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Investigating the impacts of plausible Canadian policies and their supporting mechanisms on export-based regional air pollution in China: A cement manufacturing case study

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Abstract

The *Canadian Environmental Protection Act* (CEPA) enables the Minister of Environment and Climate Change to develop policy to curtail international air pollution. However, regional air pollution generated during the manufacturing of products outside of Canada is not addressed in CEPA. Using cement manufacturing in China as a case study, three policy options were devised to manage export-based regional air pollution. The options investigated included Policy 1—an open border with direct support for domestic cement manufacturers, Policy 2—a restricted border with no support for domestic cement manufacturers, and Policy 3—a selective border with partial support for domestic cement manufacturers. An analytic hierarchy process, in conjunction with the three actionable solidarities of cultural theory, was applied to the policy options and their supporting mechanisms. Results indicated that Policy 3 was strongly favoured (52.5%), followed by Policy 2 (33.4%), with Policy 1 being the least favoured (14.2%). Regarding policy mechanisms, a verification process was preferred by all three solidarities. From the standpoint of a universal approach to trade it is recommended that an air quality agreement between China and Canada under CEPA be established with a framework to eventually incorporate environmental production declarations. With respect to cement exports, it is recommended that manufacturers in China provide emissions intensities and winter smog assessments.

Key words: air pollution, energy-intensive trade-exposed (EITE) industry, cement manufacturing, leakage, analytic hierarchy process (AHP), cultural theory, environmental product declaration (EPD)

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Introduction

The *Canadian Environmental Protection Act, 1999* (CEPA) was developed for the dual purpose of pollution prevention and the protection of the environment and human health in Canada (ECCC 2014). In Part 7, Division 6 of CEPA, the Minister has the authority to act if Canadian sources are generating air pollution outside of Canada or if the air pollution violates an international binding agreement on Canada (ECCC 2014). As an example of the latter, Canada entered into the *Agreement Between the Government of Canada and the Government of the United States of America on Air Quality*

(ECCC 2013a, 2013b). The purpose of the agreement is to minimize transboundary air pollution between the two countries for mutually beneficial purposes.

Canada recognizes international air pollution issues and has provided a legislated mechanism for intervention, but it is limited to the movement of air pollution across a physical border. However, regional air pollution generated during the manufacturing of goods, which are imported to Canada, is not considered. Naturally, Canada has no direct control over how foreign jurisdictions operate. That said, if an imported product is manufactured in a manner that is not consistent with Canadian air pollution standards then a contradiction may occur. Moreover, the unintended effect of trade could potentiate pollution in the exporting country.

Intuitively, trade with developed markets poses a lower risk of pollution displacement than with emerging markets. As one of Canada's largest trading partners, and a developed market, the United States has a strong federal regulatory system to manage and control air pollution. The *Clean Air Act* (CAA) administered by the Environmental Protection Agency (EPA) is authorized to limit emissions from industrial operations and requires that individual states meet the National Ambient Air Quality Standards (NAAQS) (EPA 2016). In Canada, the regulatory approach is analogous with that of Environment and Climate Change Canada (ECCC) and the Canadian Ambient Air Quality Standards (CAAQS) (ECCC 2013a).

As a result of similar regulatory frameworks, there is a reasonable expectation that products are manufactured with comparable impacts. However, with an emerging market such as China that has no demonstrable equivalent, the uncertainty and associated risks increase. In the absence of equivalency, other mechanisms are needed to verify some level of confidence as to the embodied impact of the product. Moreover, if the process of assessment identifies additional impacts to air quality from manufacturing, the government may need to implement policy or regulation to dissuade the importation of such products.

Impact of increasing exports on China's air quality

In China, noxious air emissions negatively impact air quality and pose a substantial health risk to the population. It estimated that poor air quality contributes to 1.6 million deaths per year in China (Rhode and Muller 2015). Although the percentage of deaths with respect to the total population is relatively low, what China experiences annually in air pollution mortality is equivalent to approximately 5% of Canada's total population (Statistics Canada 2015). Furthermore, in 2012, China accounted for roughly 23% of the seven million deaths linked to air pollution worldwide (World Health Organization 2016).

