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GRAVITY MODELS VERSUS COMPARATIVE ADVANTAGE: IT IS NOT ENOUGH FOR TRADE TO BE FREE; TRADE SHOULD ALSO BE FIT

THIERRY WARIN

CS
2025s-21
WORKING PAPER

ISSN 2292-0838 (online version)

Gravity Models versus Comparative Advantage: It is not enough for trade to be free; trade should also be fit[*]

Thierry Warin[†]

Abstract/Résumé

Trade-gravity equations remain the empirical "workhorse" for bilateral flows, yet their strictly positive orientation can normalise volumes that depart from welfare-maximising cost allocations. Building on a friction-adjusted theory of comparative advantage, this article pairs gravity's descriptive power with two normative indicators. First, a Cost-Based Comparative Advantage (CCA) index ranks exporters by total landed cost—combining f.o.b. factory prices with good-specific freight, insurance and policy wedges—for every product–destination pair. Second, the Redirection Advantage (CBRA) metric tests whether diverting an exporter's incumbent shipments toward an alternative market would lower that market's import bill, thereby revealing latent efficiency losses masked by path dependence, preferential agreements or behavioural frictions. Applying the framework to the densely intertwined Canada–United States corridor uncovers sizeable but highly asymmetric misallocations. Canadian aerospace producers could undercut incumbent suppliers in several European and Gulf economies by more than US$3,000 per kg, while U.S. petroleum refiners enjoy occasional triple-digit mark-ups inWest Africa and the Caribbean. By contrast, cross-border automotive and most energy exchanges exhibit negative CBRA values, signalling that the prevailing North-American supply chains are already cost-efficient. The results demonstrate how proximity, home-market bias and rules of origin can simultaneously stimulate large trade volumes and conceal Viner-style trade diversion. The study advances three contributions: (i) a tractable, product-level toolkit for diagnosing cost-inefficient trade; (ii) a theoretical bridge that embeds comparative-advantage logic inside a multi-country gravity structure; and (iii) a policy agenda that combines multilateral tariff cuts, infrastructure upgrades and real-time cost monitoring to align observed flows with global cost minima. Integrating CCA and CBRA with gravity thus offers researchers and policymakers a unified lens for ensuring that "who trades with whom" also reflects "who should trade with whom."

Le modèle de gravité demeure le cheval de bataille empirique des flux bilatéraux. Cet article associe le pouvoir descriptif du modèle à deux indicateurs normatifs. Premièrement, un indice d'avantage comparatif basé sur les coûts (ACC) classe les exportateurs selon le coût total au débarquement – combinant les prix f.à.b. usine avec les écarts de fret, d'assurance et de police spécifiques aux produits – pour chaque paire produit-destination. Deuxièmement, l'indicateur d'avantage de réorientation (AR) vérifie si le détournement des expéditions existantes d'un exportateur vers un autre marché réduirait la facture d'importation de ce marché, révélant ainsi des pertes d'efficacité latentes masquées par la dépendance au sentier, les accords préférentiels

[*] The author would like to thank Aïchata Kone, Mohammed Bilal Siddika, Jeremy Schneider, Adam Touré and Lucien Chaffa. The usual disclaimers apply.

[†] Fellow at CIRANO (Canada).

ou les frictions comportementales. L'application de ce cadre au corridor Canada-États-Unis, étroitement imbriqué, révèle des allocations très asymétriques. Les résultats démontrent comment la proximité, la préférence pour le marché intérieur et les règles d'origine peuvent simultanément stimuler d'importants volumes d'échanges et masquer un détournement des échanges de type Viner. L'étude propose trois contributions : (i) une boîte à outils exploitable au niveau des produits pour diagnostiquer les échanges commerciaux inefficaces en termes de coûts ; (ii) un cadre théorique qui intègre la logique de l'avantage comparatif dans une structure gravitationnelle multi-pays ; et (iii) un agenda de politique économique qui combine des réductions tarifaires multilatérales, des mises à niveau des infrastructures et une surveillance des coûts en temps réel pour aligner les flux observés sur les coûts minimaux mondiaux.

Keywords/Mots-clés: gravity model; comparative advantage; Canada–US trade; behavioural biases; cost-based trade indicators / modèle de gravité; avantage comparatif; commerce Canada-États-Unis; biais comportementaux; indicateurs commerciaux basés sur les coûts .

Pour citer ce document / To quote this document

Warin, T. (2025). Gravity Models versus Comparative Advantage: It is not enough for trade to be free; trade should also be fit (2025s-21, Cahiers scientifiques, CIRANO.)

https://doi.org/10.54932/XQAY2333

1 Introduction

For centuries, analysts have observed that international commerce is often shaped by political arrangements and historical ties as much as by fundamental costs. In the mid-20th century, Jacob Viner (1950) famously formalized one such concern with the concept of **trade diversion**, describing how preferential agreements can redirect trade from the most efficient suppliers to favored partners, thereby undermining global welfare. This insight highlights a persistent question: do observed trade flows truly reflect an optimal (welfare-maximizing) allocation of resources, or are they partly an artifact of policy biases and path-dependent relationships?

Yet international trade scholarship has long relied on the gravity model to explain **who trades with whom**, attributing bilateral exchange to the joint pull of economic mass and the pushback of geographic or policy frictions (Anderson & van Wincoop, 2003). The gravity framework provides a parsimonious and empirically robust description of trade patterns, but its strictly positive orientation carries a risk: it may normalize large trade volumes that persist due to historical inertia or institutional preferences even when those flows deviate from what comparative-cost efficiency would dictate. In other words, gravity models can explain why certain trade relationships are intense without evaluating whether such intensity is efficient. Building on a friction-adjusted theory of comparative advantage, this article argues that rigorous efficiency diagnostics must complement gravity's descriptive power in order to assess how and whether current trade flows minimize global production and logistics costs.

To that end, we integrate **cost-based comparative advantage** indicators that combine free-on-board production prices with good-specific freight and insurance charges. This approach yields a granular measure of each product's total delivery cost to different markets, going beyond factory-gate prices to incorporate transportation. Leveraging these indicators, we introduce the **Cost-Based Redirection Advantage (CBRA)** – a product-level metric that tests whether diverting an exporter's current shipments to an alternative destination would reduce that market's landed import cost after accounting for incremental transport expenses. By aggregating CBRA outcomes across an exporter's bundle of goods, we derive a destination-specific index of latent cost savings and identify three channels of inefficiency: policy wedges, infrastructural frictions, and behavioral barriers. In this way, the CBRA framework bridges the positive and normative dimensions of trade analysis, pinpointing where trade is robust but not necessarily optimal.

A conceptual application to Canada–United States commerce illustrates the value of this approach. Gravity factors such as geographic proximity, deep cultural ties, and the United States–Mexico–Canada Agreement (USMCA) predict an exceptionally high bilateral intensity, and indeed about 75% of Canada's goods exports go to its southern neighbor. However, the CBRA calculations reveal notable misalignments behind this headline integration. For instance, Canadian aerospace manufacturers could serve several European and Gulf markets at prices well below those paid to incumbent suppliers, indicating unexploited cost advantages abroad. Similarly, U.S. petroleum refiners would, after transportation costs, profitably reorient certain exports toward West African and Caribbean importers if not for the current regional focus. Conversely, some entrenched automotive supply chains show little scope for cost-efficient redirection, underscoring how rules of origin and long-term contracts lock in production along regionally convenient – but not globally minimal-cost – paths. These findings demonstrate that preferential trade agreements, home-market biases, and historical path dependencies can perpetuate the very inefficiencies that Viner warned about, resulting in a form of suboptimal globalization that a gravity analysis alone cannot detect (Viner, 1950).

Accordingly, the analysis points to a forward-looking policy agenda that couples broad multilateral tariff reduction and mutual recognition of technical standards with data-driven monitoring of real-time cost gaps. Only by pairing gravity's explanatory strength with CBRA's normative lens can policymakers ensure that large trade volumes translate into genuinely efficient resource allocation. **Research Question:** To what extent do contemporary trade patterns deviate from a cost-minimizing global allocation of production (i.e. exhibit trade diversion), and through which policy, infrastructural, or behavioral factors do such inefficiencies persist?

2 Literature Review

Gravity Models of Trade: The gravity model has become a fundamental tool in international economics, often described as a "workhorse" for empirical trade analysis. Analogous to Newton's law of gravitation, the traditional gravity equation posits that the volume of trade between two countries is proportional to the product of their economic "masses" (usually GDP) and inversely proportional to the distance between them. In its simplest form:

$$T_{ij} = A \frac{Y_i \times Y_j}{D_{ij}^{\beta}}, \tag{1}$$

where T_{ij} is trade between country i and j, Y_i, Y_j are their economic sizes, D_{ij} is the distance between them, and β is an estimated parameter reflecting how strongly distance (and other resistance factors) curtail trade. Augmented gravity models include additional terms for shared borders, language, colonial history, tariffs, and other factors that facilitate or hinder trade. The empirical success of gravity models is well-documented: they can explain a large portion of the variation in bilateral trade flows across country pairs and yield consistently robust coefficient estimates for key variables like GDP and distance. For decades, gravity was used in a mostly ad-hoc manner, but since the early 2000s it has been placed on firmer theoretical footing. Important contributions by Anderson and van Wincoop (2003) and others derived gravity equations from micro-founded trade theories, showing that gravity can arise from models of differentiated goods and trade costs. As Anderson (2011) notes, gravity's "good fit" and the tight clustering of results in countless studies suggested an underlying economic law at work, which subsequent theoretical advances managed to elucidate.

Despite its empirical strength, the gravity model is inherently an **ex post** description – it tells us how trade is distributed given the existing economic geography and policies. Gravity models do not judge whether the resulting trade pattern is economically optimal or not; they simply predict what it will be. Leamer and Levinsohn's oft-cited remark captures this dual nature: gravity estimates have been "singularly successful" empirically, yet for a long time had "virtually no effect" on the core theory of trade focused on comparative costs. This disconnect has since narrowed, but it highlights that gravity was largely separate from the welfare-based narrative of trade theory. Gravity can be thought of as explaining who trades with whom, as opposed to who should trade what with whom for maximum efficiency.

Comparative Advantage and Trade Efficiency: The concept of comparative advantage originates from David Ricardo's 19th-century insight that what matters for trade is not absolute cost differences, but relative cost differences (Warin, 2025a). A country can benefit from trade by exporting goods in which it has a lower opportunity cost of production and importing those in which it has a higher opportunity cost, even if it is absolutely more efficient in everything. This principle underpins why specialization and trade can make all parties better off, and it establishes an ideal benchmark: **trade patterns that conform to comparative advantage should lead to an efficient global allocation of resources and maximize joint gains from trade**. In theoretical models (Ricardian or Heckscher-Ohlin), when countries specialize according to comparative advantage, the world's consumption possibilities expand and overall welfare improves. Indeed, as summarized by an OECD analysis, "specialisation according to comparative advantage is a precondition for reaping gains from trade". If something interferes with that specialization – say, a policy or friction that causes a country to produce a good at higher cost domestically rather than importing it from a more efficient foreign producer – then the potential gains from trade are reduced or lost.

Empirically identifying comparative advantage can be challenging. A common metric is **Revealed Comparative Advantage (RCA)**, introduced by Balassa (1965), which infers comparative advantage from observed export patterns. If a country's share of world exports in a product exceeds its share of total world exports, that product is said to be a revealed comparative advantage for the country. However, RCA is an imperfect proxy; it is revealed by current trade data, which themselves are influenced by existing tariffs, transport costs, and historical contingencies. RCA does not distinguish whether a strong export position is due to fundamental cost superiority or due to other factors like subsidies or proximity. Moreover, RCA remains agnostic to the underlying cost structure that firms actually face. Extensions to RCA have tried to incorporate quality and dynamic factors, but until recently few measures explicitly integrated actual production and transport cost data into comparative advantage assessment.

