This paper empirically examines how sectoral co-movement are correlated with trade credit usage in a multi-region setting. Extending the models in Shea (2002) and Raddatz (2010), we develop a framework that captures the impact of trade credit usage on co-movement between sectors within a country and cross countries separately. Using the Multi-Regional Input-Output Table developed by Asian Development Bank, we assemble a dataset consisting of 14 manufacturing industries for 53 countries. We provide empirical evidence that trade credit linkage is an influential channel for both the domestic and cross-border shocks to propagate and to create a more profound impact in industries around the globe. We find the impact of domestic credit chain on sectoral co-movement is twice as strong as the international ones. We further examine the time trend of this relationship, and find that from 2000 to 2018, the positive relationship between the intensity of trade credit usage and sectoral correlation decreases. We posit that this could be due to a more diversified global trade pattern changes during these two decades.

Key words: trade credit, credit chain, sectoral co-movement, Input-Output Table, systemic risk

1. Introduction

As the volume of global trade nearly quadrupled over the last two decades, the global supply chain becomes increasingly interconnected. While such interconnection allows companies to lower cost, it also results co-movement across different sectors and regions. Consequently, a shock originates from one specific sector or one geographic region could cascade to different sectors across the globe. For example, in 2011, Thailand experienced severe flooding during the monsoon season. In addition to hundreds of deaths, the floods also caused tremendous economic damages. The damages are mostly due to the disruption in the manufacturing industry, where several industrial estates were inundated in water as much as 3 meters deep during the flood. These industrial estates host a large amount of global production capacity in a few sectors. For example, as the second largest hard disk drives producer in the world, Thailand produced approximately a quarter of total hard drives in
the world. As many of these factories were flooded, it caused a global hard drive shortage, pushing up hard drive prices and affecting the profitability of downstream sectors. Such shocks propagated far beyond Thailand. As Japanese companies such as Canon, Honda, and Toyota all produce a large share of products and/or components in Thailand, the flood has negatively influenced not only these companies’ profit, but also worker incomes in Japan.

Natural disaster is only one type of shocks that demonstrate how the global supply chain are intertwined. Other shocks, from the Global Financial Crisis in 2008 to the Covid-19 pandemic, all highlighted that sectors and regions are closely linked by the flow of physical goods. In addition to such physical flow, different sectors and regions also experience co-movement due to the financial flow in between. One of the most important financial linkage between companies within supply chains is trade credit. Trade credit (credit extended by sellers to buyers in supply chains) is one of the most important sources of external financing around the world (Rajan and Zingales 1995). For example, in the United States, trade credit amounted to $5.4 trillion in 2019, with its growth outpacing that of GDP (Federal Reserve Board 2019). Thus, it is a financial instrument with macroeconomic significance.

Trade credit creates credit chains across firms in different sectors of the economy (Kiyotaki and Moore 1998). That is, different sectors in the economy are not only linked through business transactions (sellers and buyers of products and service), but also financially by providing and receiving trade credit from each other. An important implication of such credit chains is that trade credit could serve as an additional channel that links different sectors together. Thus, it is natural to hypothesize that the intensity of trade credit usage has a positive influence on sectoral correlation. Put differently, if sector A (buyer) receives a lot of trade credit from sector B (supplier), then a shock in sector A could translate into a larger shock in sector B relative to those sector pairs with less trade credit in between.

The above hypothesis was first confirmed empirically by Raddatz (2010) by combining standard input-output matrix from US Bureau of Labor Statistics and firm financial data from WorldScope and CompuStat. However, due to data limitation, a few questions remains unanswered in the paper: first, without a multi-region input and output matrix, Raddatz (2010) studies exclusively transactions within each country. Thus, it is unclear whether such credit chains act differently for domestic and international trade. Second, Raddatz (2010) focuses on a single time period in the early 2000s. However, the development of global supply chain in the last two decades begs the question whether the dynamics between credit chain and sectoral co-movement has changed over time. Finally, as an increasingly important powerhouse of the global economy, do the Asia countries exhibit any special patterns?
To answer the above questions, in this paper, we first extend the model in Shea (2002) and Raddatz (2010) to decompose the impact of trade credit usage on sectoral co-movement by domestic and cross-border trade. Specifically, our model allows the shock propagation via domestic credit chains has a different rate from that via cross-border chains. This allows us to empirically examine whether within- and cross-country credit chains have different impact on sectoral co-movement.

We then construct a new dataset to identify these two effects. Specifically, we triangulate the financial data from Compustat and Worldscope, the input-output table from the Multi-Region Input-Output (MRIO) Database developed by the Asian Development Bank, and growth rate of real value added using the Industrial Statistics database (INDSTAT) developed by the Industrial Development Organization under the United Nations (UNIDO) and the consumer price index (CPI) from World Bank, and construct a data set that consists of 14 industries from 53 countries.

Our empirical results suggest that the use of trade credit indeed have a positive correlation with sectoral co-movement. The intensity of such correlation via the domestic credit chain is twice as strong as that via the cross-border credit chain. The results are robust to training and the change of time windows in computing sectoral correlations.

Further, we examine how the correlation between trade credit usage and sectoral co-movement evolves throughout time by using different MRIO data at 2000, 2007, 2013, and 2018. We find that both the positive relation between trade-credit usage intensity and correlations decreases. We posit that this could be due to a more dissected supply chain structures that enables industries to diversify their production as well as trade credit linkage intensity from a domestic based to foreign based. By ruling out a number of plausible explanations, we provide robust empirical support to our hypothesis.

Finally, similar to Raddatz (2010), we investigate the interaction between bank credit and trade credit, with a special focus on whether such interaction is different between Asian countries and the rest of the world. We find that while the availability of bank financing does not help mitigate risk propagation in the rest of the world, it does help when both parties in the transaction are located in Asia, including domestic trade within an Asian country, or cross-border trade between two Asian countries.

Our paper contributes to two strands of research: trade credit and sectoral co-movement. There is a rich literature on trade credit, both theoretical and empirical. The theoretical literature of trade credit focuses on explaining the existence of trade credit, that is, why buyers borrow money from sellers in the presence of specialized financial institutions. This literature dates back to at least in the 1950s, when Meltzer highlights that trade credit is used as an effective marketing tool. Following research identified various reasons why trade credit is adopted, such as suppliers having easier access to financing (Schwartz 1974), price discrimination (Brennan et al. 1988), quality assurance
(Long et al. 1993, Babich and Tang 2012), alleviating moral hazard (Burkart and Ellingsen 2004), facilitating relationship specific investment (Cuñat 2007), demand risk-sharing (Kouvelis and Zhao 2012, Yang and Birge 2018), softening competition (Peura et al. 2017).

Relative to the theoretical literature, the empirical literature of trade credit is relatively new, which is largely attributable to data limitation. Earlier research in this field focuses on validating theories of trade credit and identifying determinants of trade credit, such as Petersen and Rajan (1997), Ng et al. (1999) and Giannetti et al. (2011). In a developing setting, McMillan and Woodruff (1999) document that trade credit is closely related to relationship building. Fisman and Love (2003) find that trade credit access could facilitate industry growth. Boissay and Gropp (2013) and Jacobson and Von Schedvin (2015) quantify how trade credit default cascades along the supply chain. Lee et al. (2018) and Chod et al. (2019) examine the interaction between trade credit usage and the horizontal relationship between firms. Most recently, several studies focused on identifying the causal relationship between trade credit and operational and financial performance. Barrot (2016) shows that limiting trade credit provision improves the financial strength of upstream firms; Breza and Liberman (2017) and Chen et al. (2020), on the other hand, find that restricting trade credit provision reduces transaction volume between different firms and negatively affect downstream firms’ investment and revenue.

On the other hand, sectoral co-movement is an important topic in macroeconomics. Macroeconomics model are in general concerned with business cycles, both correlated movements in economy-wide output over time and co-movement between sectors (Lucas 1995). Long Jr and Plosser (1983) develop a multi-sector economy to capture shocks moving along input-output linkages. The model is further extended by Shea (2002). Lilien (1982) points out that labor movement could be another source of linkage between sectoral co-movement. Cooper and Haltiwanger (1990) develop a dynamic model to capture the sectoral co-movement with inventory and offer empirical evidence to support their theory.

Combining the above two streams of work, Kiyotaki and Moore (1998) is the first to formalize the idea of credit chain, that is, different sectors are linked financially. This model is further extended by Cardoso-Lecourtois (2004) and Boissay (2006). These literature highlight that through trade credit, sectoral shocks can move both from upstream to downstream, but also the other way around. Finally, Raddatz (2010) provide empirical evidence that the usage of trade credit does have a material impact on sectoral co-movement.

Our paper extend Raddatz (2010) in three aspects: first, we extend the model in Raddatz (2010) to distinguish domestic and international trade. Second and relatedly, using the multi-regional input-output table developed by Asian Development Bank, we empirically quantify the impact of
trade credit on sectoral co-movement for domestic and international transactions separately, revealing that such impact is stronger within country than cross-border trade. Finally, unlike Raddatz (2010), which documents results from one year due to data limitation, we conduct the empirical analysis over nearly two decades. This longitude analysis shows the aforementioned impact change over time, implying important trend in global supply chain.

2. The Model

This section extends the model in Raddatz (2010) that examines the intra-country sectoral co-movement to analyze the sectoral co-movement not only within but also cross various countries. To do so, we consider an economy comprised of \(J\) sectors (indexed by subscripts \(i\) and \(j\)) and \(N\) countries (indexed by superscripts \(n\) and \(m\)). Following the notation in Raddatz (2010), we represent sectoral output fluctuations for sectors 1 to \(J\) at countries 1 to \(N\) in the following reduced form:

\[
y = By + \lambda. \tag{1}
\]

In the above equation, \(\lambda\) is also a \((JN) \times 1\) vector consists of elements \(\lambda^m_i\) for \(i = 1, ..., J\) and \(m = 1, ..., N\), where \(\lambda^m_i\) represents the sectoral shocks for sector \(i\) at country \(m\). \(B\) is a \((JN) \times (JN)\) matrix with elements \(b^m_{ij}\) representing the share of total demand faced by sector \(i\) in country \(m\) (the supplier) directly attributable to sector \(j\) in country \(n\) (the customer). Combined, \(y\) is a \((JN) \times 1\) vector with elements \(y^m_i\) for \(i = 1, ..., J\) and \(m = 1, ..., N\), where \(y^m_i\) represents the sectoral output fluctuations for sector \(i\) at country \(m\).

To build trade credit into the model, denote \(P^m_{ij} \in [0, 1]\) as the fraction of direct demand \(b^m_{ij}\) supplied by trade credit. Thus, we have:

\[
b^m_{ij} = P^m_{ij}b^m_{ij} + (1 - P^m_{ij})b^m_{ij}. \tag{2}
\]

If trade credit has an additional effect on the transmission of shocks (let the impact coefficient be \(\alpha^m_{ij}\)), the coefficient of direct linkages would be \(b^m_{ij}(1 + \alpha^m_{ij} P^m_{ij})\), in which we have a maximum of \((JN)^2\) different \(\alpha^m_{ij}\).

To ensure that the model is tractable and that it could fits with data for estimation, we make the following two assumptions.

**Assumption 1.** \(P^m_{ij}\) is constant across suppliers. That is, \(\forall i\) and \(m\), \(P^m_{ij} = P^m_j\).

**Assumption 2.** \(\alpha^m_{ij} = \alpha^m_{i} := \alpha^D\) and \(\alpha^m_{ij} = \alpha^m_{i} := \alpha^F\) for \(n \neq m\).

