Asymmetrical Spillover Effects of Policy Uncertainty and Macroeconomic Shock Transmission Across Economies

Sovini Mondal[1], Adesh Acharya[2], Tarun Khandelwal[3]

Abstract

Amid rising global uncertainties and shifting economic alliances, understanding the dynamic transmission of macroeconomic shocks is essential for informed and resilient policy-making. This study explores the evolving macroeconomic connectedness among the largest four economies using a Time-Varying Parameter Vector Autoregression (TVP-VAR) framework. By analyzing key uncertainty indices such as Economic Policy Uncertainty (EPU), Trade Policy Uncertainty (TPU), and macroeconomic indicators such as GDP, FDI, and trade flows reveal time-varying, variable-specific patterns of shock diffusion across countries. Our findings reveal the scalability impact of asymmetric shock transmissions across them. The EPU shock is mainly transmitted by the U.S., and China is at the receiving end. Contradicting the TPU shock pattern between these two countries. This shows that the policy adoption by the U.S. is actively reshaping its trade dynamics to become a secure trade partner, while China's intricate link to its global trade drives this TPU shocks outflow. On the other side, India acts as a major export shock transmission, followed by Germany, while import shocks are transmitted by the U.S. and China. These asymmetrical spillover effects highlight the policy implications, like diversifying trade partnerships and engagement through regional and plurilateral agreements, with stable trade partnerships across countries. Focusing on sector-specific trade agreements can help build resilience amid uncertainty. Additionally, reducing reliance on high-risk partners, diversifying value chains, and strengthening critical sectors are key strategies to mitigate external shocks and build sustainable long-term economic stability.

Keywords: Economic Policy Uncertainty (EPU), Trade Policy Uncertainty (TPU), TVP-VAR, Economic Connectedness, US-China tension

JEL Classification
E02, F01, F13, F14, D80

Introduction

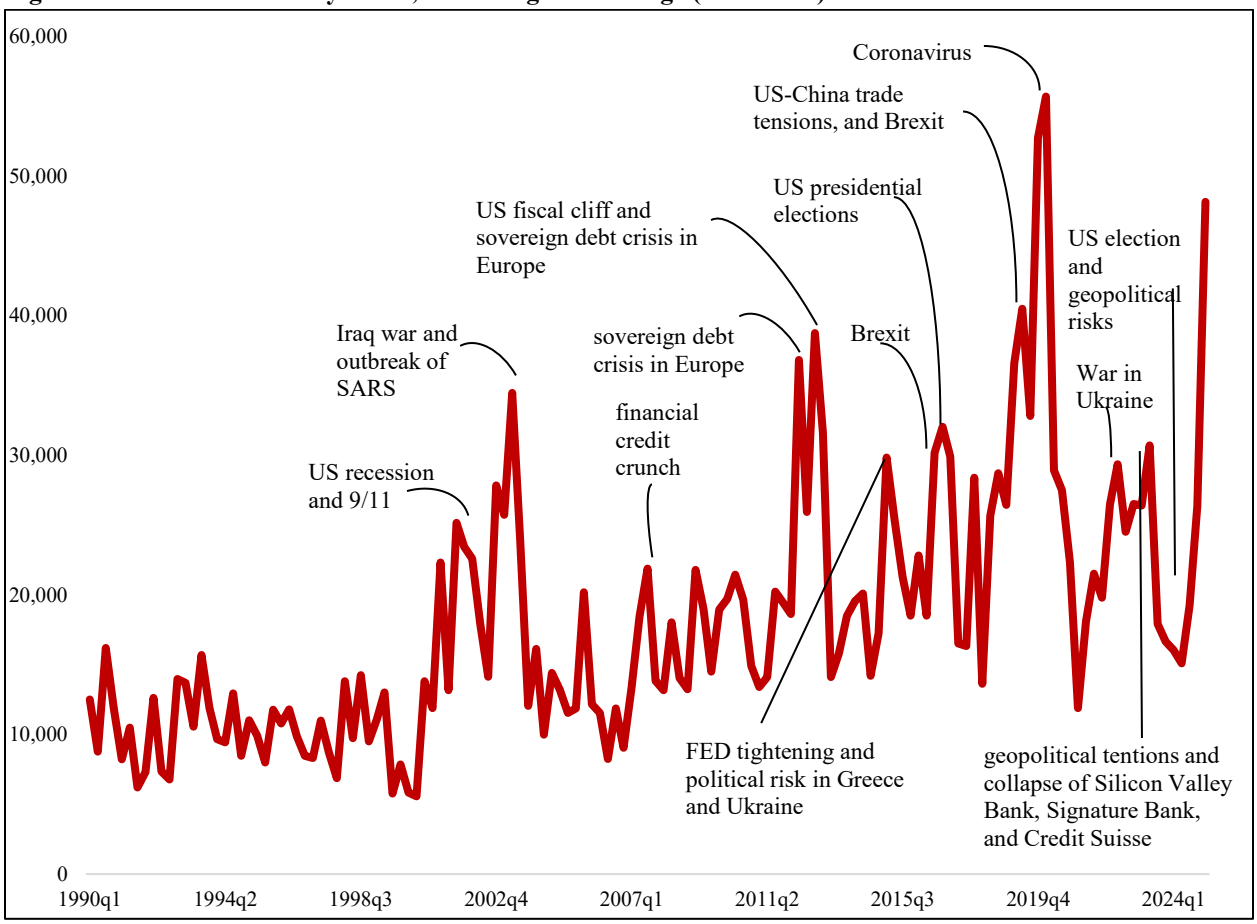
In the era of highly integrated and open global economies, the interconnectedness of countries' macroeconomic indicators plays a crucial role in shaping their respective economic responses. This interconnectedness implies that policy measures implemented by one country can reverberate across others, adding complexity and fueling uncertainty within the policy landscape. This brings about the concept of 'Uncertainty,' which acts as a defining factor in the global economy, influencing trade, investment, and financial markets. Over the last two decades, Economic Policy Uncertainty (EPU) has gained significant attention as a crucial driver of market fluctuations and economic interdependencies (Zhou et.al. 2024). EPU directly influences macro and micro decision-making, whether triggered by financial crises, geopolitical conflicts, trade wars, or pandemics (An et.al. 2023). Additionally, Trade Policy Uncertainty (TPU), a key indicator capturing fluctuations in international trade dynamics, gained equal prominence during the third quarter of 2018 due to heightened trade tensions (Caldara et.al. 2019). The tit-for-tat tariff exchanges between the US and China primarily drove this surge in uncertainty and led to the trade war, imposing retaliatory tariffs and protectionist measures (Riaz et.al. 2024). These uncertainties heighten risk perceptions, prompting shifts in investment behavior and capital allocation (Choi et.al. 2020; Sinha and Ghosh 2021; Biljanovska et.al. 2021; Meng

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et. al. 2024). As a result, they undermine supply chain resilience and disrupt the functioning of global value chains (Handfield et.al. 2020). The cascading effects of such volatility extend across economies, triggering ripple effects that impact trade volumes, value chains, and long-term economic integration (Istiak and Serletis 2018; Thankgod 2023). Therefore, understanding their role in shaping global economic connectedness is crucial in today's volatile world.

