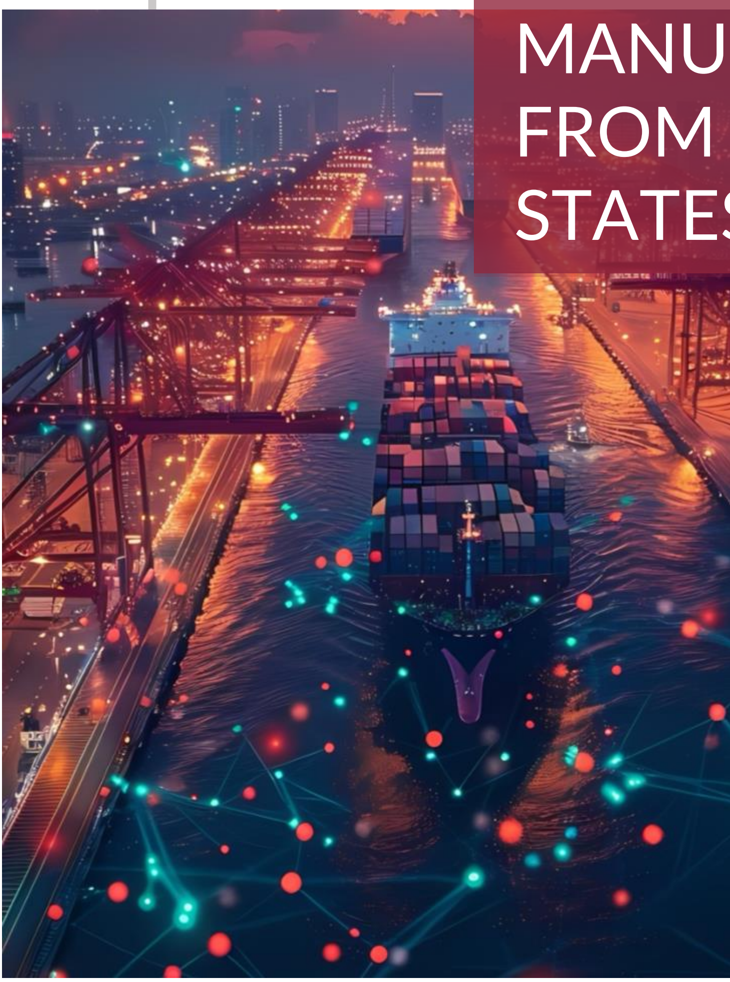
CROSS-BORDER PRODUCER PRICE TRANSMISSION IN NORTH AMERICAN MANUFACTURING: EVIDENCE FROM CANADA–UNITED STATES INDUSTRY NETWORKS



ADAM TOURÉ, PHD
MARTIN TRÉPANIER, PHD
THIERRY WARIN, PHD

CS
2025s-32
WORKING PAPER

ISSN 2292-0838 (online version)

Cross-Border Producer Price Transmission in North American Manufacturing: Evidence from Canada–United States Industry Networks[*]

Adam Touré[†], *Martin Trépanier*[‡], *Thierry Warin*[§]

Abstract/Résumé

This study investigates the extent and mechanisms of producer price connectedness between Canadian and U.S. manufacturing sectors, with a focus on cross-border interdependencies and the impact of tariff-related shocks. Leveraging monthly Industrial Product Price Index (IPPI) data for 21 harmonized NAICS industries from 2004 to 2025, and incorporating exchange rate dynamics, we apply a Vector Autoregression (VAR) model with Elastic Net regularization to capture the structure of price transmission. Using the Diebold and Yılmaz (2012) framework, we compute static and dynamic measures of connectedness. Our findings reveal a high degree of cross-border price transmission, with Canadian industries—especially Transportation Equipment, Machinery, and Computer & Electronics—playing central roles in both influencing and absorbing price shocks. U.S. sectors such as PetroCoal andWood also exhibit strong bilateral ties with their Canadian counterparts. The results underscore the importance of production linkages and trade integration in shaping inflation dynamics in North America, offering key insights for policymakers aiming to balance trade policy and economic resilience.

Cette étude examine l'ampleur et les mécanismes de la connectivité des prix à la production entre les secteurs manufacturiers du Canada et des États-Unis, en mettant l'accent sur les interdépendances transfrontalières et l'impact des chocs liés aux droits de douane. En exploitant les données mensuelles de l'Indice des prix des produits industriels (IPPI) pour 21 industries harmonisées selon la classification NAICS sur la période 2004–2025, et en intégrant la dynamique du taux de change, nous appliquons un modèle vectoriel autorégressif (VAR) régularisé par la méthode Elastic Net afin de capturer la structure de la transmission des prix. À l'aide du cadre méthodologique proposé par Diebold et Yılmaz (2012), nous calculons des mesures statiques et dynamiques de connectivité. Nos résultats mettent en évidence un degré élevé de transmission transfrontalière des prix, les industries canadiennes — notamment celles de l'Équipement de transport, de la Machinerie et des Produits informatiques et électroniques — occupant un rôle central tant dans la propagation que dans l'absorption des chocs de prix. Du côté américain, les secteurs du Pétrole-charbon et du Bois présentent également de fortes interconnexions bilatérales avec leurs homologues canadiens. Ces résultats soulignent l'importance des liens de production et de l'intégration commerciale dans la dynamique de l'inflation nord-américaine,

---

[*] The author would like to thank the FNCC team. The usual disclaimers apply.

[†] PhD, CIRANO (Canada), FNCC Project

[‡] PhD, Polytechnique Montréal, Department of Mathematics and Industrial Engineering

[§] PhD, Fellow at CIRANO (Canada), HEC Montréal, Department of International Business

apportant des éléments clés pour les décideurs publics soucieux d'équilibrer politiques commerciales et résilience économique.

Keywords/Mots-clés: Price Connectedness; Canada; United States; Manufacturing; Tariffs / Connectivité; Prix ; Canada ; États-Unis ; Secteur manufacturier ; Droits de douane

Pour citer ce document / To quote this document
Touré, A. A. K., Trépanier, M., & Warin, T. (2025). Cross-Border Producer Price Transmission in North American Manufacturing: Evidence from Canada–United States Industry Networks (2025S-32, Cahiers scientifiques, CIRANO.) https://doi.org/10.54932/GCPY2392

1 Introduction

The manufacturing sectors of Canada and the United States are deeply integrated, with goods often crossing the border multiple times throughout the production process. This high level of interdependence means that price fluctuations in one country can transmit across industries and borders, affecting production costs, competitiveness, and overall economic stability. In the context of international trade policy, tariffs play a crucial role in shaping these dynamics, as they can directly impact producer prices by increasing input costs and altering supply chain structures. Understanding how producer prices are connected across Canadian and U.S. manufacturing industries is essential for anticipating the effects of trade policy changes on inflation and output. This knowledge is crucial for both policymakers and industry leaders. For policymakers, it helps in designing trade policies that minimize unintended economic disruptions. For businesses, recognizing the risks associated with cross-border price transmission can improve strategic planning, cost management, and supply chain resilience. This study aims to analyze the extent and mechanisms of producer price connectedness between Canadian and U.S. manufacturing sectors, thereby providing insights into economic vulnerabilities and policy implications in a highly integrated trade environment.

The proposed analysis seeks to answer two key research questions regarding price transmission across manufacturing sub-sectors in both countries:

- RQ1: How strong is the price transmission mechanism between specific manufacturing industries in Canada and the U.S.?
- RQ2: Are there asymmetries in how price changes propagate across borders (for example, does one country's industry exert a stronger influence on the other)?

Addressing these questions is critical for policymakers seeking to design trade policies that minimize economic disruptions, and for industry leaders aiming to manage risks and enhance supply chain resilience. Economic connectedness, introduced by Diebold and Yılmaz (2012), aims to assess the degree of influence and exposure among economic entities (industries, in our case). It captures several aspects: the bilateral spillovers between any pair of industries, the total exposure of one industry to shocks from others, the total influence of one industry on others, and the overall connectivity within the network (measuring, on average, the share of volatility in all industries caused by cross-industry shock transmission). To measure the connectedness among North American manufacturing industries, we employ the Diebold–Yılmaz methodology on their price indices. We collect the Industrial Product Price Index (IPPI) for 21 comparable industries in both countries based on the North American Industry Classification System (NAICS). The data span from December 2003 to January 2025. We also include the monthly average Canada–U.S. exchange rate as a control, since currency fluctuations could affect relative price dynamics between the two countries. Integrating Elastic Net regularization into the Diebold–Yılmaz VAR framework (Diebold and Yılmaz, 2012; Zou and Hastie, 2005), to handle high-dimensional interactions efficiently, we compute both static and dynamic connectedness metrics. Static connectedness indicators are computed using the full sample, while dynamic results are based on a rolling-window analysis.

In preview, our analysis reveals a robust network of producer price transmission across North America, with a system-wide connectedness of about 55%. Canadian industries—especially Transportation Equipment, Machinery, and Computer & Electronics—act as key transmitters of shocks and are also among the most exposed to price fluctuations originating elsewhere. On the U.S. side, sectors like Petroleum & Coal Products and Wood exhibit strong bilateral influences with their Canadian counterparts. Dynamic connectedness varies over time, peaking during major policy or economic disruptions such as the 2015 oil price collapse in Canada, the 2018 U.S. tariff implementations, and the COVID-19 crisis. These surges suggest that shocks, whether commodity-driven, policy-induced, or global in origin, can significantly amplify price spillovers. The findings highlight the importance of upstream sectors (e.g. energy and primary materials) and reveal an asymmetric cross-border influence: U.S. industries generally exert a stronger influence, while Canadian industries are more exposed to external shocks, though Canadian sectors occasionally drive significant spillovers back into the U.S. By addressing the above research questions, this study sheds light on how production linkages and trade integration shape inflation dynamics in North America, offering empirical evidence to inform both economic policy and corporate strategy.

Recent years have seen a growing interest in the study of producer price connectedness, particularly as inflationary pressures, global supply chain disruptions, and trade policy shifts have reshaped the dynamics of industrial networks. A number of influential papers have explored this topic. For example, Bilgin and Yılmaz (2018) examine producer price inflation spillovers across U.S. manufacturing sectors using the Diebold–Yılmaz Connectedness Index. Their work highlights how input–output linkages—especially in upstream industries—propagate price shocks across the economy, with spillover effects intensifying during major supply-side disturbances. Similarly, recent research on China by Jia et al. (2022) applied the connectedness framework to domestic industries, confirming that producer price transmission is significantly shaped by the country's production network structure. Notably, they find that price spillovers from upstream (producer prices) to downstream (consumer prices) are larger than vice versa, and that direct input–output linkages increase the intensity of price spillovers, while indirect transmission channels have an even greater aggregate influence. While these studies provide important insights into domestic price propagation mechanisms, they focus on within-country networks and largely overlook the increasingly cross-border nature of modern supply chains.

In contrast, our paper offers a novel perspective by analyzing producer price connectedness between Canada and the United States, two of the world's most integrated manufacturing economies. Studies on international price spillovers have shown that global input–output networks contribute substantially to synchronizing producer price inflation across countries. For instance, Auer et al. (2019) report that international input linkages account for roughly half of the global co-movement in producer price inflation. However, existing international studies typically focus on broad multi-country aggregates or macro-level interdependencies (such as the interactions between inflation, commodity prices, and uncertainty), rather than zeroing in on bilateral, industry-to-industry relationships. Research on cross-country macroeconomic connectedness (e.g., inflation and output co-movements in G7 or other groups) confirms that trade linkages and openness play a role in transmitting shocks (Auer et al., 2019; Pham and Sala, 2022; Takongmo and Toure, 2023), but these works do not concentrate on the granular industry-level producer prices that are directly affected by integrated supply chains.

Despite extensive research on domestic price connectedness and broad international inflation spillovers, a significant gap remains in understanding the bilateral, industry-specific producer price connectedness between highly integrated economies like the U.S. and Canada. Existing studies either focus on national networks, examine multi-country averages, or analyze different macroeconomic variables, leaving the nuanced dynamics of cross-border, industry-level price transmission largely unaddressed. This study directly tackles that gap. To the best of our knowledge, it is the first to explicitly analyze industry-specific producer price index (PPI) connectedness between the Canadian and U.S. manufacturing sectors. We quantify the strength and direction of bilateral price spillovers, distinguish between domestic and foreign sources of price volatility, and identify which industries act as influential transmitters versus vulnerable receivers of price shocks across the border. Methodologically, we demonstrate that applying Elastic Net regularization within a large-scale VAR can effectively capture complex inter-industry linkages without overfitting, providing a robust approach to this high-dimensional problem. By offering insights into the two-way, industry-specific exposures and influences, this study presents a more nuanced and realistic view of modern North American supply chain interactions. These insights hold direct and timely implications for international trade and industrial policy—particularly in the context of tariff disruptions and the USMCA agreement—by highlighting which sectors are most at risk from cross-border price contagion and thus where policy coordination or support measures might be most needed.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature to contextualize our study. Section 3 outlines the methodology and describes the data employed in the analysis. Section 4 presents the empirical results, followed by a discussion in Section 5. Finally, Section 6 concludes the pape5.