As an economic powerhouse, China has become the largest exporter in the world (Wang et al. 2015). In 2012, China exported over two trillion in US dollars by volume (Song et al. 2015). However, this market dominance has not been achieved without a serious impact on air quality. Huo et al. (2014) postulated that the embodied emissions of the exports contributed to 24% of total NO_x emissions, 25% of total SO_2 emissions, and 23% of total $PM_{2.5}$ emissions in China. These estimates excluded emissions from capital project development and international transportation. Huo et al. (2014) further suggested that major factors in China's poor air quality can be attributed to high emissions per unit product and a high proportion of emissions-intense industry.

The reason that China has become the world's factory is largely attributed to the pollution haven hypothesis, in that emissions-intense industry relocates from developed countries to take advantage of lower production costs and less stringent environmental regulations in emerging markets (Wang et al. 2015). This is also aligns with the concept of carbon emissions leakage between regulated and non-regulated jurisdictions in consideration of energy-intensive and trade-exposed (EITE) industry

(Brown et al. 2014). However, unlike greenhouse gases (GHGs), which add to the global concentration of emissions, leakage associated with regional air pollutants such as oxides of nitrogen (NO_x), sulphur dioxide (SO_2), particulate matter (PM), and carbon monoxide (CO) have localized effects.

EITE cement manufacturing industry

As an EITE industry, cement manufacturing provides a unique opportunity to study the potential for increasing regional air pollution in the exporting country. Given that the cement industry is global and energy intense (which is tantamount to emissions intense), relocating manufacturing to emerging markets would be expected (Brown et al. 2014). Consequently, China has become the largest producer of cement, with billions of tonnes of capacity, and accounts for approximately 60% of global production (Xu et al. 2015). In contrast, Canada's relatively small cement industry, with a total capacity of less than 20 million tonnes, operating in a more stringent regulatory environment, is under considerable competitive pressure from imported cement (Brown et al. 2014).

This competitive pressure on the cement manufacturing industry is demonstrated by the implementation of the carbon tax in British Columbia (BC), Canada. In 2008, the BC Government introduced a tax on the fossilized carbon component of fuels. Initially at $10 CAD per tonne of carbon dioxide equivalent (CO_{2e}) emissions, the carbon tax incrementally increased by $5 CAD each year to its present rate of $30 CAD per tonne of CO_{2e}. As indicated in **Table 1**, the tax rate is based on the CO_{2e} emissions intensity of the fuel.

Since the inception of the carbon tax in 2008, the BC cement industry has experienced considerable deterioration of domestic market share to imported cement (**Fig. 1**). In 2005, imported cement accounted for approximately 5.9% of total domestic cement consumption (CAC 2016). At the end of 2015, with carbon tax at $30 CAD per tonne CO_{2e}, imports accounted for approximately 50% of total domestic cement consumption (CAC 2016).

Although there may be several factors that influence market share, **Fig. 1** clearly shows a trend between the percentage of imports and the increase in the tax from $10 CAD per tonne in 2008 to $30 CAD per tonne of CO_{2e}. Since 2012, with carbon tax at a fixed price of $30 CAD per tonne CO_{2e}, imports have not dropped below 35% of total domestic cement consumption. The critical difference being exploited here is that imported cement is not subject to carbon tax because the tax only applies to the fuel combustion CO_{2e} associated with manufacturing.

Accompanying the drop in domestic cement production is an apparent drop in total CO_{2e}. However, this is only because imported cement, and its embodied CO_{2e}, is not accounted for by BC GHG

Table 1. Selected carbon tax rates by fuel type (1 July 2012[a]).

Fuel type	Unit	Tax rate (%)
Gasoline	¢/litre	6.67
Diesel (light fuel oil)	¢/litre	7.67
Jet fuel	¢/litre	7.83
Natural gas	¢/cubic metre	5.70
Propane	¢/litre	4.62
Coal—high heat value	$/tonne	62.31
Coal—low heat value	$/tonne	53.31