Since 2000, the world has witnessed several significant economic uncertainties that fundamentally alter global trade dynamics (see Figure 1). The early 2000s saw the dot-com bubble burst, causing financial turbulence across economies (Delossantos 2023). The 2008 global financial crisis further amplified economic instability, leading to recessionary pressures and widespread regulatory overhauls (Dagher 2018). The TPU gained prominence more significantly with Brexit, disrupting trade relationships and adversely affecting investor confidence (Steinberg 2018; Canh et al. 2020). Similarly, the ongoing U.S.-China trade war introduced an era of economic protectionism, affecting global supply chains (Wu et.al. 2021). More recently, the COVID-19 pandemic and the Russia-Ukraine war have exacerbated uncertainties, causing significant disruptions in financial markets and global trade flows (Allam et.al. 2022). The crises in Eastern Europe and the Middle East have a significant impact on investment decisions, economic development, and stock markets (Khan et al. 2024). These events highlight how EPU and TPU have evolved from a localized concern to a systemic risk influencing interconnected economies worldwide.

Figure 1: World Uncertainty Index, GDP weighted average (1990-2025)



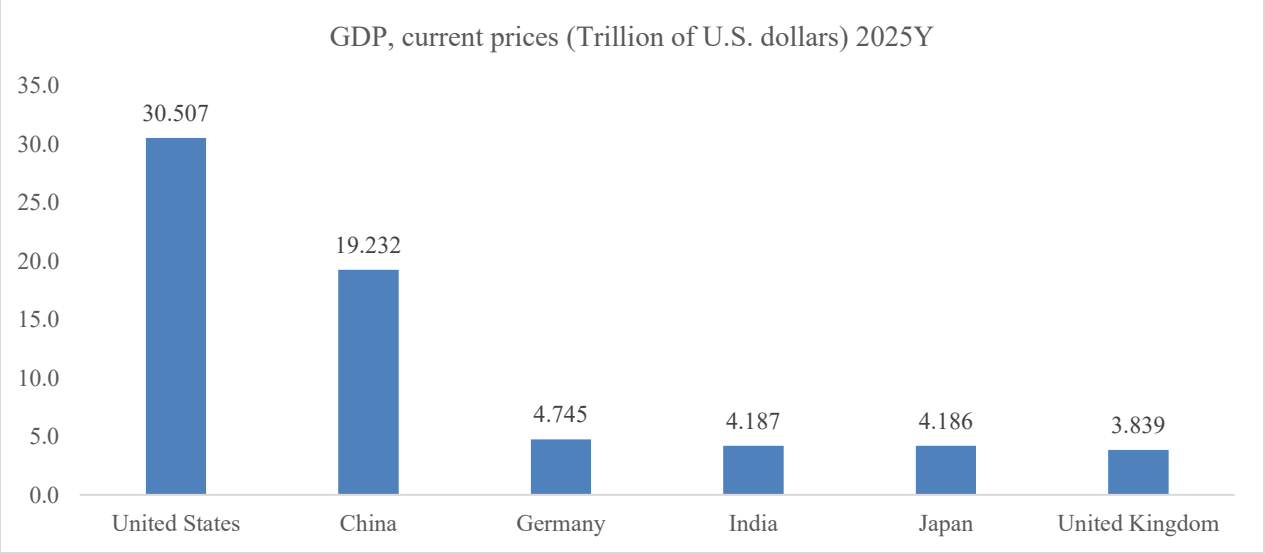
Authors' compilation. Source: World Uncertainty Index

Despite extensive research on these uncertainties, a critical gap exists in understanding their impact on the scalability of global economic connectedness. Existing literature has predominantly focused on country-specific analyses or sectoral spillovers (Benlagha and Hemrit 2022; Nyakurukwa and Seetharam 2023; Yaya et.al. 2024). However, a

comprehensive assessment to access its scalable measures and the intensity of interdependence among major economies remains underexplored. To understand the scalable impact across the economies, it is important to have a precise cross-country-specific analysis of how interconnectedness evolves under these macro-economic shocks and what strategies could mitigate its adverse effects.

Therefore, this paper aims to fill this fine line of gap and contribute to the existing literature by examining the intensity of interconnectedness of four major economies through the lens of macroeconomic parameters, EPU and TPU indexes for US-China trade tension. Data constraints restrict our analysis to observing the impact of TPU only on the US-China relationship. However, for EPU and other macro variable connectedness, we consider two developed nations—the United States and Germany—and two developing nations—India and China—representing around half of the global GDP (World Bank 2024) (see Figure 2). These economies are key players in international trade and exhibit varying degrees of policy-driven economic dependencies. These crossings between the developed and the developing nations are purposefully considered to understand the heterogeneity of the net impact across these economic groups and to understand which country faces the major bottlenecks. As mentioned, this analysis also considered the other macro variables to capture a wider frame of interconnectedness. Therefore, by analyzing these, we can better understand how policy uncertainties and macro variables propagate across these economies, impacting overall economic and global trade dynamics.

Figure 2: Country-Specific GDP Contribution to the World (Nominal, 2025)



Authors' compilation, Source: IMF

Recognizing the structural patterns of economic interdependence under uncertainty can yield critical insights for enhancing trade diversification and macroeconomic resilience. Accordingly, this paper examines the role of economic policy frameworks in shaping long-term sustainability and fostering stable global linkages. By significantly contributing to the literature, the study proposes targeted policy interventions that strengthen inter-economy integration. It further deepened the connectedness heterogeneity across these economies and tried to capture the shock flow directions. Ultimately, this research contributes to the discourse on sustaining economic stability amid persistent global uncertainties.

This section underlines the introduction, followed by the subsequent section detailing the structure of the paper. Section two presents the existing literature, drafts the nuanced factors explored, critically addresses the gaps and arrives at the research questions. The third section represents the methodology used to assess economic connectedness,

presents empirical findings on how EPU impacts major economies in the fourth section, and discusses strategic implications for global trade and investment policies in the final section of this paper.

Literature Review

The EPU index was developed by economists Scott R. Baker, Nicholas Bloom, and Steven J. Davis in their 2016 paper "Measuring Economic Policy Uncertainty" (Baker et.al. 2016). It provides a comprehensive measure of uncertainty linked to economic policy. Conversely, the TPU index—developed by economists from the Federal Reserve—captures the frequency with which terms related to trade policy and uncertainty appear together in leading newspaper tensions (Caldara et.al. 2019).

These indices influence macroeconomic indicators such as trade, domestic and foreign investments, employment, financial markets, and overall economic dependency (Eickmeier and Kühnlenz 2016; Zhang et.al. 2019; Andritzky et.al. 2018). However, the impact of uncertainty is not uniform across economies; instead, it varies based on a country's structural characteristics and policy frameworks, shaping economic decision-making and influencing both short-term volatility and long-term growth prospects (Blanchard et.al. 2010).

Moreover, these indices having the significant influence on stock market volatility and economic activity, particularly in financial markets, is inconclusive. For instance, (Baker et.al. 2016; Caldara et.al. 2019) heightened policy uncertainties, increased market instability, reduced investment, and negatively impacted employment and output. The turbulence observed during the early months of the COVID-19 pandemic serves as a compelling example— (Baker et al. 2020) reported that stock market movements were highly responsive to pandemic-related negative news while the uncertainty index surged dramatically. The Indian oil and gas sector faced substantial shocks from other industries, with volatility peaking during the pandemic (Guru and Das 2021).

Beyond its direct macroeconomic effects, the COVID-19 crisis functioned as an external health shock, introducing a distinct contagion mechanism. The lockdown, fiscal and monetary policy responses and disruptions to global supply chains added layers of unpredictability, severely impacting businesses and labor markets worldwide (Suharsono and Candra 2020; Eichenbaum et.al. 2020; Ma et.al. 2020). In response to this shock, countries adopted varied yet broadly Keynesian policy measures to stabilize their economies (Byrialsen and Madsen 2021). These demand-side interventions aimed to boost aggregate demand and sustain economic activity during the downturn (Chohan 2022).