2 Literature Review

In today's integrated global economy, understanding how price fluctuations transmit across industries and national borders is paramount, particularly within manufacturing. The tightly intertwined Canadian and U.S. manufacturing sectors—where inputs and outputs frequently cross borders during production—exemplify this challenge. Price changes in one country can rapidly influence production costs, competitiveness, and economic stability in the other. This study aims to analyze such cross-border producer price connectedness, especially in the context of trade policy and tariffs. This literature review synthesizes existing research on economic connectedness and price transmission, identifying a critical gap that this study will address by focusing on the unique bilateral, industry-specific producer price dynamics within the North American manufacturing sector.

The Diebold and Yılmaz (D–Y) connectedness framework (Diebold and Yılmaz, 2009, 2012) has become a standard tool for quantifying spillover effects and network interdependencies in economic time series. Utilizing generalized forecast error variance decompositions from VAR models, it assesses how shocks to one entity propagate through a system. This framework has been widely applied in various contexts, from financial markets (e.g., volatility spillovers across asset classes) to macroeconomic variables across countries (Greenwood-Nimmo et al., 2021; Takongmo and Toure, 2023). Its broad utility notwithstanding, the D–Y methodology's application to granular bilateral producer price dynamics between highly integrated economies remains limited.

Research on price connectedness has largely focused on domestic dynamics. Within national economies, studies consistently highlight the crucial role of input–output (IO) structures in transmitting price shocks. For instance, in the U.S. manufacturing sector, the IO network's structure significantly influences PPI connectedness, identifying key influential and exposed sectors domestically (Bilgin and Yılmaz, 2018). Bilgin and Yılmaz (2018) find that the relationship between the production network and inflation spillovers becomes stronger during major supply-side shocks (such as surges in oil or metal prices) and weaker during demand-driven episodes. They also provide preliminary evidence that trade policy changes (e.g., sudden tariffs) can spike inter-industry inflation connectedness. Similarly, analysis in China by Jia et al. (2022) confirms how IO linkages drive domestic price dynamics. Their results show significant spillovers from producer prices (supply side) to consumer prices (demand side), with the spillover from PPI to CPI being larger than the reverse. Furthermore, direct IO linkages between industries increase the intensity of price spillovers, and indirect transmission has an even greater aggregate effect on overall price connectedness. These national studies provide robust insights into internal price propagation but inherently do not capture cross-border mechanisms.

On an international scale, research has explored inflation synchronization and price spillovers often through the lens of global production networks. Multi-country studies show that international IO linkages contribute significantly to synchronizing producer price inflation across countries. For example, Auer et al. (2019) report that about half of the global co-movement in PPI can be explained by observed international input–output relationships, as firms' reliance on foreign intermediate inputs transmits cost shocks globally. While these works establish the existence of international transmission at a broad scale, they typically focus on aggregate cross-country measures or large panels of economies, without zooming in on specific bilateral relationships. Other international studies address broader macroeconomic interdependencies—for instance, examining how global commodity price swings or uncertainty shocks propagate into national inflation rates (Forbes, 2019; Pham and Sala, 2022)—but they do not concentrate on bilateral, industry-level producer price interactions.

Despite extensive research on domestic price connectedness and broader international inflation spillovers, a notable gap exists in understanding the specific, industry-level price connectedness between two highly integrated economies like the U.S. and Canada. Existing studies either examine networks within a single country, consider cross-country linkages only at a macro level, or investigate different variables (e.g., consumer prices or output). As a result, the nuanced dynamics of how producer price shocks in one country's specific industries affect the other country's industries remain largely unexamined. This study directly addresses this gap. We focus on the bilateral Canada–U.S. manufacturing context to explore how shocks propagate across the border at a disaggregated industry scale. In doing so, we distinguish between domestic and foreign sources of volatility for each industry's prices, identify which sectors are the major transmitters versus receivers of cross-border price shocks, and evaluate the time-varying nature of these spillovers. Our approach also introduces a methodological innovation by using Elastic Net regularization (Zou and Hastie, 2005) to estimate a large VAR system comprising dozens of industry price indices plus the exchange rate. This approach enhances the reliability of the spillover estimates by efficiently handling the high dimensionality and multicollinearity inherent in a dense network of industries. By providing empirical evidence on bi-directional, industry-specific price spillovers between Canada and the U.S., our study offers a more granular understanding of North American supply chain interconnectedness. This is not only academically novel but also of practical importance, given current debates on trade policy (such as tariff impacts and the USMCA implementation) and the quest for inflation stability amid global supply chain challenges.

3 Data and Methods

3.1 Data

To investigate producer price connectedness between the Canadian and United States manufacturing sectors, this study utilizes the Industrial Product Price Index (IPPI) for each country. This index provides a comprehensive measure of the prices received by domestic producers for their manufactured goods at the factory gate. Focusing on the manufacturing sector, we leverage the North American Industry Classification System (NAICS) to obtain detailed price indices for 21 comparable manufacturing industries in both countries.

The Canadian IPPI data are sourced from Statistics Canada, while the corresponding Producer Price Index (PPI) data for the United States are obtained from the Federal Reserve Economic Data (FRED) repository. The sample period spans from January 2004 through February 2025, providing a robust timeframe to analyze price dynamics and to capture the effects of various economic events (e.g. the mid-2000s commodity boom, the 2008–09 financial crisis, the 2015 oil price shock, U.S. trade policy changes in 2018, and the COVID-19 pandemic).

For the analysis, the price indices (which are in index form) are transformed into monthly growth rates (log-differences). This stationarization focuses the analysis on price changes and their interrelationships over time, mitigating the influence of non-stationary price levels or long-run trends. All series are seasonally adjusted where necessary. Recognizing the potential influence of currency movements on cross-border price dynamics, we also include the monthly average USD/CAD exchange rate as an exogenous variable in the model. This allows us to control for the impact of exchange rate fluctuations on relative producer prices in the two countries and to better isolate direct price spillovers attributable to industry shocks.

Therefore, our dataset comprises disaggregated manufacturing industry price indices for both Canada and the U.S. (21 industries each), along with the bilateral exchange rate. This rich dataset serves as the foundation for examining the mechanisms of price transmission and connectedness within the North American manufacturing network.

3.2 Methods

Our connectedness analysis follows the methodology of Diebold and Yılmaz (2012), which is based on variance decomposition of a Vector Autoregression. We first specify a VAR model to capture the dynamic interactions among the Canadian and U.S. industry price series (and the exchange rate). We then estimate this high-dimensional VAR using Elastic Net regularization. Finally, we compute connectedness measures from the generalized forecast error variance decomposition of the VAR.

This section details each of these steps.

3.2.1 VAR Model Specification

We employ a vector autoregression of order p (VAR(p)) to model the joint dynamics of the price indices. Let $Y_t = [y_{1,t}, y_{2,t}, \ldots, y_{k,t}]'$ be a vector containing the variables in our system (which include the 21 Canadian industry price growth rates, 21 U.S. industry price growth rates, and the exchange rate, so $k = 43$ variables in total). A VAR(p) model can be written as:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + \varepsilon_t \,, \tag{1}$$

or using the lag operator L:

$$Y_t = A(L) Y_{t-1} + \varepsilon_t, \qquad A(L) = A_1 L + A_2 L^2 + \cdots + A_p L^p \,, \tag{2}$$

where each A_i is a $k \times k$ coefficient matrix for lag i, and ε_t is a vector of error terms (shocks) with zero mean and covariance matrix Σ. We set the number of lags to $p = 12$ (allowing up to one year of monthly lags, which is useful to capture delayed transmission or seasonality). We assume the VAR model is stable and invertible, permitting a moving average representation:

$$Y_t = B(L)\, \varepsilon_t = \sum_{\ell=0}^{\infty} B_\ell \, \varepsilon_{t-\ell} \,, \tag{3}$$

where $B_0 = I$ (the identity matrix) and B_ℓ for $\ell > 0$ are matrices of moving average coefficients derived from the VAR parameters. This representation forms the basis for variance decomposition analysis, as it relates current values of Y_t to current and past shocks $\varepsilon_{t-\ell}$.

In our context, each element of Y_t corresponds to the price growth of a particular industry in Canada or the U.S. (or the exchange rate). Thus, the VAR allows each industry's price to depend on its own past values and the past values of all other industries (both domestic and foreign), as well as past exchange rate movements. Given the large number of variables and parameters, a standard Ordinary Least Squares (OLS) estimation for this VAR would involve estimating on the order of $k^2 \times p$ parameters (which in our case is $43^2 \times 12 \approx 22164$ coefficients), risking overfitting and multicollinearity. To address this, we employ a penalized regression approach—Elastic Net—which performs variable selection and regularization.

3.2.2 Elastic Net Estimation

Elastic Net, introduced by Zou and Hastie (2005), is a regularization and variable selection method that combines the strengths of Lasso (L1 penalty) and Ridge (L2 penalty) regression. It is particularly well-suited for high-dimensional VAR estimation where the number of parameters is large relative to the sample size, as it can shrink small coefficients towards zero (to avoid overfitting) and select a simpler model by setting some coefficients exactly to zero (achieving a form of model selection).

For a single equation of our VAR(p), we can write it as a linear regression: $y_{i,t} = \mathbf{x}*t'\boldsymbol{\beta}*i + u*i,t$, where $y*i,t$ is the growth rate of industry i's price at time t, $\mathbf{x}*t$ is a vector containing all right-hand side variables for that equation (which would be the lagged values of all k variables for p lags: $[y*1, t-1, ..., y_{k,t-1}, \ldots, y_{1,t-p}, ..., y_{k,t-p}]'$), and $\boldsymbol{\beta}*i$ is the corresponding coefficient vector for equation i. The Elastic Net estimator $\hat{\boldsymbol{\beta}}*i^{EN}$ is obtained by solving:

$$\hat{\boldsymbol{\beta}}_i^{EN} = \arg\min_{\boldsymbol{\beta}_i} \left\{ \sum_t \left(y_{i,t} - \mathbf{x}_t'\boldsymbol{\beta}_i\right)^2 \;+\; \lambda\Big(\alpha\|\boldsymbol{\beta}_i\|_2^2 \;+\; (1-\alpha)\|\boldsymbol{\beta}_i\|_1\Big) \right\}, \tag{4}$$

where $|\boldsymbol{\beta}_i|*2^2 = \sum_j \beta*i,j^2$ is the sum of squared coefficients (L2 norm) and $|\boldsymbol{\beta}_i|*1 = \sum_j |\beta*i,j|$ is the sum of absolute coefficients (L1 norm). The parameter $\lambda \geq 0$ controls the overall strength of regularization, and $\alpha \in [0,1]$ controls the mix between Ridge ($\alpha = 1$) and Lasso ($\alpha = 0$) penalties. In our application, we set $\alpha = 0.5$ (an equal mix of L1 and L2), following the suggestion in Demirer et al. (2018) for similar connectedness analyses, and we select λ via 10-fold cross-validation on a training subset of the data.

By using Elastic Net, many of the VAR coefficients associated with negligible cross-industry linkages will be shrunk towards zero, effectively eliminating noise and focusing on the strongest connections. This yields a more parsimonious and stable VAR model, improving the accuracy of subsequent variance decomposition calculations.

3.2.3 Forecast Error Variance Decomposition

With the VAR model estimated, we proceed to quantify the connectedness of industries using forecast error variance decompositions (FEVD). The FEVD asks: for each industry i, what fraction of the H-step-ahead forecast error variance of $y_{i,t}$ is due to shocks in industry j? This gives a natural measure of how much shocks spill over from j to i. Formally, using the moving average representation $Y_t = \sum_{\ell=0}^{\infty} B_\ell \varepsilon_{t-\ell}$, the contribution of shocks in variable j to the H-step forecast error variance of variable i is given by:

$$\Omega_{ij}(H) = \frac{\sum_{\ell=0}^{H-1} \left(e_i' B_\ell \Sigma\, e_j\right)^2}{\sum_{\ell=0}^{H-1} \left(e_i' B_\ell \Sigma\, B_\ell' e_i\right)}, \tag{5}$$

where e_i is a selection vector (with a 1 in the ith position and 0 elsewhere), and Σ is the covariance matrix of the VAR innovations ε_t. In this formulation, $\Omega_{ij}(H)$ is the (unnormalized) share of variance in i coming from shocks in j over an H-month horizon. We use the generalized variance decomposition approach of Pesaran and Shin (1998) , which does not require any arbitrary ordering of variables and produces variance contributions that are invariant to the ordering of Y_t. In this approach, the shocks are not orthogonalized; instead, each shock's contribution is evaluated in isolation while accounting for the observed covariance structure Σ. We set the forecast horizon to $H = 12$ months for computing connectedness (a one-year horizon, which captures medium-term spillovers).