Modern trade literature has expanded the concept of comparative advantage beyond technology or factor endowments to include factors like institutional quality, human capital, and even cultural influences. Nevertheless, at its core, comparative advantage is about **relative cost differences**. If country A can produce good X more cheaply (in terms of forgone output of other goods) than country B, then A has a comparative advantage in X. In an unconstrained world, A should export X to B and both can gain. This is the normative ideal against which we may assess real trade patterns.

Gravity vs. Comparative Advantage – Bridging the Gap: Traditionally, international economics textbooks treated comparative advantage theory (Ricardian, Heckscher-Ohlin models) as the explanation for why trade occurs and what its benefits are, whereas gravity was often presented as an empirical fact needing separate explanation (e.g. based on trade costs or increasing returns). Deardorff (1998) asked pointedly, “Does gravity work in a neoclassical world?” and concluded that standard comparative advantage models could be consistent with gravity, but only under certain conditions. In other words, one can derive a gravity-like relationship even when trade is driven by comparative advantage, especially if trade costs are incorporated. But an important distinction arises: **comparative advantage is fundamentally a prescriptive concept about optimal specialization for welfare gains, while gravity is a positive concept describing trade volumes given various frictions**. Gravity by itself does not ensure that the pattern it predicts is welfare-maximizing.

In practice, actual trade patterns result from both comparative-cost forces and gravity-type frictions. Multiple empirical approaches have been used to study comparative advantage in the real world, including: (1) **Revealed Comparative Advantage indices** (Balassa and successors), (2) **factor content analyses** (which examine whether trade in goods corresponds to implicit trade in factors as comparative advantage theory would suggest), and (3) **gravity-based decompositions** that include cost-related variables. An OECD report by Deardorff (2011) reviewed these approaches, noting that each provides useful information but none alone can fully delineate comparative advantage or its sources. For instance, factor content studies check if countries export goods that intensively use their abundant factors (as Heckscher-Ohlin theory predicts). Gravity models can be adapted to test comparative advantage by adding variables representing productivity or cost differences between countries in certain industries. If those comparative-cost variables significantly explain bilateral trade flows (beyond just GDP and distance), it supports the idea that comparative advantage is shaping the pattern. Conversely, if standard gravity variables like distance or regional trade agreements dominate while cost differences play a smaller role, it might indicate that trade flows are swayed more by geography/policy factors than by fundamental efficiencies.

One key insight from the literature is that **trade agreements and trade costs can cause systematic deviations from a pure comparative advantage allocation**. Jacob Viner’s classic analysis (1950) introduced the concepts of trade creation and trade diversion in preferential trade agreements. Trade creation occurs when an FTA enables a member country to import a good from a partner that can produce it more cheaply than its own domestic producers – this is efficiency-enhancing and aligns with comparative advantage (the partner had the relative efficiency). Trade diversion, in contrast, happens when an FTA causes a country to shift imports **away** from the lowest-cost global supplier to a higher-cost supplier within the FTA, simply because the latter enjoys a tariff preference. In Viner’s words, a low-cost supplier in the rest of the world is displaced by a higher-cost partner supplier due to the preferential agreement. Trade diversion is precisely a case of suboptimal trade: it increases intra-bloc trade (which a gravity model might applaud as “closer integration”) but reduces global efficiency and can even hurt the importing country’s welfare because it ends up paying higher prices than it would under multilateral free trade. Empirical studies of NAFTA, for example, have tried to measure the extent of trade creation vs. diversion. Krueger (1999) found that by the late 1990s, there was little evidence of major trade diversion against U.S. interests (in part because Mexico's entry coincided with broader trade liberalization), but other work (e.g., Romalis 2007) did find instances of diversion, particularly in sectors like textiles where Mexico temporarily replaced more efficient Asian suppliers due to preferential access.

Another relevant body of literature relevant concerns **intra-industry trade** and trade between similar advanced economies. New Trade Theory (Krugman, 1980s) explained that countries with similar factor endowments and technologies (like Canada and the US) might still trade extensively, not because of classical comparative advantage, but due to increasing returns to scale and consumers' love of variety. This results in substantial intra-industry trade (e.g., both countries export and import automobiles) driven by specialization in different product varieties rather than stark differences in unit costs. Such trade can yield gains (from greater variety and scale economies) even if it's not guided by comparative advantage in the classical sense. However, from an efficiency perspective, intra-industry trade among similar countries often implies duplication of production across borders. For instance, both the US and Canada maintain automobile manufacturing and trade cars with each other. Each country has some specialized models or components, but both incur the high fixed costs of auto production. Could it be more efficient if one country produced more of the automobiles and the other specialized in something else entirely? Traditional theory would say yes if there were clear cost differences, but new trade theory suggests consumers in each country benefit from having both countries' differentiated products. This literature complicates the simple comparative advantage story by adding consumer preferences and scale economies as efficiency considerations. Yet, even in these models, the market outcome is typically efficient given preferences – the concern for us is that **policy or geography might lock in a particular structure of intra-industry trade that isn't truly optimal**. For example, each country might protect certain varieties or subsidize duplicate industries for strategic reasons, leading to an outcome that deviates from what unfettered cost considerations would dictate.

Behavioral and Informational Frictions: Recent research also highlights that not all deviations from comparative advantage are policy-driven; some stem from information gaps and trust barriers. Firms may not instantly shift to the globally cheapest supplier due to uncertainty, search costs, or lack of trust in foreign partners. Guiso, Sapienza, and Zingales (2009) provided evidence that cultural biases and lack of trust have a measurable impact on trade: lower bilateral trust between two countries leads to significantly less trade between them, even when controlling for economic fundamentals. This suggests that behavioral frictions can cause countries to under-exploit some comparative advantages – for instance, trading less with certain low-cost countries because of perceived risks or unfamiliarity – and instead over-rely on familiar partners. Likewise, historical ties or networks (e.g., a common language or diaspora communities) can facilitate trade beyond what cost factors alone would predict, potentially resulting in trade patterns that favor familiar partners over purely cost-minimizing arrangements. In gravity equations, these intangibles show up as dummy variables for common language, colonial history, or past political ties – they consistently increase trade flows. But a high level of trade due to such factors is not necessarily aligned with cost efficiency; it could simply reflect reduced transaction costs or preferences for the familiar, rather than the lowest cost (Warin, 2025b).

The literature establishes that: (1) Gravity models are powerful in explaining trade patterns but are agnostic about optimality. (2) Comparative advantage theory provides a benchmark for what efficient trade should look like, yet real-world patterns often deviate from that benchmark due to various frictions and policies. (3) These deviations encompass formal phenomena like trade diversion under preferential agreements and more informal ones like cultural bias or informational barriers. (4) Therefore, a combination of approaches – including new cost-based metrics and multi-dimensional analyses – is needed to evaluate the efficiency of observed trade flows. This synthesis sets the stage for our theoretical framework, where we explicitly contrast gravity's positive predictions with the normative criteria of comparative advantage, and then examine how the Canada–US trade case illuminates this dichotomy.

3 Theoretical Framework: Cost Efficiency, Comparative Advantage, and Trade Redirection

3.1 An efficiency benchmark for any exporter–importer pair

For every product k and country pair (i, j), global welfare is maximised when the landed-cost inequality:

$$c_{ik} + t_{ij,k} \; < \; c_{jk}(1 + \tau_{ij,k}) \tag{2}$$

holds, where

Symbol	Meaning
c_{ik}	Marginal production cost in exporting country i
$t_{ij,k}$	Full transport, insurance and handling cost from i to j
$\tau_{ij,k}$	Ad-valorem policy wedge imposed by j on imports from i

If the inequality is violated, the good is procured from a higher-cost source and potential gains from trade are foregone.

3.2 Cost is multi-dimensional

"Cost" is a vector rather than a scalar:

$$\mathbf{c}_{ik} = (c_{ik}^{\text{prod}}, c_{ik}^{\text{risk}}, c_{ik}^{\text{reg}}, \dots), \tag{3}$$

spanning plant-gate expenses, risk premia, compliance outlays and more. Customs statistics aggregate these components into a money metric via the well-known **CIF–FOB identity**:

$$\text{CIF}_{i\to j,k} = P_{i,k}^{\text{FOB}} + C_{i,j,k}^{\text{trans}} \tag{4}$$

with $P_{i,k}^{\text{FOB}}$ the exporter's ex-border price and $C_{i,j,k}^{\text{trans}}$ the freight-and-insurance charge to market j.

3.3 Cost-Based Comparative Advantage (CCA)

For any exporter i, importer j and product k we define:

$$\text{CCA}_{i\to j,k} = CIF_{j,k}^{\text{import},-i} - (P_{i,k}^{\text{FOB}} + C_{i,j,k}^{\text{trans}}) \tag{5}$$

Term	Interpretation
$CIF_{j,k}^{\text{import},-i}$	Average CIF unit price that j pays to **all suppliers other than** i
$P_{i,k}^{\text{FOB}}$	Exporter-specific FOB price (independent of destination)
$C_{i,j,k}^{\text{trans}}$	Freight & insurance cost from i to j

$$\text{CCA}_{i\to j,k} > 0 \implies i \text{ can land } k \text{ in } j \text{ more cheaply than incumbents at FOB.} \tag{6}$$

3.4 Cost-Based Redirection Advantage (CBRA)

Let u denote an exporter's current major outlet. The question is whether shipments destined for u can be **profitably redirected** to a new market j. We define:

$$\text{CBRA}_{i\to j,k}^{(u)} = CIF_{j,k}^{\text{import},-i} - (P_{i,u,k}^{\text{FOB}} + C_{i,j,k}^{\text{trans}}) \tag{7}$$

with $P_{i,u,k}^{\text{FOB}} = P_{i,u,k}^{\text{export}} - C_{i,u,k}^{\text{trans}}$. A positive value indicates that rerouting exporter i's existing sales of k from u to j would still undercut the price j pays to its non-i suppliers.

3.5 Decision matrix for policy and strategy

CCA	CBRA	Interpretation	Suggested policy response
+	+	Fundamental cost edge and rerouting feasible	Priority for diversification support, export promotion
+	–	Competitive long-run but supply chain sticky	Address entry barriers, invest in logistics or standards harmonisation
–	+	Tactical diversion only (temporary price edge)	Short-term relief; monitor sustainability
–	–	No cost-based rationale	Focus policy elsewhere

Aggregating CBRA over all products with export-volume weights yields a **destination-level redirection score** that ranks markets by the total cost saving achievable if incumbent shipments were redeployed. In what follows, we apply our equations to Canada–U.S. trade, quantify unrealised cost advantages, and discuss tariff, logistics, and information policies that can translate latent efficiencies into realised diversification.

4 Empirical Case Study: Canada–US Trade

4.1 Macro Level

Overview of Canada–US Trade: Canada and the United States share the world's longest undefended border and a deeply integrated economic relationship. In 2024, two-way goods trade between the countries was about $762 billion, reflecting the magnitude of their economic interdependence. Canada has consistently been among the top two trading partners of the US (often vying with Mexico and China for the #1 spot). For Canada, the reliance is even more pronounced: the United States is by far Canada's largest trading partner. Roughly **77% of Canada's merchandise exports** went to the US in 2023, while about 44% of Canada's imports came from the US. No other single country accounts for more than 5% of Canada's exports, underscoring a heavy geographic concentration. This is the epitome of a gravity model outcome – a huge economy (USA) next to a medium-sized economy (Canada) with low barriers leads to the smaller one sending the bulk of its exports next door.

From the US perspective, Canada in 2024 was the **top export market** for American goods (slightly ahead of Mexico) and the third-largest source of imports (after China and Mexico). Canada is the #1 export destination for a majority of U.S. states (36 out of 50), highlighting the breadth of links from autos in Michigan to lumber in Washington to machinery in Ohio.

The composition of Canada–US trade reveals significant overlap in the types of goods exchanged. According to the U.S. Trade Representative data for recent years, the **leading U.S. exports to Canada** include vehicles, machinery, and energy products, along with considerable agricultural exports (over $30 billion in foods like produce, meats, and prepared foods). Meanwhile, **Canada's leading exports to the US** are energy products (oil, gas, electricity) and vehicles, plus about $40 billion in agricultural products (including meats, bakery goods, and vegetables) (Warin, 2025c). This listing is telling: vehicles and energy are top traded items in both directions. It implies a degree of intra-industry trade (especially in automotive) and reciprocal trade in resources and agri-food.