The United States employed direct fiscal stimulus through cash transfers, injecting liquidity into households to spur consumption (Beckworth 2020). Germany relied on automatic stabilizers, particularly unemployment benefits, to maintain disposable income and prevent a collapse in domestic demand (Ebbinghaus et.al. 2022). Similarly, developing nations like India implemented targeted fiscal policies, such as free ration distribution, to ensure minimum consumption levels among vulnerable groups (Mishra and Rampal 2020). Meanwhile, China adopted expansionary fiscal and monetary policies, including public investment and credit support, which sustained industrial output and enabled positive GDP growth in 2020 despite the global contraction caused by the COVID-19 pandemic (Huang 2024).

The Chinese stock market has strong interdependence between the energy and utilities, while consumer sectors exhibited weaker connections (Shahzad et.al. 2021). The Indian stock market shows high volatility and is strongly influenced by the EPU index. Rising uncertainty boosts the India VIX and lowers the Sensex, reflecting investor risk aversion. Additionally, the US EPU has a spillover effect, positively impacting both the India VIX and Sensex (Idnan et al. 2023). In the U.S. stock market, Baruník et.al. (2016) identified notable sectoral spillovers, with consumer, healthcare, and telecom sectors demonstrating more significant asymmetry than the financial, technology, and energy sectors. Similarly, (Su and Liu 2021) revealed that China's consumer discretionary, industrial, and material indices serve as key volatility spillover sources.

On the other side, the trade war between the U.S. and China has a significantly negative impact on stock market connectedness in both countries, which was also broadly aligned with the findings by (Wise and Turnbull 2019; Bheenick et.al. 2022). However, the impact is more pronounced for negative than positive volatility, reinforcing theories of volatility asymmetry, asymmetric investor attention, and loss aversion (Chen et.al. 2020). Another (Liu et.al. 2023) reveals that during the subprime crisis, the U.S. and U.K. were the primary "exporters" of sentiment, while Germany took on this role during the European sovereign debt crisis.

The resulting surge in trade policy uncertainty, driven by tensions surrounding NAFTA and the US-China trade conflict, significantly influenced economic responses in highly exposed countries, leading to contractions in output and stagnation in global growth trajectories (Maurya et.al. 2024). Unlike the COVID-19 pandemic, the Russian invasion was largely foreseen, leading to significant market volatility before and after the event. A notable pattern emerges—volatility transmission primarily flows from developed to developing countries, with advanced economies acting as net transmitters and developing economies as net receivers (Cheng, et al. 2024). In contrast, India's trade-related uncertainty has remained relatively moderate, reflecting limited exposure to these geopolitical frictions and a comparatively stable trade environment (Kumar et.al. 2021; Yaseen et.al 2025).

Given that India, China, Germany, and the United States contribute significantly to global GDP, understanding their economic interdependencies is critical in assessing EPUs and TPUs, particularly for US-China trade tension as a broader implication. The recent retaliatory tariff impositions, global supply chain disruption and uncertain responses by different economies made this an urgent need for an hour to understand where the economies are heading. While previous studies have explored the effects of policy uncertainty and trade disruptions, through these indexations, strategically strengthening economic interdependencies to enhance global economic scalability, sustainability, and trade resilience remains a crucial concern.

This paper seeks to bridge this gap by examining the scalable interconnectedness of these, which is influenced by various macro indicators and shapes a country's overall economic dynamics. Additionally, this paper intends to provide a comprehension section exploring how trade tension in US-China is escalating this uncertainty using the TPU index. Comprehensively, it aims to assess the implications of this economic connectedness for long-term economic sustainability, which is a need of the hour. Finally, this paper will suggest policy intervention measures to strategies and enhance economic interdependence while mitigating risks.

Materials and Methodology

Description of Variables and Database

The data used in this study comprised quarterly observations from 2000 to 2024. We refer to the updated data from the Economic Policy Uncertainty website for the EPU and TPU indexes. The other macroeconomic variables are taken from the Caixin Economic Information Centre (CEIC) database and the FRED (Federal Reserve Economic Data) database (see Table 1).

Table 1: Variable Descriptions

Variable	Description	Units	Source
gdp	GDP Growth Rate Y-o-Y	percentage	FRED
fdi	FDI Growth Rate Y-o-Y	percentage	CEIC
exp	Export Growth Rate Y-o-Y	percentage	CEIC
imp	Import Growth Rate Y-o-Y	percentage	CEIC
EPU	Economic Policy Uncertainty Growth Rate Y-o-Y	percentage	EPU website
TPU	Trade Policy Uncertainty Growth Rate Y-o-Y	percentage	EPU website

Ascertaining these uncertainty dynamics across these economies, the existing literature necessitates other key variables—foreign direct investment (FDI), trade flows (imports and exports), and real GDP—as critical determinants along with the EPU and the TPU index in shaping an economy (Ogbuabor et.al., 2020). Studies underscore the interconnectedness among these variables as well. For instance, a study highlighted that EPU adversely affects FDI inflows, particularly increases in domestic EPU, which significantly and adversely affect FDI inflows (Baker et al. 2020). Trade-related variables, such as imports, are significantly affected by policy uncertainty, which has been particularly evident from the Indian perspective. (Sharma and Paramati 2021). However, the study by (Lin and Bai 2021) finds that economic policy uncertainty, driven by asymmetric oil price shocks, has a more pronounced negative impact on exports in oil-exporting countries compared to oil importers.

Macroeconomic indicators like real GDP also play pivotal roles in shaping a country's economy (Melas et.al. 2025). Fluctuations in GDP growth can reflect underlying economic stability or volatility, affecting policy predictability (Melas et.al. 2025). Collectively, these variables provide a comprehensive framework for analyzing the multifaceted nature and overall economies' connectedness. Therefore, we considered the growth rates of these variables for our estimations.

Henceforth, this paper has undertaken a connectedness analysis using the TVP-VAR model to examine the total macroeconomic total connectedness among the selected economies, and ii) additionally Trade Policy Uncertainty (TPU) index has been considered to understand the US-China tension.

We assess stationarity using the Phillips-Perron test, confirming that all series are stationary. The VIF test confirms that there is no multicollinearity across the variables. Additionally, we checked stationarity using the Phillips-Perron test, confirming that all series are stationary. The VIF test confirms that there is no multicollinearity across the variables. For connectedness analysis, lag lengths are determined based on the Akaike Information Criterion (AIC) and Final Prediction Error (FPE) criteria. Table 3 reports the selected lag lengths for all the variables considered here.