Because the generalized FEVDs $\Omega_{ij}(H)$ will in general not sum to exactly 100% for each i (due to not orthogonalizing shocks), we follow Diebold and Yılmaz (2012) in normalizing the variance shares. Specifically, we define the normalized spillover share from j to i as:

$$\theta_{ij}(H) = \frac{\Omega_{ij}(H)}{\sum_{m=1}^{k} \Omega_{im}(H)}, \tag{6}$$

so that $\sum_{m=1}^{k} \theta_{im}(H) = 1$ (for each i) and $\sum_{i,j=1}^{k} \theta_{ij}(H) = k$. Here θ_{ij} can be interpreted as the proportion of i's H-step variance attributed to shocks in j (including $j = i$ self-shocks).

3.2.4 Connectedness Measures

Using the normalized FEVD matrix $[\theta_{ij}(H)]$, we can derive several connectedness measures as defined byDiebold and Yılmaz (2012):

- Pairwise Spillover (from j to i): $C_{i\leftarrow j}(H) = \theta_{ij}(H)$, the share of i's forecast variance due to shocks in j. This is a bilateral measure of how much j influences i. Note that in general $C_{i\leftarrow j} \neq C_{j\leftarrow i}$, so spillovers are directional.

- Total Directional Connectedness from Others (Exposure): For industry i, $C_{i\leftarrow\bullet}(H) = \sum_{j\neq i}\theta_{ij}(H)$. This measures how much of industry i's volatility comes from shocks in all other industries. It captures how exposed industry i is to external disturbances.

- Total Directional Connectedness to Others (Influence): For industry i, $C_{\bullet\leftarrow i}(H) = \sum_{j\neq i}\theta_{ji}(H)$. This measures how much volatility in other industries is due to shocks originating in industry i. It captures how influential industry i is in propagating shocks to the rest of the network.

- System-Wide Connectedness Index: This is an aggregate measure of spillovers in the system. It is defined as the share of forecast variance that comes from cross-industry shocks (as opposed to idiosyncratic/self shocks), averaged across all industries. Formally, $C^{(H)} = \frac{\sum_{i\neq j}\theta_{ij}(H)}{\sum_{i,j}\theta_{ij}(H)} = \frac{1}{k}\sum_{i=1}^{k}\sum_{j\neq i}\theta_{ij}(H)$. After normalization, this simplifies to $C^{(H)} = \frac{1}{k}\sum_{i,j;i\neq j}\theta_{ij}(H)$, which can be interpreted as the average percentage of variance in the system that is due to spillovers (cross-effects). Intuitively, a higher $C^{(H)}$ (closer to 100%) means the system is highly interconnected (most volatility comes from shared shocks), whereas a lower value means industries move more independently.

To analyze how connectedness evolves over time — for instance, whether spillovers intensify during certain crisis periods or under changing trade regimes — we implement a rolling window estimation. Specifically, we use a 60-month (5-year) rolling window: we re-estimate the VAR model and recompute the connectedness measures for each window as we slide it from the beginning to the end of the sample. In our dynamic analysis, we present the system-wide connectedness index $C^{(H)}$ and selected directional connectedness measures as functions of time. This rolling estimation allows us to capture time-varying connectedness and to identify episodes where price spillovers were particularly high or low, thus giving insight into the impact of events like the Great Recession, trade policy changes, or the pandemic on the Canada–U.S. price linkage structure.

4 Results

This section presents the empirical findings on connectedness between Canadian and U.S. manufacturing producer prices. We first examine static connectedness measures using the full sample period, which provide an overall sense of how industries influence each other on average. We then turn to dynamic connectedness results obtained from the rolling window analysis, which show how these relationships have changed over time in response to various shocks and policy changes.

4.1 Static Connectedness

For the static analysis, we use the full sample of monthly data from January 2004 to February 2025. All series are in growth rates (as described in the Data section), and the VAR(12) with Elastic Net estimation is applied to this entire period. We focus on a 12-month forecast horizon ($H = 12$) for variance decompositions. The connectedness measures are thus interpreted as the share of one-year ahead price variance attributable to shocks from various sources.

Overall Connectedness: We find that the system-wide connectedness in the North American manufacturing network is 55.14%. This means that, on average, more than half of the forecast variance of industry price changes is due to spillovers from shocks in other industries (including cross-border shocks). In other words, only about 45% of the volatility is idiosyncratic to individual industries, while the rest is explained by interconnected movements. This high level of interconnectedness underscores the strong integration of Canada–U.S. manufacturing: prices do not move in isolation but are heavily influenced by developments across the network.

Most Influential and Most Exposed Industries (Total Directional Measures): Figures 1 and 2 show the total directional connectedness measures for each industry, sorted in descending order. Figure 1 displays the "from others" connectedness, which is the share of an industry's variance coming from shocks in all other industries (exposure). Figure 1 shows the "to others" connectedness, the share of variance in all other industries attributable to shocks in a given industry (influence). These can be interpreted as measures of how vulnerable an industry is to external shocks (Figure 1) and how critical an industry is as a source of shocks (Figure 1).

From Figure 1, we observe that the Canadian Transportation Equipment industry (CA_TranspEquip) is the most exposed industry, with about 78.2% of its price variance

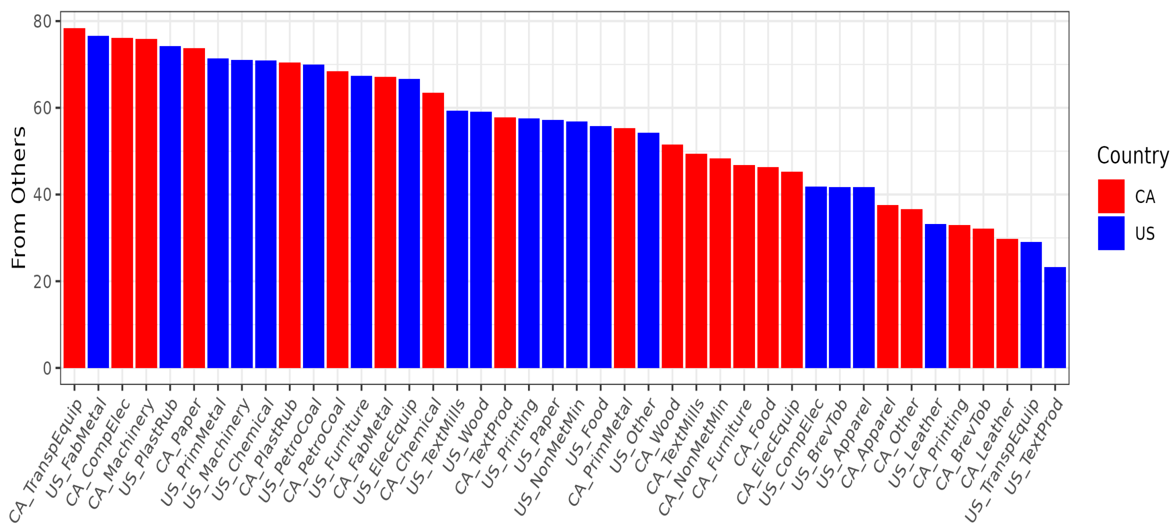


Figure 1: Connectedness From Others.

Note: This graphic presents the connectedness 'from others' of each industry. Which, for a given industry is the share of its variance coming from shocks in all other industries.

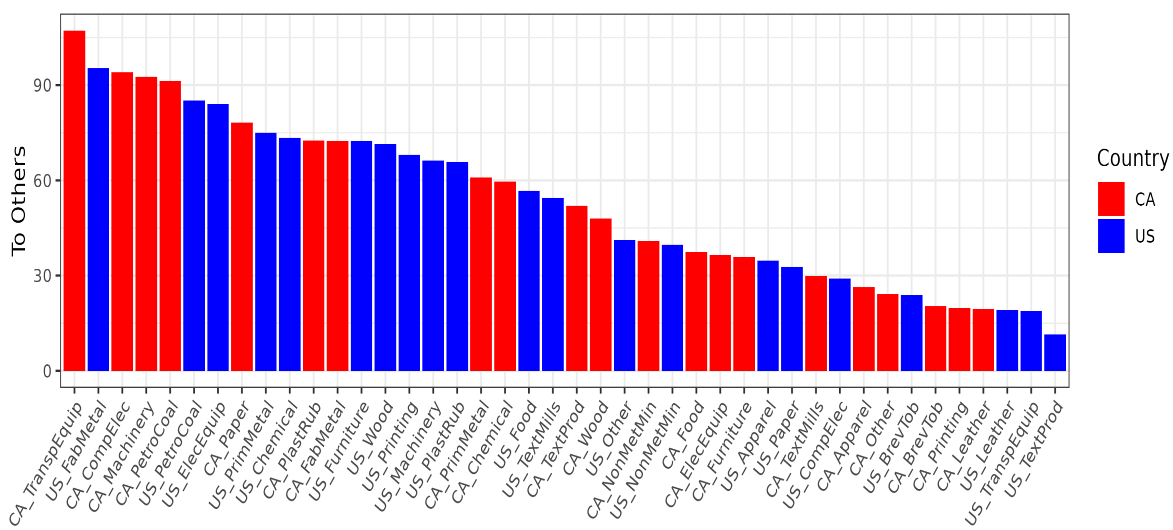


Figure 2: Connectedness To Others.

Note: This graphic presents the connectedness 'To others' of each industry. Which is the sum of the share of variance in all other industries attributable to shocks in a given industry.

coming from shocks in other industries. In other words, only ~21.8% of its movements are due to its own shocks, highlighting a heavy reliance on (or sensitivity to) external developments. The next most exposed industries are U.S. Plastics & Rubber Products (US_PlastRub, 76.8% from others) and Canadian Machinery (CA_Machinery, 76.1%). On the low end, the U.S. Textile Product Mills sector (US_TextProd) is the least exposed, with only ~21.9% of its variance due to others (meaning nearly 78% of its volatility is idiosyncratic). Generally, Canadian industries tend to appear more frequently among the high-exposure list, suggesting Canadian manufacturing sectors are, on average, more susceptible to external price shocks than U.S. sectors. This may reflect Canada's smaller domestic market and greater reliance on cross-border supply chains.

Turning to Figure 1, which ranks industries by their influence on others, the Canadian Transportation Equipment sector again tops the list. CA_TranspEquip has the highest total influence, with a score of 107.2 (in our units, this can be interpreted as it contributes, on average, about 107 percentage points of variance spread across other industries—since the index can exceed 100 when one industry has an outsized impact on many others). This indicates that shocks originating in Canada's transportation equipment sector propagate widely through the North American manufacturing network. The next most influential industries are U.S. Fabricated Metal Products (US_FabMetal, 95.4) and Canadian Computer & Electronic Products (CA_CompElec, 94.0). In contrast, US_TextProd (textile product mills) is the least influential, with an influence score of only 11.4, meaning it has minimal impact on volatility in other industries. Notably, several Canadian industries (Transportation Equip, Computer & Electronic, Machinery) rank very high in influence, underscoring that Canada is not just passively affected by U.S. shocks, but also actively transmits shocks to the U.S. through key sectors.

Cross-Border Spillovers: To dive deeper, we decompose the source and destination of these spillovers by country. In other words, for each industry's connectedness measures, we can separate how much comes from (or goes to) Canadian industries versus U.S. industries (and the exchange rate). Figures 3 and 4 provide this decomposition for the "from others" (exposure) measure, for Canadian and U.S. industries respectively. In these bar charts, each industry's bar is split into two components: contributions from U.S. industries (blue) and from Canadian industries (red). Figures 5 and 6 provide an analogous breakdown for the "to others" (influence) measures by country of destination.

