Impact of seasonal temperature rise on labour and capital productivity in manufacturing sector: a study with Canadian panel data

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Abstract: Rising global temperature is one of the manifestations of climate change. This study analyses the impact of average temperature rise in summer and winter on production in the manufacturing sector, which is mostly indoor production. This study also compares the differential impact of temperature rise on indoor and outdoor production. Using panel data from ten Canadian provinces for the period of 1997 to 2010, it finds that the rise of average temperature in summer causes labour and capital productivity in manufacturing sector to decline. As a result the production of manufacturing goods falls, but this impact is much weaker compared to that on outdoor production, i.e., the production in agriculture, forestry, fishing, and hunting sectors together. Average temperature rise in winter, however, leaves production in the manufacturing sector unaffected. These results are obtained by controlling for population growth, GDP per capita, and yearly-dummies. These findings may have some policy implications for Canada and other countries that have been experiencing warmer than usual summer and winter temperatures due to climate change.

Keywords: climate; manufacturing production; government policy; panel data; Canada.

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1 Introduction

Temperature rise due to climate change is a growing concern for all. The Kyoto Protocol (1997) was the first large-scale international treaty that set targets for countries for the reduction of anthropogenic greenhouse gas emissions to prevent or slow down global warming. Under the agreement, Canada was committed to bring down its greenhouse gas emissions to 6% below 1990 levels by 2012, but its emission levels were 17% higher than the 1990 levels in 2009. In 2011, it decided to withdraw from the treaty. However, the long-term adverse consequences of temperature rise on Canadian economy were not recognised in that decision-process. The recent Paris Agreement on Climate Change (2015) set the goal to keep global temperature rise below 2°C above the pre-industrial levels. Canada, under the new leadership, has recognised its importance and has become one of the signatories of this agreement. In this study, we will examine the effects of temperature rise on the production of primary sector, where production happens mainly outdoor, and the secondary/manufacturing sector, where the production happens mainly indoor.

Some earlier studies focused on the influence of climate change on crop production (e.g., Jones and Thornton, 2003; Parrya et al., 2004; Salim and Islam, 2010; Chen et al., 2012; Eregha et al., 2014; Hatfield et al., 2011; Luo, 2011; Schlenker and Roberts, 2008). Some others examined the impact of climate change on fisheries, which are mostly about how to deal with potential risk of extinction of fish species due to climate change (e.g., McDaniels et al., 2010; Holbrook and Johnson, 2014; Cheung et al., 2013a, 2013b; Brander, 2010, 2013; Loeng, 1989; Portner and Peck, 2010). Likewise, there are studies about the impact of climate change on forestry production (e.g., Wang et al., 2011), dairy production (e.g., Key and Sneeringer, 2014), and on the secondary production sector (e.g., Kumar and Yalew, 2012). Most of these studies show that production would be adversely affected by climate change. Nevertheless, there is a void in the literature in dealing with temperature rise on indoor production. This paper attempts to fill part of that gap.

In order to examine the impact of temperature rise on production, first, we must compare the differences, if any, in labour and capital productivity due to temperature change. Second, we must recognise that the impact of a hot summer caused by climate change on production may not be the same as the impact of a mild winter caused by climate change on production. Third, not only the outdoor production (e.g., the production in agricultural and fishing sectors), the indoor production (e.g., the production in manufacturing sector) can also be affected by climate change. In this study, we will examine how indoor production in Canada is affected by a rise in summer and winter temperature, and how the effects are different from those of outdoor production. In order to do that we control for other factors that can influence the production.

Canada has ten provinces and three territories with myriad climate zones. Different climate conditions are measured by multiple meteorological stations located in different parts of the country. Using panel data from ten provinces for the period of 1997 to 2010, this study finds that not only outdoor production, the production of manufacturing goods is also adversely affected by temperature change. Average temperature rise in the summer is associated with the reduction of labour and capital productivity, and lower contribution of manufacturing sector in real GDP. However, the adverse effect of temperature rise in summer on manufacturing production is relatively much weaker than that on outdoor production (agriculture, forestry, fishing, and hunting sectors together). The impact of temperature rise in the winter on labour and capital productivity, and the change in contribution of the manufacturing sector in real GDP is statistically insignificant.