[a]fin.gov.bc.ca/tbs/tp/climate/A4.htm

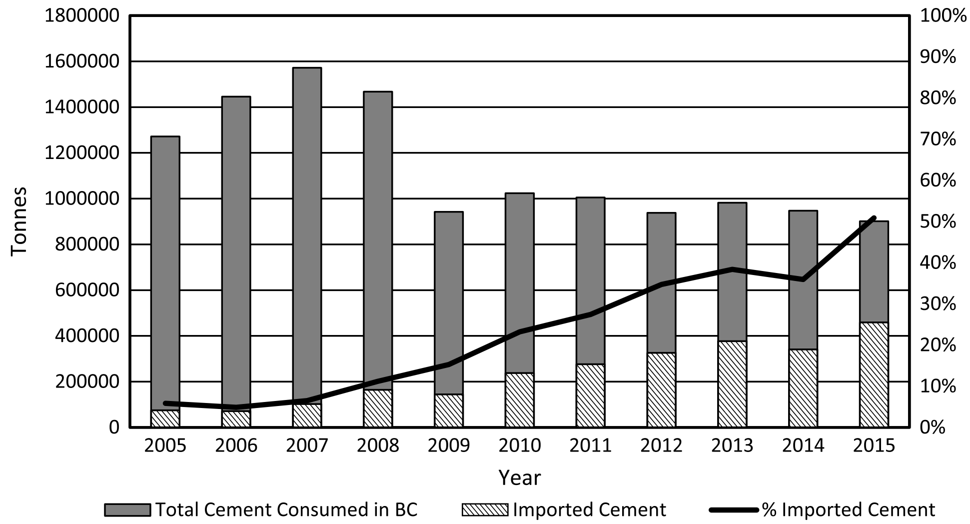

Fig. 1. Cement consumption in British Columbia (BC), Canada, by year (based on data from CAC 2016).

reporting mechanisms. It is plausible that, in the case of the EITE cement industry, the intended purpose of the carbon tax to reduce GHGs is ineffective. Moreover, if the CO_{2e} intensity of the exporting manufacturing facilities is higher than domestic producers, then the carbon tax has resulted in a net increase in global CO_{2e} emissions.

Extending the scope of leakage beyond production and CO_{2e} emissions to include regional noxious air pollutants (NO_x, SO_2, PM, and CO) further exacerbates the issue. According to Brown et al. (2017), the impact on regional air quality from cement production in China, in terms of disability adjusted life years (DALYs) from these four regional pollutants, is twice that in Canada. Based on this, unchecked importation of cement from China will have a net increase on the health and environmental impact of cement production.

Emissions leakage protection: plausible policy scenarios

For Canada, there are three general policy directions that can be taken to minimize the potential for emissions leakage associated with the international trade of cement. These policies include the following (**Table 2**):

Policy 1—provide direct support for local cement manufacturing to cut costs and increase competitiveness;

Policy 2—create barriers for importation such that foreign manufacturers either comply with Canadian standards or are dissuaded from exporting; and

Policy 3—a combination of 1 and 2.

Table 2. Plausible policy scenarios for emission leakage protection.

Policy	Border type	Domestic cement producer support status
Policy 1	Open	Supported
Policy 2	Restricted	Not supported
Policy 3	Selective	Partly supported

Within each policy, there are various supporting mechanisms available to achieve the intended outcome. For Policy 1, these mechanisms may include the relaxation of emission standards, subsidies, and (or) direct funding. In support of Policy 2, mechanisms may include prohibiting cement imports, environmental tariffs, and (or) a verification process, such as life cycle impact assessment (LCIA) that can demonstrate equivalency with Canadian standards. Lastly, Policy 3 may include a combination of Policy 1 and Policy 2 mechanisms.

This paper utilizes the cement manufacturing sector to evaluate the efficacy of these three plausible policy scenarios and their supporting mechanisms. The ideal outcome of this process will be a well-supported policy and mechanisms that best mitigate emissions leakage of the regional noxious air pollutants to foreign jurisdictions. At the same time, the policy will maintain an economically strong trading partnership. However, minimizing regional air pollution loading in emerging markets, such as China, is the key objective. Ultimately, the valuation of imported products needs to incorporate the potential impacts generated by manufacturing.

Materials and methods

This phase of research builds on two previous studies, as indicated in **Fig. 2**. The initial assessment characterized the environmental performance of cement manufacturing on a national scale in Canada. In the work by Brown et al. (2014), the emission intensities for regional noxious air pollutants were developed for the Canadian cement sector. In their evaluation, Brown et al. (2014) identified that potential concerns with emissions leakage associated with carbon policy could expand to include regional air pollutants, particularly in emerging markets such as China.

In the subsequent phase, a comparative evaluation of national cement production in China and Canada was carried out based on emission intensities for NO_x, SO_2, PM, and CO, and life cycle impact assessment (LCIA). In their results, Brown et al. (2017) found that the embodied emissions of cement manufactured in China had much greater impact on regional air quality and human health than cement manufactured in Canada. Brown et al. (2017) further postulated that the regional air pollution was occurring in China as a result of production leakage.