On the Canadian side (Figure 3), we see that on average a Canadian manufacturing industry's variance is explained by 20.5% by shocks from U.S. industries, 29.3% by shocks from other Canadian industries, and about 4.4% by exchange rate shocks (the remainder ~45.8% is its own shock, not

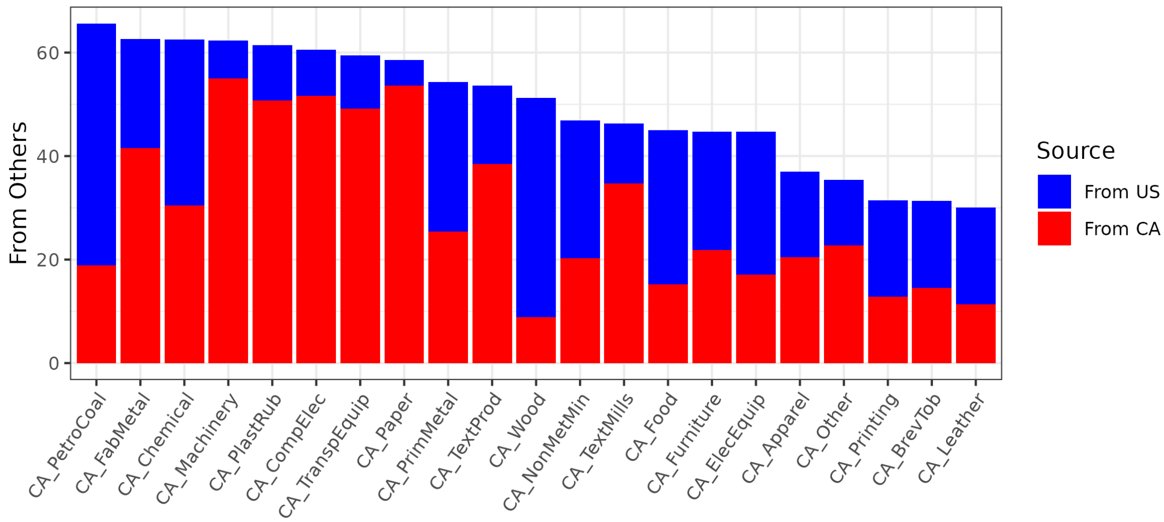


Figure 3: Decomposition of Canadian industry's connectedness from others by country source.

Note: This graphic presents the connectedness from other industries for Canadian industries, broken down by the source country: the US (blue) and Canada (red).

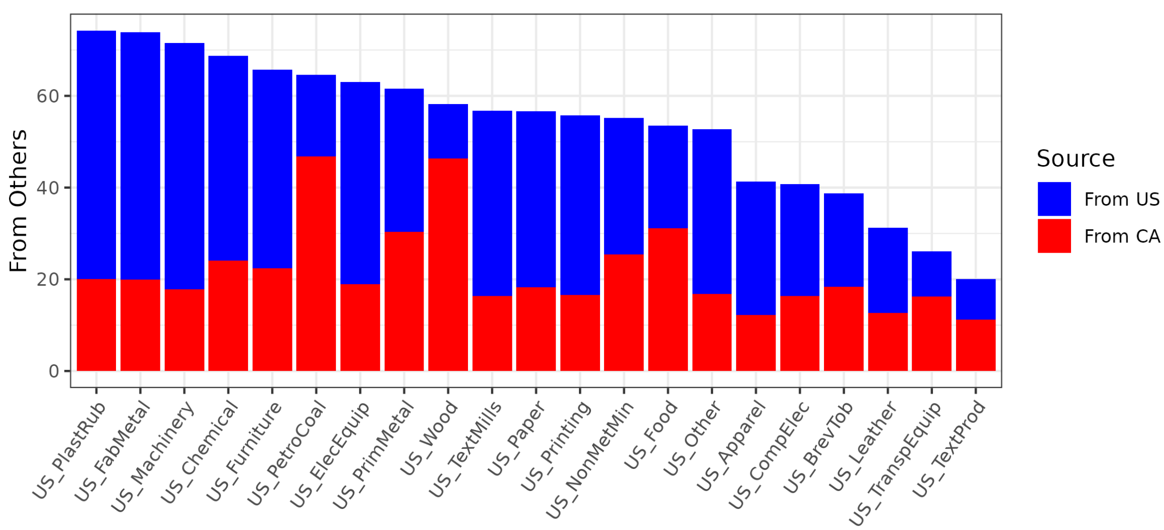


Figure 4: Decomposition of US industry's connectedness from others by country source.

Note: This graphic presents the connectedness from other industries for U.S. industries, broken down by the source country: the US (blue) and Canada (red).

shown in the "from others" breakdown). The Canadian industry most exposed to U.S. shocks is Petroleum & Coal Products (CA_PetroCoal): nearly 46.7% of its variance is due to shocks from U.S. industries. A significant portion of that comes specifically from the U.S. Petroleum & Coal sector

(US_PetroCoal alone contributes ~25% to the Canadian PetroCoal variance), reflecting the tight integration of the oil and refined products markets across the border. Other Canadian industries with high U.S.-driven exposure include Wood Products (42.3% from U.S.) and Chemicals (31.4% from U.S.). By contrast, the Canadian Paper industry is the least exposed to U.S. shocks (only ~5% from U.S.), meaning its price volatility is dominated by domestic factors. It's notable that even the more domestically-oriented Canadian industries still have a non-trivial foreign exposure, underlining the influence of U.S. economic conditions on Canadian producer prices.

On the U.S. side (Figure **??**), the average U.S. manufacturing industry gets about 21.8% of its variance from Canadian industry shocks, 32.0% from other U.S. industries, and about 1.2% from the exchange rate (with ~45% from its own shocks). The U.S. industries most exposed to Canadian shocks are Petroleum & Coal Products (46.8% from Canadian sources) and Wood Products (46.3%). In both cases, their Canadian counterpart industries are the dominant foreign contributors (e.g., Canadian PetroCoal shocks explain ~24.5% of U.S. PetroCoal variance, and Canadian Wood shocks explain ~32.9% of U.S. Wood variance). U.S. Food Manufacturing also has a substantial exposure to Canadian shocks (31.1%), much of which comes from Canada's Food industry (CA_Food contributes ~17.1% to US_Food variance). The U.S. Textile Product Mills sector again shows the lowest exposure from abroad (around 11.2% from Canadian sources), consistent with its overall low connectedness. Broadly, while U.S. industries are generally more self-contained than Canadian ones (owing to the larger domestic economy), certain U.S. sectors that rely on cross-border supply chains (notably natural resources and related products) are highly sensitive to Canadian industry shocks.

Examining influence to others, Figure **??** shows how much each Canadian industry contributes to variance in <u>U.S. industries</u> (blue) versus <u>other Canadian industries</u> (red). On average, a Canadian industry's total influence score (which was ~54.4 points) is split into 21.1 points directed at U.S. industries and 33.3 points at domestic industries. The Canadian industries with the largest impact on U.S. manufacturing are Petroleum & Coal Products (impacting U.S. industries by 67.8 points out of its total 98.2 influence), Wood Products (38.2 out of 63.7 directed to U.S.), Primary Metals (34.0 out of 53.5), Chemicals (33.8 out of 56.5), and Fabricated Metal Products (29.4 out of 49.9). These are all relatively upstream industries whose outputs are often inputs for other industries, and their strong influence on U.S. sectors aligns with the intuitive importance of commodities and

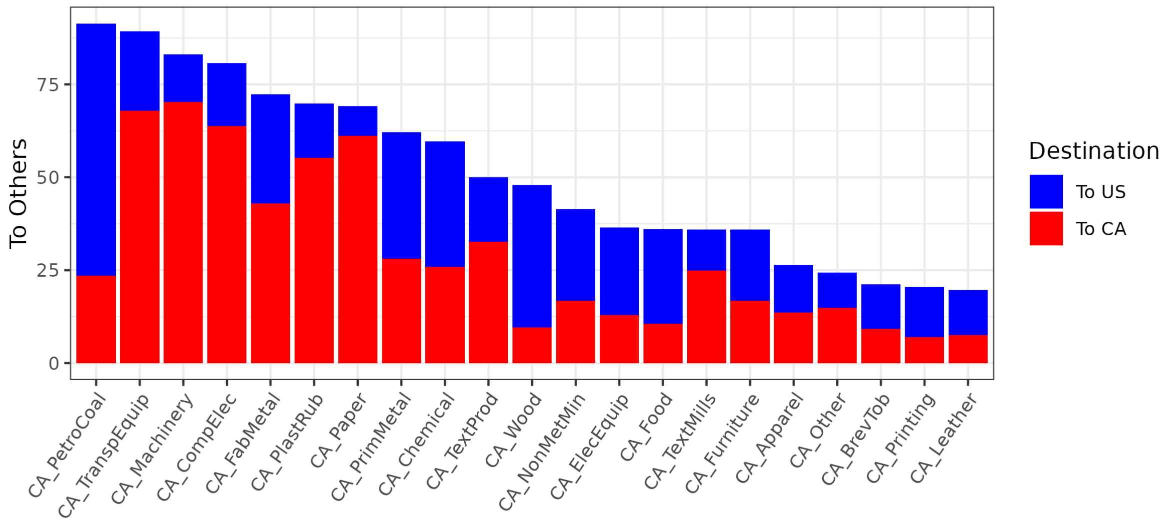


Figure 5: Decomposition of Canadian industry's connectedness to others by country destination.

Note: This graphic presents the connectedness to other industries for Canadian industries, broken down by the destination country: the US (blue) and Canada (red).

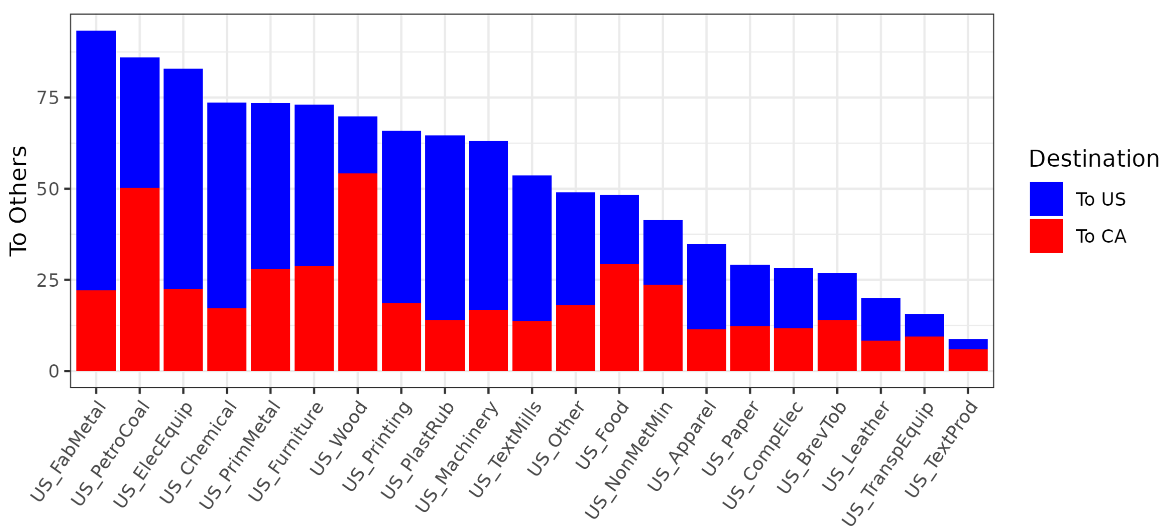


Figure 6: Decomposition of U.S. industry's connectedness to others by country destination.

Note: This graphic presents the connectedness to other industries for U.S. industries, broken down by the destination country: the US (blue) and Canada (red).

basic materials in cross-border trade. For example, shocks in Canadian PetroCoal have a sizable effect on U.S. PetroCoal prices (as noted, 24.5% of the variance of US_PetroCoal) and also affect U.S. Chemicals and Plastics industries that use petroleum products as inputs. Similarly, Canadian Wood product price shocks significantly drive U.S. Wood product price variance (~33% as noted). On the other hand, Canadian industries like Paper and Leather & Allied Products have very limited influence on U.S. industries (their bars are almost entirely red in Figure **??**, meaning their shock impacts stay within Canada).

Figure **??** depicts the influence of U.S. industries on others, split by their impact on Canadian (red) vs U.S. (blue) sectors. On average, a U.S. industry's influence (which averaged ~53.0 points) is divided into 20.5 points affecting Canadian industries and 32.5 points affecting other U.S. industries. The U.S. industries with the most impact on Canada are Wood Products (54.2 out of 69.9 total influence directed to Canada), Petroleum & Coal (52.3 out of 86.1), Food Manufacturing (29.4 out of 59.0), Furniture (28.8 out of 40.4), and Primary Metals (28.0 out of 58.2). The dominance of Wood and PetroCoal is again notable — shocks in U.S. Wood prices transmit heavily to Canadian Wood (which is logical, as the lumber industries are interlinked through trade), and U.S. PetroCoal shocks hit Canada's PetroCoal industry (e.g., through oil price movements) as well as downstream industries like Canadian Chemicals and Plastics. Interestingly, the U.S. Furniture sector shows a moderate influence on Canada spread across multiple industries (furniture manufacturing is connected to wood products, textiles, etc., some of which Canada produces and trades). As expected, U.S. Textile Product Mills has the least effect on Canada (only ~5.9 points out of 11.4 total influence goes to Canada, reflecting minimal trade integration in that sector).