Assumption 1 is similar to Raddatz (2010). Here, we assume that \(P^m_{ij}\) is constant across suppliers regardless of which sector they are selling to and which country the customers are located at. This assumption allows us to allocate trade credit received by a customer to be proportionally allocated.
to all its suppliers, as a firm only report the aggregated trade credit (account payables) it receives from all suppliers. With this assumption, \( \forall i, \forall m P_{ij}^{mn} = P_j^n \). After (A1), we have reduced \( P_{ij}^{mn} \) (and therefore \( \alpha_{ij}^{mn} \)) to \( JN \).

Assumption 2 states that we only distinguish between domestic (\( D \)) and cross-border (\( F \)) trade credit. With Assumption 2, we can separate the effects of domestic and cross-border trade credit, that is,

\[ B = B^D + B^F, \]

where \( B^D \) captures domestic trade and \( B^F \) captures cross-border trade. Let \( P \) be a diagonal matrix with elements \( P_j^n \), we then can rewrite Eq. (2) as:

\[ B(I + \alpha P) = B^D(I + \alpha^D P) + B^F(I + \alpha^F P). \]  

Define \( JN \times JN \) matrix \( A(\alpha, B, P) \) as

\[ A = [I - B(I + \alpha P)]^{-1} \]

\[ = [I - B^D(I + \alpha^D P) - B^F(I + \alpha^F P)]^{-1} \]

We can then write \( y \) as

\[ y = B(I + \alpha P)y + \lambda = A(\alpha, B, P)\lambda, \]

Taking a linear approximation to \( A \) around \( \alpha^D = 0 \) and \( \alpha^F = 0 \), we obtain:

\[ A \approx D + \alpha^D \Gamma^D + \alpha^F \Gamma^F, \]

where

\[ D = (I - B)^{-1} \]

\[ \Gamma^D = D(B^D P)D, \]

\[ \Gamma^F = D(B^F P)D. \]

If we assume that country-sector shocks \( \lambda_n^m \) are independent and identically distributed, the correlation between sector \( i \) in country \( m \) and sector \( k \) in country \( o \) is:

\[ \rho_{ik}^{mo} = \frac{\sum_n \sum_j a_{ij}^{mn} a_{kj}^{on}}{\left( \sum_n \sum_j (a_{ij}^{mn})^2 \sum_n \sum_j (a_{kj}^{on})^2 \right)^{1/2}}, \]  

in which \( a_{ij}^{mn} \) is the \(((m, i), (n, j))\) element of the matrix \( A \). Taking a first-order approximation, Eq. (12) can be re-written as:

\[ \rho_{ik}^{mo} \approx \frac{\sum_n \sum_j d_{ij}^{mn} d_{kj}^{on}}{\left( \sum_n \sum_j (d_{ij}^{mn})^2 \sum_n \sum_j (d_{kj}^{on})^2 \right)^{1/2}} + \alpha^D \sum_n \sum_j \frac{d_{ij}^{mn} d_{kj}^{on} (\tilde{c}_{ij}^{Dmn} + \tilde{c}_{kj}^{Don})}{\left( \sum_r \sum_l (d_{rl}^{mr})^2 \sum_r \sum_l (d_{lr}^{nr})^2 \right)^{1/2}} + \alpha^F \sum_n \sum_j \frac{d_{ij}^{mn} d_{kj}^{on} (\tilde{c}_{ij}^{Fmn} + \tilde{c}_{kj}^{Fon})}{\left( \sum_r \sum_l (d_{rl}^{mr})^2 \sum_r \sum_l (d_{lr}^{nr})^2 \right)^{1/2}}, \]
where

\[ \tilde{c}_{ij}^{Dmn} = \frac{\Gamma_{ij}^{Dmn} d_{ij}^{mn}}{\sum_r \sum_l (d_{il}^{mr})^2}, \quad \text{and} \]

\[ \tilde{c}_{ij}^{Fmn} = \frac{\Gamma_{ij}^{Fmn} d_{ij}^{mn}}{\sum_r \sum_l (d_{il}^{mr})^2}, \]

which measures the use of trade credit along the chain linking \((m, i)\) and \((n, j)\), relative to the chains linking \((m, i)\) and all other sectors and countries, and \(\Gamma_{ij}^{Fmn} (\Gamma_{ij}^{Dmn})\) is the \(((m, i), (n, j))\) element of the matrix \(\Gamma^F (\Gamma^D)\).

The three terms in Eq. (13) follow a similar form as those shown in Equation (6) in Raddatz (2010): the first term in Eq. (13) represents the input-output linkage between two industries in two countries (which can be the same country), whereas the second and third terms represent the credit chain linkage within the same country and across two different countries, respectively. The main difference is that in our model, both the denominator and the numerator have been expanded to include not only the sectors within a country but also sectors across different countries.

Next, let \(C_{ik}^{Dmo} (C_{ik}^{Fmo})\) denote the weighted average of the relative use of trade credit across all country-sector pair \((n, j)\) linking pairs \((m, i)\) and \((o, k)\), in which the weights are determined by the product of the direct and indirect links between the three pairs. Formally,

\[ C_{ik}^{Dmo} = \sum_n \sum_j \frac{d_{ij}^{mn} d_{kj}^{on} (\tilde{c}_{ij}^{Dmn} + \tilde{c}_{kj}^{Don})}{(\sum_r \sum_l (d_{il}^{mr})^2 \sum_r \sum_l (d_{il}^{nl})^2)^{1/2}} \]

\[ C_{ik}^{Fmo} = \sum_n \sum_j \frac{d_{ij}^{mn} d_{kj}^{on} (\tilde{c}_{ij}^{Fmn} + \tilde{c}_{kj}^{Fon})}{(\sum_r \sum_l (d_{il}^{mr})^2 \sum_r \sum_l (d_{il}^{nl})^2)^{1/2}}. \]

Intuitively, if the use of trade credit along the chain linking \((n, j)\) and other state pairs is higher than average and is important, then shocks to this \((n, j)\) pair increases the correlation between pairs \((m, i)\) and \((o, k)\).

Finally, Eq. (13) also motivates us to test whether \(\alpha^D = 0\) or \(\alpha^F = 0\) based on the following:

\[ \rho_{ik}^{mo} = \theta + \eta G_{ik}^{mo} + \alpha^D C_{ik}^{Dmo} + \alpha^F C_{ik}^{Fmo} + \gamma W_{ik}^{mo} + \epsilon_{ik}^{mo}, \]

in which \(\theta\) represents various fixed effects,\(^1\) \(G_{ik}^{mo}\) is the physical linkage between \((m, i)\) and \((o, k)\), which is computed as the first term in Eq. (13), \(C_{ik}^{Dmo}\) and \(C_{ik}^{Fmo}\) captures trade credit usage, and \(W_{ik}^{mo}\) represents other determinants of sectoral correlation.

\(^1\) In Section 4, we will consider various combinations of country and sector fixed effects so as to capture the fixed determinants of the correlation between these combinations.
3. Data and Variable Constructions

In order to test Eq. (18), we need three major data inputs:

1. the use of trade credit $P$;
2. the input-output linkages $B$ and $D$;
3. the sectoral correlations $\rho$.

We use data from Compustat and Worldscope for constructing trade credit usage $P$. To constructing $B$ and $D$, we use the Multi-Region Input-Output (MRIO) Database developed by the Asian Development Bank (ADB). This database collects the input-output data for 35 industries and 62 countries. We referee the readers to Table 22 in the Appendix for the country names. Despite that there are 62 countries from the MRIO table, Worldscope does not collect financial data from seven out of these countries (marked in red in Table 22). After dropping for these countries, we are left with 55 countries.\(^2\) Finally, to construct sectoral correlation $\rho$, we use the Industrial Statistics database (INDSTAT) at the 2-digit level of ISIC Revision 3 by the Industrial Development Organization under the United Nations (UNIDO) and the consumer price index (CPI) from World Bank.

As our unit of analysis is at the industry level and due to data availability, we follow the industry classification of the MRIO database and only include manufacturing industries in our analysis. Next, we introduce the data used, our constructions of these three sets of variables, and brief summaries of the each set.

3.1. The Use of Trade Credit (Matrix $P$)

The intensity of trade credit usage is defined as the ratio of the average accounts payable at the end of years $t$ and $t-1$ to the cost of goods sold in year $t$. Similar to Raddatz (2010), we make the following assumption, due to data availability issue:

**Assumption 3.** The ratio of an industry’s use of trade credit to the average use in a country ($P^u_j/P^u$) is assumed constant across countries, so the elements of $P$ in a given country can be expressed as the product of this ratio, $P_j$, and the country’s use of trade credit $P^u$. Formally,

$$P^u_j = P^u \times P^u.$$  \hspace{1cm} (19)

This assumption enables us to leverage the extensive data coverage for U.S. firms without sacrificing countries with much less data coverage. We will construct $P_j$ based on the Compustat database using US data, and $P^u$ based on the Worldscope database. We detail our procedures as follows. First, we extract public firms’ accounts payable and cost of goods sold from two databases, \(^2\)As shown later, we further drop two countries, Cambodia and Mongolia due to low number of firms reported in WorldScope, resulting in the final dataset with 53 countries.
Compustat and Worldscope, in which the former one is used for US publicly listed firms, whereas the latter is used for non-US firms. We resort to the Compustat database for the industry-level financial data aggregation in the United States. We collect data from 1990 to 2019, and then map these publicly listed firms using their four-digit SIC (Standard Industry Classification) code to the 35 industries used in MRIO. To clean the data, we remove observations outside of the U.S. (e.g., ADR and GDR), with missing or negative cost of goods sold, and belonging to Industry 28 (the financial intermediation industry) for it performs financial transactions differently from other industries. For observations with missing accounts payable (about 0.6% out of total observations), we treat them as zero. After the above data cleaning procedure, this data set presents 17,110 unique US firms, with 173,663 firm-year observations. In Table 1, we list the number of firms and the number of firms with more than 5 years of data for each US industry.\(^3\)

Next, we resort to Worldscope for financial information for the non-US firms in 54 countries. Similarly to Compustat, we collect data from 1990 to 2019, and then map these firms using their four-digit SIC. After data cleaning,\(^4\) we have 69,250 unique manufacturing and service firms from 32 industries across 55 countries from 1990 to 2019,\(^5\) with a total of 808,288 observations. In Table 2, we list the number of firms, and the number of firms with more than 5 years of data for each 55 countries in Worldscope. We note that in this dataset, data coverage is limited among developing countries. We also analyze the data coverage at the country-industry level. The result summary are presented in Table 3, which indicates the low data coverage of Cambodia and Mongolia. Out of the 32 industries, Table 3 suggests that only 26 countries report more than 5 firms (each with at least 5 years of data) in more than 20 industries.\(^6\)

With these raw data, we next present the computation steps to obtain the use of trade credit (the matrix \(P\)). For a given firm and year, the use of trade credit corresponds to the average of the accounts payable at the end of years \(t-1\) and \(t\) divided by the total cost of goods sold in year \(t\), and we denote it as \(p_{it}^i\).

\[
p_{it}^i = \frac{\text{Accounts Payable}_{i,t-1}^i + \text{Accounts Payable}_{i,t}^i}{2 \times \text{Cost of Goods Sold}_{i,t}^i}.
\]

\(^3\) Industry 1 (Agriculture, Hunting, Forestry and Fishing) and Industry 35 (Private Households with Employed Persons) do not have enough data for computation. After dropping these two industries, we have 32 industries, including both manufacturing and service; for comparison, Raddatz (2010) analyzed 28 manufacturing industries for 43 countries.