Analytic hierarchy process (AHP)

In the current study, multi-criteria decision analysis (MCDA) was used to investigate and evaluate the three policy scenarios. More specifically, the analytic hierarchy process (AHP) methodology was applied. Considering the potential ramifications of a policy that may impact international trade and in light of Canada's export market, which accounts for more than 30% of gross domestic product (GDP), the main criteria of evaluation are health/environment, cost, and trade retaliation (Statistics Canada 2016). The breakdown of the problem into a hierarchal structure consisting of the goal, criteria, and alternatives is presented in **Fig. 3**.

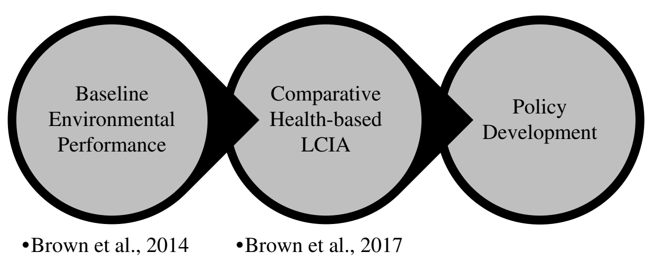

Fig. 2. Research flow diagram. LCIA, life cycle impact assessment.

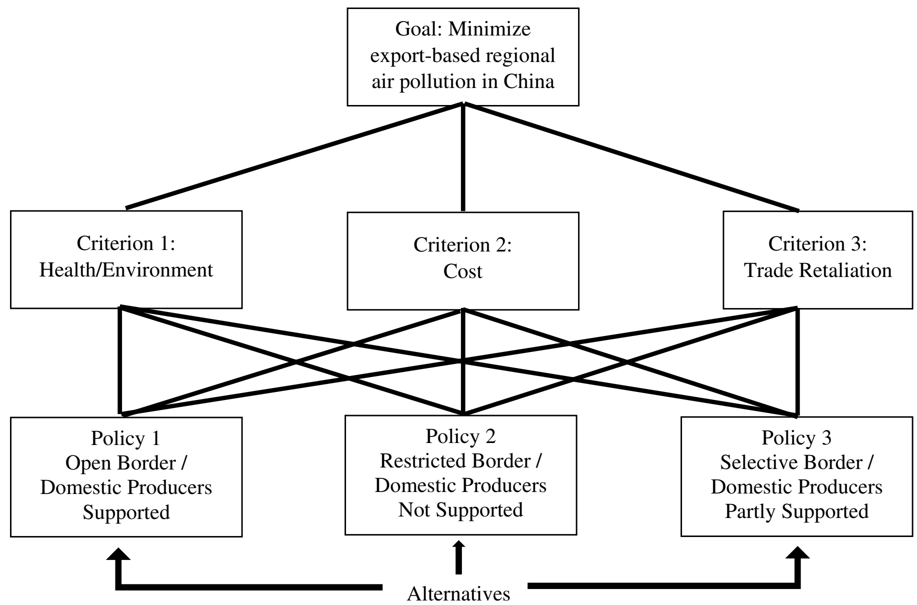

Fig. 3. Analytic hierarchy process—minimizing export-based regional air pollution in China.

Table 3. Policy scenario mechanisms.

Policy	Border type	Domestic cement producer support status	Mechanisms		
1	Open	Supported	Relaxation of emission standards	Subsidies (e.g., tax breaks, fuel, and raw materials)	Capital investment (high)
2	Restricted	Unsupported	Embargo	Environmental tariff	Verification process (e.g., LCIA, EPD, and Agreement[a])
3	Selective	Partly supported	Environmental tariff	Verification process (e.g., LCIA, EPD, and Agreement[a])	Capital investment (low)

Note: LCIA, life cycle impact assessment; EPD, environmental product declaration.
[a]Agreement as per the *Canadian Environmental Protection Act*.

Although not directly included in the AHP structure, the mechanisms that may, in part, support each policy alternative are presented in Table 3. The mechanisms indicated for each policy scenario are not prioritized, and it is possible that more than one mechanism could be implemented. That said, the mechanisms presented are confined to the policy parameters of border status and the level of support for domestic cement producers.

Differing from the standard approach in AHP where pairwise comparisons determine the proportional weight of the criteria, in this study each criterion was automatically assigned one-third of the weight. The purpose of evenly distributing the weight across the criteria was to ensure a balanced approach to selecting the alternative to minimize export-based regional air pollution in China. Additionally, in place of expert opinions for the pairwise comparisons, the data were derived from the application and averaging of the three actionable solidarities of the cultural theory framework: individualist, egalitarian, and hierarchist (Thompson 2000).