The AIC balances model fit and complexity by rewarding models that achieve a good fit while imposing a penalty for including excessive parameters. In contrast, the FPE criterion minimizes forecasting errors, selecting the lag length that reduces prediction errors for out-of-sample data. Employing both criteria allows for a judicious selection of model specifications, ensuring that the model is neither overfitted nor underfitted, thereby enhancing the robustness and reliability of the results. Time-varying parameter vector autoregression

Table 2: Descriptive statistics and stationarity test results

Variable	Mean	Standard Deviation	Phillips Perron P-Value
China GDP growth rate	8.218	3.224	0.01
India GDP growth rate	6.744	4.410	0.01
US GDP growth rate	2.196	2.163	0.01
Germany GDP growth rate	1.136	2.741	0.01
China FDI growth rate	10.985	53.793	0.01
India FDI growth rate	31.344	94.515	0.01
US FDI growth rate	-11.273	434.0007	0.01
Germany FDI growth rate	22.285	539.968	0.01
China exports growth rate	13.533	15.780	0.01
India exports growth rate	14.938	17.253	0.01
US exports growth rate	5.161	11.886	0.01
Germany exports growth rate	5.073	9.171	0.01
China imports growth rate	13.201	17.809	0.01
India imports growth rate	16.640	22.299	0.01

US imports growth rate	5.425	11.923	0.01
Germany imports growth rate	5.070	11.016	0.01
China EPU growth rate	0.400	1.143	0.01
India EPU growth rate	0.188	0.844	0.01
US EPU growth rate	0.104	0.454	0.01
Germany EPU growth rate	0.280	0.744	0.01
China TPU growth rate	0.165	0.654	0.01
US TPU growth rate	0.570	1.731	0.01

Table 3: Lag Length Criteria

Variable	AIC lag value	FPE lag value
GDP growth rate	5	5
FDI growth rate	1	1
Exports growth rate	5	5
Imports growth rate	5	5
EPU growth rate	4	4
TPU growth rate	2	2

Methodology

We employ the connectedness framework developed by (Diebold and Yilmaz 2023) to achieve the objective, quantifying the spillovers and interdependencies among variables using forecast error variance decompositions. This approach is further extended through the dynamic connectedness methodology proposed by (Gabauer and Antonakakis 2017), which is based on a Time-Varying Parameter Vector Autoregression (TVP-VAR) model. The TVP-VAR framework allows us to capture evolving relationships and time-varying spillover effects that static models may fail to detect, especially during periods of heightened uncertainty or structural change.

The TVP-VAR model is expressed as follows:

$$W_t = \beta_t W_{t-1} + \varepsilon_t;\ \varepsilon_t, F_{t-1} \sim N(0, A_t) \quad (1)$$

$$\beta_{t=\beta_{t-1}+\nu_t;}\ \nu_t, F_{t-1} \sim N(0, B_t) \quad (2)$$

The array of data accessible at time t-1 is shown by $Ft{-}1$, where Wt denotes an N x 1 vector. The Np × 1 lagged array of dependent parameters is denoted by $Wt{-}1$. An N × Np time-varying coefficient matrix is indicated by βt. The N × 1-dimensional arrays of error terms are called εt and vt. For εt and vt, respectively, the variance-covariance matrices are N × N and Np × Np.

(Diebold and Yilmaz 2014) state that the generalized connectedness is estimated using time-varying variance-covariance matrices and time-varying coefficients.

The generalized forecast error variance decompositions (GFEVD) and generalized impulse response functions (GIRF) created by Koop et.al. (1996) serve as the foundation for the generalized connectedness approach. It is crucial to use the time-varying coefficients and error covariances to convert the time-varying-parameter vector-autoregressive model to its vector moving averages to estimate the GIRF and GFVED. Consequently, the equation is shown as follows:

$$W_t = \beta_t W_{t-1} + \varepsilon_t = Z_t \varepsilon_t \qquad (3)$$

An N × N variance-covariance matrix is represented by the matrix Zt (Z_1t, Z_2t, …Z_pt)′. The GFVED shows the pairwise directional connectivity from j to i, and the GIRFs show how each variable responded to a shock in variable i. The sum of these variances' accounts for 100% of the volatility in the variable's forecast error. Therefore, the forecast error variance can be written as follows:

$$\psi^g_{i\,j,t}(J) = \frac{\sum_{t=1}^{j-1} \psi^{2,g}_{i\,j,t}}{\sum_{j=1}^{N} \sum_{t=1}^{J-1} \psi^{2,g}_{i\,j,t}} \qquad (4)$$

The GFVED is used to build the Total Connectedness Index (TCI), which illustrates how a shock to one variable affects other variables and depicts the overall interconnectivity in the framework. The TCI can be expressed as follows:

$$C^g_t(J) = \frac{\sum^N_{i,j=1,i\neq j} \psi^g_{i\,j,t}(J)}{N} * 100 \qquad (5)$$

The equation for total directional connectedness, which moves from i to j, is expressed as:

$$C^g_{i\rightarrow j,t}(J) = \frac{\sum^N_{i,j=1,i\neq j} \psi^g_{i\,j,t}(J)}{\sum^N_{j=1} \psi^N_{i\,j,t}(J)} * 100 \qquad (6)$$

Or, the equation is written as follows when complete directional connectedness moves from j to i:

$$C^g_{i\leftarrow j,t}(J) = \frac{\sum^N_{i,j=1,i\neq j} \psi^g_{i\,j,t}(J)}{\sum^N_{j=1} \psi^N_{i\,j,t}(J)} * 100 \qquad (7)$$

Ultimately, we are determining the net total directional connectedness or the effect variable i have over the other variables:

$$C^g_{i,t}(J) = C^g_{i\rightarrow j,t}(J) - C^g_{i\leftarrow j,t}(J) \qquad (8)$$

If C_i,$(J) > 0$, the variable *i* is a transmitter, whereas if $Ci,tg(J) < 0$, the variable *i* is a receiver of spillover.

Results and Discussion

EPU

Our analysis of EPU growth connectedness across these four economies reveals a nuanced structure of cross-country spillovers shaped by the past two decades of global economic transformations. A TCI of 40.53% suggests that while domestic factors continue to dominate EPU dynamics, global events and policy actions have increasingly influenced the uncertainty landscape across these major economies (refer to Table 4).

Table 4: EPU Growth Connectedness

Variables	ChinaEPU	IndEPU	USEPU	GerEPU	FROM
ChinaEPU	"53.44"	"13.34"	"12.87"	"20.35"	"46.56"
IndEPU	" 9.43"	"48.34"	"31.31"	"10.92"	"51.66"
USEPU	"10.84"	"11.37"	"64.42"	"13.36"	"35.58"
GerEPU	" 7.69"	" 7.52"	"13.12"	"71.67"	"28.33"

TO	**" 27.96"**	**" 32.24"**	**" 57.30"**	**" 44.64"**	"162.13"
Inc.Own	" 81.40"	" 80.58"	"121.72"	"116.31"	"cTCI/TCI"
NET	**"-18.60"**	**"-19.42"**	**" 21.72"**	**" 16.31"**	**"54.04/40.53"**
NPT	"0.00"	"1.00"	"2.00"	"3.00"	""

The largest economy, the United States, stands out as the largest net transmitter of policy uncertainty shocks, with a *TO* value of 57.30 and a *NET* spillover of +21.72. This is consistent with its status as the global economic hegemon, where monetary policy shifts by the Federal Reserve, fiscal debates around the debt ceiling, and trade policy decisions—especially during the Trump administration's trade war with China—have had ripple effects globally (Evans 2019). The 2008 Global Financial Crisis, the taper tantrum of 2013, and recent monetary tightening in response to post-COVID inflation all exemplify the U.S.'s dominant role in generating global EPU.

Germany also emerges as a significant transmitter (NET = +16.31). Events such as the 2010–2012 Eurozone debt crisis, Germany's leadership in EU fiscal policy, and uncertainties surrounding the post-Brexit EU trade environment have positioned it as a policy influencer within and beyond Europe. Its strong industrial base and export-oriented model link it closely with global demand cycles, amplifying its capacity to transmit policy signals.

In contrast, China and India appear as net receivers of policy uncertainty, with NET values of –18.60 and –19.42, respectively (refer to Table 4). China's position is particularly notable given its economic rise over the past two decades. However, while China's domestic EPU has increased due to internal policy shifts, such as regulatory crackdowns on tech and real estate sectors and zero-COVID policies, it still absorbs more external uncertainty than it transmits. This could be due to its managed exchange rate regime, capital controls, and relatively closed financial system, which dampen outward policy spillovers despite its global trade presence (L. Liu 2022).