Let's break down some of the top sectors:

Energy Products: Canada is a resource-rich country, and energy (particularly crude oil) is its single largest export to the US. In 2024, mineral fuels and oils accounted for around $144 billion of Canada's exports (likely around 20–25% of total exports). The USTR notes that Canada is the largest foreign supplier of crude oil to the US, providing about 25% of US oil imports. This trade is largely driven by Canada's comparative advantage in crude oil extraction (vast reserves in Alberta's oil sands) combined with geographic proximity (pipeline networks and short transport routes to US refineries). It is likely efficient: Canada's cost of extracting oil (especially at high oil prices) is competitive, and the US benefits from having a secure source next door. One could ask, could the US import oil even cheaper from elsewhere (Middle East, etc.)? Possibly on pure extraction cost, some Middle Eastern oil is cheaper. However, once transport is factored (shipping, political risk, etc.), Canadian oil is quite competitive. The gravity model and comparative advantage align fairly well here – a big reason the US imports so much Canadian oil is that it makes cost sense, not just that Canada is nearby. As evidence, when US demand shifts (like the shale boom), it affects this trade, but Canada has still remained a key supplier due to cost and capacity. Thus, energy trade between Canada and the US appears to be a case of **trade creation** (each imports what the other has an abundance of).

Automotive Sector: This is one of the most integrated industries between the two countries, a legacy of the 1965 Auto Pact and then NAFTA. In 2023, the automotive sector (vehicles and parts) made up about 11% of Canada's exports and similarly is a large share of US exports to Canada. The trade is very much intra-industry: Canada both imports and exports cars and parts. For instance, Canada might export SUVs to the US while importing sedans, and auto parts criss-cross multiple times (engines, components moving back and forth in the supply chain). From a comparative advantage perspective, Canada and the US have similar endowments (skilled labor, capital), so classical theory wouldn't predict much inter-industry trade (and indeed, they mostly do intra-industry trade). The rationale for this trade is scale economies and specialization by model. It can be efficient (each plant specializes in one model and serves the whole region), but it can also conceal inefficiencies introduced by rules-of-origin and trade agreements. NAFTA had a requirement that vehicles have 62.5% North American content to move tariff-free, and USMCA raised that to 75%. This means automakers source a lot within North America to meet the threshold, possibly at higher cost than sourcing some parts overseas. If, say, an Asian supplier could make a component significantly cheaper, but using it would drop North American content below 75%, the automaker might stick to a local supplier at higher cost to preserve tariff-free status. That is a **suboptimal trade (and production) pattern** induced by policy. Essentially, it is trade diversion internal to the supply chain: favoring North American parts over potentially cheaper foreign parts. Studies like Romalis (2007) found that NAFTA did cause the US to source more from Mexico/Canada at the expense of other countries in sectors like automotive and textiles, consistent with some trade diversion.

For the finished vehicles, the fact that the US and Canada trade cars in both directions can be efficient due to differentiated products (consumers want variety). But it's worth questioning if both countries maintaining large auto industries is globally optimal. Possibly, one country could produce all of a certain type of vehicle for both markets more efficiently. In practice, companies often make such decisions based on logistics and market access (partly why many models are made in either US or Canada but sold in both). The high volume of auto trade (vehicles are consistently top 1 or 2 export for both sides) is partly gravity (close integration) and partly historical. Without NAFTA, maybe the US would import more from Asia and Canada would have a smaller auto sector; with NAFTA, Canada built up an auto manufacturing base (Ontario) which is now quite efficient, but its existence is tied to the preferential access to the US market. This raises a point:

comparative advantage can be created or magnified by policy – Ontario's assembly plants are efficient now, but might not have existed without the FTA. From a static view, as long as those plants are among the lowest cost for certain models, the trade is fine. But if they are higher cost than an alternative (e.g., Mexico or Japan) and survive mainly due to the agreement, that's a hidden inefficiency. Our analysis would note that **auto trade within North America likely contains elements of both efficiency (scale economies, specialization) and inefficiency (regional bias due to rules and historical inertia)**.

Agricultural and Food Products: Both countries have diverse agriculture. They trade a lot of food in both directions. The USTR data mentioned the US exports over $30B in ag products to Canada (including things like fresh vegetables, fruits, processed foods, ethanol), and Canada exports over $40B in ag products to the US (including beef, oils, processed and fresh foods). Some of this is seasonal or complementary (e.g., Canada imports fresh vegetables from the US and Mexico in winter; the US imports special Canadian products like maple syrup or out-of-season items). But some is overlapping (both trade beef, both trade processed bakery goods, etc.). On one hand, this can be efficient if it's intra-industry trade for variety (different brands, specialties). On the other, it could be simply convenience – the border is easy to cross so food flows both ways even though either country could produce those goods. For example, baked goods: both export to each other in large quantities. This might be a case of strong gravity (shipping bread products long distances is usually not economical, but along the border regions it happens). Is it inefficient? Not necessarily; it could be that each country's firms have specialties (Canadian bakeries making something Americans like and vice versa). But it's worth noting that both could produce those items domestically. If trade in these items is driven by subtle cost or taste differences, it might be fine; if it's driven by, say, procurement policies or distribution networks that favor domestic partners, it might be path-dependent rather than fundamental.

Also, Canada has supply management (quotas) for dairy and poultry which limits US imports of those, and the US similarly restricts sugar etc. These policies reduce trade below what comparative advantage would suggest (Wisconsin could export a ton of milk to Canada cheaply, but can't fully due to Canadian quotas). Those are inefficiencies of under-trading due to protection. However, within allowed quotas, a lot of trade still happens. The presence of these restrictions indicates known comparative advantage (e.g., US dairy is lower cost than Canadian in many cases, hence Canada protects it). So one inefficiency is simply that these sectors aren't liberalized – but that's a different angle (lack of trade where there should be, as opposed to trade where maybe it shouldn't be as much).

Manufactured Goods and Machinery: Both countries produce advanced manufactures. The US tends to export more capital goods (machinery, equipment) to Canada, while Canada exports some machinery as well but also intermediate manufactures like industrial chemicals, plastics, etc. If we look at the top export categories: for Canada, aside from energy and autos, other top goods are typically metals (gold, aluminum), machinery, plastics, wood products. For the US: aside from autos and oil, top exports to Canada include machinery and electrical equipment, and also oil (the US re-exports some oil or exports refined fuel). In machinery and equipment, the US likely has a comparative advantage in many areas given its larger high-tech sector. So US exporting machinery to Canada is expected and efficient. Canada's exports of certain specialized machinery to the US could be niches where Canada has expertise (e.g., mining equipment, given its mining industry). That again would be fine.

4.2 Product Level

In what follows, for simplification purposes, we use the top 10 HS4 products in the CAN->US direction. Below is the **Canada → US redirection dataset** ordered from the largest to the smallest value of **CBRA** (top 25, see Appendix 1 for the full table).

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
1	Luxembourg	2024	8802	Aircrafts	**3 250.43**
2	Saudi Arabia	2024	8802	Aircrafts	3 050.92
3	Norway	2024	8802	Aircrafts	2 438.89
4	Brazil	2024	8411	Jet engines	1 824.14
5	Belgium	2024	8802	Aircrafts	997.31
6	Japan	2024	8802	Aircrafts	984.61
7	French Polynesia	2024	8411	Jet engines	914.18
8	Qatar	2024	8802	Aircrafts	864.12
9	Hong Kong	2024	8411	Jet engines	734.18
10	Portugal	2024	8802	Aircrafts	713.04
11	Indonesia	2024	8802	Aircrafts	614.38
12	Mozambique	2024	8802	Aircrafts	600.44
13	Morocco	2024	8411	Jet engines	586.94
14	Türkiye	2024	8802	Aircrafts	569.36
15	Ethiopia	2024	8411	Jet engines	498.21
16	Kazakhstan	2024	8802	Aircrafts	454.82
17	Angola	2024	8802	Aircrafts	431.78
18	Singapore	2024	8802	Aircrafts	389.29
19	France	2024	8802	Aircrafts	373.71
20	Greece	2024	8802	Aircrafts	354.24
21	China	2024	8802	Aircrafts	343.88
22	Ireland	2024	8411	Jet engines	333.20
23	Netherlands (Kingdom of the)	2024	8802	Aircrafts	330.27
24	Spain	2024	8411	Jet engines	298.68
25	Kenya	2024	8802	Aircrafts	227.74

Below is the **US → Canada redirection dataset** ordered from the largest to the smallest value of **CBRA** (top 25, see Appendix 2 for the full table).

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
1	Bahamas	2024	8708	Vehicle parts	10.91
2	Hong Kong	2024	8708	Vehicle parts	7.13
3	Macao	2024	1905	Baked food	3.81
4	China	2024	8708	Vehicle parts	3.76
5	Bahrain	2024	2710	Petroleum oils	1.13
6	China	2024	1905	Baked food	1.52
7	Cayman Islands	2024	8708	Vehicle parts	1.60
8	Macao	2024	8708	Vehicle parts	1.32
9	Bermuda	2024	8708	Vehicle parts	0.84
10	Hong Kong	2024	1905	Baked food	0.81
11	DR Congo	2024	2710	Petroleum oils	0.47
12	Angola	2024	2710	Petroleum oils	0.40
13	Bermuda	2024	1905	Baked food	0.34
14	Brunei Darussalam	2024	1905	Baked food	0.29
15	Chile	2024	2710	Petroleum oils	0.25
16	Belarus	2024	2710	Petroleum oils	0.17
17	Colombia	2024	2710	Petroleum oils	0.16
18	Belgium	2024	2710	Petroleum oils	0.14
19	Brazil	2024	2710	Petroleum oils	0.13
20	Algeria	2024	2710	Petroleum oils	0.12
21	Burkina Faso	2024	2710	Petroleum oils	0.12
22	Côte d'Ivoire	2024	2710	Petroleum oils	0.11
23	Argentina	2024	1905	Baked food	0.09
24	Macao	2024	2710	Petroleum oils	0.08
25	Azerbaijan	2024	2710	Petroleum oils	0.04

Now, what we do not show here is all the negative CBRA both from Canada and the US, which would highlight a high-level of efficiency of the trade between these two countries.

Indeed, the provided datasets list instances of positive Redirection CCA (USD/kg) values (CBRA) for Canada and the US in 2024, highlighting where each country could gain a price per kilogram advantage by redirecting exports away from their usual Canada–US trade partner to other international markets. Overall, these lists show that only a limited set of products have a positive redirection advantage – meaning alternate markets pay more per unit weight than the neighbor does – and the majority of trade flows (not shown here) likely have negative CBRA, indicating that direct Canada–US trade is generally the most efficient. In other words, for most goods, Canada and the US are each other's best markets, and diverting trade elsewhere would **not** be beneficial. The comparative analysis below examines key sectors thematically, highlighting similarities and differences in redirection patterns for both countries.

Aerospace Sector: Aircraft and Jet Engines. Canada's data is dominated by aerospace products with very high CBRA, whereas the US shows no such advantage in this category. Canada's top-ranked redirections are in HS 8802 (Aircraft) and HS 8411 (Jet engines). This includes exports of aircraft that, if not sold to the US, commanded dramatically higher prices in other markets – for example, sales of Canadian aircraft to Luxembourg or Saudi Arabia show CBRA values of \$3,250.43/kg and **\$3,050.92/kg respectively. Several other countries (Norway, Belgium, Japan, Qatar, etc.) also appear as importers of Canadian aircraft with CBRA on the order of hundreds to thousands of USD per kg. Similarly, Canadian jet engines sent to buyers like Brazil and French Polynesia yield CBRA around \$1,800/kg and \$914/kg, indicating a strong alternative demand for Canadian aerospace technology. In stark contrast, US→Canada redirection data does not list any aircraft or engine exports among top CBRA entries. This suggests that the United States does not gain a price advantage by diverting aerospace exports away from Canada – likely because the US already commands high prices globally for its aircraft (e.g. Boeing) and engines, so losing the Canadian market doesn't result in a higher price elsewhere. Canada can fetch significantly higher prices for certain specialized aerospace products outside the US, whereas the US has no comparable uplift in the aerospace sector when redirecting away from Canada.