Cultural theory

Described by Thompson (2000), the cultural theory identifies four main "solidarities" of how people perceive nature: individualist, egalitarian, hierarchist, and fatalist. Each solidarity has a unique approach to the environment and society (Schwarz and Thompson 1990).

The individualist is characterized as the self-seeking solidarity that believes that the natural environment is robust enough to absorb and recover from any impact of human activity (Schwarz and Thompson 1990; Thompson 2000). Ultimately, the individualist is concerned with personal wealth and success. They recognize the value of relationships to advance their personal gain and retaliate against those that work against them. They are not opposed to risk and believe that whoever puts the most in deserves to get the most out.

The egalitarian solidarity is the opposite of the individualist. Egalitarians believe that the natural environment is fragile and interconnected, and that people genuinely care for each other and recognize the importance of the collective (Schwarz and Thompson 1990; Thompson 2000). They do not readily accept risk; instead, they cling to the precautionary principle. Egalitarians believe in equality for all people, and the equal distribution of wealth.

Hierarchists take a more neutral approach than the individualist or egalitarian. This solidarity views the natural environment as resilient, but with limitations, and believes that the collective is important but cannot function without control in the form of rank and position (Schwarz and Thompson 1990; Thompson 2000). Hierarchists can accept some level of risk, but that risk would first be tied to the hierarchical structure and then to the collective. In short, they would need assurance, and they aren't upsetting the apple cart.

The last of the four solidarities is the fatalist. This solidarity is both disconnected from the natural environment and non-participating in society (Schwarz and Thompson 1990; Thompson 2000). The fatalist solidarity would not consider contributing a point of view given their belief that they have no ability to influence and that nothing really matters.

In terms of participation for the pairwise comparisons performed as part of the policy evaluations, only the individualist, egalitarian, and hierarchist are considered actionable. As previously indicated, these actionable solidarities were applied in place of expert opinions for the AHP. Given the characteristics of the fatalist, which would see the entire process as futile, it is not considered an actionable solidarity or included in the pairwise comparisons.

Adapted from PRé (2001) and Thompson (2000), the approach of each solidarity to the pairwise comparisons is explained in **Table 4**. Given the perspectives of the solidarities, and based on the criteria in **Fig. 2**, the following relational expressions form the basis of decision-making:

Individualist: cost $>$ trade retaliation $\gg$ health/environment;

Egalitarian: health/environment $\gg$ trade retaliation $>$ cost; and

Hierarchist: trade retaliation $>$ cost $\geq$ health/environment.

Table 4. Cultural theory solidarity perspectives (Thompson 2000; PRé 2001).

	Perspectives		
Solidarity	**View on the environment**	**Societal thinking**	**Time horizon**
Individualist	Adaptable	Self-seeking	Short term
Egalitarian	Fragile and interconnected (precautionary principle)	Collective	Long term
Hierarchist	Controllable	Hierarchical	Balanced

Solidarity	Policy	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9	Policy
x	1	⟸								=								⟹	2
	1	⟸								=								⟹	3
	2	⟸								=								⟹	3

Fig. 4. Format for pairwise comparison of alternatives. The qualitative scale ranges from the weakest relative preference (1/9) to the strongest relative preference (9), and a score of 1 indicates an equal importance (Saaty 2008).

In addition to these expressions, each solidarity considers the policy mechanisms listed in **Table 3**. The ranking or judgement scale for the pairwise comparison adheres to the fundamental scale of absolute numbers (Saaty 2008). The qualitative scale ranges from the weakest relative preference (1/9) to the strongest relative preference (9), and a score of 1 indicates an equal importance (Saaty 2008).

Figure 4 provides an example of the scoring format for a solidarity applied to the paired alternatives. As denoted by the arrows in **Fig. 4**, a score of 9 in the first pairing would indicate an extremely strong preference for Policy 2. Conversely, a score of 1/9 would indicate a very weak preference for Policy 2, but an extremely strong preference for Policy 1.

AHP results

The individual scores for the pairwise comparisons are presented in **Table 5**. Intuitively, the individualist prioritizes cost and then trade retaliation, whereas the egalitarian focuses primarily on health/environment and to a lesser extent trade retaliation (with respect to supporting the collective). Lastly, the hierarchist attempts to balance the interests while recognizing the potential impact of trade retaliation. Ultimately, all solidarities are directed toward the goal of implementing an effective solution for export-based regional air pollution in China.