Therefore, the static connectedness analysis reveals a highly interconnected Canada–U.S. manufacturing price network, with roughly half of all volatility shared through spillovers. Canadian industries are on average slightly more exposed to foreign shocks ($\approx$ 24.9% including the exchange rate, compared with $\approx$ 23.0% for U.S. industries). At the same time, several Canadian sectors — notably Petroleum & Coal, Wood, Primary Metals, Chemicals, and Fabricated Metal Products — stand out as major transmitters of shocks across the border. U.S. industries, with a larger domestic base, are relatively less affected by foreign shocks overall, but certain sectors such as Petroleum & Coal and Wood are deeply entwined with Canadian industries, creating strong two-way linkages. Upstream industries (commodities, energy, and basic materials) emerge as the principal channels of cross-border spillovers, consistent with the idea that shocks in these sectors (e.g., oil price shifts or metal tariffs) cascade through supply chains. By contrast, downstream industries (such as textiles, paper, or certain consumer goods) remain more insulated. These findings provide a baseline for examining how connectedness evolves under changing economic conditions, which we explore next in the dynamic analysis.

4.2 Dynamic Connectedness

We now turn to the time-varying connectedness measures, which are estimated using a 60-month rolling window (with 12-step forecast horizon, as before). This analysis helps us identify how and when the degree of price spillovers has changed, and it allows us to link surges or dips in connectedness to specific historical events or policy changes. We present the dynamic results in a series of figures and focus on notable trends and episodes from 2010 onward (the first few years of the sample are needed to initialize the rolling windows).

4.2.1 System-Wide Connectedness over Time

Figure 7 presents the evolution of the system-wide connectedness index from 2010 to early 2025. Several patterns emerge. First, the connectedness index remains at a high level (generally between 60% and 75%) throughout, underscoring persistent integration. However, it is not static: we observe distinct peaks and troughs corresponding to economic events:

- Around 2015–2016, the system-wide connectedness spiked, reaching roughly 75%. This period coincides with a sharp decline in global oil prices that significantly affected Canada (often termed the 2015 oil shock for the Canadian economy). The surge in connectedness suggests that this commodity-driven shock led to elevated spillovers across industries, consistent with the idea that a major supply-side shock can reverberate widely. Indeed, sectors like PetroCoal, Chemicals, and Primary Metals likely experienced simultaneous price disruptions that spread across the network.

- In 2018–2019, another uptick in connectedness is visible. This aligns with the implementation of several rounds of U.S. tariffs (on steel, aluminum, and various Chinese goods, among others) and retaliatory measures by trade partners, including Canada. Our results indicate that North American industry price linkages tightened during this trade policy turbulence. This is supported by other findings in the literature, which report that the introduction of U.S. tariffs in early 2018 corresponded to an increase in inflation connectedness due to shocks emanating from the directly impacted industries (metal products and machinery). In our context, we indeed find that during 2018–2019, industries like Primary Metals and Fabricated Metals showed heightened spillovers to others, reflecting the tariff shock transmission.

- The COVID-19 period (2020) stands out as well. System-wide connectedness jumped in 2020, peaking at around 78% — the highest in our sample. The onset of the pandemic was an unprecedented global shock, causing simultaneous disruptions in supply, demand, and logistics. For North American manufacturing, this meant highly synchronized price movements (for instance, a crash and then surge in lumber prices, volatility in petroleum products, etc.), which translated into stronger-than-usual spillovers among industries. After the initial COVID shock, connectedness remained elevated through 2021, likely reflecting ongoing supply chain strains and recovery swings, before easing slightly by 2022.
- In the latest part of the sample (2023–early 2025), the system connectedness index stabilizes in the mid-60% range, still above the pre-2015 "baseline." This suggests that the experience of the pandemic and other recent shocks may have led to a more interconnected normal state, possibly due to enduring changes in supply chain management or pricing behaviors.

Figure 7: Dynamic system-wide connectedness.

Note: This graphic presents the evolution of the system-wide connectedness between Canadian and U.S. manufacturing producer prices.

Overall, Figure 7 highlights that while the North American manufacturing price network is always interconnected, the intensity of these connections can increase markedly during periods of stress or major structural changes. External shocks—such as commodity price collapses or global crises—tend to tighten the linkages (i.e., a shock in one industry more readily spills to others when the system is under strain). Conversely, in more tranquil periods, industries have a somewhat greater tendency to move independently. Notably, even the "low" points of connectedness (e.g., around 2013 or 2017) are still near 60%, which is high. This underscores a key policy point: interdependence is the norm, and crises only make it stronger. For policymakers, this means that during crises (like pandemics or trade wars), inflationary or deflationary pressures can quickly become a regional issue rather than a local one, complicating stabilization efforts.

4.2.2 Dynamics of Canadian Industries' Connectedness

We next examine how the connectedness of individual Canadian industries has evolved. Figures 8 and 9): show the rolling "from others" and "to others" connectedness for each Canadian industry, with a decomposition by source or destination (blue areas indicating the portion attributable to U.S. industries, red for Canadian, and green for exchange rate). These stacked area graphs illustrate the changing exposure and influence of each Canadian sector over time.

Exposure of Canadian Industries (Figure 8): A general observation is that most Canadian industries saw their total exposure to external shocks rise significantly during the 2015 oil shock and the 2020 COVID shock, in line with the system-wide pattern. However, the composition of that exposure (domestic vs U.S.) varies by industry and time:

- Machinery, Computer & Electronics, and Transportation Equipment – these sectors show persistently high exposure (their "from others" lines are generally near the top of the chart). Their exposure is primarily driven by domestic Canadian shocks (red area), reflecting that these sectors are tightly linked with other industries within Canada's economy (and many of those industries themselves are connected to global cycles). That said, a notable portion of their exposure also comes from U.S. shocks (blue area), especially during turbulence. For instance, in 2020, the blue area for these sectors widens, indicating U.S. shocks (perhaps from U.S. supply chain disruptions in autos and tech) significantly contributed to volatility in Canadian machinery and electronics prices.

- Wood Products and Petroleum & Coal – these sectors have exposure profiles dominated by U.S. shocks (large blue areas) throughout much of the sample. This aligns with the static result that they are highly sensitive to U.S. developments. We see that in 2015–2016, Canadian PetroCoal's exposure to U.S. shocks surged (likely due to the global oil price movements and how the U.S. shale revolution and demand shifts played out), and similarly Canadian Wood's exposure to U.S. shocks was very high during 2020–2021 (when U.S. lumber demand spiked and then corrected).

- Food and Chemicals – these industries have a moderate and steady exposure, with a balance of Canadian and U.S. sources. For Food, the U.S. portion grew in 2020 (food supply chain disruptions were cross-border during COVID). For Chemicals, the exposure peaked in 2015 (oil-related) and again in 2018 (tariffs on chemical feedstocks perhaps), each time with both Canadian and U.S. contributions visible.

- Printing and Leather – these have the lowest exposure among Canadian industries over time (consistent with being relatively isolated sectors). They do show small bumps in exposure during global shocks, but remain much less influenced by others compared to the sectors above.

Therefore, Canadian industries that are resource-intensive or heavily traded (like PetroCoal, Wood, and to some extent Food and Primary Metals) tend to have a larger fraction of their volatility coming from U.S. shocks over time. Meanwhile, industries that are more part of Canada's manufacturing supply chain (like Machinery, Autos, Electronics) are strongly affected by domestic network shocks (which in turn can be influenced by global factors). Exchange rate (green area) contributions are generally modest but not negligible; interestingly, during the mid-2010s, the exchange rate explained a noticeable chunk of variance for some industries (e.g., Machinery and Autos around 2015–2016), reflecting how the Canadian dollar's drop in that period cushioned or amplified price changes.

Influence of Canadian Industries (Figure 9): On the flip side, we see how Canadian industries' ability to transmit shocks has changed:

- Transportation Equipment (Autos)– consistently a top transmitter domestically (large red area). Its influence on the U.S. (blue) also rises in key periods (notably 2018 and 2020). The 2018 bump likely reflects how Canadian auto sector price changes (perhaps due to steel/aluminum tariffs affecting inputs) spilled into U.S. auto prices. The 2020 spike shows Canadian autos transmitting shocks when the auto supply chains were disrupted globally.

- Petroleum & Coal, Wood– these show significant blue portions, meaning they have transmitted a lot of volatility to U.S. industries over time. Canadian PetroCoal's influence on the U.S. is especially pronounced in 2015–2016 and 2020, coinciding with oil price swings. Canadian Wood's influence on the U.S. is high around 2021 (periods of lumber price volatility). Canadian Primary Metals saw a spike in influence to the U.S. around 2021, consistent with metal price volatility during this period (Canada is a major steel/aluminum exporter to the U.S., so price shocks in Canadian metals likely impacted U.S. metal product prices).
- Chemicals and Plastics – also transmit some shocks to the U.S., though to a lesser degree. They show elevated influence in 2015 (oil shock affecting petrochemicals) and 2018.
- Machinery and Electronics – their influence is mostly within Canada (red area). They are key domestic propagators but don't directly transmit as much to U.S. prices. This suggests that while these sectors are heavily integrated (lots of trade in machinery and electronics parts), pricing shocks in these industries in Canada often originate from or get absorbed by domestic conditions (or possibly they transmit to the U.S. indirectly via other sectors, rather than directly).

Overall, the dynamic analysis for Canadian industries illustrates that shocks emanating from Canada's resource-based industries have substantial and time-varying impacts on U.S. industry prices, particularly when global commodity markets are in flux or when trade policies change. Meanwhile, Canadian manufacturing sectors (like autos and machinery), while very important domestically, tend to have a more moderate direct influence on U.S. prices, potentially because U.S. analogues of those industries are large enough to set their own prices. The exchange rate's influence tends to appear as a factor when there are big currency moves (e.g., the 2014–2016 period when the CAD depreciated significantly), affecting the relative pricing power of Canadian exporters.

4.2.3 Dynamics of U.S. Industries' Connectedness

Finally, Figures 10 and 11 provide the rolling connectedness measures for U.S. industries, with the contributions broken down by source or destination country (analogous to the Canadian figures).

Exposure of U.S. Industries (Figure 10): We can make several observations:

- Petroleum & Coal, Wood, Primary Metals – these U.S. industries exhibit high exposure to Canadian shocks (red area in this context represents Canadian source for U.S. industries). Over time, their exposure to Canadian shocks is quite pronounced and volatile. For instance, U.S. Wood's foreign exposure (red) ballooned during 2017–2021, aligning with significant lumber trade and pricing issues (tariffs on Canadian lumber, then huge demand in COVID). U.S. PetroCoal's exposure to Canadian shocks spiked in 2015–2016 (as Canada's oil sands and U.S. shale are interconnected) and again in 2020. U.S. Primary Metals saw a peak in Canadian-driven exposure around 2018–2019, likely due to the trade conflict affecting steel/aluminum where Canada is a major supplier.

- Chemical and Plastics – these have moderate exposure mainly to domestic factors, but with noticeable Canadian contributions during certain periods (e.g., 2014–2016 for Chemicals, possibly due to imported inputs from Canada or global chemical price movements).

- Fabricated Metal, Machinery, Electrical Equipment – largely driven by domestic U.S. shocks (blue). These sectors' exposure to Canadian shocks is relatively low and stable, reflecting that U.S. internal dynamics (and perhaps multi-country factors beyond Canada) are more important.

- Food Manufacturing – interestingly, U.S. Food has a sizable chunk of exposure to Canadian shocks consistently (red area on U.S. Food is fairly thick). This suggests cross-border integration in food prices (likely through agricultural commodity trade and processed food imports/exports between the two countries). The exposure grew around 2016–2017 and 2020.

- Textile, Apparel, Leather – these remain mostly low and primarily domestically driven, with little cross-border exposure visible (which fits their smaller role in bilateral trade).

Overall, while the U.S. economy is more self-contained, certain U.S. industries show considerable vulnerability to Canadian shocks at times, contrary to a simple narrative of one-way influence. On average (as also noted in static results), the share of variance coming from Canadian sources for U.S. industries (around 22% overall) was slightly higher than the reverse share (Canadian industries getting ~20% from U.S.). Our dynamic plots reinforce this: during key episodes, Canadian shocks (especially from commodity sectors) have materially impacted U.S. industrial prices. This highlights a two-way dependency — for example, a supply or policy shock in Canada's oil sector can transmit to U.S. fuel and plastic prices, or a lumber supply issue in Canada can hit U.S. construction costs.