\(^4\) We remove observations with missing country, industry, or cost of goods sold, and then treat missing accounts payable as zero. To be consistent, we remove observations in Industry 1, 28, and 35.

\(^5\) Raddatz (2010) uses Worldscope 2006, which contains 10,500 manufacturing firms in 58 countries.

\(^6\) In Raddatz (2010), 21 countries report more than 5 firms in more than ten industries without the requirement each firm to have at least 5 years of data.
Table 1 Data Coverage of US Industries based on Compustat

| Industry code | Number of firms | Number of firms with at least 5 years of data |
|---------------|-----------------|---------------------------------------------|
| 2 (Mining and Quarrying) | 986             | 641                                         |
| 3 (Food, Beverages and Tobacco) | 390             | 261                                         |
| 4 (Textiles and Textile Products) | 226             | 156                                         |
| 5 (Leather, Leather and Footwear) | 31              | 27                                          |
| 6 (Wood and Products of Wood and Cork) | 148             | 102                                         |
| 7 (Pulp, Paper, Paper, Printing and Publishing) | 307             | 230                                         |
| 8 (Coke, Refined Petroleum and Nuclear Fuel) | 94              | 62                                          |
| 9 (Chemicals and Chemical Products) | 1611            | 1116                                        |
| 10 (Rubber and Plastics) | 172             | 128                                         |
| 11 (Other Non-Metallic Mineral) | 86              | 61                                          |
| 12 (Basic Metals and Fabricated Metal) | 382             | 298                                         |
| 13 (Machinery, Nec) | 888             | 655                                         |
| 14 (Electrical and Optical Equipment) | 2091            | 1531                                        |
| 15 (Transport Equipment) | 309             | 232                                         |
| 16 (Manufacturing, Nec; Recycling) | 187             | 123                                         |
| 17 (Electricity, Gas and Water Supply) | 661             | 546                                         |
| 18 (Construction) | 212             | 146                                         |
| 19 (Sale, Maintenance and Repair of Motor Vehicles) | 110             | 80                                          |
| 20 (Wholesale Trade and Commission Trade) | 693             | 472                                         |
| 21 (Retail Trade; Repair of Household Goods) | 790             | 547                                         |
| 22 (Hotels and Restaurants) | 375             | 271                                         |
| 23 (Inland Transport) | 156             | 106                                         |
| 24 (Water Transport) | 40              | 27                                          |
| 25 (Air Transport) | 96              | 64                                          |
| 26 (Other Supporting and Auxiliary Transport Activities) | 98              | 75                                          |
| 27 (Post and Telecommunications) | 703             | 473                                         |
| 29 (Real Estate Activities) | 238             | 155                                         |
| 30 (Renting of M&Eq and Other Business Activities) | 855             | 661                                         |
| 31 (Public Admin and Defence; Compulsory Social Security) | 284             | 180                                         |
| 32 (Education) | 79              | 54                                          |
| 33 (Health and Social Work) | 441             | 302                                         |
| 34 (Other Community, Social and Personal Services) | 3371            | 2190                                        |

Thus, the first step is to construct the firm-level representative measure of payables by taking the median of $p_i$ across time for each firm reporting data to the Worldscope database. Only firms with more than five years of (annual) data from 1990 to 2019 are kept in the sample to reduce the impact of cyclical fluctuation.

Next, within country $n$ (except the United States), the median of the representative ratios of those firms located in $n$ is used as a country-level representative value of payables financing ($P^n$). For industry level trade credit usage $P_j$, by using data from Compustat, we construct representative ratios for each industry $j$ in the United States ($P_j^{US}$) by taking the median ratio across U.S. firms within the industry. Based on Assumption 3, we then can have: $P_j = P_j^{US} / P_j^{US}$, and $P^n_j = P_j \times P^n$.
Table 2  Data Coverage based on Worldscope (Country Level)

| Country (Region)     | Number of firms | Number of firms with at least 5 years of data |
|----------------------|-----------------|----------------------------------------------|
| Cambodia             | 1               | 1                                            |
| Mongolia             | 3               | 3                                            |
| Fiji                 | 13              | 13                                           |
| Estonia              | 21              | 19                                           |
| Malta                | 31              | 21                                           |
| Latvia               | 35              | 34                                           |
| Slovakia             | 40              | 28                                           |
| Lithuania            | 43              | 41                                           |
| Slovenia             | 51              | 49                                           |
| Kazakhstan           | 60              | 56                                           |
| Hungary              | 79              | 73                                           |
| Bangladesh           | 96              | 85                                           |
| Croatia              | 116             | 113                                          |
| Luxembourg           | 118             | 98                                           |
| Portugal             | 121             | 98                                           |
| Cyprus               | 140             | 119                                          |
| Austria              | 191             | 157                                          |
| Romania              | 193             | 183                                          |
| Sri Lanka            | 205             | 199                                          |
| Ireland              | 210             | 166                                          |
| Bulgaria             | 282             | 271                                          |
| Belgium              | 283             | 227                                          |
| Finland              | 284             | 228                                          |
| Philippines          | 285             | 259                                          |
| Mexico               | 322             | 275                                          |
| Pakistan             | 334             | 312                                          |
| Denmark              | 356             | 288                                          |
| Spain                | 403             | 301                                          |
| Greece               | 416             | 373                                          |
| Turkey               | 447             | 407                                          |
| Switzerland          | 457             | 391                                          |
| Netherlands          | 460             | 391                                          |
| Norway               | 469             | 356                                          |
| Italy                | 643             | 494                                          |
| Indonesia            | 661             | 542                                          |
| Poland               | 694             | 625                                          |
| Brazil               | 698             | 607                                          |
| Thailand             | 861             | 793                                          |
| Singapore            | 1039            | 932                                          |
| Sweden               | 1116            | 856                                          |
| Russian Federation   | 1145            | 1062                                         |
| Vietnam              | 1208            | 1038                                         |
| Malaysia             | 1423            | 1293                                         |
| Germany              | 1586            | 1305                                         |
| France               | 1651            | 1348                                         |
| Hong Kong            | 1895            | 1662                                         |
| Taipei,China         | 2415            | 2191                                         |
| Korea (South)        | 2719            | 2284                                         |
| Australia            | 3150            | 2548                                         |
| India                | 3537            | 3244                                         |
| United Kingdom       | 4204            | 3184                                         |
| Canada               | 4717            | 3293                                         |
| Japan                | 5499            | 5031                                         |
| China                | 5612            | 4934                                         |
| United States        | 16212           | 11282                                        |
Table 3  Data Coverage based on Worldscope (Industry Level Summary)

| Number of countries | More than # industries with at least 5 firms (each firm has at least 5 years of data) |
|---------------------|-------------------------------------------------------------------------------------|
| 45                  | 5                                                                                    |
| 39                  | 10                                                                                  |
| 36                  | 15                                                                                  |
| 26                  | 20                                                                                  |
| 18                  | 25                                                                                  |
| 11                  | 30                                                                                  |

of bank credit (columns with Short-Term Debt to Payables) for countries listed in Worldscope. In Table 5, we present these two for the manufacturing industries in the U.S. we reported these summary statistics for 2000, 2007, 2018, and 2018 due to the data availability from 2000 to 2018 as well as as a preparation for the time trend analyses later.

3.2. Input-Output Linkages (B and D)

Similar to World Input-Output Database (WIOD) and the input-output (IO) table developed by the U.S. Bureau of Economic Analysis (BEA), the Asian Development Bank includes more Asian countries to respond to the increasing needs to expand the coverage of the WIOD in its MRIO project. In this paper, we use the 2018 MRIO table as the benchmark in our analysis, and will use other years’ MRIO tables for our exploration of the time changes of sectoral co-movements.

The benefit of using the MRIO tables comes from the coverage of trade information. In Raddatz (2010), who uses the 1992 Input-Output (or USE and MAKE) tables provided by BEA. As only one country’s IO table is used, Raddatz (2010) assumes that the IO linkages across industries are technologically determined, and therefore, linkage measures obtained in a country with good available information, such as the United States, can be extrapolated to the rest of the countries in the sample. In our paper, the MRIO tables not only provide intra-country trade volumes but also inter-country trade volumes, which enable us to study beyond the industry-level co-movement within a country, but also those across different countries.

Another advantage of the MRIO table is that, instead of using USE and MAKE tables, the structure of the MRIO table directly records the trade flows. Hence, we can compute matrix $B$ directly from the MRIO data without making additional assumptions. Finally, we consider 53 countries (the 55 countries that overlapped with the Worldscope database less Cambodia and Mongolia, which have insufficient data issues) and 14 manufacturing sectors because the UNIDO INDSTAT database only provides information for manufacturing industries. The 14 sectors are denoted as sectors 3 to 16.

To construct the variables with Short-Term Debt to Payables, we follow the same procedure described above but replace account payables by short-term debts.
Table 4  Trade Credit and Short-Term Debt Use by Country (previous 20 years)