This paper is structured as follows. The next section presents the literature review. Section 3 illustrates the variables and the hypotheses. Section 4 explains the empirical model and presents the regression results. The concluding remarks are made in Section 5.

2 Literature review

One of the studies that is somewhat similar to our study is by Kumar and Yalew (2012) that focused on the impact of climate change on economic activities in secondary and tertiary sectors of an economy. Their study finds that the impacts of climate change on these sectors are wide and complex. According to them the production in these sectors are more adversely affected than the production in agricultural sector.

The impact of climate change on food production was analysed by Parrya et al. (2004). Their study uses a transfer function that is derived from crop model simulations for projected climate change scenarios. Their paper shows that the global crop yields will drop in the long run because of climate change, of which rising temperature is an integral part. In spite of lower crop yields, they predicted that the world food supply would likely remain steady. The reason is that the developed nations would adopt newer technologies and produce goods with higher efficiency in harsh climate, which would compensate for the drop of crop yields in the developing nations. Similar to Parrya et al., Hatfield et al. (2011) also showed that climate change posed a big threat for crop production in the long run. However, their study showed that the impact of climate change was not the same for all types of crops and across various regions.

Key and Sneeringer (2014) studied the impact of climate change on American dairy products. Their study shows that similar to the crop production, dairy production is also adversely affected by climate change. Kjellstrom et al. (2009) examined the impact of climate change on labour productivity. They find that if no adaptive policy is taken labour productivity will decrease in most regions of the world. However, the largest loss of labour productivity will happen in the tropical regions such as the Southeast Asia, part of South and Central America, and the Caribbean.

Based on expert judgements, McDaniels et al. (2010) analysed the vulnerability of sockeye salmon in Fraser River due to climate change. They find that rising temperature due to climate change causes a big concern for the sockeye salmon. Considering all stages of life-cycle of the salmon, their paper attempted to assess the future vulnerability of the species due to climate change. According to them, high temperature imposes a high risk for the stock of salmon, but the ways to mitigate this adverse effect is limited.

By reviewing some recent studies, Brander (2010) showed that the distribution, productivity, and resilience of fish stocks could be influenced by climate change. This study found that the long term effect of climate change on fisheries could be very large, but uncertain. Brander recommended for climate adaptive policies to maintain normal fish stock.

3 Variables and the hypotheses

3.1 Adverse climate and indoor and outdoor production

The production of manufacturing or secondary sector is mostly indoor or factory-based. However, it often uses raw materials produced in the primary sector, where production happens mostly in outdoor. The production in the manufacturing sector can, therefore, be adversely affected by temperature change though it may not be as severe as that in the primary sector. As the production is a function of capital and labour productivity, which are partly affected by environmental changes, we consider both capital and labour productivity, and the contribution of the manufacturing sector to GDP to assess the impact of rising temperature on the production of this sector. These are the dependent variables for our empirical study. We must note here that technological change is an important determinant of capital and labour productivity in the long run, but it should not contribute to short-run fluctuations in production. Also, technological change will make any negative effect on productivity due to temperature change smaller.

3.2 Average temperature rise in summer and winter

As evident from the title of this paper, the main explanatory variable in our model is temperature rise in summer and winter in Canada. In one hand, the rising temperature is causing some summers to have frequent hot spells causing the manufacturing workers to be less productive; machines, tools and raw materials to be less-functional or short-lasting; and the scope and the scale of overall production of the sector to be hampered. On the other hand, the rising temperature makes some winters much milder, which could increase productivity of the workers; make machines, tools, and raw materials more functional; and increase production by not hampering the scope and the scale of overall production of the sector.

The average summer and winter temperatures for the period of 1961 to 1990 are considered to be normal for Canada. Therefore, we use the deviation of seasonal temperatures in our study period 1997 to 2010 from the average temperature between 1961 and 1990 in order to examine the impact of rising temperature on the production of manufacturing sector.