Influence of U.S. Industries (Figure 11): Lastly, we consider how U.S. industries have transmitted shocks over time:

- Petroleum & Coal, Wood – as expected, these are major transmitters to Canada (red areas for these industries are substantial). We see that U.S. Wood's influence on Canadian industries was extremely high in 2020–2021, reflecting how skyrocketing lumber prices in the U.S. drove up prices in Canada (despite Canada being a net exporter, the integrated market means Canadian prices often follow U.S. trends). U.S. PetroCoal's influence on Canada spiked in 2015 (when the oil price plunged, U.S. and global factors heavily impacted Canadian oil prices) and again in 2020.

- Food – U.S. Food's influence on Canada grew in the late 2010s and during COVID, indicating stronger spillovers of U.S. food price shocks to Canadian food prices in those times (possibly due to trade of food products and common shocks like diseases or supply chain issues).

- Primary Metals and Fabricated Metals – these show increased influence on Canada around 2018–2019, as one would expect from the U.S. imposing tariffs (raising U.S. steel prices, which then impacted Canadian steel/aluminum markets and downstream prices).

- Machinery and Electronics – U.S. shocks in these sectors have modest direct influence on Canadian industries (their red areas are relatively small), suggesting that price disturbances in U.S. machinery or tech manufacturing did not heavily spill into Canada beyond what was already coming through shared upstream inputs. This could be because Canadian firms in these areas face global competition or source inputs globally, muting direct U.S. price influence.

- Furniture – interestingly, U.S. Furniture manufacturing shows a moderate influence on Canadian sectors around 2016–2019 (with a notable red area). This could be related to housing market cycles affecting furniture demand/prices across the border, or trade in furniture components.

Therefore, U.S. industries remain the dominant drivers of domestic price fluctuations (naturally, given the size of the U.S. market), but they also contribute significantly to Canadian price variability in key sectors. The dynamic patterns underscore that trade policy changes (like tariffs) and global shocks (like oil crashes or pandemic demand shifts) often manifest first in U.S. price changes and then propagate into Canada. Conversely, Canadian-origin shocks (especially in resources) can propagate into the U.S., but often these Canadian shocks are themselves triggered by global price movements. Thus, many of the spillovers are jointly driven by global events and then transmitted across the Canada–U.S. network.

Taken together, the dynamic analysis reveals a complex, evolving tapestry of connectedness. The degree of price spillover is not constant: it amplifies during turbulent times and recedes slightly in calmer periods. Both countries have industries that serve as pivotal nodes in transmitting shocks across the border. For Canada, those nodes include energy and commodity sectors (which funnel global shocks into the U.S.) as well as large manufacturing sectors (autos, etc., which propagate shocks internally). For the U.S., key nodes include commodity-related sectors and those targeted by policy changes (which can send shocks into Canada). An important insight is the reciprocal nature of these relationships: while the U.S. economy often sets the tone due to its size, it is not immune to feedback from Canadian developments. This mutual dependence means that ensuring stability in producer prices may require coordination or at least awareness of cross-border effects when formulating policies (monetary, fiscal, or trade-related). We will discuss these implications and how our findings address the initial research questions in the next section.

5 Discussion

In this section, we interpret our findings in light of the research questions and hypotheses outlined earlier, and we relate them back to the gaps identified in the literature. The central questions were: (RQ1) How strong is cross-border price transmission between Canadian and U.S. manufacturing industries? and (RQ2) Are there asymmetries in this transmission? Based on these, we posited a couple of working hypotheses:

- H1: Producer price changes are strongly transmitted across the Canada–U.S. border due to the high integration of their manufacturing supply chains.
- H2: Price spillovers are asymmetric, potentially with U.S. industries exerting a larger influence on Canadian industries than vice versa, given the larger size of the U.S. market and its role as a key export destination for Canada.
- H3: Industries with deeper cross-border integration (through trade and input-output linkages) experience greater spillovers than less-integrated industries, and upstream commodity sectors serve as important conduits for shocks.

Our empirical results largely validate H1. The static system-wide connectedness index of roughly 55% and consistently high dynamic connectedness (60–75% range) provide clear evidence that a majority of price variance in these industries is attributable to inter-industry and cross-border shock transmission. In practical terms, this means that inflationary pressures in one country's manufacturing sector do not stay contained, they spill over significantly to the other country. This confirms the intuition that, under an integrated trade regime (NAFTA/USMCA), producer prices are tightly linked. It also extends prior single-country findings (Bilgin and Yılmaz, 2018; Jia et al., 2022) into a cross-border context, showing that international connectedness is as important as domestic connectedness in explaining industry-level price movements. Our analysis thereby fills a gap in the literature by providing quantitative estimates of bilateral spillovers where previously only aggregate or single-country measures were known.

Regarding H2 (asymmetry), the evidence is more nuanced but broadly consistent with expectations of asymmetry. If we consider only cross-country industry shocks (excluding exchange-rate effects), U.S. industries receive slightly more variance from Canadian industries (~21.8%) than

Canadian industries do from U.S. industries (~20.5%). However, including the exchange-rate channel reverses that ordering: Canada becomes slightly more foreign-exposed ($\approx$ 20.5% + 4.4% = 24.9%) than the U.S. ($\approx$ 21.8% + 1.2% = 23.0%). Thus both statements that the U.S. leads and that Canada is more exposed—can be true depending on the metric used. We note that the difference is small in the aggregate, but the composition matters. Many individual Canadian industries are heavily influenced by U.S.-origin shocks, whereas only certain U.S. industries (notably those reliant on Canadian commodities, like Oil and Wood) are significantly influenced by Canadian shocks. Moreover, Canada's most influential sectors domestically (Transportation Equipment, etc.) still operate in the shadow of larger U.S. or global industries. The dynamic results further highlight asymmetry: in times of stress, U.S. shock influence on Canada often surged (e.g., U.S. metals affecting Canadian metals during tariffs, U.S. lumber prices driving Canadian lumber). That said, we also documented instances where Canadian shocks strongly affected the U.S. (for example, during commodity price swings that hit Canada first or hardest, such as the 2015 oil shock). Therefore, H2 is validated in the sense that the leadership in shock transmission often leans towards the U.S., but it is not a one-way street. The relationship is better described as a two-way dependence with an imbalance: the U.S. is the source of more shocks that matter system-wide (due to its economic weight), yet Canada can and does send significant shocks back along the network under specific conditions. This finding addresses a gap in the literature by moving beyond the simple notion of U.S.-dominant influence (common in global macro studies) and showing that even a smaller economy's industries can induce sizable spillovers in a tightly coupled network (consistent with network propagation theories like Acemoglu et al. (2012).

Our results also support H3. Industries that we know to be deeply integrated through trade and supply chains (e.g., the auto industry, which spans the border, or the oil & gas industry) showed the largest connectedness measures. For instance, the Petroleum & Coal Products and Wood Products sectors in both countries exhibited extremely high bilateral spillovers, reflecting heavy cross-border trade (oil, gasoline, lumber) and common exposure to global commodity prices. Similarly, sectors like Primary Metals and Fabricated Metals became highly connected during the tariff episode, indicating that where direct trade linkages exist (steel and aluminum trade between Canada and the U.S.), policy-induced shocks propagated strongly. In contrast, more insular sectors (textiles, apparel) with little cross-border integration had low spillovers. This aligns with the idea that the input-output structure of trade plays a key role in transmission. Upstream sectors (like metals, chemicals, energy) that feed into many downstream industries acted as major shock transmitters – for example, an oil price collapse didn't just affect fuel prices, it rippled into chemicals, plastics, and transportation costs across both countries. Downstream sectors (like final consumer goods) tended to absorb rather than transmit shocks. These observations resonate with prior findings in closed-economy studies (Bilgin and Yılmaz, 2018; Jia et al., 2022) and confirm them in an international context. We thus provide concrete evidence for policymakers that supply chain integration is a double-edged sword: it offers efficiency and synchronicity in good times, but it also means shocks are quickly shared. This underscores the importance of resilience strategies (diversifying sources, maintaining inventories, etc.) in the most integrated sectors.

Linking back to the research gaps identified in the literature review, our discussion highlights how the present study contributes to filling those gaps. First, we have delivered an explicit quantification of bilateral connectedness between two specific economies, whereas previous literature either stayed within one country or aggregated many countries without detail. This bilateral focus revealed, for example, that the Canada–U.S. pair has a higher connectedness (55%) than many individual countries' internal connectedness reported in other studies(38,2 % for US industries connectedness, see Bilgin and Yılmaz (2018), emphasizing just how intertwined these two economies are. Second, by incorporating the exchange rate in our model, we could gauge its role: interestingly, we found that while the exchange rate does matter, it played a relatively minor direct role (only a few percent of variance) compared to direct industry linkages. This suggests that price spillovers are driven more by real linkages (trade of goods) than by nominal exchange rate pass-through—at least in our sample period where inflation was moderate and exchange rates mostly stable except for 2015–2016. This addresses a question often raised in international studies: whether exchange rates dominate or not. In our case, they do not; the network of production linkages is the primary channel.

It is also instructive to compare our findings to analogous studies. For instance, Bilgin and Yılmaz (2018) found that U.S. domestic connectedness in manufacturing was higher during supply shocks, which we similarly observe internationally: supply shocks like the oil price crash caused an uptick in cross-border connectedness. They also noted the effect of the Trump tariffs in raising connectedness, which our dynamic results confirm for the cross-border case in 2018. Auer et al.

(2019) highlighted that half of PPI co-movements globally are due to input linkages; our Canada–U.S. study exemplifies that in a microcosm, with well over half of variance explained by linkages. Thus, our work not only fills a gap but also bridges the insights of domestic and global studies, positioning a bilateral analysis as a crucial middle ground.

In terms of hypotheses, none of our initial assumptions were outright rejected; rather, they were refined by the data. H1 (strong transmission) is clearly affirmed. H2 (asymmetry) is supported but with the twist of reciprocal influence. H3 (role of integration) is strongly supported by the sectoral evidence. If we were to articulate any unexpected findings, it would be the extent of reciprocity: we anticipated U.S. shocks to dominate, but we found that shocks in Canada's key sectors can impose nearly equally significant effects on U.S. industries during certain periods. This nuance is important because it suggests that U.S. policymakers also need to pay attention to Canadian developments (for example, a disruption in Canadian oil production or a strike in Canadian auto plants could quickly reflect in U.S. producer prices).

Finally, discussing the implications: Our results speak directly to the importance of policy coordination in a highly integrated region. Trade policies (tariffs, trade agreements) have immediate and measurable impacts on producer prices beyond the country implementing them. For instance, U.S. tariffs not only raised U.S. metal prices but also Canadian prices, effectively exporting some inflation to Canada—something the Bank of Canada would have to consider in its policy. Likewise, supply shocks like pandemics or natural disasters require a joint understanding; unilateral action (export restrictions, etc.) could amplify spillovers. For central bankers, the message is that inflation is a shared challenge in such a tightly knit network. The strong spillovers imply that if one country experiences a surge in input costs, the other is likely to feel it soon after, so there may be benefits in sharing information and perhaps coordinating aspects of inflation targeting or macroprudential measures.

Therefore, the discussion underscores that the research gap—the lack of knowledge on bilateral industry-level connectedness—has now been partly filled with evidence that Canada and the U.S. are strongly and asymmetrically linked in terms of producer prices. Our hypotheses about strong and uneven spillovers are largely confirmed, with sector-specific insights adding depth. This contributes a piece to the broader puzzle of how globalization and regional integration affect inflation dynamics, illustrating that even between two advanced, friendly economies with a longstanding free trade agreement, price shocks readily cross borders. It also sets the stage for further work, such as examining whether similar patterns hold in other country pairs or if firm-level data would reveal additional mechanisms (e.g., multi-national enterprises' pricing). The next section, the conclusion, will wrap up these points and suggest directions for future research and policy considerations.

6 Conclusion

This paper set out to investigate the structure and intensity of producer price connectedness between Canadian and U.S. manufacturing sectors, with a focus on cross-border spillovers and their evolution in the face of trade policy shifts, global shocks, and exchange rate movements. Using monthly Industrial Product Price Index (IPPI) data for 21 matched NAICS industries in each country from 2004 to 2025, and applying a high-dimensional VAR model estimated via Elastic Net, we computed both static and dynamic connectedness metrics following the Diebold and Yılmaz (2012) framework. The inclusion of the USD/CAD exchange rate in the VAR allowed us to control for currency effects and isolate real economic linkages.