| Country (Region) | Payables Financing 2000 2007 2013 2018 | Short-Term Debt to Payables 2000 2007 2013 2018 |
|------------------|----------------------------------------|-----------------------------------------------|
| Australia        | 0.10 0.13 0.14 0.17                   | 0.41 0.30 0.23 0.18                           |
| Austria          | 0.11 0.11 0.11 0.13                   | 1.21 1.06 1.01 0.94                           |
| Belgium          | 0.10 0.14 0.16 0.18                   | 0.84 0.84 0.80 0.67                           |
| Bulgaria         | – – 0.23 0.23                        | – – 0.23 0.21                                 |
| Brazil           | 0.09 0.10 0.11 0.12                   | 2.46 1.94 1.89 1.69                           |
| Canada           | 0.14 0.18 0.20 0.22                   | 0.30 0.30 0.22 0.21                           |
| Switzerland      | 0.12 0.12 0.12 0.13                   | 1.07 0.85 0.65 0.47                           |
| China            | 0.24 0.17 0.18 0.20                   | 2.14 2.53 1.68 1.35                           |
| Cyprus           | – – 0.23 0.23                        | – – 0.80 0.80                                 |
| Germany          | 0.09 0.10 0.11 0.12                   | 0.76 0.67 0.61 0.54                           |
| Denmark          | 0.09 0.11 0.12 0.13                   | 1.14 1.03 0.84 0.66                           |
| Spain            | 0.17 0.20 0.22 0.24                   | 0.80 0.80 0.72 0.74                           |
| Estonia          | – – 0.12 0.12                        | – – 0.48 0.54                                 |
| Finland          | 0.08 0.10 0.10 0.11                   | 1.35 1.14 1.09 0.85                           |
| France           | 0.16 0.18 0.19 0.19                   | 0.63 0.55 0.46 0.44                           |
| United Kingdom   | 0.15 0.16 0.17 0.18                   | 0.48 0.45 0.38 0.35                           |
| Greece           | 0.13 0.18 0.22 0.24                   | 1.98 1.84 1.88 1.75                           |
| Croatia          | – – 0.22 0.22                        | – – 0.77 0.80                                 |
| Hungary          | 0.08 0.12 0.12 0.15                   | 0.64 0.70 0.63 0.60                           |
| Indonesia        | 0.14 0.12 0.11 0.12                   | 3.57 2.41 1.89 1.59                           |
| India            | 0.17 0.16 0.15 0.15                   | 1.10 0.86 1.08 1.18                           |
| Ireland          | 0.12 0.15 0.18 0.21                   | 0.36 0.40 0.41 0.38                           |
| Italy            | 0.25 0.31 0.35 0.37                   | 0.74 0.72 0.67 0.63                           |
| Japan            | 0.23 0.22 0.21 0.20                   | 0.73 0.71 0.71 0.63                           |
| Korea (South)    | 0.14 0.12 0.11 0.11                   | 2.71 1.67 1.73 1.72                           |
| Lithuania        | – – 0.14 0.13                        | – – 1.07 1.07                                 |
| Luxembourg       | 0.13 0.14 0.15 0.16                   | 1.07 0.77 0.50 0.31                           |
| Latvia           | – – 0.10 0.11                        | – – 0.86 0.91                                 |
| Mexico           | 0.10 0.12 0.13 0.14                   | 1.69 0.98 0.59 0.51                           |
| Malta            | – – 0.10 0.10                        | – – 3.18 1.41                                 |
| Netherlands      | 0.11 0.13 0.13 0.16                   | 0.70 0.69 0.74 0.72                           |
| Norway           | 0.09 0.11 0.12 0.13                   | 0.63 0.46 0.43 0.41                           |
| Poland           | 0.02 0.11 0.16 0.16                   | 0.97 0.63 0.67 0.69                           |
| Portugal         | 0.11 0.12 0.13 0.15                   | 1.56 1.43 1.39 1.08                           |
| Romania          | – – 0.15 0.19                        | – – 0.67 0.68                                 |
| Russian Federation| – 0.10 0.10 0.14                | 1.42 1.45 1.12 0.84                           |
| Slovakia         | – 0.13 0.13 0.16                     | 1.82 0.72 0.53 0.48                           |
| Slovenia         | – 0.20 0.13 0.12                     | – – 0.76 0.82                                 |
| Sweden           | 0.09 0.11 0.11 0.13                   | 0.66 0.50 0.34 0.37                           |
| Turkey           | 0.11 0.13 0.14 0.16                   | 1.17 1.03 1.03 1.00                           |
| Taiwan           | 0.11 0.15 0.16 0.16                   | 2.44 1.07 0.97 0.97                           |
| United States    | 0.09 0.12 0.13 0.14                   | 0.25 0.24 0.22 0.19                           |
| Bangladesh       | – – 0.07 0.07                        | – – 2.06 0.24                                 |
| Malaysia         | 0.11 0.11 0.11 0.12                   | 1.84 1.88 1.68 1.42                           |
| Philippines      | 0.19 0.16 0.16 0.14                   | 1.25 1.65 1.39 1.10                           |
| Thailand         | 0.12 0.10 0.11 0.11                   | 4.17 2.37 1.95 1.34                           |
| Vietnam          | – – 0.09 0.09                        | 1.07 2.08 1.98 1.98                           |
| Kazakhstan       | – – 0.11 0.11                        | – – 1.97 2.18                                 |
| Sri Lanka        | 0.05 0.08 0.08 0.08                   | 4.31 2.98 1.75 1.97                           |
| Pakistan         | 0.07 0.07 0.07 0.09                   | 3.74 3.38 3.30 2.64                           |
| Fiji             | – – 0.10 0.12                        | – – 0.55 0.48                                 |
| Singapore        | 0.13 0.15 0.15 0.16                   | 0.95 0.74 0.82 0.69                           |
| Hong Kong        | 0.15 0.15 0.15 0.15                   | 0.97 0.99 1.01 1.02                           |

Mean                          | 0.12 0.14 0.14 0.15                   | 1.43 1.13 1.05 1.01                           |
Median                        | 0.11 0.13 0.13 0.14                   | 1.09 0.86 0.82 0.74                           |
S.d.                          | 0.05 0.04 0.05 0.05                   | 1.04 0.73 0.69 0.91                           |

Electronic copy available at: https://ssrn.com/abstract=3897212
| Industry Code                                      | Relative Payables Financing | Relative Short-term Debt to Payables |
|--------------------------------------------------|----------------------------|-----------------------------------|
| 3 (Food, Beverages and Tobacco)                   | 0.96 0.99 0.97 0.99         | 1.15 1.26 1.57 1.73              |
| 4 (Textiles and Textile Products)                 | 0.89 0.86 0.87 0.83         | 1.27 1.29 1.34 1.56              |
| 5 (Leather, Leather and Footwear)                 | 0.72 0.75 0.83 0.82         | 1.45 1.12 0.33 0.18              |
| 6 (Wood and Products of Wood and Cork)            | 0.78 0.75 0.69 0.68         | 0.85 0.79 0.90 0.95              |
| 7 (Pulp, Paper, Paper, Printing and Publishing)   | 1.01 1.00 1.02 1.01         | 0.92 0.98 1.16 1.34              |
| 8 (Coke, Refined Petroleum and Nuclear Fuel)      | 1.09 1.00 0.88 0.80         | 0.55 0.56 0.58 0.52              |
| 9 (Chemicals and Chemical Products)               | 1.31 1.24 1.17 1.13         | 0.78 0.70 0.89 0.73              |
| 10 (Rubber and Plastics)                          | 1.04 1.05 1.09 1.04         | 1.16 1.21 1.21 1.28              |
| 11 (Other Non-Metallic Mineral)                   | 0.94 0.92 0.98 0.97         | 1.29 1.08 1.56 1.55              |
| 12 (Basic Metals and Fabricated Metal)            | 0.97 0.96 0.97 0.96         | 1.02 1.02 1.09 1.05              |
| 13 (Machinery, Nec)                               | 1.34 1.33 1.37 1.39         | 0.85 0.67 0.63 0.65              |
| 14 (Electrical and Optical Equipment)             | 1.33 1.35 1.37 1.41         | 0.98 0.82 0.78 0.70              |
| 15 (Transport Equipment)                          | 0.99 1.03 1.06 1.14         | 0.82 0.81 0.91 0.91              |
| 16 (Manufacturing, Nec; Recycling)                | 1.16 1.16 1.20 1.23         | 1.92 1.99 2.08 3.03              |

Notes. Relative payables financing is the payables financing in a given manufacturing industry in U.S. to the overall U.S. median in manufactures. Similar ratios are reported for short-term debt to payables. The values of each measure for a given industry correspond to the median across all U.S. firms in that industry included in Compustat. The value for the U.S. manufacturing sector as a whole corresponds to the median across industries. For a given firm, the ratios correspond to their median across the corresponding years.

To obtain both $B$ and $D$, we follow Shea (2002). Specifically, We start by computing $D$. According to Miller and Blair (2009), the technical input coefficient matrix, $\beta$, is defined as:

$$\beta_{ij}^{mn} = \frac{\text{Value of input (m, i) bought by (n, j) producers}}{\text{Total value of (n, j) production}}.$$  \hspace{1cm} (21)

Based on the multi-sectoral general equilibrium model developed by Shea (2002), we can estimate the fluctuations in industry $i$ (denoted as $q_i$) as following:

$$q_i = K_i + \sum_{k=1}^{N} \text{COST}_{ik} s_k + \sum_{k=1}^{N} \text{DEM}_{ik} d_k,$$  \hspace{1cm} (22)

which suggests that fluctuations in industry $i$ ($q_i$) depend on technology shock $s_k$ and taste (demand) shock $d_k$. $\text{COST}_{ik}$ is the ultimate dollar requirement of good $k$ per dollar sold of good $i$, after incorporating both direct and indirect linkages. $\text{DEM}_{ik}$ is the steady state share of demand for $i$ ultimately embodied in final purchases of $k$, which is the $D$ matrix in Raddatz (2010) and our targeted matrix. Technology shocks propagate downstream, so they affect only sectors that use $k$ as an input, but not upstream sectors that supply inputs to $k$. Conversely, taste shocks propagate...
Computations for COST and DEM according to Eq. (A.11) and (A.12) in Shea (2002) are as follows:

\[
\text{COST} = [(I - \beta)^{-1}]^T, \quad (23)
\]

where \(\beta\) is a matrix whose \((m,i),(n,j)\) element is the share of country \(m\) industry \(i\)'s cost directly attributable to country \(n\) industry \(j\) (computed according to Eq. (21)), and

\[
\text{DEM}_{ik} = \frac{\text{COST}_{ki} f_k}{\sum_{z=1}^{N} \text{COST}_{zi} f_z}, \quad (24)
\]

where \(f_k\) is industry \(k\)'s final demand defined as the sum of purchases from consumption, government, and non-manufacturing industries.\(^9\)

As a result, to compute \(D\) and \(B\), we start by computing technical input coefficient matrix \(\beta\) using Equation (21), and then compute the COST matrix using Equation (23).\(^10\) Next, we compute the final demand \(f_k\) by summing over final consumption in the MRIO table and finally compute matrix \(D\) based on Eq. (24). With \(D\), we compute matrix \(B = I - D^{-1}\), and decompose \(B\) into \(B^D\) for domestic flows and \(B^F\) for cross-country flows: \(B = B^D + B^F\).

With the matrices \(P\), \(B\), and \(D\), we finally can compute the credit linkages, \(C^D_{ik}\) and \(C^F_{ik}\), and then present our model specifications. Recall that Raddatz (2010) defines \(\Gamma = D(BP)D\). We then start by computing \(\Gamma^D = D(B^D P)D\), \(\Gamma^F = D(B^F P)D\), and \(\Gamma = D(BP)D\), using the three matrices obtained from previous sections, and we have \(\Gamma = \Gamma^D + \Gamma^F\). Then using Eq. (13), we compute \(C^D_{ik}\) (stored in matrix \(C^D\)), \(C^F_{ik}\) (stored in matrix \(C^F\)) and \(C^W_{ik}\) (stored in matrix \(C^W\)). In Tables 6 and 7, we report the top 20 country-industry pairs with strongest domestic and cross-border trade credit linkage, respectively.

### 3.3. Sectoral Correlations (\(\rho\))

Finally, we illustrate how we construct the correlation of the growth rates of real value added across all industries in multiple countries. We use the UNIDO INDSTAT database\(^11\) as the source for nominal value added from 1963 to 2018 and World Bank’s consumer price index (CPI) data from 1960 to 2019 (which sets base year 2010 = 100) for 54 regions (except Taipei,China).\(^12\) For Taipei,China, we obtain CPI from 1981 to 2019 from the Statistics official website of Taipei,China.\(^13\)

---

\(^8\) As the use of trade credit affects upstream shock propagation, so in Equation (1) of Raddatz (2010), it only contains matrix \(D\).

\(^9\) In the MRIO table, the “final uses” item contains five elements: final consumption expenditure by households, final consumption expenditure by non-profit organizations serving households (NPISH), final consumption expenditure by government, gross fixed capital formation, changes in inventories and valuables. We currently use the first three elements to approximate for the final demand.

\(^10\) In this step, we remove the five region-sectors that has a almost zero-column sums in COST or \(D\). Originally, number of region-sector should be 53 \(\times\) 14, which is 742. After moving these five region-sectors, our final matrix size is 737 \(\times\) 737.

\(^11\) We use the 2020 edition of INDSTAT2 ISIC Revision 3.