India's net receiver status reflects its transitional position in the global economy. Though increasingly integrated through trade and capital markets, India's domestic policy remains more reactive to external shocks—such as oil price volatility, U.S. Fed policy, and global geopolitical tensions—than it is a source of global uncertainty.

The net pairwise transmission (NPT) metrics further reflect developed–developing asymmetries. Germany, with NPT = 3.00, and the U.S. (NPT = 2.00) have broader transmission footprints, while China (NPT = 0.00) and India (NPT = 1.00) show limited outward spillovers (refer to Table 4). This dichotomy emphasizes structural differences: developed economies, with globally exposed financial markets and institutionalized policy frameworks, tend to export policy shocks; emerging economies, by contrast, remain more vulnerable to global volatility due to weaker shock-absorption mechanisms and policy credibility constraints.

Import

The import growth connectedness among China, India, the United States, and Germany underscores the evolving nature of global trade dynamics, and import is significantly influenced by this, with a TCI of 61.58%, indicating that more than half of the variation in import growth is influenced by cross-country spillovers. This high level of interconnectedness reflects the increasing integration of global value chains over the past two decades, driven by trade liberalization, technological advancements, and shifting geopolitical alliances.

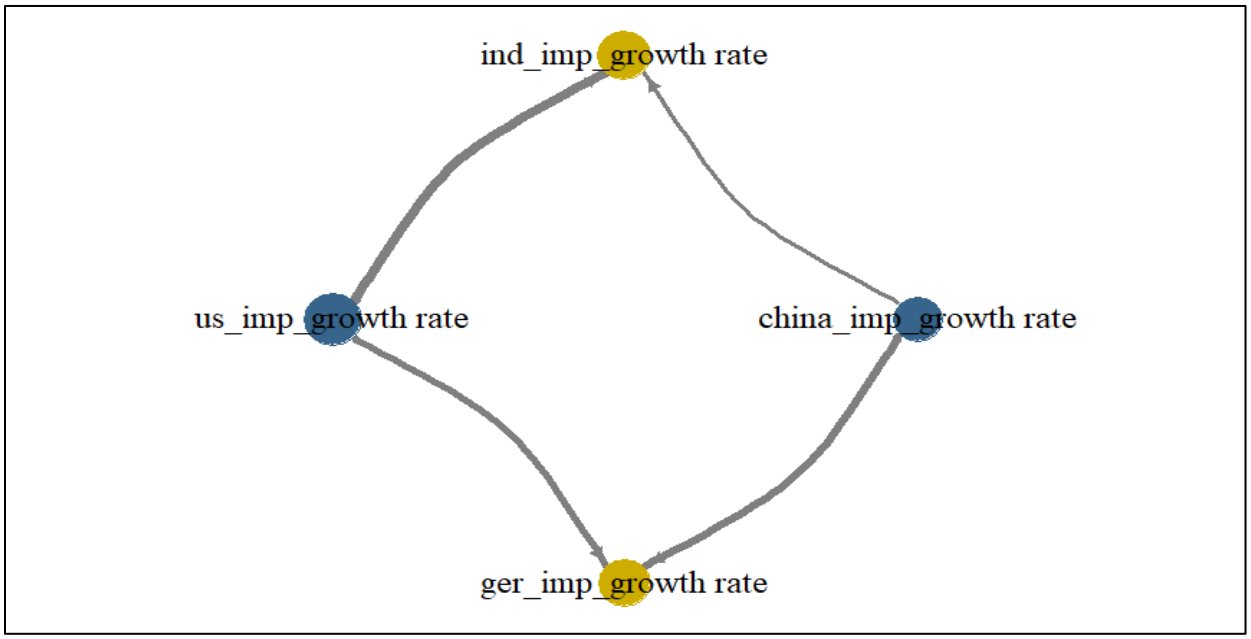
Table 5: Import Growth Connectedness

Variables	china_imp	ind_imp	us_imp	ger_imp	FROM
china_imp	"45.96"	"12.72"	"32.47"	" 8.86"	"54.04"
ind_imp	"23.59"	"35.05"	"34.29"	" 7.08"	"64.95"
us_imp	"32.96"	" 8.75"	"42.37"	"15.93"	"57.63"

ger_imp	"29.34"	" 4.54"	"35.81"	"30.30"	"69.70"
TO	**" 85.89"**	**" 26.01"**	**"102.57"**	**" 31.86"**	"246.33"
Inc.Own	"131.85"	" 61.06"	"144.94"	" 62.16"	"cTCI/TCI"
NET	**" 31.85"**	**"-38.94"**	**" 44.94"**	**"-37.84"**	**"82.11/61.58"**
NPT	"3.00"	"0.00"	"2.00"	"1.00"	""

The U.S. emerges as the most significant net transmitter of import shocks, with a TO value of 102.57 and a net spillover of +44.94, suggesting that fluctuations in the U.S. (refer to Table 5) import growth have widespread effects on other economies. This shock is transmitted to India and Germany, with India receiving shocks at greater intensity than Germany (see Figure 3). This can be traced to its consumption-led growth model, which has high demands for intermediate and finished goods from global suppliers but better footholds in the service sector. Closely following the U.S., China also acts as a net transmitter (NET = +31.85), reflecting its transformation from an import-dependent economy to one that influences global trade flows through its dominant role in manufacturing and intermediate goods export.

Figure 3: Import Growth Net Transmitter and Net Receiver Network Plot



Authors' compilation

The U.S. and China's outward spillovers indicate that their domestic trade and policy decisions, including tariff shifts, supply chain restructuring, and investment cycles, significantly shape import behavior in partner economies (see Figure 3). In contrast, India and Germany are net recipients of shocks, with NET values of –38.94 and –37.84, respectively, which reflects their greater sensitivity to global trade conditions from both the U.S. and China. China transmits fewer shocks to India than it does to Germany, which is the opposite of the pattern seen with the U.S. (see Figure 3). This is linked to India's dependency on the Global North for importing commodities, particularly oil, and its susceptibility to exchange rate volatility and global interest rate movements. Despite being a major exporter, Germany's vulnerability arises from its reliance on raw materials and components imported majorly from China.

The asymmetry becomes more apparent when examining net pairwise transmission (NPT): China (3.00) and the U.S. (2.00) influence most other economies, whereas Germany (1.00) and India (0.00) have minimal outward spillovers

(refer to Table 5). This imbalance reflects a structural divergence, where the advanced economies, particularly the U.S., retain dominant positions in trade-related influence. In contrast, China's rising influence signals a shift in the global trade power structure. Meanwhile, India's passive role suggests that although it is increasingly integrated into the global economy, it has yet to exert a comparable influence on others' import behavior. Thus, the observed pattern not only highlights the hierarchical nature of global trade networks but also signals the importance of diversifying import sources and strengthening domestic capacities to manage external shocks effectively.

Export

Export, being one of the most determinant factors having significant influence over an economic trade basket, shows us that the TCI among these economies is 59.68, suggesting that nearly 60% of the fluctuations in export growth across these major economies are driven by mutual linkages, underlining the intricate web of global demand, production networks, and policy shifts over the last two decades.

India emerges as the most prominent net transmitter of export shocks, with a net spillover value of +35.79 and a TO contribution of 79.08, indicating its increasingly outward-oriented trade structure (refer to Table 6). Over the years, India has diversified its export base—from traditional goods to pharmaceuticals, IT services, and engineering products—gaining a stronger foothold in both developed and developing markets (Malik & Velan 2020; Chakraborty 2020). This strategic reorientation, along with policy reforms and trade agreements in the Indo-Pacific, has allowed India to exert a growing influence on the export behavior of other nations.