The findings reveal a deeply interconnected North American manufacturing price network. In answer to our first research question, we find that cross-border price transmission is very strong: roughly 55% of the volatility in industry prices is attributable to spillovers rather than industry-specific factors. In particular, several industries stand out as hubs of connectivity. On the Canadian side, Transportation Equipment, Computer & Electronic Products, and Machinery are both significant transmitters and receivers of price shocks. On the U.S. side, industries such as Petroleum & Coal Products and Wood Products have especially tight linkages with their Canadian counterparts, reflecting integrated markets for commodities and materials. These results underscore that producer prices in one country cannot be analyzed in isolation from the other; shocks propagate through supply chains that span the border.

Addressing the second research question, we do observe asymmetries in spillovers. Canadian industries, on average, are somewhat more influenced by U.S. shocks than U.S. industries are by Canadian shocks. For example, a shock to U.S. primary metal prices has a larger impact on Canadian metal prices than vice versa. This asymmetry is consistent with the differences in economic size and the fact that Canadian firms often depend on U.S. demand and inputs. However, the asymmetry is not absolute; crucially, we find that shocks in certain Canadian industries (notably in natural resources like oil or lumber) can significantly affect U.S. prices. In some periods, the influence of Canadian shocks on U.S. industries was nearly on par with or even exceeded the reverse. Thus, the price transmission is bidirectional, with a tilt toward U.S.-driven influence but also notable feedback effects. This insight adds a layer of complexity to the common narrative of U.S. dominance, highlighting that interdependence means vulnerability runs both ways.

The dynamic analysis adds further nuance. We document that connectedness is time-varying and tends to intensify during periods of major disruptions. For instance, during the 2015 oil price collapse (which hit Canada's energy sector hard), the overall connectedness spiked as that shock was transmitted across industries and into the U.S. supply chain. Similarly, the trade policy turbulence around 2018, marked by U.S. tariff impositions, corresponded with a rise in spillovers—consistent with the notion that tariffs on intermediate goods (like metals) cause cost shocks that permeate through manufacturing in both countries. The COVID-19 pandemic led to an even larger surge in connectedness, reaching unprecedented levels (~78%). This reflects the synchronized and far-reaching nature of the pandemic shock: simultaneously affecting demand, supply, and logistics across virtually all industries. Post-2020, connectedness remained elevated, suggesting some lasting increase in integration or commonality of shocks (possibly due to global supply chain reconfigurations or the broad impact of synchronized monetary/fiscal responses). These temporal patterns align with findings in other contexts that global crises amplify spillovers. An implication is that stress-testing for economic resilience should account for the likelihood that shock transmission will be higher exactly when adverse shocks occur.

Methodologically, our use of an Elastic Net VAR proved effective in handling a large, complex dataset and uncovering a sparse structure of significant linkages. This is a contribution in its own right, demonstrating a practical approach to applying connectedness measures in a high-dimensional setting (a necessary step when dealing with many industries and potential connections). It opens the door for similar analyses in other country pairs or extended industry sets, where traditional VAR estimation would be infeasible. By doing so, we extend the Diebold-Yılmaz connectedness framework beyond its typical domain (financial markets or small sets of macro variables) to a realm of rich industry-level data in an international context. The incorporation of the exchange rate in the framework also provided insights—specifically, that direct exchange rate effects on producer price variance were relatively small compared to cross-industry effects, which is an interesting finding for macroeconomists concerned with exchange rate pass-through.

From a policy perspective, our results carry several messages. For one, they highlight the inflationary interdependence of Canada and the U.S. When one country experiences cost-push inflation in manufacturing (say due to a commodity boom or a policy change), the other country is likely to "import" some of that inflation through higher prices of traded inputs and goods. This is happening over and above any exchange rate adjustments. Therefore, central banks (like the Bank of Canada and the U.S. Federal Reserve) need to be mindful that their inflation outlooks are correlated; purely domestic models may miss important drivers. It also means that any uncoordinated trade policies (like tariffs or export restrictions) enacted for domestic reasons can boomerang, affecting not just foreign producers but also domestic industries via supply chain links. For instance, U.S. tariffs on steel raised prices for U.S. manufacturers (intended) but also for Canadian manufacturers (unintended), demonstrating how such policy actions propagate. Policymakers aiming for economic resilience should consider mechanisms to buffer key sectors from such spillovers—this could include strategic reserves (for commodities), diversified sourcing, or bilateral agreements to avoid beggar-thy-neighbor policies during crises. The integrated nature of the North American manufacturing ecosystem, as evidenced by our connectedness measures, suggests that collaborative approaches (for example, joint supply chain task forces or coordinated strategic stockpiles) might be beneficial in mitigating the impact of global shocks.

Finally, while our study has provided a comprehensive look at Canada–U.S. industry price linkages, it also opens several avenues for future research. One limitation of our approach is that it treats industries as aggregates; future work could incorporate firm-level data or more granular supply chain information to see how much of the spillovers are driven by multinational enterprises or specific input-output relationships. Another extension could be to include Mexico to analyze the full NAFTA/USMCA region, as Mexico's manufacturing sector is also deeply integrated with the U.S. (and to a lesser extent with Canada). Additionally, while we controlled for the exchange rate, further research could explore the role of financial conditions or commodity prices explicitly—perhaps augmenting the VAR with global factors to disentangle how much of the spillover is due to common global shocks versus bilateral transmission. Investigating potential non-linearities (are spillovers disproportionately higher beyond certain shock thresholds?) or structural breaks (did the 2008 crisis or the 2020 pandemic permanently change the network?) would also be valuable.

In conclusion, this study underscores that in an era of global production networks, economic borders are porous for producer prices. Canada and the United States, through decades of trade integration, have essentially formed a joint manufacturing market where a price tremor in one corner is felt across the continent. A key takeaway is that maintaining stable producer prices and managing inflation requires a view that extends beyond one's own borders. For North America, policies that strengthen supply chain resilience and maintain open lines of trade cooperation will be crucial in ensuring that this high connectedness translates into shared growth and stability, rather than mutual vulnerability.

Annex A

Table 1: Industry codes and acronyms (NAICS classification)

NAICS	Acronym	Industry description
311	Food	Food manufacturing
313	TextMills	Textile mills
314	TextProd	Textile product mills
315	Apparel	Apparel manufacturing
316	Leather	Leather and allied products
321	Wood	Wood product manufacturing
322	Paper	Paper manufacturing
323	Printing	Printing and related support activities
324	PetroCoal	Petroleum and coal products manufacturing
325	Chemical	Chemical manufacturing
326	PlastRub	Plastics and rubber products
327	NonMetMin	Non-metallic mineral products
331	PrimMetal	Primary metal manufacturing
332	FabMetal	Fabricated metal products
333	Machinery	Machinery manufacturing
334	CompElec	Computer and electronic products
335	ElecEquip	Electrical equipment, appliance & component
336	TranspEquip	Transportation equipment (incl. automobiles)
337	Furniture	Furniture and related products
339	Other	Miscellaneous manufacturing

Note: This table summarizes the industry codes and acronyms used in the analysis, based on the North American Industry Classification System (NAICS). These categories are used to classify manufacturing sectors for empirical comparison.

References

Acemoglu, Daron, Vasco M. Carvalho, Asuman Ozdaglar, and Alireza Tahbaz-Salehi (2012) "The network origins of aggregate fluctuations," *Econometrica*, 80 (5), 1977–2016.

Auer, Raphael A., Andrei A. Levchenko, and Philip Sauré (2019) "International inflation spillovers through input linkages," *Review of Economics and Statistics*, 101 (3), 507–521.

Bilgin, Nuri M. and Kamil Yılmaz (2018) "Producer price inflation connectedness and input-output networks,"Technical report, SSRN Working Paper No. 3244645.

Demirer, Mert, Francis X. Diebold, Levent Liu, and Kamil Yılmaz (2018) "Estimating global bank network connectedness," *Journal of Applied Econometrics*, 33 (1), 1–15.

Diebold, Francis X. and Kamil Yılmaz (2009) "Measuring financial asset return and volatility spillovers, with application to global equity markets," *The Economic Journal*, 119 (534), 158–171.

——— (2012) "Better to give than to receive: Predictive directional measurement of volatility spillovers," *International Journal of Forecasting*, 28 (1), 57–66.

Forbes, Kristin J. (2019) "Inflation dynamics: Dead, dormant, or determined abroad?" *Brookings Papers on Economic Activity*, 2019 (Fall), 257–338.

Greenwood-Nimmo, Matthew, Van H. Nguyen, and Yongcheol Shin (2021) "Measuring the connectedness of the global economy," *International Journal of Forecasting*, 37 (2), 899–919.

Jia, Yifan, Yuxin Fang, Zhongbo Jing, and Feng Lin (2022) "Price connectedness and input–output linkages: Evidence from China," *Economic Modelling*, 116, 105997.

Pesaran, M. Hashem and Yongcheol Shin (1998) "Generalized impulse response analysis in linear multivariate models," *Economics Letters*, 58 (1), 17–29.

Pham, Bao T. and Hector Sala (2022) "Cross-country connectedness in inflation and unemployment: Measurement and macroeconomic consequences," *Empirical Economics*, 62 (3), 1123–1146.

Takongmo, Charles O. M. and Amadou Toure (2023) "Trade openness and connectedness of national productions: Do financial openness, economic specialization, and the size of the country matter?" *Economic Modelling*, 125, 106340.

Zou, Hui and Trevor Hastie (2005) "Regularization and variable selection via the elastic net," *Journal of the Royal Statistical Society Series B: Statistical Methodology*, 67 (2), 301–320.

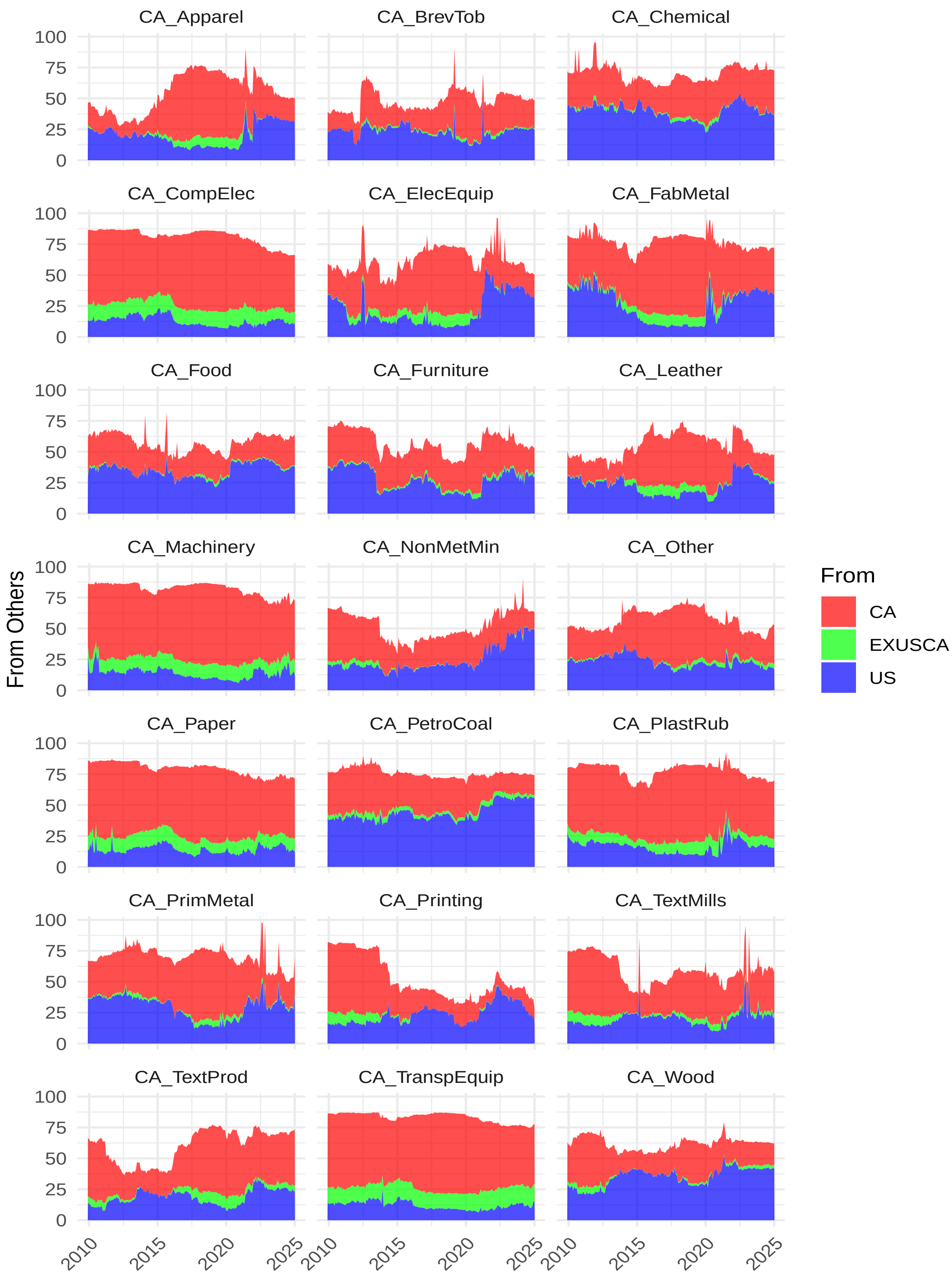


Figure 8: Dynamic connectedness from others of canadian industries.