\(^12\) Downloaded from https://data.worldbank.org/indicator/FP.CPI.TOTL

\(^13\) Downloaded from http://statdb.dgbas.gov.tw/pxweb/dialog/statfile1L.asp
### Table 6  Country-Industry Pairs with the Strongest Domestic Trade Credit Linkages (1998-2018)

| Country 1 | Industry 1 | Country 2 | Industry 2 | Domestic Trade Credit Linkage ($C^D$) | Ranking |
|-----------|------------|-----------|------------|---------------------------------------|---------|
| Italy     | 6          | Italy     | 16         | 0.1180                                | 1       |
| Spain     | 11         | Spain     | 6          | 0.0830                                 | 2       |
| Spain     | 12         | Spain     | 10         | 0.0798                                 | 3       |
| Italy     | 12         | Italy     | 15         | 0.0796                                 | 4       |
| China     | 11         | China     | 13         | 0.0785                                 | 5       |
| China     | 8          | China     | 11         | 0.0759                                 | 6       |
| Japan     | 4          | Japan     | 11         | 0.0751                                 | 7       |
| China     | 10         | China     | 8          | 0.0751                                 | 8       |
| Japan     | 6          | Japan     | 4          | 0.0747                                 | 9       |
| Spain     | 11         | Spain     | 10         | 0.0733                                 | 10      |
| Japan     | 6          | Japan     | 11         | 0.0724                                 | 11      |
| Spain     | 11         | Spain     | 13         | 0.0723                                 | 12      |
| China     | 7          | China     | 8          | 0.0720                                 | 13      |
| China     | 10         | China     | 11         | 0.0719                                 | 14      |
| Spain     | 13         | Spain     | 6          | 0.0717                                 | 15      |
| China     | 8          | China     | 13         | 0.0715                                 | 16      |
| Cyprus    | 3          | Cyprus    | 6          | 0.0710                                 | 17      |
| Spain     | 3          | Spain     | 11         | 0.0707                                 | 18      |
| Spain     | 6          | Spain     | 10         | 0.0705                                 | 19      |
| Spain     | 10         | Spain     | 13         | 0.0700                                 | 20      |

### Table 7  Country-Industry Pairs with the Strongest Cross-border Trade Credit Linkages (1998-2018)

| Country 1 | Industry 1 | Country 2 | Industry 2 | Cross-border Trade Credit Linkage ($C^F$) | Ranking |
|-----------|------------|-----------|------------|------------------------------------------|---------|
| Austria   | 6          | Hungary   | 6          | 0.1285                                   | 1       |
| Hungary   | 6          | Italy     | 16         | 0.1130                                   | 2       |
| Slovenia  | 6          | Hungary   | 6          | 0.1054                                   | 3       |
| Slovenia  | 6          | Austria   | 6          | 0.1024                                   | 4       |
| Taipei,China | 14         | Vietnam   | 14         | 0.1012                                   | 5       |
| Italy     | 16         | Austria   | 6          | 0.1005                                   | 6       |
| Slovenia  | 6          | Italy     | 16         | 0.0945                                   | 7       |
| Taiwan    | 14         | China     | 14         | 0.0938                                   | 8       |
| Vietnam   | 14         | China     | 14         | 0.0914                                   | 9       |
| Taipei,China | 14         | Philippines | 14     | 0.0908                                   | 10      |
| Belgium   | 12         | Luxembourg| 12         | 0.0841                                   | 11      |
| China     | 14         | Philippines| 14     | 0.0833                                   | 12      |
| Belgium   | 12         | Norway    | 12         | 0.0832                                   | 13      |
| Taipei,China | 14         | Singapore | 11         | 0.0829                                   | 14      |
| China     | 12         | Taipei,China | 14     | 0.0820                                   | 15      |
| Norway    | 12         | Luxembourg| 12         | 0.0814                                   | 16      |
| Slovakia  | 12         | Belgium   | 12         | 0.0805                                   | 17      |
| Netherlands| 12         | Luxembourg| 12         | 0.0804                                   | 18      |
| Luxembourg| 12         | Slovakia  | 12         | 0.0800                                   | 19      |
| Belgium   | 12         | Bulgaria  | 12         | 0.0796                                   | 20      |
The UNIDO INDSTAT data includes 174 countries (full coverage for the 55 countries in Table 2) and comprises 23 manufacturing sectors (based on 2-digit level of ISIC industry classification). As a result, our unit of analysis will be on the manufacturing industries. We choose CPI as our deflator when computing sectoral correlation, whereas Raddatz (2010) used producer price index (PPI). We use the CPI data from World Bank as it was the only deflator with historical data across regions and sufficiently good data coverage. After data cleaning, we construct real value added equals nominal value added divided by CPI/100.

Next, we illustrate the steps to construct the sectoral co-movement across regions and across years. First, we compute the growth rate for the real value added $g_{it}^m$, which is the growth rate of industry $i$ in country $m$ between years $t - 1$ and $t$. Then, we compute the average $\bar{g}_{it}^m$ across times, which is taking average of $g_{it}^m$ for all $t$. Finally, the correlation across regions and years is computed as:

$$
\rho_{ij}^{mn} = \frac{\left(\sum_{t=1}^{T} (g_{it}^m - \bar{g}_{it}^m)(g_{jt}^n - \bar{g}_{jt}^n)\right) (T_{ij}^{mn})^{-1}}{\left(\sum_{t=1}^{T} ((T_m^m - 1)/T_m^m)(g_{it}^m - \bar{g}_{it}^m)^2 + \sum_{t=1}^{T} ((T_j^n - 1)/T_j^n)(g_{jt}^n - \bar{g}_{jt}^n)^2\right)^{1/2}} \\
= \frac{\sum_{t=1}^{T} (g_{it}^m - \bar{g}_{it}^m)(g_{jt}^n - \bar{g}_{jt}^n)}{\sqrt{T_{ij}^{mn} SD(g_{it}^m)} \sqrt{T_{ij}^{mn} SD(g_{jt}^n)}},
$$

in which $T_{ij}^{mn}$ is the number of observations with data for sector $i$ country $m$ and sector $j$ country $n$ and $T_{ij}^{mn}$ is the number of observations for sector $i$ country $m$.

Computing correlation based on Eq. (25) from 1990 to 2018, we have further cleaned the data. See the summary statistics in Table 8, in which we report the summary statistics for overall correlations, domestic (i.e., within-country) correlations, and the cross-border (i.e., across-country) correlations for the entire data. We note that the domestic correlation is higher than the ones from Raddatz (2010), likely because of a higher level of aggregation in our setting. To further justify the needs to differentiate domestic from cross-border correlations for our country-industry setup, we also report the domestic and cross-border correlations using 20 years of prior data from the year specified in Table 9.

---

14 We remove observations with missing nominal value added, we map the 23 manufacturing sectors (based on 2-digit level of ISIC industry classification) from UNIDO to 14 manufacturing sectors from MRIO and aggregate values for these 14 sectors, and we merge the CPI data based on region $\times$ year while removing observations with missing or zero CPI.

15 Raddatz (2010) (footnote 15 on page 991) specified that “[w]ith $N$ sectors and $T$ observations (per sector), there are $N(N − 1)/2$ correlation coefficients to be estimated from $NT$ observations. The order condition therefore requires that $T > (N − 1)/2$ for a full rank matrix. With 28 sectors, this requires 14 observations at a minimum. I allowed for one more than that.”

16 We drop missing correlations, correlations with higher than 1 or smaller than −1; these cases are likely to occur when $T_{ij}^{mn}$ is small. At the end, there are 416,469 region-sectors left.
Table 8  Summary Statistics for Sectoral Correlation

|                        | mean | sd  | min | p(25) | p(50) | p(75) | max |
|------------------------|------|-----|-----|-------|-------|-------|-----|
| Overall correlation    | 0.16 | 0.28| -1  | -0.01 | 0.16  | 0.34  | 1   |
| Domestic correlation   | 0.50 | 0.36| -0.99 | 0.24 | 0.54  | 0.80  | 1   |
| Cross-border correlation| 0.16 | 0.27| -1  | -0.02 | 0.15  | 0.33  | 1   |

One potential concern with the baseline measure is the use of a common deflator: in the presence of significant heterogeneity in the evolution of prices across industries, the correlations computed with a common deflator may be driven by the correlation of relative inflation rates instead of the correlation of real output growth. This concern can be addressed by using the correlation of the growth rates of the index of industrial production, also reported in UNIDO. Results obtained using this measure are not affected by the relative price problem, but results obtained using real value added are preferable because the production index data are of lower quality and smaller coverage than the value-added data. Nevertheless, this choice does not affect the results.

4. Empirical Results

4.1. Base Results

With all variables constructed, our model specification is thus:

$$
\rho_{ik}^{mo} = \theta + \eta G_{ik}^{mo} + \alpha^D C_{ik}^{D^{mo}} + \alpha^F C_{ik}^{F^{mo}} + \gamma W_{ik}^{mo} + \epsilon_{ik}^{mo},
$$

in which $W_{ik}^{mo}$ includes other determinants of sectoral correlation, and $C_{ik}^{mo}$ is the physical linkage between $(m, i)$ and $(a, k)$, which is computed as the first term in Eq. (13). We consider two fixed effects combinations: (1) country fixed effects for input and output countries separately, and industry fixed effects for input and output industries separately, and (2) country-industry joint fixed effects for input and output country-industry pairs. We cluster standard errors based on the fixed effects combinations.

We present our results in Models 1 to 4 of Table 10. Models (1) and (2) consider only an aggregate credit linkage (i.e., we do not separate the within and across country credit linkages) for the two fixed effects combinations, and (3) and (4) consider the domestic and cross-border credit linkages, separately. In this specification, we use the 2018 MRIO table in computing the input-output linkage, and we compute the sectoral correlation using the prior 20 years INDSTAT and CPI data.

Two observations are notable. First, we echo the results shown in Raddatz (2010); the significant and positive coefficient of $C_{ik}^{mo}$ in (1) and (2) support the hypothesis that the intensity of the use of trade credit increases the correlation between the two industries linked by the credit chain.
Second, we find that after separating the credit linkage, $C_{ik}^{mo}$, to the domestic component (or within country linkage), $C_{ik}^{Dmo}$, and the cross-border component (or cross-border linkage), $C_{ik}^{Fmo}$, the results remain similar in that the intensity of the use of trade credit still increases the correlation between the two industries, regardless of these two industries are in the same country or different countries, as the coefficients of the two are positive and significant. Moreover, the comparison between the coefficients of $C_{ik}^{Dmo}$ and $C_{ik}^{Fmo}$ suggest that the domestic credit linkage has higher impact on the correlation between two industries within the same country than that between two in two different countries.

4.2. Robustness

We note that one possible concern of the base specification is whether the results are robust to outliers. It could be possible that our results are driven by the strong correlations between a few strong countries and/or dominating industries. To address this concern, we follow two traditional approach to reduce the effect of outliers: winsorization or trimming, the former is to set the extreme values of sectoral correlations (higher or lower than a certain threshold) to the value at the threshold, whereas the latter is to drop these extreme values from the sample.

We report the results of the above two robustness tests in Table 11. The first three columns are the results after winsorizing the sectoral correlation based on the top 1, 3, and 5 percentile, and the last column shows the result after we trim the top 5% values. As we can observe from the coefficients of $C_{ik}^{Dmo}$ and $C_{ik}^{Fmo}$, these two remain positive and significant, thereby, again, supporting our hypothesis that the intensity of the use of trade credit increases sectoral correlation. The magnitude of the two also suggests that the influence of domestic trade intensity is higher than that of cross-border one; although the extreme values indeed have impact on how much these trade intensity influences correlation (as the gap between the two slightly reduced), the impact is minor.