Table 5. Solidarity-based pairwise comparisons of alternatives.

Solidarity	Policy	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9	Policy
Individualist	1	—	—	—	—	—	—	—	—	—	—	√	—	—	—	—	—	—	2
	1	—	—	—	—	—	—	—	—	—	—	√	—	—	—	—	—	—	3
	2	—	—	—	—	—	—	√	—	—	—	—	—	—	—	—	—	—	3
Egalitarian	1	—	—	—	—	—	—	—	—	—	—	—	—	√	—	—	—	—	2
	1	—	—	—	—	—	—	—	—	—	—	—	—	√	—	—	—	—	3
	2	—	—	—	—	—	—	—	—	√	—	—	—	—	—	—	—	—	3
Hierarchist	1	—	—	—	—	√	—	—	—	—	—	—	—	—	—	—	—	—	2
	1	—	—	—	—	—	—	√	—	—	—	—	—	—	—	—	—	—	3
	2	—	—	—	—	—	—	—	—	—	—	—	—	√	—	—	—	—	3
Average	1	—	—	—	—	—	—	—	—	—	—	√	—	—	—	—	—	—	2
	1	—	—	—	—	—	—	—	—	—	—	√	—	—	—	—	—	—	3
	2	—	—	—	—	—	—	—	—	—	√	—	—	—	—	—	—	—	3

Note: The qualitative scale ranges from the weakest relative preference (1/9) to the strongest relative preference (9), and a score of 1 indicates an equal importance (Saaty 2008).

In averaging the pairwise comparisons, the values were rounded to the nearest whole number. Based on the averaged values of the alternate policies the reciprocal matrix, normalized matrix, and priority vector were calculated as follows.

$$A = \begin{bmatrix} 1 & \frac{1}{3} & \frac{1}{3} \\ 3 & 1 & \frac{1}{2} \\ 3 & 2 & 1 \end{bmatrix}$$

$$\mathrm{SUM} = 7 \; \frac{10}{3} \; \frac{11}{6}$$

$$A = \begin{bmatrix} \frac{1}{7} & \frac{1}{10} & \frac{2}{11} \\ \frac{3}{7} & \frac{3}{10} & \frac{3}{11} \\ \frac{3}{7} & \frac{6}{10} & \frac{6}{11} \end{bmatrix}$$

$$\mathrm{SUM} = 1 \; 1 \; 1$$

$$w = \frac{1}{3}\begin{bmatrix} \frac{1}{7} & \frac{1}{10} & \frac{2}{11} \\ \frac{3}{7} & \frac{3}{10} & \frac{3}{11} \\ \frac{3}{7} & \frac{6}{10} & \frac{6}{11} \end{bmatrix} = \begin{bmatrix} 0.1416 \\ 0.3338 \\ 0.5248 \end{bmatrix}$$

The principal eigenvalue was 3.065, and the consistency ratio was 5.6%, indicating consistency in judgement for the preference of Policy 3. Given that each criterion was assigned an equal weighting of one-third, no further analysis was required to determine the final weightings. Figure 3 provides the AHP structure, and the proportional weightings are 0.1416 for Policy 1, 0.3338 for Policy 2, and 0.5248 for Policy 3. Converting the results of the analysis into percentages, Policy 3 is strongly favoured (52.5%), followed by Policy 2 (33.4%). The least favoured is Policy 1 (14.2%).

Sensitivity analysis

To evaluate the robustness of the results, two additional scenarios were evaluated. In the first scenario, each solidarity provided a less assertive opinion in the pairwise comparisons, and the rankings moved towards equal importance by two levels (i.e., a score of 5 became 3, and a score of 1/5 became 1/3). In this conservative evaluation, Policy 3 was still favoured (50%); however, Policies 1 and 2 were equally favoured (25%). The consistency ratio of 0% indicates no inconsistency in judgement; however, it also indicates the proximity of the scoring to 1.

The opposite occurred in the second scenario. Each solidarity had a stronger opinion in the pairwise comparisons, moving away from equal importance by two levels. In this exaggerated evaluation, support for Policy 3 increased to approximately 60%, and the gap between Policy 2 (30%) and Policy 1 (10%) widened. However, the consistency ratio increased to 16%, indicating that the judgement was no longer consistent. Consequently, the results of the primary analysis are well situated within the 10% limit.