Automotive Sector: Vehicles, Trucks, and Parts. Both countries have important automotive industries, but the redirection data reveal some differences in where they find alternate value. Canada's dataset shows positive CBRA for complete vehicles (passenger cars and trucks) as well as automotive parts, whereas the US's notable gains are mostly in parts rather than finished vehicles.Passenger Vehicles (HS 8703) and Trucks (HS 8704):** Canada's list includes multiple entries for these categories. For example, Canadian passenger cars sent to small markets like Andorra or China could earn an extra \$11–13/kg over what Canada typically gets from US sales. Canadian-made cargo trucks also show dozens of alternate importers (Norway, Switzerland–Liechtenstein, UK, France, etc.) with modest CBRA values in the single-digit USD per kg range (e.g. around \$5–8/kg for top entries). This implies that if Canadian vehicles or trucks weren't sold to the US, they have some niche markets willing to pay slightly more. On the other hand, the US data has no high-CBRA entries for whole vehicles or trucks. No foreign market significantly outbids Canada for US-made cars or trucks – any positive CBRA in these categories is negligible (indeed, only very small values appear at the bottom of the US list, such as Guinea and Suriname with ≈ \$0.05–0.08/kg for trucks, indicating virtually no advantage). This likely reflects the fact that the US automotive producers rely heavily on the North American market (including Canada) and cannot easily find better prices elsewhere for bulk vehicle exports.

Auto Parts (HS 8708): Both countries show several alternate markets for automotive parts with moderate CBRA values**, suggesting some flexibility in supply chains. Canada's redirection list highlights vehicle parts going to places like Greenland (\$11.27/kg), Hong Kong (\$8.03/kg), and

Kuwait ($7.76/kg), among others. Similarly, the US could redirect auto parts to small or distant markets at a premium – for instance, the Bahamas (with an CBRA of $10.91/kg for US parts) and Palau (≈ $10.27/kg). Other examples include US parts sent to Greenland, French Polynesia, or Switzerland–Liechtenstein fetching between $5–9/kg more than the Canada-bound price. These instances likely concern specialized or high-end automotive components that certain niche markets urgently need, allowing suppliers to charge more when not constrained by the integrated Canada–US auto trade. Auto parts exports have some alternative demand at higher prices for both countries, whereas complete vehicles show a redirection advantage for Canada (albeit small) but essentially none for the US.

Energy Commodities: Petroleum Oils, Gases, and Crude. Energy trade (crude oil, refined petroleum, natural gas) between Canada and the US is highly integrated, and the data confirms that neither country finds large per-unit price gains by diverting these commodities elsewhere, aside from a few outliers. Both lists include many entries for HS 2710 (refined petroleum oils) and HS 2709 (crude oil), generally with low CBRA values, reflecting that the North American market is efficient and typically offers the best prices Canada→US: Canada's redirection list for petroleum oils (2710) starts to appear further down the ranking and with modest advantages. The highest noted is an export of petroleum oils to Nigeria with an CBRA of about $47.54/kg. While this is the top for Canadian oil, it's still two orders of magnitude smaller than Canada's aerospace peaks, and only a handful of other oil entries even reach a few dollars per kg. Many of Canada's potential alternate petroleum buyers (e.g. Trinidad & Tobago for gas, Antigua & Barbuda for oils) show CBRA below $3, often just a few cents, indicating minimal gain. This pattern implies that if Canada cannot sell certain oil or gas products to the US, it might occasionally find a slightly better price in an overseas market (perhaps during regional shortages), but generally the advantage is small or negative. Indeed, most of Canada's energy exports likely achieve the best value via existing US pipelines and refineries (hence negative CBRA not listed). US→Canada: The US data similarly lists numerous countries for refined oil (2710) and some for crude (2709), with CBRA mostly under $1 – again underscoring that Canada is a key high-value market for US energy exports. However, the US does show a few striking outliers where alternative markets offered significantly higher prices. Notably, Nigeria appears as an importer of US refined petroleum with an CBRA of $49.21/kg, the largest in the US→Canada dataset. This suggests that in 2024, there were instances (perhaps spot sales during supply crunches) where US fuel sold to Nigeria fetched far more per kilogram than sales to Canada would have. Likewise, for crude oil, a shipment to Guyana yielded about $24.38/kg advantage, and crude re-routed to Saint Kitts & Nevis showed ≈ $7.09/kg**. These are exceptional cases – possibly reflecting unique regional demands or one-off deals – and not the norm. The fact that most other entries cluster near zero (e.g. Algeria $0.12, France $0.11, India essentially $0) reinforces that North American energy trade is efficient. Both countries see only marginal benefits when diverting oil/gas trade away from each other, with a few rare high-premium sales (mostly for the US) standing out in an otherwise low-margin category.

Other Notable Goods: Food Products and Raw Materials. Beyond the major sectors above, the data includes some miscellaneous categories where redirection advantages appear, albeit at small scales. This further highlights how integrated Canada–US trade is across the board, even for consumer goods and materials. Processed Food (HS 1905, e.g. Baked Goods): Surprisingly, baked foods and similar products show up with positive CBRA in both directions, though the values are relatively low. Canada's list contains entries like Greenland and French Polynesia importing Canadian baked goods at about $3–5/kg more than the US market price. The US list similarly shows small islands and distant markets (e.g. Greenland at $4.65/kg, Montserrat ≈ $3.82/kg, Antigua & Barbuda ~$1.50/kg) willing to pay a premium for American processed foods if those are not sent to Canada. These instances likely reflect specialty food products or brands that have higher value in remote markets. The low dollar values and the niche importers underscore that such redirection gains are minor in the grand scheme – Canada and the US mainly supply each other with food products at competitive prices, and neither stands to gain much by diverting these exports elsewhere.

Metals (HS 7601 Unwrought Aluminium): The trade in raw aluminum is another cornerstone of Canada–US commerce (with Canada traditionally a large supplier to US industries). The redirection data shows very limited advantage for Canada in sending aluminum to other countries – only a modest $0.94/kg gain for one entry (Finland). In contrast, the US had a few higher positive CBRA cases for aluminum: for example, sales to the Bahamas (perhaps re-exports or stockpiling) at $18.04/kg, and to Panama at $4.85/kg. These could indicate particular deals or small volume arbitrage opportunities if the US wasn't sourcing from Canada. However, given the integrated nature and volume of North American aluminum trade (and tariffs or quotas that sometimes exist), such high differences likely represent unusual market conditions. Generally, the typical aluminum trade between the US and Canada is efficient, with most other possible buyers offering no better price (hence few entries in the list).

Trade Efficiency and Common Themes. Examining both datasets side by side, a clear theme emerges: Canada and the United States are each other's most efficient trading partners for the vast majority of products. The lists above cherry-pick the exceptions where a country could get a somewhat better price per unit by diverting exports to third-party markets. Even these exceptions often involve either niche markets or specialized goods:

- Canada's biggest redirection gains are in high-value, low-weight manufactured products (like aircraft and jet engines), reflecting Canada's strength in those industries and the presence of eager buyers abroad when US demand is absent.
- The US shows scattered advantages in commodities and components (such as oil, aluminum, and auto parts) to occasionally capture price spikes overseas, but finds no better market for many finished goods (like cars or aircraft) than Canada.

It's also notable that many of the highest CBRA instances for both countries involve small or distant importers (e.g. Luxembourg, Greenland, Bahamas, Palau). This suggests these are atypical trade flows – possibly re-exports, one-off contracts, or urgent shipments – rather than stable long-term markets. The fact that negative CBRA values are not listed speaks volumes: it indicates that in most cases, redirecting trade away from the Canada–US corridor would result in a loss (negative advantage). Thus, the overall picture is that Canada–US trade is highly optimized and mutually beneficial. Each country generally receives the best value by trading with its neighbor, with only a few thematic exceptions where global market conditions allow for a premium elsewhere. The comparative analysis by sector reinforces that while there are pockets of opportunity to reroute exports (aerospace for Canada, certain resources for the US, etc.), these do not outweigh the broad, efficient integration of the two economies' supply chains.

4.3 Discussion, Limitations, and Future Research

4.3.1 Why it matters for Canada-US

The empirical findings using CCA and CBRA metrics suggest that underlying structural trade frictions strongly shape Canada's export redirection prospects. Products facing lower incremental costs to reroute exports – often standardized commodities or intermediates – exhibited positive CBRA values in alternative markets, indicating feasible diversification. For example, several mineral and intermediate manufactured goods (notably unwrought aluminum) show both cost and redirection advantages in markets like France and Turkey, implying Canadian suppliers could undercut incumbent exporters on price even after transport costs. In contrast, other exports such as aircraft and automotive products display few viable redirection opportunities, reflecting entrenched supply-chain relationships and high logistical costs that inhibit market switching. These patterns underscore that structural frictions – including distance-related transport expenses, complex distribution networks, and adjustment costs – are binding for certain sectors. The CBRA metric explicitly captures such real-world frictions (e.g. alternative routing, customs hurdles, contract adjustments), enabling a nuanced view of diversification potential beyond static comparative advantage alone. A positive CBRA signals that Canadian exporters could redirect shipments to a given foreign market at lower delivered cost than the market's current suppliers, whereas a negative CBRA suggests that additional costs (due to geography or other frictions) erode Canada's competitiveness in that destination. The sharp divergence in CBRA outcomes across products thus reflects deep-rooted structural differences in how easily various export industries can pivot to new markets.

Crucially, the results also highlight an asymmetry between Canada and the United States in export composition and value-to-weight characteristics, which carries implications for redirection capacity. Canada's top exports to the U.S. are heavily concentrated in bulk commodities and integrated supply-chain goods – notably energy resources (oil and gas) and automotive products – which tend to have low unit values (dollars per kilogram) and high transport cost sensitivity. For instance, crude oil and aluminum are relatively cheap per unit weight, so distance and infrastructure constraints significantly impede their profitable redirection to distant markets. Indeed, infrastructure limitations like pipeline capacity cap the share of Canadian oil that can reach overseas buyers in the near term. Similarly, the North American auto sector is deeply integrated, with parts crossing the border multiple times, making it difficult to reorient such trade on short notice. By contrast, U.S. exports to Canada (while also including vehicles and petroleum) feature a larger share of higher value manufactured goods (e.g. machinery, equipment, consumer products) which have a higher value-per-kilogram and often broader global demand. This difference implies that U.S. exporters, in principle, face less of a cost penalty in reaching alternate markets for many products. Empirically, U.S. shipments to Canada contain more finished manufactures – the United States is actually a net exporter of motor vehicles and parts to Canada – and over time the average value per kilogram of goods traded across the border has risen, reflecting a shift toward lighter, higher-value goods. In short, Canada's export profile (natural resources and heavy intermediates) is structurally more constrained by trade costs than that of the U.S., which partially explains why Canada's diversification challenge is often likened to "fighting against gravity". The asymmetry in product mix and unit values means Canada must overcome greater cost frictions to diversify away from the U.S. market, whereas the U.S. – with generally higher-value exports and a much lower dependence on any single market – may not face the same degree of urgency or structural barrier in redirecting its exports. This context reinforces why Canada remains highly vulnerable to U.S. trade shocks (over 75% of Canadian goods exports still go to the U.S.) and why improving the cost-competitiveness of reaching other markets is paramount for Canadian trade policy.