The reason for using 1997 to 2010 as the study period is because data on all variables of our model are not available after 2010.

3.3 The hypotheses

Following hypotheses are to be tested:

Hypothesis 1 Labour productivity in the manufacturing sector declines as the average summer temperature rises, but it remains unaffected as average winter temperature rises.

Hypothesis 2 Capital productivity in the manufacturing sector drops as average summer temperature rises, but it remains unaffected as average winter temperature rises.

Hypothesis 3 Some studies (e.g., Parrya et al., 2004; Hatfield et al., 2011; Kjellstrom et al., 2009; McDaniels et al., 2010) found that adverse climate had negative impact on the production of primary sector, which is a supplier of inputs for the manufacturing sector. This together with lower capital and labour productivity causes overall production of the manufacturing sector to decline. We, therefore, hypothesise that contribution of the manufacturing sector in real GDP is negatively affected by average temperature rise in summer, but not by average temperature rise in winter.

3.4 Control variables

In addition to labour, capital and climate conditions, other factors such as population growth also affects production. By increasing labour supply, population growth can cause labour productivity to decline. Another contributing factor to production is per capita GDP. High per capita GDP helps achieve high per person machine and tools, and hence increases labour productivity. It also increases capital productivity by improving technology, ensuring better education, and so on. Consequently, the higher the GDP per capita, the higher is the productivity of labour and capital, and the higher is the contribution of the sector in real GDP.

Production can also be affected by annual economic conditions and by business cycles. To take that into consideration, we use yearly-dummies in our model.

4 Empirical model and the results

4.1 Regression model

We use ordinary least squares (OLS) model for data analysis. The regression equation that we use to estimate the coefficients is:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots + \beta_k X_k + \varepsilon,$$

where Y is the dependent variable, which refers to labour productivity, capital productivity, and the contribution of manufacturing sector in real GDP in different model specifications. $X_1,\ldots,X_k$ refer to the explanatory variables of the model. α is the constant term and βs are the coefficients of different explanatory variables. ε is the error term. We use robust standard errors in our estimation.

The reason for using the OLS model is that it is simple to understand and interpret. We have used annual and regional dummies to control for any fixed effects. A fixed effect model will not work well in this case due to slow changing nature of the variables over time.

4.2 Regression results

The estimated regression results are reported in Tables 1–4. As reported in Table 1, we see that the rise of average temperature in summer is significant and negatively associated with

1 labour productivity (significant at 10% level)

2 capital productivity (significant at 5% level)

3 the contribution of manufacturing sector in real GDP (significant at 10% level).

Our study finds that labour productivity drops not only in the primary sector (e.g., agriculture) as found in other studies (e.g., Kjellstrom et al., 2009), it also drops in the manufacturing sector, where production is mostly indoor. A rise in average summer temperature with frequent hot spells lowers labour productivity by making the workers sick or by preventing them from contributing with full productivity.

Table 1 Impact of rising average summer temperature on the production of manufacturing sector

	Manufacturing sector						*Agriculture, forestry, fishing, and hunting sectors together*	
	Sp.1: dep. var. = labour productivity		*Sp.2: dep. var. = capital productivity*		*Sp.3: dep. var. = contribution in real GDP*		*Sp.4: dep. var. = contribution in real GDP*	
	Co-eff.	*S.E.*	*Co-eff.*	*S.E.*	*Co-eff.*	*S.E.*	*Co-eff.*	*S.E.*
Population growth	–1.10	1.22	–2.30	1.46	–0.72	1.11	–5.03	3.68
GDP per capita	3.38***	1.24	6.76***	1.61	5.68***	1.18	22.67***	3.25
Summer temp. rise	–1.60*	0.90	–2.91**	1.45	–1.86*	1.03	–9.20***	3.12
Constant	84.3***	4.18	75.24***	6.24	68.45***	3.99	41.3***	10.2
Yearly-dummies	*(Results are not reported for space limitation)*							
Number of obs	140		140		140		140	
F	3.95		5.12		10.13		16.96	
Prob > F	0		0		0		0	
R-squared	0.3285		0.3743		0.5542		0.5584	
Root MSE	8.4082		11.085		8.3139		20.176	

Notes: ***, **, and * refer to level of significance at 1%, 5%, and 10% level respectively.