Discussion

It is not surprising that Policy 3 was the preferred alternative among the three options given that it provides a middle ground between Policies 1 and 2. However, the preference for Policy 3 suggests that there are key influencing factors. Less expected, given the direct impact on trade, was that the support for Policy 2 was more than double that for Policy 1, particularly given that the Canadian government would likely select Policy 1 to avoid potential impact on the export industry and its contribution to the GDP.

Cultural theory review

In reviewing the mechanisms that support the policies, some can clearly be removed. The egalitarian solidarity, and to a lesser extent the hierarchist solidarity, would not accept the relaxation of regulatory standards indicated in Policy 1. In addition, none of the solidarities would support the embargo mechanism in Policy 2. The individualists would be concerned about the opportunity cost, egalitarians would prefer to avoid impacting the global community, and the most strongly opposed would be the hierarchists and their sensitivity to trade retaliation.

Although capital investment and subsidies are practicable, they are less than desirable mechanisms. The main influencing factor for the individualist to select Policy 3 over Policy 1 was to minimize costs associated with the implementation of the program. The egalitarian supported Policy 3 over Policy 1 for two reasons: relaxing emission standards is completely counter to the precautionary principle, and domestic capital investments and subsidies have no direct influence on reducing export-based regional air pollution in China. It is possible that embodied emissions in the cement from China may increase as a result of a shift to lower pollution safeguards to be more cost competitive.

The two remaining mechanisms, environmental tariff and verification process, are supported by the AHP analysis through the policy preferences. From the individualist perspective, either mechanism puts the cost and responsibility on the exporter. Egalitarians are satisfied that the domestic emission standards are maintained, and for either mechanism there is incentive for cement manufacturers in China to improve emissions performance.

Although hierarchists prefer an environmental tariff or a verification process to embargoing non-compliant cement, there is still is concern with trade retaliation. It is possible that both mechanisms may be viewed as a barrier to trade and challenged by the World Trade Organization (WTO). That said, the verification process mechanism would likely be preferred, given that it implicitly provides a procedure for achieving compliance and not a fee. Table 6 provides a summary of the solidarity assessments of the policy mechanisms.

Verification process mechanism

Based on the analysis, the most accepted policy mechanism is the verification process. This is substantiated by the support for Policy 3 in the AHP analysis and in the assessment of policy mechanisms in Table 6. As previously indicated, the verification process mechanism can be approached more than one way; however, the underlying requirement is that, at minimum, there is equivalency with Canadian standards and performance. As such, Canada could pursue an agreement under CEPA with

Table 6. Summary of policy mechanisms by solidarity type.

	Mechanisms					
Solidarity	Relaxation of standards	Embargo	Environmental tariff	Subsidies	Capital investment	Verification process
Individualist	√	×	√	×	×	√
Egalitarian	×	×	√	×	×	√
Hierarchist	×	×	×	√	√	√

China that is similar to the existing arrangement with the United States, or a robust environment product declaration (EPD), or a cement-based LCIA.

It is unlikely that the Canadian government would allocate time and resources for a single industry agreement like the cement sector under CEPA. However, in terms of the broader picture, an overarching agreement on trade may be appropriate. Procedures could be incorporated in the agreement to evaluate imported products for their embodied emissions. This framework could be applied universally.

An EPD provides the most thorough evaluation of the environmental impact of a product. Tantamount to a nutritional label on food, an EPD details the environmental aspects of a product based on a full life cycle assessment (LCA) (ISO 14025:2006 2015). The purpose of an EPD is to allow for comparison between products that provide the same function (ISO 14025:2006 2015). The challenge with an EPD is that the data collection phase requires considerable effort to address the complete life cycle of the product. That said, the product category rules (PCR) that define the required data for the LCA can be incorporated into a Canada–China agreement prior to the development of an EPD (ISO 14025:2006 2015).

For the cement industry, specifically, the bulk of NO_x, SO_2, PM, and CO emissions are generated at the manufacturing facility and emitted from the stack (Brown et al. 2017, Brown et al. 2014). As such, these emissions can be efficiently monitored and quantified. With production volumes, the emissions intensity per tonne of cement can be calculated and used for comparative purposes between China and Canada (Brown et al. 2014). However, comparing emission intensities alone provides limited understanding of the potential impact.