To further examine the outlier issues, we winsorize and trim our sample based on the respective percentile cutoffs based on the country pairs instead of doing so for the entire sample and report the results in Table 12, and we again obtain qualitatively the same results.
### Table 9  Domestic and Cross-Border Correlations by Country (previous 20 years)

| Country (Region) | Domestic Average Correlation | Cross-Border Average Correlation |
|------------------|-----------------------------|----------------------------------|
|                  | 2000 | 2007 | 2013 | 2018 | 2000 | 2007 | 2013 | 2018 |
| Australia        | 0.76 | 0.60 | 0.55 | 0.49 | 0.11 | 0.18 | 0.17 | 0.24 |
| Austria          | 0.59 | 0.51 | 0.55 | 0.58 | 0.23 | 0.19 | 0.24 | 0.30 |
| Belgium          | 0.46 | 0.51 | 0.31 | 0.40 | 0.20 | 0.23 | 0.18 | 0.23 |
| Bulgaria         | -    | -    | 0.63 | 0.47 | -    | -    | 0.22 | 0.24 |
| Brazil           | 0.70 | 0.72 | 0.72 | 0.78 | -0.07| 0.14 | 0.15 | 0.25 |
| Canada           | 0.52 | 0.35 | 0.37 | 0.42 | 0.12 | 0.09 | 0.15 | 0.19 |
| Switzerland      | 0.56 | 0.53 | 0.37 | 0.30 | 0.14 | 0.22 | 0.17 | 0.16 |
| China            | 0.82 | 0.70 | 0.77 | 0.81 | -0.13| 0.07 | 0.19 | 0.21 |
| Cyprus           | -    | -    | 0.50 | 0.52 | -    | -    | 0.20 | 0.20 |
| Germany          | 0.71 | 0.65 | 0.59 | 0.60 | 0.10 | 0.23 | 0.25 | 0.27 |
| Denmark          | 0.63 | 0.46 | 0.39 | 0.47 | 0.22 | 0.17 | 0.19 | 0.26 |
| Spain            | 0.75 | 0.68 | 0.71 | 0.70 | 0.29 | 0.24 | 0.27 | 0.31 |
| Estonia          | -    | -    | 0.57 | 0.56 | -    | -    | 0.27 | 0.29 |
| Finland          | 0.64 | 0.57 | 0.47 | 0.43 | 0.22 | 0.21 | 0.21 | 0.28 |
| France           | 0.78 | 0.67 | 0.58 | 0.57 | 0.27 | 0.23 | 0.24 | 0.30 |
| United Kingdom   | 0.71 | 0.64 | 0.57 | 0.53 | 0.25 | 0.19 | 0.22 | 0.25 |
| Greece           | 0.49 | 0.76 | 0.69 | 0.61 | 0.19 | 0.25 | 0.19 | 0.19 |
| Croatia          | -    | -    | 0.47 | 0.43 | -    | -    | 0.18 | 0.23 |
| Hungary          | 0.49 | 0.56 | 0.52 | 0.50 | 0.12 | 0.16 | 0.21 | 0.25 |
| Indonesia        | 0.58 | 0.56 | 0.53 | 0.32 | 0.05 | 0.13 | 0.16 | 0.12 |
| India            | 0.23 | 0.37 | 0.33 | 0.37 | 0.07 | 0.16 | 0.17 | 0.18 |
| Ireland          | 0.53 | 0.35 | 0.24 | 0.22 | 0.19 | 0.13 | 0.13 | 0.16 |
| Italy            | 0.72 | 0.64 | 0.69 | 0.71 | 0.25 | 0.21 | 0.25 | 0.35 |
| Japan            | 0.85 | 0.77 | 0.56 | 0.52 | 0.22 | 0.13 | 0.16 | 0.13 |
| Korea (South)    | 0.78 | 0.65 | 0.68 | 0.61 | 0.20 | 0.11 | 0.18 | 0.13 |
| Lithuania        | -    | -    | 0.51 | 0.50 | -    | -    | 0.27 | 0.28 |
| Luxembourg       | 0.45 | 0.32 | 0.29 | 0.33 | 0.21 | 0.19 | 0.18 | 0.23 |
| Latvia           | -    | -    | 0.38 | 0.46 | -    | -    | 0.16 | 0.20 |
| Mexico           | 0.57 | 0.52 | 0.61 | 0.50 | -0.17| 0.04 | 0.06 | 0.12 |
| Malta            | -    | -    | 0.13 | 0.10 | -    | -    | 0.05 | 0.06 |
| Netherlands      | 0.67 | 0.60 | 0.53 | 0.53 | 0.25 | 0.21 | 0.22 | 0.29 |
| Norway           | 0.48 | 0.38 | 0.43 | 0.45 | 0.19 | 0.17 | 0.21 | 0.25 |
| Poland           | 0.62 | 0.69 | 0.53 | 0.53 | 0.00 | 0.10 | 0.21 | 0.24 |
| Portugal         | 0.58 | 0.45 | 0.43 | 0.44 | 0.20 | 0.15 | 0.19 | 0.24 |
| Romania          | -    | -    | 0.74 | 0.65 | -    | -    | 0.18 | 0.17 |
| Russian Federation| -   | 0.73 | 0.74 | 0.70 | -0.17| 0.21 | 0.21 | 0.27 |
| Slovakia         | -    | 0.56 | 0.48 | 0.55 | -0.09| 0.15 | 0.21 | 0.21 |
| Slovenia         | -    | 0.64 | 0.47 | 0.58 | -0.08| 0.24 | 0.31 | 0.31 |
| Sweden           | 0.64 | 0.60 | 0.50 | 0.51 | 0.23 | 0.23 | 0.25 | 0.29 |
| Turkey           | 0.74 | 0.75 | 0.78 | 0.67 | 0.07 | 0.25 | 0.21 | 0.20 |
| Taipei,China     | 0.69 | 0.41 | 0.42 | 0.38 | 0.17 | 0.10 | 0.14 | 0.14 |
| United States    | 0.31 | 0.28 | 0.24 | 0.26 | 0.10 | 0.04 | 0.08 | 0.10 |
| Bangladesh       | -    | -    | 0.09 | 0.05 | -    | -    | 0.03 | -0.05|
| Malaysia         | 0.48 | 0.49 | 0.47 | 0.36 | 0.07 | 0.05 | 0.14 | 0.10 |
| Philippines      | 0.42 | 0.44 | 0.32 | 0.26 | 0.15 | 0.10 | 0.06 | 0.04 |
| Thailand         | 0.35 | 0.36 | 0.50 | 0.52 | 0.01 | 0.04 | 0.10 | 0.09 |
| Vietnam          | -    | -    | 0.45 | 0.46 | -    | -    | -0.04| -0.02|
| Kazakhstan       | -    | 0.46 | 0.47 | 0.67 | -    | -    | 0.15 | 0.15 |
| Sri Lanka        | 0.38 | 0.55 | 0.49 | 0.48 | -0.04| 0.07 | 0.08 | 0.08 |
| Pakistan         | 0.21 | 0.60 | 0.70 | -    | 0.04 | 0.15 | 0.24 | -    |
| Fiji             | -    | -    | 0.27 | 0.30 | -    | -    | 0.09 | 0.16 |
| Singapore        | 0.47 | 0.45 | 0.34 | 0.19 | 0.12 | 0.13 | 0.13 | 0.11 |
| Hong Kong        | 0.36 | 0.14 | 0.16 | 0.17 | 0.13 | 0.02 | -0.01| -0.01|
| Mean             | 0.57 | 0.54 | 0.49 | 0.47 | 0.13 | 0.15 | 0.17 | 0.19 |
| Median           | 0.58 | 0.56 | 0.50 | 0.50 | 0.14 | 0.15 | 0.18 | 0.21 |
| S.d.             | 0.16 | 0.14 | 0.16 | 0.17 | 0.11 | 0.07 | 0.07 | 0.09 |
Table 10  Regression Table (2018, previous 20 years)

|               | (1)  | (2)  | (3)  | (4)  |
|---------------|------|------|------|------|
| $G_{ik}^{mo}$ | 0.781*** | 0.784*** | 0.759*** | 0.763*** |
|              | (0.0364) | (0.0151) | (0.0374) | (0.0146) |
| $C_{ik}^{mo}$ | 3.271**  | 3.342*** |        |       |
|              | (1.018)  | (0.461)  |        |       |
| $C_{ik}^{Dmo}$|       | 6.050*** | 5.883*** |       |
|              |        | (1.138)  | (0.524)  |       |
| $C_{ik}^{Fmo}$|       | 2.990**  | 2.880*** |       |
|              |        | (0.865)  | (0.456)  |       |
| Constant     | 0.185*** | 0.185*** | 0.186*** | 0.186*** |
|              | (0.000561) | (0.000796) | (0.000412) | (0.000824) |

Country $m$ FE | yes | no | yes | no |
Country $o$ FE | yes | no | yes | no |
Industry $i$ FE | yes | no | yes | no |
Industry $k$ FE | yes | no | yes | no |
Country industry pair ($m, i$) FE | no | yes | no | yes |
Country industry pair ($o, k$) FE | no | yes | no | yes |
Obs. | 511,589 | 511,589 | 511,589 | 511,589 |
$R^2$ | 0.226 | 0.427 | 0.227 | 0.428 |
Within $R^2$ | 0.024 | 0.031 | 0.025 | 0.031 |

Standard errors in parentheses and are robust to heteroskedasticity.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Table 11  Winsorizing or Trimming based on Regression (4) in Table 10

|                  | Winsor 1% | Winsor 3% | Winsor 5% | Trim 5% |
|------------------|-----------|-----------|-----------|---------|
| $G_{ik}^{mo}$    | 0.636***  | 0.550***  | 0.497***  | 0.306***|
|                  | (0.0143)  | (0.0136)  | (0.0131)  | (0.0634)|
| $C_{ik}^{Dmo}$   | 6.742***  | 6.671***  | 6.364***  | 6.122***|
|                  | (0.524)   | (0.504)   | (0.484)   | (0.742)|
| $C_{ik}^{Fmo}$   | 3.515***  | 3.583***  | 3.452***  | 3.334***|
|                  | (0.447)   | (0.421)   | (0.398)   | (0.569)|
| Constant         | 0.187***  | 0.190***  | 0.192***  | 0.197***|
|                  | (0.000802)| (0.000753)| (0.000712)| (0.000639)|

Country industry pair $(m,i)$ FE yes yes yes yes
Country industry pair $(o,k)$ FE yes yes yes yes
Obs. 511,589 511,589 511,589 460,432
$R^2$ 0.429 0.431 0.432 0.379
Within $R^2$ 0.027 0.025 0.023 0.009

Standard errors in parentheses and are robust to heteroskedasticity.

$^*$ $p < 0.05$, $^*$ $p < 0.01$, $^{***}$ $p < 0.001$

Table 12  Winsorizing or Trimming by Group (country industry pair $(m,i)$)

|                  | Winsor 1% | Winsor 3% | Winsor 5% | Trim 5% |
|------------------|-----------|-----------|-----------|---------|
| $G_{ik}^{mo}$    | 0.573***  | 0.460***  | 0.405***  | 0.0867  |
|                  | (0.0138)  | (0.0109)  | (0.00949) | (0.0544)|
| $C_{ik}^{Dmo}$   | 7.115***  | 6.700***  | 6.349***  | 6.592***|
|                  | (0.510)   | (0.481)   | (0.454)   | (0.693)|
| $C_{ik}^{Fmo}$   | 3.912***  | 4.122***  | 4.147***  | 4.903***|
|                  | (0.451)   | (0.437)   | (0.424)   | (0.573)|
| Constant         | 0.186***  | 0.188***  | 0.190***  | 0.196***|
|                  | (0.000812)| (0.000777)| (0.000750)| (0.000684)|

Country industry pair $(m,i)$ FE yes yes yes yes
Country industry pair $(o,k)$ FE yes yes yes yes
Obs. 511,589 511,589 511,589 461,570
$R^2$ 0.430 0.444 0.458 0.482
Within $R^2$ 0.025 0.021 0.019 0.008

Standard errors in parentheses and are robust to heteroskedasticity.