Table 6: Export Growth Connectedness

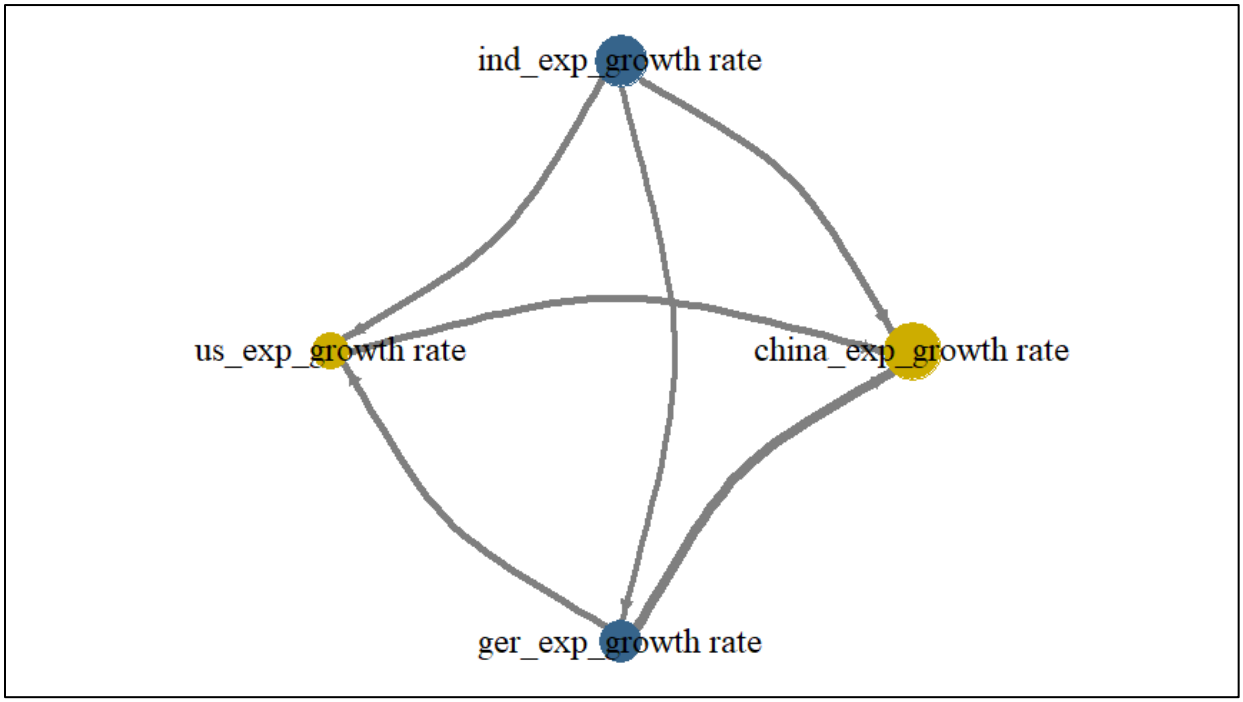
Variables	china_exp	ind_exp	us_exp	ger_exp	FROM
china_exp	"24.62"	"23.11"	"28.02"	"24.25"	"75.38"
ind_exp	" 9.46"	"56.71"	"17.61"	"16.22"	"43.29"
us_exp	"14.71"	"30.34"	"27.07"	"27.88"	"72.93"
ger_exp	" 6.85"	"25.63"	"14.64"	"52.87"	"47.13"
TO	**" 31.02"**	**" 79.08"**	**" 60.27"**	**" 68.35"**	"238.72"
Inc.Own	" 55.64"	"135.79"	" 87.35"	"121.22"	"cTCI/TCI"
NET	**"-44.36"**	**" 35.79"**	**"-12.65"**	**" 21.22"**	**"79.57/59.68"**
NPT	"0.00"	"3.00"	"1.00"	"2.00"	""

Germany also acts as a moderate net transmitter (NET = +21.22), reflective of its deeply integrated position in the European and global manufacturing value chain. Germany's export strength, particularly in automobiles, machinery, and chemicals, often responds to and shapes global investment and consumption trends. The country's significant TO value of 68.35 confirms its responsiveness to international shifts while also suggesting its influence on trade partners, especially during periods of cyclical upturns or industrial transitions.

In contrast, China and the United States are identified as net recipients of export shocks, with NET values of –44.36 and –12.65, respectively (see Figure 4). China plays a major role in global trade, but its smaller impact in spreading export shocks in recent years suggests it has been more reactive. This may be due to events like the U.S.-China trade war, COVID-19 lockdowns, and recent geopolitical changes affecting its trade patterns. Also, China is receiving shocks from all these partners with significant intensity, and more from Germany. This could be a prominent reason when the European Union has intensified scrutiny over China's manufacturing practices, particularly concerning overcapacity in sectors like electric vehicles (EVs) and steel. In 2023, the EU initiated anti-dumping investigations into Chinese products, including EVs and tinplate steel (Bown 2024). Overall, companies worldwide are adopting a "China+1" strategy, diversifying their supply chains to reduce dependence on China and finding avenues for resilient

trading partners for long-term sustainability (Iida 2024; Shih et.al. 2025). This shift is influenced by geopolitical tensions and the desire for more resilient supply networks, impacting China's export dynamics.

Figure 4: Export Growth Net Transmitter and Net Receiver Network Plot



Authors' compilation

The U.S., while still a major trade player, appears to be absorbing more external shocks than it emits, pointing to vulnerabilities linked to shifting global demand and domestic policy uncertainty. The U.S. is mainly receiving shocks from India and Germany, not China. This portrays the US as less dependent on China and more focused on diversifying its trade partners from China to other stable and resilient trade partners, and Mexico is one of its largest trading partners (see Figure 4).

The NPT values further reinforce these distinctions—India (3.00) and Germany (2.00) influence most other economies, whereas China (0.00) and the U.S. (1.00) play a less dominant role in exporting shocks. This pattern reflects a changing landscape where emerging economies like India are beginning to shape global trade flows more actively and are becoming more resilient trade partners.

FDI

The FDI growth rate of connectedness among China, India, the U.S., and Germany reveals a relatively weak interlinkage compared to other macroeconomic indicators like trade or policy uncertainty. The TCI stands at a modest 8.00, suggesting that domestic factors rather than cross-country spillovers largely influence FDI flows. All four economies show high levels of own shocks—over 86% in each case—with minimal outward influence, especially for India and the U.S. *TO* values are only 3.68 and 4.81, respectively (refer to Table 7).

Table 7: FDI Growth Connectedness

Variables	China FDI growth rate	India FDI growth rate	US FDI growth rate	Germany_fdi growth rate	FROM

China FDI growth rate	"90.14"	" 1.79"	" 2.50"	" 5.57"	" 9.86"
India FDI growth rate	"11.02"	"86.40"	" 0.88"	" 1.70"	"13.60"
US FDI growth rate	" 1.55"	" 0.38"	"95.19"	" 2.88"	" 4.81"
Germany_fdi growth rate	" 0.77"	" 1.51"	" 1.43"	"96.29"	" 3.71"
TO	**"13.35"**	**" 3.68"**	**" 4.81"**	**"10.15"**	"31.99"
Inc.Own	"103.49"	" 90.08"	"100.00"	"106.44"	"cTCI/TCI"
NET	**" 3.49"**	**"-9.92"**	**" 0.00"**	**" 6.44"**	**"10.66/8.00"**
NPT	"1.00"	"0.00"	"2.00"	"3.00"	""

This weak connectedness may stem from the fact that FDI is often driven by country-specific regulatory regimes, geopolitical risks, and sectoral strategies rather than short-term macroeconomic trends. In sum, the analysis points to the localized nature of FDI decisions, making it structurally less responsive to global macroeconomic shocks compared to trade or uncertainty-related variables.