The results also show that capital productivity in the manufacturing sector is more adversely affected than labour productivity by the rise of average summer temperature. With 1°C increase in average summer temperature, capital productivity drops by –2.91 units, while labour productivity drops by –1.60 units. The coefficient of capital productivity is significant at 5% level, while that of labour productivity is significant at 10% level. These results are justified as the manufacturing sector is capital-intensive, and the capital such as factory buildings, machines, tools, raw materials, etc. could be more exposed to and adversely affected by hot weather in summer.

Rise in average summer temperature not only reduces the overall production of agricultural, dairy, and fishing sector as previous studies have found (see Parrya et al., 2004; Key and Sneeringer, 2014; McDaniels et al., 2010; Brander, 2010), it does so for the manufacturing sector as well. The contribution of this sector in real GDP drops by 1.86 units compared to a drop of 9.20 units in the primary sector for every 1°C increase in average summer temperature. The reasons are lower labour and capital productivity, and decrease in production in the primary sector, which is a supplier of inputs for the manufacturing sector.

The negative impact of rising average summer temperature on the production of primary sector is relatively more significant than that of manufacturing sector (specifications 3 and 4 in Table 1). This is an expected result as outdoor or primary production is more exposed to weather conditions.

In Canada, Ontario and Quebec are two provinces with relatively large manufacturing sector. Using a dummy variable for these provinces (1, if Ontario or Quebec; 0, otherwise), we see no significant difference in signs or magnitudes of the coefficients of our model except one. The contribution of manufacturing sector in real GDP, which was significant at 10% in model specification 3 (Table 1) is now significant only at 16% (Table 2).

Table 2 Impact of rising average summer temperature on the production of manufacturing sector by using a dummy variable for Ontario and Quebec

	Manufacturing sector						*Agriculture, forestry, fishing, and hunting sectors together*	
	Sp.1: dep. var. = labour productivity		*Sp.2: dep. var. = capital productivity*		*Sp.3: dep. var. = contribution in real GDP*		*Sp.4: dep. var. = contribution in real GDP*	
	Co-eff.	*S.E.*	*Co-eff.*	*S.E.*	*Co-eff.*	*S.E.*	*Co-eff.*	*S.E.*
Population growth	–0.97	1.30	–2.60*	1.58	0.83	1.14	–3.86	3.72
GDP per capita	3.31***	1.28	6.93***	1.64	4.84***	1.12	22.03***	3.25
Summer temp. rise	–1.57*	0.93	–3.00**	1.47	–1.41$^{(16\%)}$	0.99	–8.85***	3.17
Constant	84.58***	4.33	74.65***	6.48	71.46***	4.09	43.57***	10.14
Dummy variables	*(Results are not reported for space limitation)*							
Number of obs	140		140		140		140	
F	3.82		4.96		11.52		16.75	
Prob > F	0		0		0		0	
R-squared	0.3291		0.3762		0.6165		0.5644	
Root MSE	8.4389		11.114		7.7427		20.12	

Notes: ***, **, and * refer to level of significance at 1%, 5%, and 10% level respectively.

The impact of rising winter temperature on capital and labour productivity, and the contribution of manufacturing sector in real GDP shows a clear contrast with what we saw in Tables 1 and 2 (see Table 3). None of the coefficients of winter temperature change is statistically significant. The signs of the coefficients are positive for model specifications 1 and 2, and negative for model specification 3. Among the control variables, GDP per capita is strongly significant and has the expected sign in all of the specifications. Unlike a harsh summer, a milder winter does not adversely affect labour and capital productivity. Therefore, the results are as expected.