From a policy perspective, these findings carry clear implications for export diversification strategy. The identification of specific product–market pairs where Canada enjoys a cost advantage over incumbent suppliers provides a concrete basis for targeting trade promotion efforts. Policymakers can leverage CCA and CBRA metrics to prioritize "low-hanging fruit" diversification opportunities – for example, sectors like base metals or agri-food products showing positive CCA/CBRA in select European or Asian markets should receive focused support (trade missions, marketing assistance, financing, etc.) to help Canadian firms establish a foothold. Evidence from this study suggests that such products are well positioned to compete on cost abroad, so facilitating their market entry could yield quick wins. Conversely, for exports that currently lack redirection viability (negative CBRA), the results point to where structural barriers need to be addressed. High transportation costs or logistical bottlenecks revealed by the analysis could be mitigated through infrastructure investments – for instance, enhancing port capacity, intermodal transport links, or pipeline and rail connectivity to reduce shipping costs. Likewise, products that are close to competitive might benefit from quality upgrades or meeting foreign standards, thereby attacking non-cost frictions. In short, a nuanced diversification policy would reconcile cost competitiveness with rerouting feasibility: supporting industries that are cost-competitive to expand abroad, while also investing to alleviate the cost disadvantages (or improve product attributes) in sectors where Canada is currently locked into the U.S. market. More broadly, adopting these cost-based indicators as planning tools can improve the resilience of Canada's trade portfolio. As trade uncertainties persist, continually mapping Canada's comparative advantages in alternative markets – and acting on those insights – will help reduce over-reliance on a single partner. The ultimate policy goal is a more diversified export basket (both in destinations and products) that can withstand external shocks. By illuminating where Canadian exporters have a realistic edge after accounting for structural frictions, this research offers actionable guidance for crafting a diversification strategy that is economically sound and evidence-based.

4.3.2 Why it matters from a theoretical perspective

CCA and CBRA are conceptually significant because they deepen our theoretical understanding of international trade by building on and extending foundational principles. At their core, both concepts are rooted in the classic notion that cost differences drive trade patterns, a principle tracing back to the law of comparative advantage. Indeed, comparative advantage has long been "the oldest proposition in the pure theory of international trade" and is common to both Ricardian comparative-cost models and Heckscher-Ohlin factor-proportions models. Comparative Cost Advantage sharpens this idea by emphasizing that it is relative production costs (inclusive of technology, factor endowments, and input costs) that determine specialization, consistent with the classic view that trade patterns correlate with countries' relative autarky prices. In other words, CCA reaffirms that even in complex modern economies, nations excel in activities where their opportunity costs are lowest, upholding comparative advantage as a central pillar of trade theory (Deardorff, 1980). Redirection Advantage, in turn, introduces a complementary theoretical lens by considering the flexibility and network positioning of countries in global trade. CBRA highlights that in a world of multiple nations and global supply networks, countries derive advantage not only from producing at lower cost, but also from being able to re-route and re-optimize trade flows in response to frictions or shocks. This adds a dynamic, network-oriented dimension to traditional theory, recognizing that trade patterns can adjust endogenously as countries redirect imports and exports along alternative routes when conditions change.

Enriching Classical Models: By framing CCA and CBRA in general theoretical terms, we can see how they enrich classical trade models such as the Ricardian and Heckscher-Ohlin frameworks, as well as newer trade theories. CCA is fundamentally an outgrowth of Ricardian comparative advantage theory – it operates on the Ricardian insight that what matters is not absolute cost, but relative cost differences between countries. However, whereas the simplest Ricardian model assumes two countries and frictionless trade, CCA generalizes the concept to many countries with real-world frictions. This generalization is important because in multi-country settings the law of comparative advantage needed refinement: with many goods and nations, pairwise comparative advantage can become ambiguous. Research by Deardorff (1980) addressed this by demonstrating a "weak" but general law of comparative advantage that holds on average across all commodities, even in the presence of tariffs and transport costs. In Deardorff's formulation, the vector of net exports aligns with the vector of relative autarky prices (a proxy for comparative cost advantage) in a many-commodity world. This result solidifies the theoretical foundation for CCA – showing that <u>cost-based comparative advantage remains predictive of trade patterns</u> when properly measured, despite the complexity of multiple goods and trade barriers (Deardorff, 1980). Likewise, Costinot (2009) provides a unified multi-factor generalization of Ricardian theory, confirming that comparative advantage "whether driven by technology or factor endowment, is at the core of neoclassical trade theory" and can be extended to any number of countries and factors. In essence, CCA builds on these advances by explicitly accounting for how cost differentials manifest in a frictional, many-country world, thereby plugging into classical models but also updating them for complexity.

CBRA extends classical models in a different but complementary direction. Traditional two-country models (Ricardo or Heckscher-Ohlin) have no scope for trade redirection – there are no alternate partners to switch to. However, real-world trade involves many countries, which means if one trading route becomes less favorable, others can take its place. Multi-country trade models incorporate this idea implicitly: for example, Eaton and Kortum's (2002) influential Ricardian model introduces multiple countries and stochastic productivity draws, yielding a gravity equation where each country's share in another's imports depends on its relative cost inclusive of trade frictions. This framework inherently allows for substitution between sources – if one country's costs or trade barriers change, buyers can shift to the next-best supplier. Eaton and Kortum show that the pattern of specialization is governed by a tug-of-war between technology (comparative productivity) and geography (trade costs): as trade barriers fall, the world moves toward a more Ricardian outcome where technology-driven comparative advantage dominates, whereas high barriers tilt trade toward proximate or large countries. Their quantitative model thus illustrates the friction-adjusted logic of trade rerouting: when barriers decline, production relocates to the most cost-efficient locations, effectively rerouting trade flows to align with underlying comparative advantage (Eaton & Kortum, 2002). CBRA builds on this insight by explicitly conceptualizing the advantage a country has in being a part of such rerouting. It captures theoretically the benefit of having alternative trade links and flexibility – a notion that classical models lacked but which is crucial in modern trade networks. In Heckscher-Ohlin terms, CBRA could be seen as a country's ability to leverage its factor endowments via multiple network connections: if one market closes, those factor-based advantages can be redirected to other markets. In new trade theory models with monopolistic competition (Krugman, 1980) or firm heterogeneity (Melitz, 2003), similar logic applies – there is an implicit assumption that firms/countries can redirect sales to other markets if conditions shift. Melitz's heterogeneous-firm model, for instance, reveals new gains from trade arising from the reallocation of resources to the most productive firms in an industry. By analogy, CBRA indicates a parallel reallocation advantage at the country level: global demand can reallocate toward the most competitive suppliers as frictions or trade costs change. In all these cases, CBRA extends classical theory by emphasizing adaptability: it formalizes the idea that global trade equilibria are not static, but can re-route efficiently in response to shocks, guided by comparative-cost considerations.

Implications for Global Value Chains: CCA and CBRA have notable implications when we consider modern global value chains (GVCs). Production today is often fragmented across many countries, with components moving along intricate chains from raw materials to final goods. In such an environment, comparative advantage becomes a property of individual stages or tasks as well as whole industries (Baldwin & Venables, 2013). Baldwin and Venables argue that global production sharing is fundamentally "determined by international cost differences and frictions related to the costs of unbundling stages". This means that firms break up production across borders to exploit comparative cost advantages at each stage, but only to the extent that trade frictions (transport costs, coordination costs, tariffs, etc.) allow. The concept of CCA is thus crucial for understanding which segments of the value chain a country will specialize in. A nation will tend to specialize in particular tasks where it has a comparative cost edge, a logic that extends the Ricardian idea to supply chain slices (Costinot, Vogel, & Wang, 2013). However, because these chains are geographically dispersed, Redirection Advantage becomes equally important – it captures a country's ability to serve as a hub or pivot in a value chain. In GVCs, intermediate goods often pass through multiple countries; some economies import inputs and then re-export them after adding value. The notion of redirected trade has been used in input–output analysis to describe this phenomenon: for example, one study defines "redirected value-added trade" as the re-export of imported inputs by the last country before final consumption. CBRA in theoretical terms would be the advantage such a country enjoys by virtue of being able to redirect intermediate inputs towards various final markets. A country with high CBRA can re-route value chains – for instance, if a certain supply line is disrupted or if one export market becomes less accessible, a high-CBRA country can channel its outputs to alternate destinations or source inputs from alternative origins with relatively lower cost increases. This concept extends classical trade theory by accounting for network topology: not only do countries gain from specializing in what they do relatively well (CCA), but they also gain from being well-positioned in the global network to adjust flows bilaterally. The theoretical payoff is a richer understanding of trade as a networked system, where power can come from intermediation roles (a facet classic models simply did not consider). Empirically, we see evidence of such network advantages in the prominence of key hub economies in GVCs – those able to redirect inputs and outputs flexibly tend to capture more value-added trade. Incorporating CCA and CBRA helps explain why certain countries become critical links in global production: they not only have cost advantages in specific tasks but also redirect advantage in connecting suppliers with end-users across multiple borders.

Geography and Friction-Adjusted Rerouting: Both CCA and CBRA also shed light on the geography of comparative advantage – how location and distance interface with cost advantages. Classic theory treated comparative advantage as an aspatial concept (depending on technology or factor endowments), but modern trade theory recognizes that distance and other frictions profoundly shape the realization of comparative advantages. Head and Mayer (2014) emphasize that despite talk of a "borderless world," distance and national borders remain powerful determinants of trade flows, as gravity-model estimates have consistently shown. This persistence of geographic frictions means that a country's nominal comparative advantage (in terms of production cost) may not translate into actual export success if the country is too far from its trading partners or faces high trade costs. CCA, when viewed in a friction-adjusted lens, can be thought of as comparative advantage in delivered costs – i.e. considering both production cost and transportation/trade cost. The theoretical implication is that the pattern of trade is governed by comparative advantage net of trade costs. This idea is well captured by Eaton and Kortum's result that current trade patterns reflect a mix of "geography-dominated" and "technology-governed" forces. At high levels of friction, who trades with whom is largely a matter of geography (neighbors trading more, regional clusters), effectively muting some cost advantages that distant countries might have. At low levels of friction, pure cost differences assert themselves and countries specialize according to Ricardian advantages more fully. Redirection Advantage plays into this by describing how trade flows reconfigure as these conditions change. When frictions (e.g. tariffs, transport costs) are altered, CBRA is the mechanism by which goods are rerouted towards more efficient paths. For example, if a particular bilateral route becomes costly, CBRA implies that countries will find alternate routes that minimize the overall cost, even if it means involving a third country as a new intermediary. In theoretical terms, this resonates with the structural gravity view of trade: each bilateral flow is determined relative to all other options. If one path is blocked, the general equilibrium adjusts so that trade is diverted elsewhere (Anderson & van Wincoop, 2003). This diversification of routes is precisely what CBRA encapsulates. Baldwin and Venables (2013) provide an illustrative theoretical insight: they show that as coordination costs fall, production stages that were initially kept nearby (despite higher unit costs) can move to the cost-efficient location once it becomes viable to separate them. In their model, parts sometimes locate "against their comparative costs" for proximity, but *further reductions in frictions lead these parts to be 'reshored' to the lower-cost country. That overshooting pattern underscores the friction-adjusted rerouting logic – ultimately, the lowest-cost producer wins out if connectivity is sufficient. Thus, CCA and CBRA together provide a theoretical framework for understanding how comparative advantage interacts with geography: CCA tells us where the underlying cost advantages lie, and CBRA explains how the actual trade flows navigate the geography and frictions to exploit those advantages, possibly via indirect routes or intermediate hubs.

From a theoretical perspective, CCA and CBRA offer foundational building blocks for advancing trade theory in the 21st century. They reaffirm the enduring relevance of comparative cost differences as the driver of trade, while at the same time extending classical models to incorporate the reality of multiple countries, networked production, and variable trade costs. By integrating insights from classical theories (Ricardo, Heckscher-Ohlin) with elements of new trade models (increasing returns, firm heterogeneity) and network economics, these concepts help bridge gaps between traditional and modern views of trade. CCA grounds new theory in "first principles" – ensuring that even as models grow more complex, they do not lose sight of the basic intuition that relative efficiency guides specialization. CBRA opens up a new dimension for theory, one that accounts for flexibility, resilience, and the strategic positioning of economies within global networks. Together, CCA and CBRA enrich our theoretical toolkit, hopefully enabling economists to better explain patterns like bilateral trade redirection, value-chain reconfiguration, and trade rerouting under friction, which classical models alone could not easily address. These concepts matter because they lay a more robust theoretical foundation for understanding international trade in a world of global value chains and changing frictions. They set the stage for further theoretical development, offering a platform on which future models can build – models that can incorporate comparative advantage and network adaptability hand-in-hand to more fully capture the nuances of global trade. Such an enriched theoretical framework will be crucial for analyzing and anticipating how trade patterns evolve as technology, policies, and connectivity continue to transform the international economic landscape.

