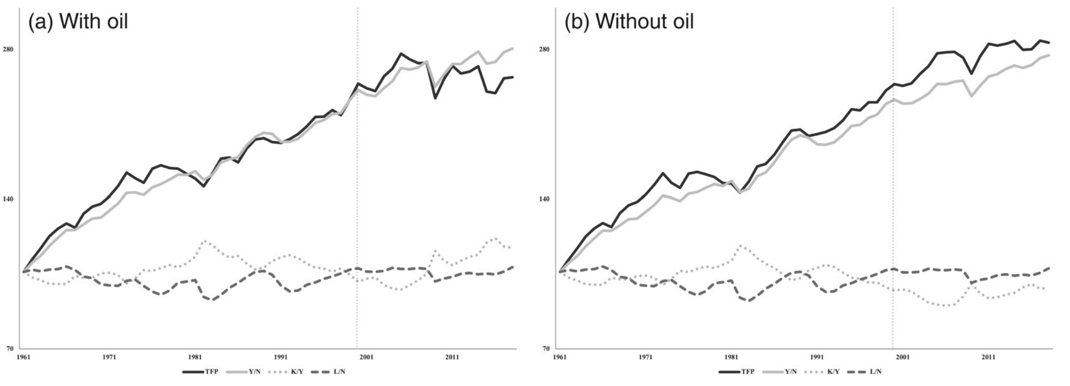

Figure C1 PPP adjusted growth accounting decomposition

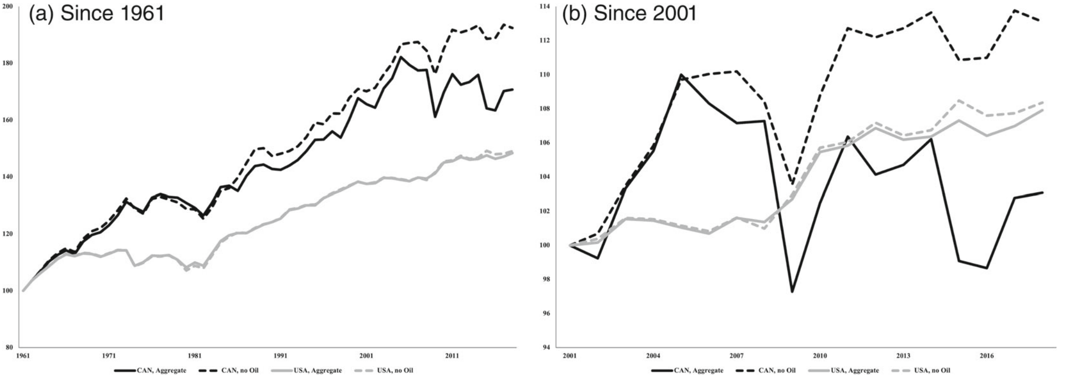

Figure C2 PPP adjusted TFP and net-of-oil TFP, Canada and United States

accounting, Canadian TFP evolved comparably to the United States post-2001. In fact, coming out of the Great Recession, Canada's net-of-oil TFP grew significantly more than that of the United States before slowing down towards the end of our sample.

D. Alternative α in growth accounting decompositions exercise

In our analysis of TFP performance between the whole economy and the net-of-oil economy, we use different values of α, which is the parameter that governs the capital share of the economy. It is natural to wonder if the lack of TFP growth being accounted for by netting out the oil sector is due to the use of different parameter values. To address this question, we perform an alternative decomposition using the benchmark α value on the net-of-oil economy, and the resulting picture is very similar to the one in the main text. Figure D1 shows the decomposition.

Another natural concern with our exercise has to do with the evolution of the labour share. As documented by Karabarbounis and Neiman (2014) and many others, the labour share of income may be declining in the data. In our exercise, the labour share is used to determine parameter α in the production function, which plays a crucial role in the measurement of TFP. In the benchmark exercise, this parameter is calculated using (one minus) the average of the series for the labour share. As a robustness check, we compute TFP using a different value of α in every year, ensuring that it is consistent with that year's labour share. We plot the results in figures D2(a) and D2(b).

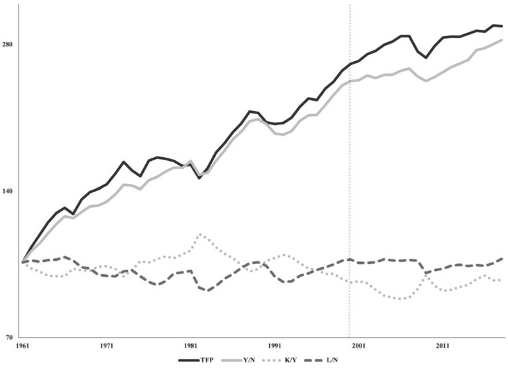

Figure D1 Robustness: Alternative α

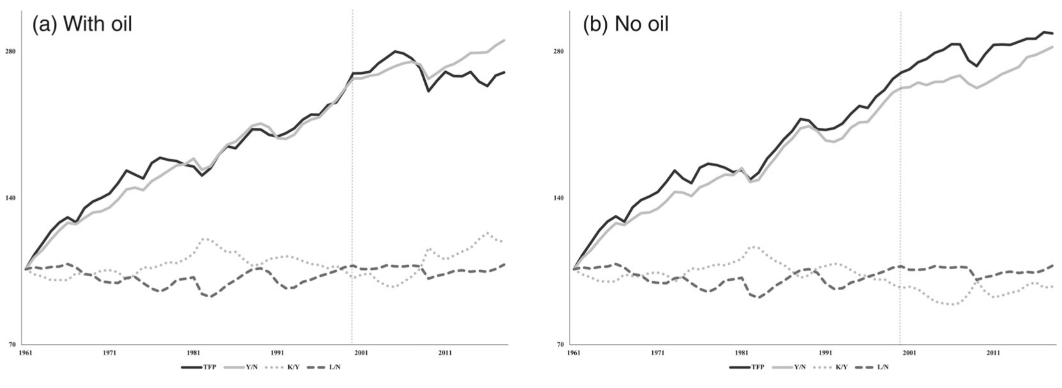

Figure D2 Changing labour share growth accounting decomposition

Our results show that the growth accounting exercises—with a flat TFP when oil is included and a growing TFP when oil is excluded—are very similar to those of a constant parameter α.

Therefore, given the two exercises in this appendix, we conclude that the difference in TFP growth between the whole economy and the net-of-oil economy is not an artefact of the parameter value (or values) α used in our analysis.

Supporting information

Supplementary material accompanies this article. The data and code that support the findings of this study are available in the Canadian Journal of Economics Dataverse at https://doi.org/10.5683/SP3/H0WIHX.

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