GDP

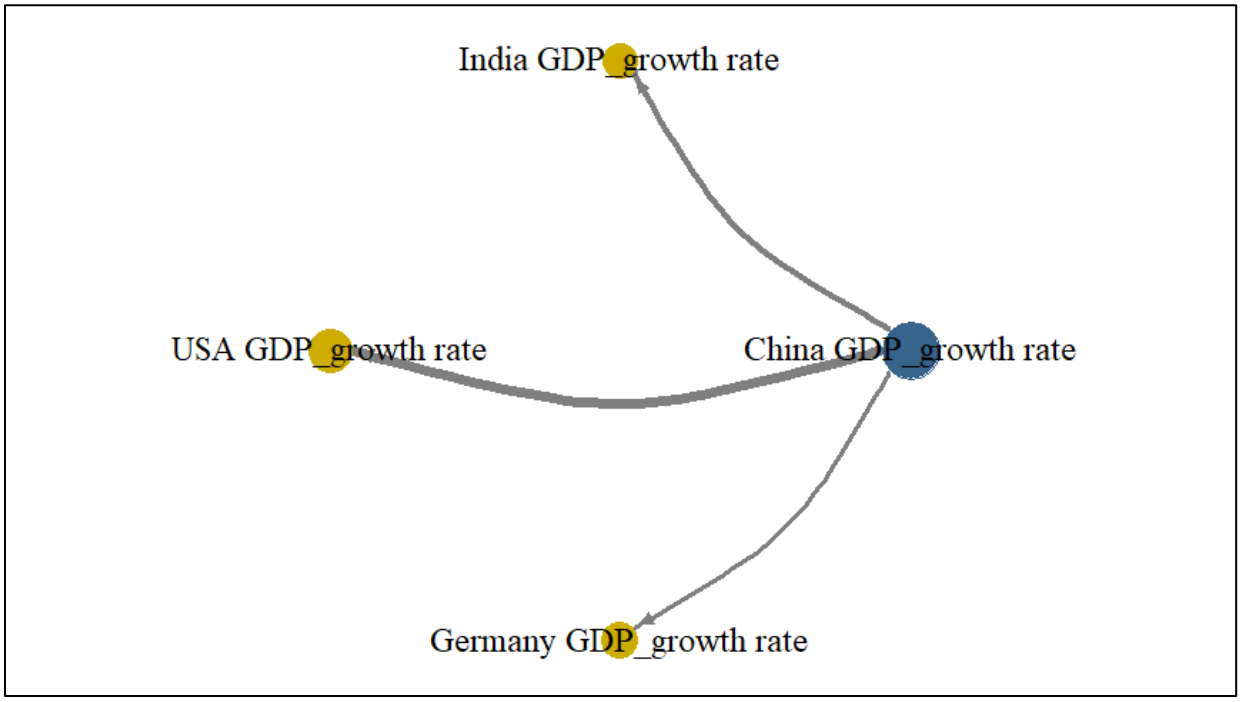
The GDP, which acts as the bigger umbrella encompassing other macro elements, reveals notable asymmetries in the transmission and reception of economic shocks (refer to Table 8). Based on our analysis, the TCI stands at 58.26, indicating that more than half of the variation in GDP growth across these economies stems from cross-country spillovers rather than domestic shocks alone. This moderate-to-high level of interconnectedness underscores the growing interdependence of the global economy, particularly among large and strategically positioned countries.

Table 8: GDP Growth Connectedness

Variables	China GDP	India GDP	USA GDP	Germany GDP	FROM
China GDP	"64.72"	" 9.61"	" 9.39"	"16.28"	"35.28"
India GDP	"25.11"	"38.28"	"13.03"	"23.57"	"61.72"
USA GDP	"34.78"	"15.43"	"34.31"	"15.48"	"65.69"
Germany GDP	"28.94"	"25.09"	"16.34"	"29.63"	"70.37"
TO	**" 88.83"**	**" 50.14"**	**" 38.76"**	**" 55.33"**	"233.06"
Inc.Own	"153.54"	" 88.42"	" 73.08"	" 84.96"	"cTCI/TCI"
NET	**" 53.54"**	**"-11.58"**	**"-26.92"**	**"-15.04"**	**"77.69/58.26"**
NPT	"3.00"	"2.00"	"1.00"	"0.00"	""

China emerges as the dominant transmitter of GDP growth shocks, with 64.72% of its growth driven by domestic factors and a substantial 88.83% of shocks transmitted to others (refer to Figure 5). This shock transmission from China to the rest of these economies has different intensities – the US exhibits as the major receiver here (Figure 5). This brings the talks to the plate about China being the world's largest manufacturing hub and the largest exporter of more than 120 countries (Kroeber 2020). Its net spillover score of +53.54 signals a strong systemic influence, likely driven by its expansive trade footprint, investment flows, and rising geopolitical clout. In contrast, India is more dependent on external policy uncertainty, with 61.72% of its GDP growth influenced by foreign shocks and a net spillover score of –11.58. This positions India as a net receiver, highly influenced by the global economy and deeply interconnected value chain tension, albeit without the same influence as China.

Figure 5: GDP Growth Net Transmitter and Net Receiver Network Plot



Authors' compilation

Surprisingly, the United States and Germany, traditionally seen as global economic anchors—are also net receivers of growth shocks, with net scores of –26.92 and –15.04, respectively. Our analysis shows that the USA transmits only 38.76% of shocks while receiving 65.69%, suggesting a shift in global dynamics where external vulnerabilities counterbalance its influence. Recent structural adjustments, such as global value chain shifts, oil price shocks and tariff tensions, reflect these dynamics. Germany also acts as a net receiver (NET = –15.04), with a *FROM* value of 70.37% and a *TO* value of 55.33% (Picciolo et.al. 2017; Tunc et.al. 2022), indicating strong exposure to external economic conditions, particularly due to its deep entrenchment in EU trade dynamics and its export-driven economy (refer to Table 4).

These findings highlight a clearly developed–developing dichotomy. While China, a developing economy, increasingly transmits shocks outward, developed economies like the USA and Germany appear more reactive to global trends.