Table 3 Impact of rising average winter temperature on the production of manufacturing sector

	Sp.1: dep. var. = labour productivity		*Sp.2: dep. var. = capital productivity*		*Sp.3: dep. var. = contribution in real GDP*	
	Co-eff.	*S.E.*	*Co-eff.*	*S.E.*	*Co-eff.*	*S.E.*
Population growth	–1.21	1.26	–2.51*	1.48	–0.74	1.16
GDP per capita	3.76***	1.25	7.46***	1.59	6.15***	1.21
Winter temp. rise	0.08	0.73	0.30	1.03	–0.56	0.69
Constant	82.9***	4.31	72.66***	6.23	67.12***	3.73
Yearly-dummies	*(Results are not reported for space limitation)*					
Number of obs	140		140		140	
F	3.76		3.9		10.44	
Prob > F	0		0		0	
R-squared	0.3179		0.356		0.5469	
Root MSE	8.4743		11.246		8.3816	

Notes: ***, **, and * refer to level of significance at 1%, 5%, and 10% level respectively.

Table 4 Impact of rising average winter temperature on the production of manufacturing sector by using a dummy variable for Ontario and Quebec

	Sp.1: dep. var. = labour productivity		*Sp.2: dep. var. = capital productivity*		*Sp.3: dep. var. = contribution in real GDP*	
	Co-eff.	*S.E.*	*Co-eff.*	*Co-eff.*	*S.E.*	*Co-eff.*
Population growth	–1.03	1.34	–2.72*	1.61	0.86	1.17
GDP per capita	3.65***	1.30	7.58***	1.64	5.17***	1.14
Winter temp. rise	0.09	0.72	0.29	1.04	–0.48	0.64
Constant	83.33***	4.49	72.22***	6.50	70.56***	3.91
Dummy variables	*(Results are not reported for space limitation)*					
Number of obs	140		140		140	
F	3.71		3.7		11.9	
Prob > F	0		0		0	
R-squared	0.3191		0.3569		0.6128	
Root MSE	8.5016		11.284		7.7797	

Notes: ***, **, and * refer to level of significance at 1%, 5%, and 10% level respectively.

When controlled for provinces with large manufacturing sector (Ontario and Quebec), the same results hold except small changes in magnitudes of the coefficients (Table 4).

5 Concluding remarks

In this study, we have analysed the impact of rising average temperature on the production of manufacturing sector that constitutes mostly indoor production. Using panel data from ten Canadian provinces for the period of 1997–2010, this study finds that capital and labour productivity, and the contribution of the manufacturing sector in real GDP decline as the average temperature increases in summer. However, the negative impact of rising summer temperature on the production of manufacturing sector is relatively weakly significant than that of outdoor production which includes agriculture, forestry, fishing and hunting. In contrast, however, labour and capital productivity, and the contribution of manufacturing sector in real GDP are not significantly affected by rising average temperature in winter. We obtain these results by controlling for factors such as population growth, GDP per capita, and yearly-dummies.

As the manufacturing sector has significant contribution in real GDP and employment in Canada, the negative impact of rising average temperature cannot be ignored. The issue of global warming and its impact on production and general well-being of the people must have to be addressed as part of a long-term policy goal. In addition, some actions need to be taken to minimise the production loss in short-run due to rising temperature. Training of workers and ensuring climate-accustomed working conditions could be cost-effective measures to improve labour productivity during hot summers.

Investment in R&D to find ways to minimise productivity loss and increase sturdiness of capital such as machines, tools, and raw materials could be beneficial. Any production function needs to include the potential effects of rising temperature. Climate-related problems in primary sector, which is a major supplier of inputs for the manufacturing sector, and any changes to the nature of consumer demand and habits has to be considered by policy-makers in order to deal with this issue.

Not only primary and secondary sectors, tertiary sector such as tourism industry is also likely to be affected by rising temperature. A future study will look into that. We will also look at regional variation in production due to temperature rise. The scope of the present study can be further extended by doing cross-country comparison. In some countries, the effects might be more significant if temperature increase goes above the human tolerance level as many factories are not air-conditioned.

This paper makes a contribution in the literature by addressing the issue of rising global temperature on the production of manufacturing sector in Canada.

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