$^*$ $p < 0.05$, $^*$ $p < 0.01$, $^{***}$ $p < 0.001$
4.3. Time Variation

In this section, we explore how the intensity of the use of trade credit influence sectoral correlation differently from 2000 to 2018. Specifically, we repeat the regression model in Eq. (26) but use the MRIO tables in year 2000, 2007, 2013, and 2018.\(^{17}\) In Table 13, we report our empirical results when the sectoral correlations are computed based on the prior 20 years of data.

| Table 13 Regression Table (Time window: previous 20 years) |
|-----------------|-----------------|-----------------|-----------------|
|                | 2000            | 2007            | 2013            | 2018            |
| \(G_{ik}^{mo}\) | 0.862***        | 0.810***        | 0.791***        | 0.763***        |
| \(C_{ik}^{Dmo}\) | 12.12***        | 11.54***        | 7.842***        | 5.883***        |
| \(C_{ik}^{Fmo}\) | 8.477***        | 5.015***        | 3.696***        | 2.880***        |
| Constant       | 0.123***        | 0.140***        | 0.163***        | 0.186***        |
| Country industry pair \((m,i)\) FE | yes | yes | yes | yes |
| Country industry pair \((o,k)\) FE | yes | yes | yes | yes |
| Obs.           | 269,673         | 320,728         | 529,837         | 511,589         |
| \(R^2\)        | 0.347           | 0.275           | 0.329           | 0.428           |
| Within \(R^2\) | 0.058           | 0.054           | 0.033           | 0.031           |

Standard errors in parentheses and are robust to heteroskedasticity.

\(^* p < 0.05, \,** p < 0.01, \,**\(^*\) p < 0.001\)

We observe a decreasing trend of the positive relation between both the domestic and cross-border intensity of trade credit usage and correlations. First, while the coefficients of \(C_{ik}^{Dmo}\) and \(C_{ik}^{Fmo}\) remain significant and positive, the coefficient of \(C_{ik}^{Dmo}\) changes from 12.12, to 11.54, to 7.842, to 5.883 and the coefficient of \(C_{ik}^{Fmo}\) changes from 8.477, 5.015, 3.696, to 2.880 from 2000 to 2018. This decreasing trend suggest that the trade linkage intensity is gradually reducing its impact on sectoral correlations, regardless of the domestic or cross-border ones. We note that a similar pattern can be observed when we compute sectoral correlation based on the prior 10 years of data (see Table 14 for the results), except that using only 10 years of data, correlations tend to respond to sudden change of patterns. Nonetheless, we still have a roughly decreasing trend with a dip at 2013.

\(^{17}\) Although the MRIO tables first started the coverage in 2000, the next available table is conducted at 2007. Therefore, we pick the first two available tables in studying the time variation. The most updated table at the time of this study is conducted at 2018, and we find the middle year between 2007 and 2018 as another time span in our study, which is year 2013.
Table 14  Regression Table (Time window: previous 10 years)

|          | 2000   | 2007   | 2013   | 2018   |
|----------|--------|--------|--------|--------|
| $G_{ik}^{mo}$ | 0.887*** | 0.690*** | 0.725*** | 0.723*** |
|           | (0.0177) | (0.0175) | (0.0149) | (0.0166) |
| $C_{ik}^{Dmo}$ | 12.94*** | 7.428*** | 4.089*** | 7.068*** |
|           | (1.021)  | (0.811)  | (0.579)  | (0.689)  |
| $C_{ik}^{Fmo}$ | 11.75*** | 6.983*** | 1.976*** | 2.456*** |
|           | (1.753)  | (0.866)  | (0.556)  | (0.441)  |
| Constant  | 0.0544*** | 0.248*** | 0.220*** | 0.229*** |
|           | (0.00227) | (0.00156) | (0.000866) | (0.000866) |

Country industry pair $(m,i)$ FE yes yes yes yes
Country industry pair $(o,k)$ FE yes yes yes yes

Obs. 266,268 303,314 484,277 472,424
$R^2$ 0.180 0.394 0.440 0.439
Within $R^2$ 0.044 0.036 0.017 0.021

Standard errors in parentheses. Robust for heteroskedasticity.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

One plausible explanation is the booming global trade credit linkages provide a risk diversification mechanism. We provide heatmaps of $C_{ik}^{Dmo}$ and $C_{ik}^{Fmo}$ for four countries, China, Japan, Korea, and USA at years 2000 and 2018 in Figure 1. By comparing Figures 1(a) and 1(b), we observe that the intensity of the domestic use of trade credit reduced during these 18 years time frame; the diagonal values are colored by the intensity of the use of trade credit, and a more purple color refers to a higher intensity. On the other hand, by comparing Figures 1(c) and 1(d), we observe that the intensity of the cross-border use of trade credit increases during these 18 years; the off-diagonal values are colored by the intensity of the use of trade credit, and a more purple color refers to a higher intensity. From 2000 to 2018, production processes have been dissected into smaller and smaller, yet more and more specialized steps, thereby enabling international trades that searching for cheap and high quality production sites/suppliers. As a result, trade credit linkages naturally have been diversified among different industries and/or different countries. With a more diversified credit linkage, the impact of certain shocks occurring in an industry, thus, plays a less important role, regardless of whether this trade credit linkage happens domestically or aboard.

We further support our argument using the domestic and cross-border trade share changes. See Figure 2 for the two plots as well as see Table 15 for the summary statistics for the domestic trade share. We find that in Figure 2(a), the domestic trade shares are shifting to the left when time increases, whereas in Figure 2(b), the cross-border trade shares are shifting to the right. Similar pattern can also be found in Table 15 that the mean and the three percentiles are both
decreasing throughout the time. We note that although the UNCTAD’s World Investment Report (2020)\textsuperscript{18} finds that the level of the globalization of production continued to increase until 2010, then stagnated after that, our results on the share distributions on domestic and cross-border trades still in a state of changes overtime (at least, fine-tuning the distribution of trades), even after 2010. This comparison also highlights the contribution of our analysis; while the global trading volume has reached a steady state, the distribution is not, thereby leading to a still changing magnitude of sectoral co-movement.

\textsuperscript{18} https://unctad.org/webflyer/world-investment-report-2020
Another plausible explanation for the decreasing trend that the intensity of the use of trade credit increases correlation can be that the global economies are gradually reducing their sectoral correlation by means of decoupling risks (e.g., better use of inventory management to buffer against uncertainties and shocks). To rule out this alternative, we plot overall correlations, the domestic correlations, cross-border correlations in Figures 3–5, respectively, for a time window of prior 10 years (a) and a time window of prior 20 years (b). We also provide the summary statistics of these figures in Table 16.

Both the figures and the summary statistics reveal that comparing 2000 against 2018, while the overall correlation increases from 0.144 to 0.198, the domestic correlation decreases from 0.574 to 0.476 (use 20 years as our time window), whereas the cross-border correlation increases from 0.132 to 0.193. Decline in domestic sector correlations of US is also documented by Irvine and Schuh (2005), who compare US sector correlations between 1967-1983 and 1984-2001. The increasing

As we previously mentioned, we can see that by using a 20 year time window, the density of correlations tend to be more consistent throughout these 20 years, supporting our use of 20 years in our main specification and the reason why the results in Table 14 tends to be volatile for the four time points.
trend of the cross-border correlation may be a result from many factors, such as the cross-border information barriers have been lifted from 2000 to 2018. These number changes again support our previous explanation that the diversification resulting from a more dissected value chain structure. Moreover, in our regression specification, we used the overall correlation as our dependent variable. Therefore, the increasing overall correlation helps rule out this explanation that the decreasing trend that the intensity of the use of trade credit increases correlation is a result of decreasing correlations.

**Figure 3** Density of Overall Correlations

(a) Time window: previous 10 years

(b) Time window: previous 20 years

**Figure 4** Density of Domestic Correlations

(a) Time window: previous 10 years

(b) Time window: previous 20 years
Figure 5  Density of Cross-Border Correlations

(a) Time window: previous 10 years

(b) Time window: previous 20 years

Table 16  Summary Statistics of Correlation

|                | Time window: 10 years | Time window: 20 years |
|----------------|-----------------------|-----------------------|
|                | 2000  | 2007  | 2013  | 2018  | 2000  | 2007  | 2013  | 2018  |
| Overall Correlation |       |       |       |       |       |       |       |       |
| mean            | 0.081 | 0.268 | 0.230 | 0.241 | 0.144 | 0.157 | 0.175 | 0.198 |
| sd              | 0.388 | 0.354 | 0.392 | 0.395 | 0.334 | 0.291 | 0.304 | 0.316 |
| Domestic Correlation |       |       |       |       |       |       |       |       |
| mean            | 0.521 | 0.565 | 0.462 | 0.515 | 0.574 | 0.547 | 0.491 | 0.476 |
| sd              | 0.431 | 0.369 | 0.429 | 0.437 | 0.352 | 0.352 | 0.384 | 0.388 |
| Cross-Border Correlation |       |       |       |       |       |       |       |       |
| mean            | 0.069 | 0.260 | 0.225 | 0.235 | 0.132 | 0.148 | 0.169 | 0.193 |
| sd              | 0.379 | 0.350 | 0.390 | 0.392 | 0.326 | 0.283 | 0.299 | 0.312 |

Next, we examine another plausible explanation that the decreasing trend is a result of global trends reducing its needs for payables financing. In this case, despite that the intensity heatmaps show a more diversified trade credit linkages, as the overall trends less relying on payables financing, shocks are less likely to propagate via the channel of value chains. To reject this explanation, we provide summary statistics of the country-level payables financing $P_n$ (which is the median of the representative ratios of publicly listed firms in country $n$) in Table 17. As suggested from the summary statistics, we find that the country-level payables financing is increasing, including the mean as well as the 25 and 75 percentiles, suggesting that firms are more relying on payables as one way of managing their cash flow, instead of reducing their reliance on payables.