In their health-based comparative LCIA, Brown et al. (2017) combined the cement emission intensities for NO_x, SO_2, PM, and CO into a single impact category for winter smog. Although the constituents contribute to other impact categories, the focus of this research is to limit export-based regional air pollution. Interestingly, data from China indicated that their cement manufacturing sector produced lower emissions intensities than Canada's cement industry for NO_x and SO_2 (Brown et al. 2017). However, the $PM_{2.5}$ intensities were considerably higher in China, and they had a much greater impact on air quality than NO_x and SO_2 (Brown et al. 2017).

Synthesis

Given the preference for Policy 3, the parameters of the Canadian approach should be confined to, at most, a selective border and partial support for domestic cement manufacturers. Drilling down to the preferred policy mechanisms, more emphasis is placed on border adjustments than capital investment. With regard to possible border adjustments, a verification process is favoured over an environmental tariff. In review of the verification process tactics, a universal strategy is considered in addition to a cement-specific approach.

From a universal perspective on trade with China, an air quality agreement under CEPA should be established. In the agreement, a framework that provides procedures for evaluating products for their embodied emissions/environmental impact should be built in. Ultimately, the agreement will include product EPDs; however, in the interim, uniform PCR that follows ISO 14025 must be defined in the document. As a base requirement of the agreement, both countries need to acknowledge that regional air pollution extends beyond jurisdictional boundaries.

To establish specific requirements for exporting cement to Canada, manufacturers in China will need to provide emission intensities for the main regional noxious pollutants (NO_x, SO_2, PM, and CO). These intensities will be comparatively evaluated to national intensities in Canada and assessed collectively in terms of impact, applying standardized LCA damage factors for winter smog. At minimum, the exporting manufacturers must demonstrate that both emission intensities and impact do not exceed those of Canadian manufacturers. Eventually, this evaluation process would be matured and incorporated under a Canada–China agreement as an EPD for cement.

Limitations

In AHP, data for the pairwise comparisons are typically collected from experts or decisions-makers in a survey format, but no survey was performed for the current study. Instead, the three actionable solidarities of cultural theory (individualist, egalitarian, and hierarchist) and their corresponding perspectives were applied as surrogates for survey results. Although this may be considered a data limitation, unlike the less reliable responses of survey participants who may be influenced by external factors, the solidarities remain consistent (Lin and Lu 2012; Rindermann et al. 2016). Serenko and Dohan (2011) found that experts may show biased judgement based on their current research. Given that the solidarities are roughly analogous to working group perspectives on policy, the recommendation expressed may be more realistic.

In addition to forgoing the survey, the criteria weighting was not developed as a result of pairwise comparisons in accordance with AHP. Instead, each criterion was arbitrarily assigned one-third of the weighting. Even though this reduces the extent of the analysis, the benefit of equal weighting is that it minimizes the potential for a systematic error.

Ultimately, the limitations expressed simply reflect a novel approach to decision-making. The application of cultural theory with MCDA may be considered a viable alternative to expert review. Although the literature for this approach may not be directly available for evidentiary discussion, there is possible linkage to artificial intelligence paradigms. In addition, there is considerable evidence to suggest that the expert survey approach is subject to bias. Interestingly, future debate and research on the relative importance of surveying may be an indirect benefit of this work.

Conclusions

Export-based regional air pollution is not well acknowledged. Understandably, jurisdictions prioritize minimizing regional air pollution within their own borders. Unfortunately, as an unintended consequence of a strong regulatory environment, industries may relocate to jurisdictions with less stringency to avoid compliance costs. These jurisdictions are typically emerging markets, such as China.

As an importer of products from emerging markets, it is important that Canada recognizes the potential impact to these jurisdictions. The purpose and intent of regulating air emissions from industry in Canada is to protect the health of Canadians and their environment. Failing to extend these values to the global community, while knowingly importing emissions-intense products, signals a tiered approach to the value of human life.

Canada has a unique opportunity to create an international policy that positively influences the quality of life in emerging markets. Additionally, the regulatory framework and policy mechanisms discussed in this study can be universally applied. Consequently, Canada would be viewed globally as taking a leadership role in reducing export-based regional air pollution.

Author contributions

DB and RS conceived and designed the study. DB performed the experiments/collected the data. DB analyzed and interpreted the data. DB, RS, and KH contributed resources. DB and RS drafted or revised the manuscript.

Competing interests

The authors have declared that no competing interests exist.

Data availability statement

All relevant data are within the paper.

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