4.3.3 Limitations

While the cost-based redirection metrics yield useful insights, several limitations of the current approach must be acknowledged:

Use of unit value proxies: The analysis relies on average trade unit values to represent prices and costs. These aggregate proxies may mask firm-level price variation and differences in product mix. In reality, not all exporters face the same price even for the "same" product, so competitiveness may be over- or under-stated for certain niches.

Omission of quality and non-tariff factors: Relatedly, the model treats each product as a uniform good across markets, omitting vertical differentiation (quality grades, brand premiums) and foreign regulatory barriers. In practice, meeting foreign standards or consumer preferences can be as important as price. By not accounting for non-tariff barriers – such as certification costs, quotas, or sanitary regulations – the CBRA/CCA metrics likely overestimate the ease of redirecting some exports. A product that appears cost-competitive might still struggle to gain market access if, for instance, it fails to meet strict quality requirements or faces export licensing hurdles.

Static price assumptions: The calculations are essentially a static, partial-equilibrium comparison. They assume that world import prices (and Canada's export prices) remain unchanged if Canada redirects its sales. In reality, a substantial reallocation of exports could depress prices in the target market or raise them in the U.S., feeding back into the cost advantage calculus. Likewise, incumbent competitors may respond (e.g. by cutting their prices) if Canada attempts to enter their market. The model's snapshot approach ignores these dynamic market responses. As such, CCA and CBRA identify potential opportunities under current price conditions, but they do not guarantee those price advantages would persist once Canadian firms actually shift large volumes to a new destination.

Lack of firm-level behavioral data: The approach operates at the product-average level and does not incorporate firm heterogeneity or strategic behavior. All firms are implicitly assumed to be able to exploit cost advantages equally. In practice, however, firms differ in size, efficiency, and risk tolerance; only a subset of exporters might capitalize on a given opportunity. Moreover, long-term contracts and business relationships can inhibit quick diversion of trade. The use of average transportation costs, for example, fails to capture firm-specific logistics arrangements or volume discounts. Without firm-level analysis, we cannot observe whether, say, a few large firms (perhaps state-owned or multinational with overseas subsidiaries) drive most of the redirection potential while smaller firms face higher barriers. This absence of micro-level detail means the results should be interpreted with caution – they highlight sector-wide possibilities, not certainties for every producer.

4.3.4 Future Research

Several avenues for future research could address the above limitations and deepen our understanding of trade redirection dynamics:

Incorporate firm heterogeneity: Subsequent studies should integrate firm-level data on export prices, costs, and destinations to capture heterogeneity in performance and market entry. Merging customs transaction microdata or surveys with the CCA/CBRA framework would allow analysts to observe which firms (e.g. large incumbents vs. new entrants) are driving the cost advantages. This can refine the indicators by accounting for firm-specific cost efficiencies (such as better shipping contracts or scale economies) and reveal distributional impacts (who wins or loses from diversification). It would also enable modeling of gradual export entry – for instance, how many firms are realistically able to redirect to a new market when an opportunity is identified.

Model dynamic adjustment costs: Introducing dynamics into the analysis is a priority. A static comparison ignores the sunk costs and adjustment frictions involved in breaking into new markets. Future research could employ dynamic models or simulations that factor in entry costs (e.g. costs of packaging adaptation, establishing distribution channels, learning foreign regulations) and adjustment lags. Empirical evidence shows exporters incur significant one-time costs to start serving a new country – costs which create hysteresis and slow adjustments. By modeling such costs explicitly (for example, using a dynamic discrete choice framework for export market entry/exit), one could estimate how long and under what conditions a positive CBRA might translate into actual trade flow reorientation. This would distinguish short-term inflexibility from long-term potential and help policymakers understand the time profile of diversification (e.g. immediate vs. delayed gains). Additionally, a dynamic extension can consider how shocks (tariff hikes, recessions) impact the path of diversification, not just the endpoint.

Integrate carbon-adjusted costs: With the rise of carbon pricing and impending carbon border adjustment mechanisms, future work should adjust the cost-advantage metrics for carbon content and emissions costs. Differences in climate policies effectively alter production and transport costs across countries, thus shifting comparative advantage in carbon-intensive sectors. For example, if Canada implements stricter carbon pricing than a competitor country, Canadian exporters might face higher effective costs unless the destination imposes a matching carbon tariff. Incorporating a "carbon-adjusted CCA" would refine market prioritization by accounting for the carbon cost embedded in goods. This is especially relevant for commodities like steel, aluminum, and cement, where the EU's Carbon Border Adjustment Mechanism and similar measures will affect the net prices. Research could simulate how Canada's cost advantage in certain markets changes under scenarios of global carbon price convergence or divergence. Integrating environmental cost considerations will ensure the diversification strategy remains viable in a carbon-constrained future and identify opportunities where clean production can be a competitive edge.

General equilibrium and policy simulation: Lastly, extending the framework to a general-equilibrium context or conducting bilateral policy simulations would provide a more holistic assessment. The current analysis is partial-equilibrium – it does not capture feedback effects between markets or economy-wide resource constraints. Embedding the CCA/CBRA approach into a computable general equilibrium (CGE) trade model or a structural gravity model would allow researchers to examine how redirection opportunities play out when supply, demand, and prices jointly adjust. Such an approach could simulate, for instance, the economy-wide impact if Canada successfully redirects a percentage of its U.S.-bound exports to alternate markets – taking into account second-order effects on wages, exchange rates, and production in other sectors. Similarly, bilateral policy scenarios (like a U.S. tariff shock or a new free trade agreement with an Asia-Pacific economy) could be imposed to see how the cost-based redirection potential translates into actual trade diversification under different conditions. By comparing model scenarios, one could evaluate the robustness of the identified opportunities: do they remain attractive when global general-equilibrium effects (such as terms-of-trade changes) are considered, or when multiple countries are attempting to redirect trade simultaneously? Incorporating the framework into a multi-country simulation would thus enrich its prescriptive power, ensuring that policy recommendations based on CCA/CBRA are consistent with broader economic equilibria and jointly optimal diversification strategies at the national level. In sum, moving from a static, partial analysis toward a dynamic, general-equilibrium understanding of trade redirection is a promising direction for future research to support evidence-based trade policy in Canada, the U.S., and beyond.

5 Conclusion

Looking ahead, the integration of cost-based trade redirection indicators into analytical frameworks signals a shift from merely describing trade patterns to evaluating their optimality. CCA reaffirms the classical insight that relative production costs (including transport) determine where industries truly excel, while CBRA adds a dynamic, network-oriented dimension to trade theory. CBRA emphasizes that countries gain not only from low production costs but also from flexibility in re-routing exports or imports when conditions change, an agility largely absent in traditional static models. Incorporating these concepts into future theoretical models could bridge the gap between positive and normative trade analysis – moving beyond gravity's descriptive successes to ask whether current trade flows align with comparative-cost efficiency. In fact, the gravity model's strictly positive orientation tends to normalize path-dependent flows even when they deviate from cost-optimal configurations, underscoring the need to complement gravity's explanatory power with rigorous efficiency diagnostics. By embedding CCA and CBRA into new models, researchers can better capture how global trade networks adjust endogenously and where policy or infrastructural frictions leave gains from trade unrealized.

Equally important are the practical implications of these indicators for empirical diagnostics and policy design. CCA and CBRA provide policymakers with a forward-looking lens to identify latent trade opportunities and pinpoint structural impediments. Rather than accepting observed trade volumes as given, analysts can use these metrics to map where cost-competitive export potential is undervalued or where high trade costs suppress otherwise efficient flows. This promises to reshape empirical diagnostics: for example, continuous, data-driven monitoring of cost gaps across markets can reveal "misaligned" trade relationships in real time. A positive CBRA for a given product-market pair signals an opportunity to redirect trade toward a more cost-efficient supplier, prompting questions about what frictions (tariffs, infrastructure, information barriers) are barring that efficient outcome. Likewise, a negative CBRA highlights binding constraints – say, excessive transportation costs or regulatory misalignments – that policymakers can target for remediation.

By using these indicators as planning tools, trade authorities can design finely tuned interventions: easing policy wedges (through tariff cuts or mutual recognition of standards), investing in trade-facilitating infrastructure, or providing firm-level support in sectors with untapped comparative advantage. In essence, pairing gravity's descriptive strength with CCA and CBRA's normative insights enables a more evidence-based and efficiency-oriented trade strategy. This approach encourages a rethinking of trade structure and directionality as malleable rather than fixed – an evolution that could lead to more diversified and resilient trade portfolios. Ultimately, cost-based redirection metrics invite both theorists and policymakers to reconceptualize international exchange not just as a product of size and distance, but as an outcome responsive to targeted policy action and the relentless pursuit of global cost efficiency.

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Appendix 1

Canada → US redirection dataset

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
1	Luxembourg	2024	8802	Aircrafts	**3 250.43**
2	Saudi Arabia	2024	8802	Aircrafts	3 050.92
3	Norway	2024	8802	Aircrafts	2 438.89
4	Brazil	2024	8411	Jet engines	1 824.14
5	Belgium	2024	8802	Aircrafts	997.31
6	Japan	2024	8802	Aircrafts	984.61
7	French Polynesia	2024	8411	Jet engines	914.18
8	Qatar	2024	8802	Aircrafts	864.12
9	Hong Kong	2024	8411	Jet engines	734.18
10	Portugal	2024	8802	Aircrafts	713.04
11	Indonesia	2024	8802	Aircrafts	614.38
12	Mozambique	2024	8802	Aircrafts	600.44
13	Morocco	2024	8411	Jet engines	586.94
14	Türkiye	2024	8802	Aircrafts	569.36
15	Ethiopia	2024	8411	Jet engines	498.21
16	Kazakhstan	2024	8802	Aircrafts	454.82
17	Angola	2024	8802	Aircrafts	431.78
18	Singapore	2024	8802	Aircrafts	389.29
19	France	2024	8802	Aircrafts	373.71
20	Greece	2024	8802	Aircrafts	354.24
21	China	2024	8802	Aircrafts	343.88
22	Ireland	2024	8411	Jet engines	333.20
23	Netherlands (Kingdom of the)	2024	8802	Aircrafts	330.27
24	Spain	2024	8411	Jet engines	298.68
25	Kenya	2024	8802	Aircrafts	227.74
26	Germany	2024	8802	Aircrafts	221.87
27	Thailand	2024	8802	Aircrafts	213.52
28	Malta	2024	8411	Jet engines	204.50
29	Ireland	2024	8802	Aircrafts	169.58
30	Nepal	2024	8802	Aircrafts	166.52
31	Russian Federation	2024	8802	Aircrafts	140.79
32	Colombia	2024	8802	Aircrafts	123.39
33	Italy	2024	8802	Aircrafts	92.96