TPU

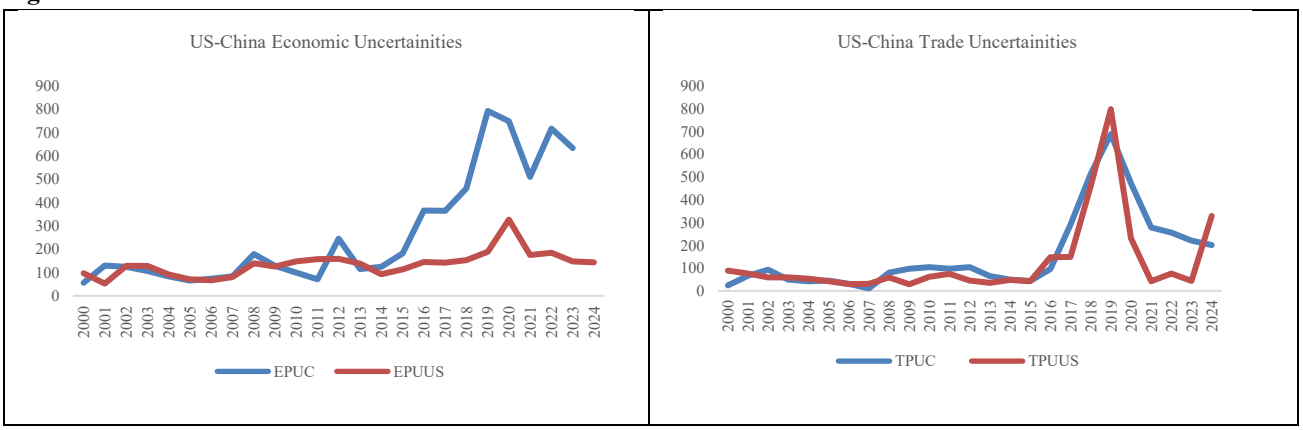
The bilateral trade policy uncertainty (BTPU) connectedness between the United States and China reveals a distinctly asymmetric structure, with China emerging as the dominant transmitter of TPU shocks. The connectedness matrix shows that 20.29% of U.S volatility is driven by China, while only 8.63% of China's TPU is driven by U.S. shocks. The net connectedness score confirms this imbalance, with China acting as a net transmitter (+11.65) and the U.S. as a net receiver (–11.65) (refer to Table 9). These dynamics indicate that Chinese trade policy actions have had a larger influence on U.S. TPU than vice versa, challenging the conventional view that the U.S. is the global primary driver of trade policy uncertainty.

Table 9: TPU Growth Connectedness

Variables	USTPU	ChinaTPU	FROM
USTPU	"91.37"	" 8.63"	" 8.63"
ChinaTPU	"20.29"	"79.71"	"20.29"
TO	**"20.29"**	**" 8.63"**	"28.92"
Inc.Own	"111.65"	" 88.35"	"cTCI/TCI"
NET	**" 11.65"**	**"-11.65"**	**"28.92/14.46"**
NPT	"1.00"	"0.00"	""

This pattern is economically significant and reflects real-world developments over the past two decades (see Figure 6). China's rising outward policy spillovers are underpinned by structural shifts such as the Belt and Road Initiative launch, export control reforms, and increased use of state-directed trade policy tools. Most notably, the prolonged U.S.-China tariff war, initiated in 2018 and continuing through subsequent administrations, has created cumulative waves of TPU. U.S. tariffs on Chinese goods—especially in tech and manufacturing—have been met with retaliatory tariffs from China, impacting global supply chains and generating uncertainty in bilateral trade and third-country markets. These developments have intensified U.S. trade exposure and heightened domestic TPU.

Figure 6: US-China Uncertainties Tension



Authors' compilation, Source: TPU Index website

Precisely for this reason, the United States—along with several other economies intricately linked to the China-centered value chain—has increasingly pursued trade diversification strategies to enhance economic resilience and long-term sustainability. The rising unpredictability driven by bilateral trade tensions and policy shifts has compelled nations to reassess their overreliance on single-country trade dependencies. In this context, diversifying trade partnerships has become not just a strategic choice, but an economic imperative. As trade uncertainty directly affects investment decisions, supply chain stability, and inflationary pressures, managing trade-related risks has moved to the forefront of policy agendas. Consequently, trade risk management is no longer a peripheral concern but a core pillar of macroeconomic planning, requiring sustained focus from policymakers. It is essential for safeguarding national interests and fostering a more balanced, shock-resistant economic structure.

The NPT scores—0.00 for China and 1.00 for the U.S.—indicate that TPU flows mainly from China to the U.S., underscoring China's growing influence as a policy transmitter in global trade. This directional uncertainty significantly shapes the broader EPU in both countries. As a key transmission channel, TPU affects trade expectations, macroeconomic forecasts, investment decisions, and fiscal strategies. In the context of the prolonged U.S.-China trade tensions, TPU has become a critical driver of EPU, with far-reaching implications for global economic sentiment.

Conclusion and Policy Implications

We capture the evolving patterns of macroeconomic connectedness among China, India, the United States, and Germany. The central motivation stems from the growing volatility in global markets, shaped by geopolitical tensions, trade wars, and economic policy shifts. Thus, this study proposed and explored the scalability and intensity of economic connectedness under macros and policy uncertainties, its implications for economic sustainability, and the policy strategies that have historically enhanced interconnectedness and resilience. By applying a TVP-VAR framework, we captured time-varying, variable-specific transmission patterns, highlighting how major economies alternate between transmitting and absorbing shocks over time. While our findings contribute to the literature by highlighting nuanced heterogeneity in shock transmission patterns, with the scalable intensity that each shock transmission exhibits among them.

While EPU shock transmission is dominated by the U.S., and China is at the receiving end, contradicting to TPU transmission pattern between them. This implies that though China maintains a strong position in global exports, policy uncertainty primarily originates from the United States, contributing to greater volatility in its economic environment. The U.S. is actively reshaping its trade policies to be a secure trade partner, and thereby emerging as a key transmission of EPU shock. For GDP growth, China acts as the dominant transmitter, while the U.S. is the primary receiver, reflecting China's expanding global economic influence. In contrast, FDI flows show weak interdependence, likely due to differing investment regimes and country-specific risks. Trade flow analysis challenges traditional assumptions: the U.S. leads in transmitting import shocks, but India and Germany emerge as net exporters transmitting shocks, highlighting their increasing integration into global value chains. EPU findings align with the traditional shocks transmission pattern from developed to developing, shaping global policy sentiment. Interestingly, as explained, TPU dynamics defy expectations—China is the major transmitter to the U.S., a pattern shaped by recent trade tensions and decoupling trends, elevating EPU in both economies, revealing the intricate link between trade policy and broader economic volatility.

These findings carry significant policy implications. First, emerging economies such as India must continue diversifying trade partners and reducing overreliance on a few dominant blocs. Targeting the five trillion economies, such a strategy will make India a stable economy with less reliant on volatile markets. Although India already possesses a broad trade network, enhancing its resilience through strategic engagements in regional and plurilateral agreements like RCEP and EU-India FTA talks will provide vital buffers against policy-induced shocks. India's diversified trade network reduces its dependence on high-risk economies and positions it as a stable and resilient trade partner in this integrated value chain.

Second, in response to rising TPU, especially emanating from protracted bilateral conflicts like the U.S.–China trade war, countries must adopt strategies that lower exposure to volatile trade relationships. For instance, the recent reciprocal tariff impositions between the U.S. and China and China's immediate non-cooperate response to it have intensified trade frictions by amplifying protectionist policies and destabilizing global supply chains. Consequently, nations should diversify their export-import portfolios and strengthen ties with economically and politically stable partners. Third, policymakers should prioritize value chain diversification in critical sectors, including semiconductors, pharmaceuticals, critical minerals and renewable energy technologies. Investing in domestic capabilities, promoting nearshoring, and fostering south-south cooperation can help maintain continuity in production and trade during global disruptions.

Future research should aim to explore the interconnectedness among a broader set of global economies. Such analysis can offer valuable insights into the underlying factors influencing these connectedness indices. Additionally, researchers are encouraged to incorporate a wider range of variables, such as geopolitical tensions, voluntary export restrictions, and international trade agreements, to better understand their roles in shaping the evolving landscape of trade and policy uncertainty. This broader approach will enrich the understanding of how diverse shocks propagate across economies and influence macroeconomic stability.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used ChatGPT and Grammarly in order to help with language, and grammar. After using these tools/services, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Data availability

Data will be made available on request.

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