Note: This graphic presents the dynamic connectedness from other industries for Canadian industries, broken down by the source country: the US (blue) and Canada (red).

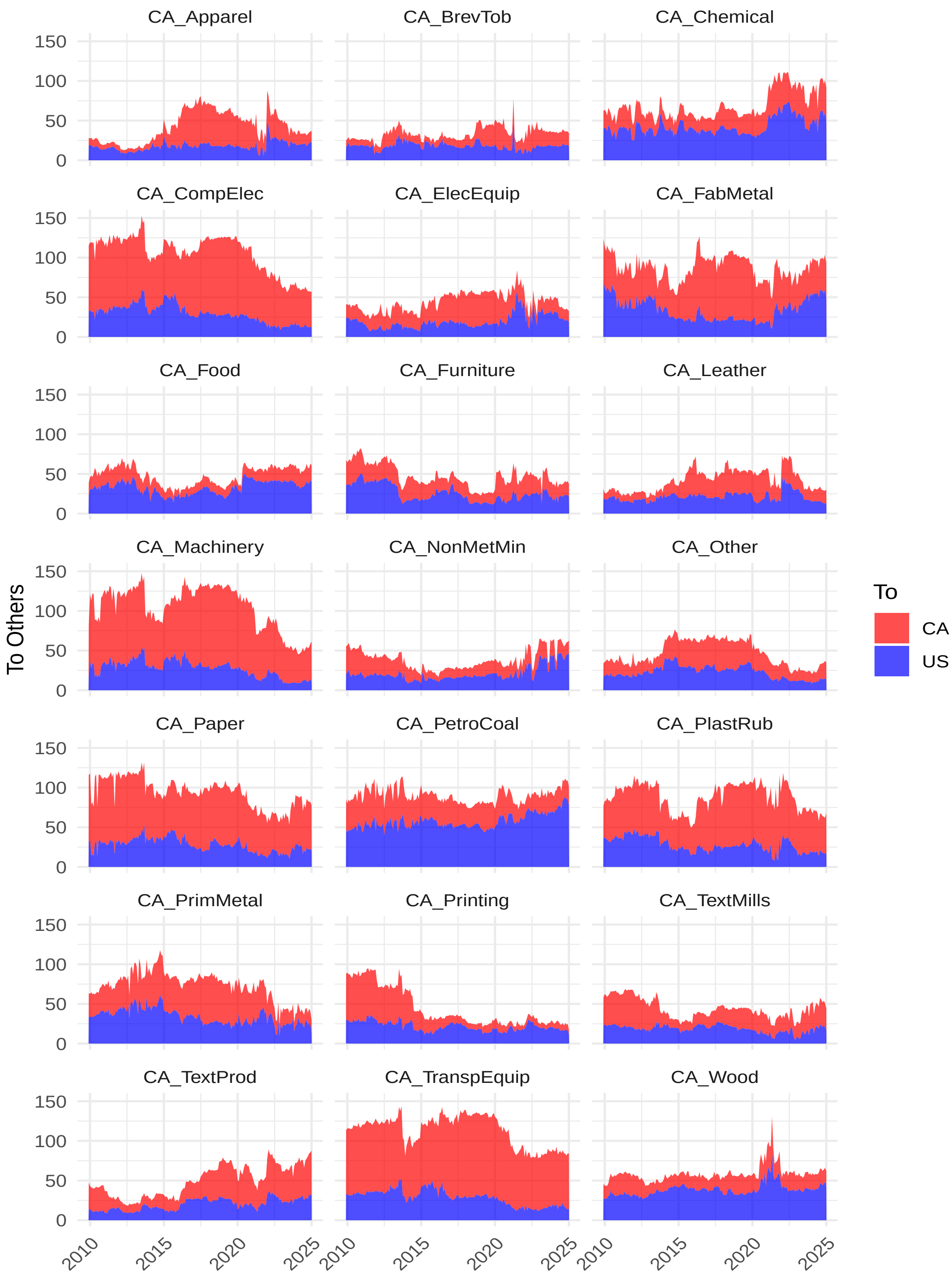


Figure 9: Dynamic connectedness to others of canadian industries.

Note: This graphic presents the dynamic connectedness to other industries for Canadian industries, broken down by the source destination: the US (blue) and Canada (red).

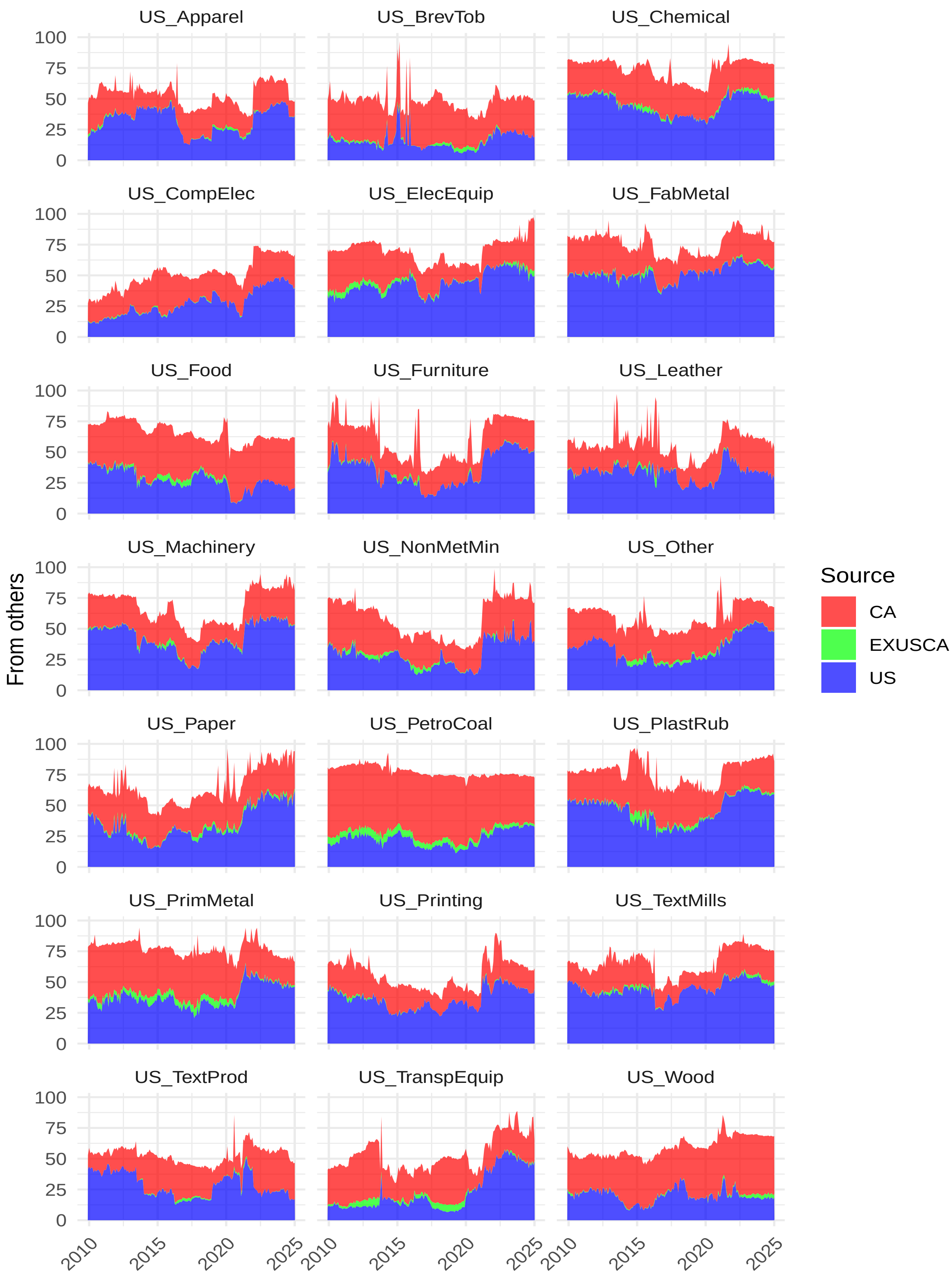


Figure 10: Dynamic connectedness from others of U.S. industries.

Note: This graphic presents the dynamic connectedness from other industries for U.S. industries, broken down by the source country: the US (blue) and Canada (red).

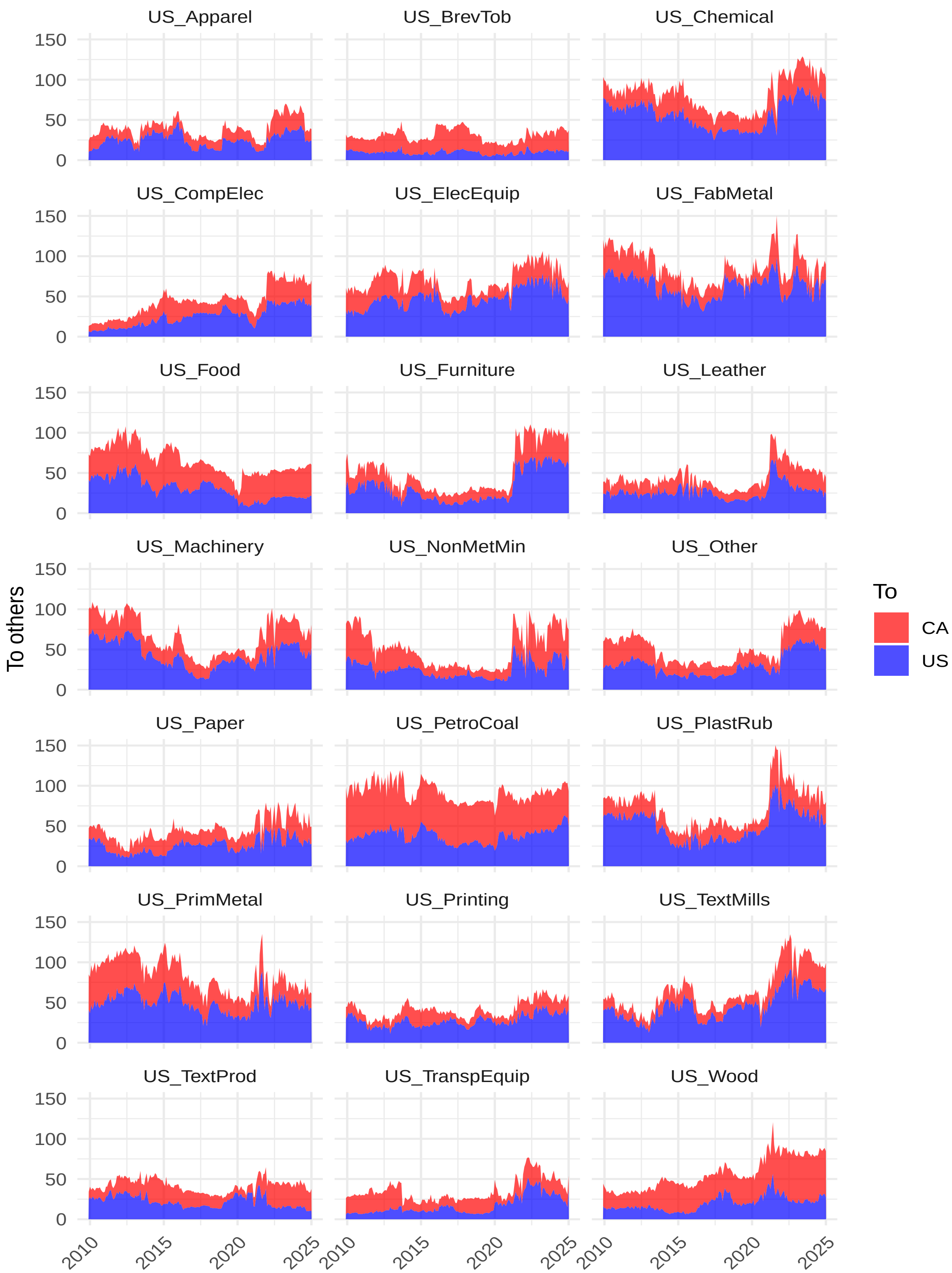


Figure 11: Dynamic connectedness to others of U.S. industries.

Note: This graphic presents the dynamic connectedness to other industries for U.S. industries, broken down by the destination country: the US (blue) and Canada (red).