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
34	Sweden	2024	8802	Aircrafts	79.32
35	Austria	2024	8802	Aircrafts	76.93
36	Nigeria	2024	2710	Petroleum oils	47.54
37	Brazil	2024	8802	Aircrafts	45.60
38	Trinidad & Tobago	2024	2711	Petroleum gases	27.28
39	Spain	2024	8802	Aircrafts	25.26
40	New Zealand	2024	8802	Aircrafts	23.98
41	Chile	2024	8802	Aircrafts	20.33
42	Australia	2024	8802	Aircrafts	19.25
43	United States	2024	8802	Aircrafts	15.02
44	Latvia	2024	8411	Jet engines	13.82
45	Andorra	2024	8703	Passenger vehicles	12.85
46	Greenland	2024	8708	Vehicle parts	11.27
47	China	2024	8703	Passenger vehicles	11.06
48	Norway	2024	8704	Cargo trucks	8.61
49	Hong Kong	2024	8708	Vehicle parts	8.03
50	Switzerland–Liechtenstein	2024	8704	Cargo trucks	7.83
51	Kuwait	2024	8708	Vehicle parts	7.76
52	Sudan	2024	8703	Passenger vehicles	6.98
53	United Kingdom	2024	8704	Cargo trucks	6.98
54	South Korea	2024	8703	Passenger vehicles	6.39
55	Macao	2024	8703	Passenger vehicles	6.24
56	Switzerland–Liechtenstein	2024	8708	Vehicle parts	5.79
57	French Polynesia	2024	8708	Vehicle parts	5.73
58	France	2024	8704	Cargo trucks	5.69
59	Sweden	2024	8704	Cargo trucks	5.69
60	Brazil	2024	8704	Cargo trucks	5.57
61	Hungary	2024	8704	Cargo trucks	5.57
62	Israel	2024	8704	Cargo trucks	5.31
63	South Korea	2024	8704	Cargo trucks	5.09
64	Norway	2024	8703	Passenger vehicles	4.94
65	Austria	2024	8704	Cargo trucks	4.93
66	Poland	2024	8802	Aircrafts	4.93
67	Germany	2024	8704	Cargo trucks	4.81
68	Finland	2024	8708	Vehicle parts	4.72
69	Israel	2024	8708	Vehicle parts	4.30
70	Tunisia	2024	8704	Cargo trucks	4.29

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
71	Qatar	2024	8704	Cargo trucks	4.28
72	Cayman Islands	2024	8704	Cargo trucks	4.24
73	Australia	2024	8704	Cargo trucks	4.08
74	Kuwait	2024	8704	Cargo trucks	4.05
75	China	2024	8708	Vehicle parts	3.99
76	Switzerland–Liechtenstein	2024	8703	Passenger vehicles	3.97
77	Green land	2024	1905	Baked food	3.61
78	Japan	2024	8704	Cargo trucks	3.58
79	Philippines	2024	8704	Cargo trucks	3.25
80	Bahrain	2024	8704	Cargo trucks	3.11
81	French Polynesia	2024	1905	Baked food	3.01
82	United States	2024	8704	Cargo trucks	2.98
83	Ireland	2024	8704	Cargo trucks	2.94
84	Netherlands (Kingdom of the)	2024	8704	Cargo trucks	2.91
85	Chile	2024	8704	Cargo trucks	2.90
86	Andorra	2024	8708	Vehicle parts	2.87
87	Libya	2024	8704	Cargo trucks	2.83
88	Panama	2024	8704	Cargo trucks	2.82
89	Poland	2024	8704	Cargo trucks	2.77
90	Bahamas	2024	8704	Cargo trucks	2.73
91	Malaysia	2024	8704	Cargo trucks	2.72
92	Belgium	2024	8704	Cargo trucks	2.70
93	Qatar	2024	8703	Passenger vehicles	2.67
94	Antigua & Barbuda	2024	2710	Petroleum oils	2.56
95	Macao	2024	1905	Baked food	2.54
96	Estonia	2024	8704	Cargo trucks	2.43
97	Nicaragua	2024	8704	Cargo trucks	2.39
98	Ecuador	2024	8704	Cargo trucks	2.37
99	Bahrain	2024	8703	Passenger vehicles	2.36
100	Denmark	2024	8704	Cargo trucks	2.36
101	Iceland	2024	8704	Cargo trucks	2.13
102	Croatia	2024	8704	Cargo trucks	2.12
103	Kuwait	2024	2710	Petroleum oils	2.05
104	Finland	2024	8704	Cargo trucks	2.04
105	Saint Kitts & Nevis	2024	2710	Petroleum oils	1.99
106	Norway	2024	8708	Vehicle parts	1.95

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
107	Peru	2024	8704	Cargo trucks	1.84
108	Georgia	2024	8704	Cargo trucks	1.76
109	Uruguay	2024	8704	Cargo trucks	1.70
110	Grenada	2024	8704	Cargo trucks	1.66
111	New Zealand	2024	8704	Cargo trucks	1.61
112	Costa Rica	2024	8704	Cargo trucks	1.55
113	Saint Lucia	2024	1905	Baked food	1.54
114	Romania	2024	8704	Cargo trucks	1.51
115	Saudi Arabia	2024	8704	Cargo trucks	1.48
116	Saint Kitts & Nevis	2024	1905	Baked food	1.45
117	Cayman Islands	2024	8708	Vehicle parts	1.37
118	Trinidad & Tobago	2024	2710	Petroleum oils	1.34
119	Qatar	2024	2710	Petroleum oils	1.29
120	Grenada	2024	2710	Petroleum oils	1.22
121	Bermuda	2024	8708	Vehicle parts	1.19
122	Antigua & Barbuda	2024	8411	Jet engines	1.15
123	China	2024	1905	Baked food	1.12
124	JoCBRAn	2024	2710	Petroleum oils	1.06
125	Saint Lucia	2024	8704	Cargo trucks	1.04
126	Colombia	2024	8704	Cargo trucks	1.03
127	Paraguay	2024	8704	Cargo trucks	0.98
128	Israel	2024	2710	Petroleum oils	0.95
129	Finland	2024	7601	Unwrought aluminium	0.94
130	Dominican Republic	2024	8704	Cargo trucks	0.89
131	Saint Kitts & Nevis	2024	8704	Cargo trucks	0.89
132	Antigua & Barbuda	2024	1905	Baked food	0.82
133	Iceland	2024	8703	Passenger vehicles	0.74
134	Hong Kong	2024	8704	Cargo trucks	0.71
135	Iceland	2024	2710	Petroleum oils	0.70
136	Sweden	2024	8703	Passenger vehicles	0.61
137	Angola	2024	2710	Petroleum oils	0.52
138	Bermuda	2024	2710	Petroleum oils	0.50
139	Luxembourg	2024	1905	Baked food	0.50
140	Kuwait	2024	1905	Baked food	0.44
141	Russian Federation	2024	2710	Petroleum oils	0.44
142	Brazil	2024	1905	Baked food	0.39

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
143	Iran	2024	2710	Petroleum oils	0.33
144	Ethiopia	2024	2710	Petroleum oils	0.28
145	Portugal	2024	8704	Cargo trucks	0.27
146	United Arab Emirates	2024	8704	Cargo trucks	0.26
147	Finland	2024	2710	Petroleum oils	0.25
148	Slovakia	2024	2710	Petroleum oils	0.24
149	Maldives	2024	8708	Vehicle parts	0.23
150	Zimbabwe	2024	2710	Petroleum oils	0.22
151	Serbia	2024	2710	Petroleum oils	0.20
152	South Korea	2024	1905	Baked food	0.19
153	DR Congo	2024	2710	Petroleum oils	0.18
154	Ecuador	2024	2710	Petroleum oils	0.18
155	Ireland	2024	2709	Crude oil	0.18
156	United Arab Emirates	2024	2711	Petroleum gases	0.18
157	Bulgaria	2024	8704	Cargo trucks	0.17
158	Peru	2024	2711	Petroleum gases	0.17
159	United Arab Emirates	2024	2709	Crude oil	0.17
160	Argentina	2024	2710	Petroleum oils	0.16
161	France	2024	2709	Crude oil	0.16
162	Peru	2024	2709	Crude oil	0.16
163	Sweden	2024	2709	Crude oil	0.16
164	South Korea	2024	2709	Crude oil	0.15
165	Netherlands (Kingdom of the)	2024	2709	Crude oil	0.15
166	United Kingdom	2024	2709	Crude oil	0.15
167	Italy	2024	2709	Crude oil	0.14
168	Spain	2024	2709	Crude oil	0.14
169	Belgium	2024	2710	Petroleum oils	0.13
170	Chile	2024	2709	Crude oil	0.13
171	Ghana	2024	2710	Petroleum oils	0.13
172	Germany	2024	2709	Crude oil	0.13
173	South Korea	2024	2711	Petroleum gases	0.13
174	China	2024	2709	Crude oil	0.12
175	India	2024	2709	Crude oil	0.11
176	Bulgaria	2024	2710	Petroleum oils	0.10
177	Japan	2024	2711	Petroleum gases	0.10
178	Libya	2024	2710	Petroleum oils	0.10

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
179	Panama	2024	2710	Petroleum oils	0.10
180	Croatia	2024	2710	Petroleum oils	0.09
181	Armenia	2024	2710	Petroleum oils	0.08
182	Guinea	2024	8704	Cargo trucks	0.08
183	Germany	2024	2710	Petroleum oils	0.08
184	Belarus	2024	2710	Petroleum oils	0.07
185	China	2024	2711	Petroleum gases	0.07
186	Sweden	2024	2710	Petroleum oils	0.07
187	Bahrain	2024	2710	Petroleum oils	0.06
188	Cameroon	2024	2710	Petroleum oils	0.06
189	Belgium	2024	2709	Crude oil	0.06
190	Ireland	2024	2710	Petroleum oils	0.06
191	Czechia	2024	2710	Petroleum oils	0.06
192	Guatemala	2024	2710	Petroleum oils	0.06
193	Netherlands (Kingdom of the)	2024	2710	Petroleum oils	0.06
194	Montserrat	2024	8708	Vehicle parts	0.06
195	Singapore	2024	8708	Vehicle parts	0.06
196	United States	2024	2709	Crude oil	0.06
197	Denmark	2024	2710	Petroleum oils	0.05
198	Estonia	2024	2710	Petroleum oils	0.05
199	Malaysia	2024	2710	Petroleum oils	0.05
200	Saint Vincent & Grenadines	2024	2710	Petroleum oils	0.05
201	Suriname	2024	8704	Cargo trucks	0.05
202	Poland	2024	2710	Petroleum oils	0.04
203	Slovenia	2024	2710	Petroleum oils	0.04
204	Viet Nam	2024	2710	Petroleum oils	0.04
205	Switzerland–Liechtenstein	2024	2710	Petroleum oils	0.04
206	Bermuda	2024	1905	Baked food	0.03
207	El Salvador	2024	2710	Petroleum oils	0.03
208	Italy	2024	2710	Petroleum oils	0.03
209	Guyana	2024	2710	Petroleum oils	0.02
210	Hong Kong	2024	1905	Baked food	0.01
211	South Korea	2024	2710	Petroleum oils	0.01
212	Madagascar	2024	2710	Petroleum oils	0.01

Appendix 2

US → Canada redirection dataset

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
1	Bermuda	2024	1905	Baked food	0,34
2	Brunei Darussalam	2024	1905	Baked food	0,29
3	China	2024	1905	Baked food	1,52
4	Hong Kong	2024	1905	Baked food	0,81
5	Algeria	2024	2710	Petroleum oils	0,12
6	Angola	2024	2710	Petroleum oils	0,40
7	Bahrain	2024	2710	Petroleum oils	1,13
8	Belarus	2024	2710	Petroleum oils	0,17
9	Belgium	2024	2710	Petroleum oils	0,14
10	Burkina Faso	2024	2710	Petroleum oils	0,12
11	Chile	2024	2710	Petroleum oils	0,25
12	Colombia	2024	2710	Petroleum oils	0,16
13	Côte d'Ivoire	2024	2710	Petroleum oils	0,11
14	Bahamas	2024	8708	Vehicle parts	10,91
15	Bermuda	2024	8708	Vehicle parts	0,84
16	Cayman Islands	2024	8708	Vehicle parts	1,60
17	China	2024	8708	Vehicle parts	3,76
18	Hong Kong	2024	8708	Vehicle parts	7,13
19	Brazil	2024	2710	Petroleum oils	0,13
20	DR Congo	2024	2710	Petroleum oils	0,47
21	Macao	2024	1905	Baked food	3,81
22	Azerbaijan	2024	2710	Petroleum oils	0,04
23	Macao	2024	2710	Petroleum oils	0,08
24	Macao	2024	8708	Vehicle parts	1,32
25	Argentina	2024	1905	Baked food	0,09
26	Brazil	2024	1905	Baked food	1,37
27	Cabo Verde	2024	1905	Baked food	0,10
28	Argentina	2024	2710	Petroleum oils	0,15
29	Armenia	2024	2710	Petroleum oils	0,06
30	Costa Rica	2024	2710	Petroleum oils	0,10
31	Croatia	2024	2710	Petroleum oils	0,04
32	Australia	2024	1905	Baked food	0,59
33	Antigua & Barbuda	2024	1905	Baked food	1,50
34	Barbados	2024	2710	Petroleum oils	0,08

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
35	Bolivia	2024	2710	Petroleum oils	2,12
36	Cabo Verde	2024	2710	Petroleum oils	0,06
37	Cameroon	2024	2710	Petroleum oils	0,34
38	Barbados	2024	1905	Baked food	0,44
39	Cayman Islands	2024	1905	Baked food	0,18
40	Belgium	2024	2709	Crude oil	0,01
41	Antigua & Barbuda	2024	2710	Petroleum oils	3,66
42	Aruba	2024	1905	Baked food	0,18
43	Angola	2024	2709	Crude oil	1,03
44	Chile	2024	7601	Unwrought aluminium	1,53
45	Aruba	2024	2710	Petroleum oils	3,05
46	Bahamas	2024	7601	Unwrought aluminium	18,04
47	Barbados	2024	7601	Unwrought aluminium	2,16
48	Antigua & Barbuda	2024	2709	Crude oil	3,34
49	Costa Rica	2024	2709	Crude oil	11,31
50	Cayman Islands	2024	2710	Petroleum oils	0,54
51	Egypt	2024	1905	Baked food	0,21
52	Finland	2024	1905	Baked food	0,01
53	French Polynesia	2024	1905	Baked food	3,77
54	Greenland	2024	1905	Baked food	4,65
55	Iceland	2024	1905	Baked food	0,02
56	Israel	2024	1905	Baked food	0,15
57	Japan	2024	1905	Baked food	0,83
58	Japan	2024	2709	Crude oil	0,01
59	Denmark	2024	2710	Petroleum oils	0,09
60	Egypt	2024	2710	Petroleum oils	0,19
61	El Salvador	2024	2710	Petroleum oils	0,06
62	Finland	2024	2710	Petroleum oils	0,45
63	France	2024	2710	Petroleum oils	0,11
64	Ghana	2024	2710	Petroleum oils	0,05
65	Iceland	2024	2710	Petroleum oils	0,69
66	India	2024	2710	Petroleum oils	0,01
67	Indonesia	2024	2710	Petroleum oils	0,13
68	Ireland	2024	2710	Petroleum oils	0,14

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
69	Japan	2024	2710	Petroleum oils	0,13
70	Finland	2024	7601	Unwrought aluminium	1,28
71	Estonia	2024	8708	Vehicle parts	0,27
72	Finland	2024	8708	Vehicle parts	1,66
73	French Polynesia	2024	8708	Vehicle parts	7,10
74	Greenland	2024	8708	Vehicle parts	9,25
75	Israel	2024	8708	Vehicle parts	4,75
76	Cyprus	2024	1905	Baked food	0,01
77	Germany	2024	2710	Petroleum oils	0,19
78	Czechia	2024	2710	Petroleum oils	0,10
79	Ecuador	2024	2710	Petroleum oils	0,20
80	Italy	2024	2709	Crude oil	0,01
81	Estonia	2024	2710	Petroleum oils	0,05
82	Israel	2024	2710	Petroleum oils	0,97
83	Italy	2024	2710	Petroleum oils	0,09
84	Jamaica	2024	2710	Petroleum oils	0,10
85	Dominican Republic	2024	2710	Petroleum oils	0,13
86	Cyprus	2024	2710	Petroleum oils	0,12
87	Jamaica	2024	1905	Baked food	0,73
88	Denmark	2024	2709	Crude oil	0,02
89	France	2024	2709	Crude oil	0,01
90	Ireland	2024	2709	Crude oil	0,01
91	Ethiopia	2024	2710	Petroleum oils	0,05
92	Gambia	2024	2710	Petroleum oils	0,15
93	Guatemala	2024	2710	Petroleum oils	0,19
94	Guyana	2024	2710	Petroleum oils	0,05
95	Grenada	2024	2710	Petroleum oils	1,56
96	Dominican Republic	2024	7601	Unwrought aluminium	0,11
97	Czechia	2024	2709	Crude oil	0,02
98	Guatemala	2024	2709	Crude oil	0,42
99	Jamaica	2024	7601	Unwrought aluminium	7,68
100	Guyana	2024	2709	Crude oil	24,38
101	Dominican Republic	2024	2709	Crude oil	0,07
102	JoCBRAn	2024	1905	Baked food	0,24

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
103	Korea	2024	1905	Baked food	0,65
104	Kuwait	2024	1905	Baked food	1,40
105	Malta	2024	1905	Baked food	0,45
106	Mauritius	2024	1905	Baked food	0,39
107	New Zealand	2024	1905	Baked food	0,51
108	South Korea	2024	2709	Crude oil	0,00
109	Netherlands (Kingdom of the)	2024	2709	Crude oil	0,01
110	South Korea	2024	2710	Petroleum oils	0,10
111	Kuwait	2024	2710	Petroleum oils	2,08
112	Morocco	2024	2710	Petroleum oils	0,08
113	Nepal	2024	2710	Petroleum oils	0,38
114	Netherlands (Kingdom of the)	2024	2710	Petroleum oils	0,11
115	Nicaragua	2024	2710	Petroleum oils	0,04
116	Kuwait	2024	8708	Vehicle parts	6,76
117	Montserrat	2024	8708	Vehicle parts	4,93
118	Montenegro	2024	2710	Petroleum oils	0,08
119	JoCBRAn	2024	2710	Petroleum oils	1,08
120	Lebanon	2024	2710	Petroleum oils	0,11
121	Libya	2024	2710	Petroleum oils	0,16
122	Lithuania	2024	2710	Petroleum oils	0,04
123	Luxembourg	2024	1905	Baked food	1,36
124	Mauritania	2024	2710	Petroleum oils	0,08
125	Montserrat	2024	2710	Petroleum oils	1,31
126	Montserrat	2024	1905	Baked food	3,82
127	Lebanon	2024	2709	Crude oil	3,85
128	Lithuania	2024	2709	Crude oil	0,00
129	Kenya	2024	2709	Crude oil	1,97
130	Qatar	2024	1905	Baked food	0,38
131	Saudi Arabia	2024	1905	Baked food	0,74
132	Singapore	2024	2709	Crude oil	0,01
133	Norway	2024	2710	Petroleum oils	0,16
134	Oman	2024	2710	Petroleum oils	0,10
135	Panama	2024	2710	Petroleum oils	0,21
136	Peru	2024	2710	Petroleum oils	0,20
137	Poland	2024	2710	Petroleum oils	0,09

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
138	Qatar	2024	2710	Petroleum oils	1,17
139	Russian Federation	2024	2710	Petroleum oils	0,47
140	Singapore	2024	2710	Petroleum oils	0,02
141	Norway	2024	8708	Vehicle parts	2,08
142	Philippines	2024	8708	Vehicle parts	0,20
143	Singapore	2024	8708	Vehicle parts	0,35
144	Serbia	2024	2710	Petroleum oils	0,11
145	Slovenia	2024	2710	Petroleum oils	0,08
146	Nigeria	2024	2710	Petroleum oils	49,21
147	Portugal	2024	2710	Petroleum oils	0,15
148	Slovakia	2024	2710	Petroleum oils	0,23
149	Romania	2024	2710	Petroleum oils	0,19
150	Paraguay	2024	2710	Petroleum oils	0,20
151	Saint Lucia	2024	2710	Petroleum oils	1,23
152	Sierra Leone	2024	2710	Petroleum oils	0,53
153	Saint Lucia	2024	1905	Baked food	2,75
154	Saint Kitts & Nevis	2024	2710	Petroleum oils	1,89
155	Saint Kitts & Nevis	2024	1905	Baked food	2,06
156	Saint Vincent & Grenadines	2024	1905	Baked food	0,03
157	Saint Vincent & Grenadines	2024	2710	Petroleum oils	0,15
158	Palau	2024	8708	Vehicle parts	10,27
159	Palau	2024	2710	Petroleum oils	0,77
160	Saint Lucia	2024	2709	Crude oil	0,34
161	Peru	2024	2709	Crude oil	0,00
162	Panama	2024	7601	Unwrought aluminium	4,85
163	Saint Kitts & Nevis	2024	2709	Crude oil	7,09
164	Solomon Islands	2024	1905	Baked food	1,58
165	Switzerland–Liechtenstein	2024	1905	Baked food	0,28
166	United Arab Emirates	2024	2709	Crude oil	0,05
167	Spain	2024	2710	Petroleum oils	0,07
168	Sweden	2024	2710	Petroleum oils	0,35
169	Uganda	2024	2710	Petroleum oils	0,07
170	United Arab Emirates	2024	2710	Petroleum oils	0,03
171	Viet Nam	2024	2710	Petroleum oils	0,06

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
172	Zambia	2024	2710	Petroleum oils	0,12
173	State of Palestine	2024	8708	Vehicle parts	0,10
174	Switzerland–Liechtenstein	2024	8708	Vehicle parts	5,43
175	Switzerland–Liechtenstein	2024	2710	Petroleum oils	0,06
176	United Kingdom	2024	2710	Petroleum oils	0,13
177	Spain	2024	2709	Crude oil	0,00
178	Trinidad & Tobago	2024	2710	Petroleum oils	1,71
179	State of Palestine	2024	1905	Baked food	0,14
180	Uzbekistan	2024	1905	Baked food	0,05
181	State of Palestine	2024	2710	Petroleum oils	0,51
182	Uruguay	2024	2710	Petroleum oils	0,19
183	Uzbekistan	2024	2710	Petroleum oils	0,63
184	Tajikistan	2024	2710	Petroleum oils	0,08
185	Yemen	2024	2710	Petroleum oils	0,21
186	Sweden	2024	2709	Crude oil	0,02
187	United Kingdom	2024	2709	Crude oil	0,02
188	Ukraine	2024	2709	Crude oil	0,02
189	Switzerland	2024	2709	Crude oil	0,03
190	Guinea	2024	8704	Cargo trucks	0,08
191	Albania	2024	2710	Petroleum oils	0,04
192	Slovenia	2024	2710	Petroleum oils	0,08
193	Slovenia	2024	1905	Baked food	0,08
194	Finland	2024	2710	Petroleum oils	0,01
195	India	2024	2710	Petroleum oils	0,01
196	Belgium	2024	2709	Crude oil	0,01
197	Cyprus	2024	1905	Baked food	0,01
198	Finland	2024	1905	Baked food	0,01
199	Iceland	2024	1905	Baked food	0,02
200	Italy	2024	2710	Petroleum oils	0,09
201	Jamaica	2024	1905	Baked food	0,73
202	Mauritania	2024	2710	Petroleum oils	0,08
203	Zimbabwe	2024	2710	Petroleum oils	0,22
204	Tajikistan	2024	2710	Petroleum oils	0,08
205	Switzerland–Liechtenstein	2024	2710	Petroleum oils	0,04
206	Suriname	2024	8704	Cargo trucks	0,05
207	Poland	2024	2710	Petroleum oils	0,04

Rank	Importer	Year	HS code	Product description	CBRA (USD / kg)
208	Saint Vincent & Grenadines	2024	2710	Petroleum oils	0,05
209	Denmark	2024	2710	Petroleum oils	0,05
210	Estonia	2024	2710	Petroleum oils	0,05
211	Malaysia	2024	2710	Petroleum oils	0,05
212	Madagascar	2024	2710	Petroleum oils	0,01