A related explanation is that, although the overall country-level increases trade credit usage, such an increasing trend only exists within the same industry for firms in the same industry have better understanding of their peers and hence, higher confidence and trusts to use trade credit. In this case, the sector-level trade credit rate, $P_j$ then should decrease, and such reduction of trade
credit rates drives our result. We report the sector-level trade credit ration in Table 18. Again, while there are some industries reduce their trade credit ratios, a good number of the sectors also rely more on trade credit, and even for the reducing ones, the difference is not high.

| Industry                          | 2000   | 2007   | 2013   | 2018   |
|-----------------------------------|--------|--------|--------|--------|
| 3 (Food, Beverages and Tobacco)   | 0.807  | 0.795  | 0.793  | 0.840  |
| 4 (Textiles and Textile Products) | 0.797  | 0.747  | 0.752  | 0.728  |
| 5 (Leather, Leather and Footwear)| 0.656  | 0.715  | 0.729  | 0.704  |
| 6 (Wood, Products of Wood and Cork)| 0.647 | 0.627  | 0.584  | 0.601  |
| 7 (Paper, Printing and Publishing)| 0.902  | 0.838  | 0.803  | 0.786  |
| 8 (Coke, Refined Petroleum and Nuclear Fuel)| 0.991 | 0.896  | 0.709  | 0.647  |
| 9 (Chemicals and Chemical Products)| 1.154  | 1.101  | 1.021  | 0.986  |
| 10 (Rubber and Plastics)         | 0.928  | 0.887  | 0.849  | 0.855  |
| 11 (Other Non-Metallic Mineral)  | 0.786  | 0.803  | 0.846  | 0.866  |
| 12 (Basic Metals and Fabricated Metal)| 0.860 | 0.854  | 0.842  | 0.815  |
| 13 (Machinery, Nec)              | 1.156  | 1.129  | 1.152  | 1.144  |
| 14 (Electrical and Optical Equipment)| 1.126 | 1.144  | 1.159  | 1.191  |
| 15 (Transport Equipment)         | 0.874  | 0.875  | 0.910  | 0.996  |
| 16 (Manufacturing, Nec; Recycling)| 0.872  | 0.915  | 0.937  | 0.985  |

Our final plausible explanation related to the trade credit ratio is that in our analysis for year 2000 and year 2018, we used different $P$ matrices, and the decreasing result is due to the fundamental differences of this different timeline in approximating the use of trade credit. While the timeline is consistent in each of the regression, we again perform another set of regression models based on the combination of MRIO table (either 2000 or 2018) and the growth rate of real value added (either between 1980 and 2000 or between 1998 and 2018) and the trade credit data (either from 1980 to 2000 or from 1998 to 2018). We make the first two consistent to reduce the number of combinations, and report the four combinations in Table 19. We then can compare the case MRIO(2018) with $P(2018)$ against MRIO(2000) with $P(2018)$ or MRIO(2018) with $P(2000)$ against MRIO(2000) with $P(2000)$. Although the magnitude slightly changes, the trend of decreasing are consistent.
4.4. Trade Credit Financing versus Bank Credit Financing

In this section, we compare trade credit and the bank financing, and examine how they influence sectoral co-movement. To do that, we follow a similar procedure in Section 3 to construct the credit linkage variables (domestic and cross-border components) of bank credit financing by replacing accounts payable by short-term debt, and denote them as $C_{D^{Dmo}}^{Dmo}$ (debt to COGS) and $C_{D^{Fmo}}^{Dmo}$ (debt to COGS), respectively. Also to better explanation the relative dependence of these two sources of financing, we also construct the related variables using the debt to payables ratios, and annotate them with debt to payables. Finally, with the newly constructed variables, we repeat our analysis and show the results in Table 20.

Model 1 in Table 20 serves as a benchmark as it includes the standard constructs in Eq. (26). Model 2 replaces the main explanatory variables of credit linkage constructed using payables by those using short-term debt, whereas Model 3 include both. Similarly, Models 4 and 5 are the regression results with debt-to-payable related variables, without and with the controls of payables to COGS variables, respectively. We observe that without controlling for the payables financing, relying more on domestic bank credit (either considering the ratio to cost of goods sold or to payables) may seem to lead to a sizable reduction on sectoral correlations, whereas more on cross-border bank credit may have reduce sectoral correlation though the effect is much minor. However, after we control for the trade credit linkage variables, the effect of bank credit linkages disappears.

Electronic copy available at: https://ssrn.com/abstract=3897212
Table 20  Regression Table with Short-Term Debt (2018, previous 20 years)

|                      | (1)       | (2)       | (3)       | (4)       | (5)       |
|----------------------|-----------|-----------|-----------|-----------|-----------|
|                      | $\rho_{ik}^{mo}$ | $\rho_{ik}^{mo}$ | $\rho_{ik}^{mo}$ | $\rho_{ik}^{mo}$ | $\rho_{ik}^{mo}$ |
| $G_{ik}^{mo}$        | 0.785***  | 0.851***  | 0.787***  | 0.871***  | 0.784***  |
|                      | (0.0136)  | (0.0174)  | (0.0137)  | (0.0186)  | (0.0135)  |
| $C_{ik}^{Dmo}$       |           |           |           |           |           |
| (payables to COGS)   | 5.681***  | 5.656***  | 5.235***  |           |           |
|                      | (0.709)   | (0.934)   | (0.777)   |           |           |
| $C_{ik}^{Fmo}$       |           |           |           |           |           |
| (payables to COGS)   | 2.678***  | 3.447***  | 2.914***  |           |           |
|                      | (0.491)   | (0.697)   | (0.566)   |           |           |
| $C_{ik}^{Dmo}$       |           |           |           |           |           |
| (debt to COGS)       | -1.370*** | -0.00124  |           |           |           |
|                      | (0.358)   | (0.397)   |           |           |           |
| $C_{ik}^{Fmo}$       |           |           |           |           |           |
| (debt to COGS)       | -0.386*   | 0.465*    |           |           |           |
|                      | (0.183)   | (0.225)   |           |           |           |
| $C_{ik}^{Dmo}$       |           |           |           |           |           |
| (debt to payables)   | -0.115**  | -0.0365   |           |           |           |
|                      | (0.0379)  | (0.0292)  |           |           |           |
| $C_{ik}^{Fmo}$       |           |           |           |           |           |
| (debt to payables)   | -0.0126   | 0.0231    |           |           |           |
|                      | (0.0155)  | (0.0141)  |           |           |           |
| Constant             | 0.187***  | 0.188***  | 0.187***  | 0.189***  | 0.187***  |
|                      | (0.000813)| (0.000650)| (0.000791)| (0.000513)| (0.000787)|

Country industry pair ($m,i$) FE | yes | yes | yes | yes | yes |
Country industry pair ($o,k$) FE | yes | yes | yes | yes | yes |
Obs. | 511,589 | 511,589 | 511,589 | 511,589 | 511,589 |
$R^2$ | 0.427 | 0.427 | 0.427 | 0.427 | 0.427 |
Within $R^2$ | 0.031 | 0.0295 | 0.0307 | 0.0293 | 0.0307 |

Standard errors in parentheses and are robust to heteroskedasticity. As we compute $G_{ik}^{mo}$ directly from the MRIO table, while Raddatz (2010) assuming that IO linkages in the U.S. can be extrapolated to the rest of the countries, therefore, the effect of bank credit in our model might be different from that of the U.S.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

While the results above suggest that bank credit financing does not help mitigate shock propagation, we suspect that this result could be due to the geographic differences. To examine whether the bank credit linkages have differential impacts for countries in Asia where the economic activities are more export-oriented and the banking industry is less mature, we consider three dummy variables for the domestic and cross-border linkage for the bank credit linkage variables. For the domestic credit linkage, we differentiate whether this domestic link happens within an Asia economy or not by considering a interaction term between $C_{ik}^{Dmo}$ with a dummy variable, $Asia = 1$ if $m$ and $o$ are both in Asia, and $Asia = 0$, otherwise. For the cross-border linkage, we include two interactions terms, $C_{ik}^{Fmo} \times \text{Either from Asia}$ and $C_{ik}^{Fmo} \times \text{Both from Asia}$, in which the former refers to the case where $m$ (exclusive) or $o$ are in Asia, and the latter refers to the case where both $m$ and $o$ are
in Asia. All $C_{ik}^{Dm_0}$ and $C_{ik}^{Fm_0}$ variable, if not noted, are based on the corresponding debt-related variables.

| Table 21 | Regression Table with Short-Term Debt and Asia Interactions (2018, previous 20 years) |
|----------|---------------------------------------------------------------------------------------|
|          | (1) | (2) | (3) | (4) | (5) | (6) |
|          | $\rho_{ik}^{D_{m_0}}$ | $\rho_{ik}^{D_{m_0}}$ | $\rho_{ik}^{D_{m_0}}$ | $\rho_{ik}^{D_{m_0}}$ | $\rho_{ik}^{D_{m_0}}$ | $\rho_{ik}^{D_{m_0}}$ |
| $G_{ik}$ | 0.851*** | 0.825*** | 0.780*** | 0.871*** | 0.832*** | 0.776*** |
|          | (0.0174) | (0.0164) | (0.0131) | (0.0186) | (0.0176) | (0.0129) |
| $C_{ik}^{D_{m_0}}$ (payables to COGS) | 4.879*** | 4.391*** |
|          | (0.930) | (0.794) |
| $C_{ik}^{F_{m_0}}$ (payables to COGS) | 2.319** |
|          | (0.722) |
| $C_{ik}^{D_{m_0}}$ (debt to COGS) | -1.370*** | -0.769* |
|          | (0.358) | (0.350) |
| $C_{ik}^{F_{m_0}}$ (debt to COGS) | -0.386* |
|          | (0.183) |
| $C_{ik}^{D_{m_0}}$ (debt to payables) | -0.115** |
|          | (0.0379) |
| $C_{ik}^{F_{m_0}}$ (debt to payables) | -0.0126 |
|          | (0.0155) |
| $C_{ik}^{D_{m_0}} \times Asia$ | -1.914*** |
|          | (0.551) |
| $C_{ik}^{F_{m_0}} \times Either from Asia$ | 1.703** |
|          | (0.568) |
| $C_{ik}^{F_{m_0}} \times Both from Asia$ | -1.841** |
|          | (0.699) |
| Constant | 0.188*** |
|          | (0.000650) |

| Country industry pair (m, i) FE | yes | yes | yes | yes | yes | yes |
| Country industry pair (o, k) FE | yes | yes | yes | yes | yes | yes |

| Obs. | 511,589 | 511,589 | 511,589 | 511,589 | 511,589 | 511,589 |
| $R^2$ | 0.427 | 0.427 | 0.428 | 0.427 | 0.428 | 0.428 |
| Within $R^2$ | 0.0295 | 0.0309 | 0.032 | 0.0293 | 0.0312 | 0.032 |

Standard errors in parentheses and are robust to heteroskedasticity.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We report the results in Table 21. Models 1 to 3 refers to the result with the debt-to-COGS related variable without Asia related interaction terms, with Asia interaction terms, and finally with additional controls of payables-to-COGS related variables. Models 4 to 6 follows a similar order, except that we do so for debt-to-payables related variables. We observe two interesting
results. First, when trading within Asia countries, regardless of domestic trades within a Asia country or cross-border trades among Asia countries, relying more on bank credit than trade credit may help mitigate shock propagation, as the coefficient of $C_{ik}^{Dmo} \times \text{Asia}$ and $C_{ik}^{Fmo} \times \text{Both from Asia}$ in Models 5 and 6 are both negative and significant. Second, using more bank credit mitigates shock propagation for domestic trades in Asia, as the coefficients of $C_{ik}^{Dmo} \times \text{Asia}$ is negative and significant in Models 2 and 3.

5. Policy Implications and Conclusion

Trade credit is a widely used source of short-term external financing and it connects buyers and sellers within a supply chain. In this paper, we develop a framework that captures the impact of credit chain on domestic and international trade separately. Leveraging on the Multi-Regional Input-Output (MRIO) Table developed by Asian Development Bank, we assemble a dataset including 14 manufacturing industries and 53 countries. We find that the use of trade credit indeed enhances sectoral co-movement, and the intensity of this impact is twice as strong for within country transactions as for international ones. We further find that over the last two decades, this intensity in general declined. Our final comparison on the use of trade credit and bank credit offers insights around the geographic use of the two financing tools.

Our work offers the following policy implications. First, similar to Raddatz (2010), trade credit linkage is indeed an effective channel for shocks to propagation via value chains. Our work extends Raddatz (2010) to differentiate domestic and cross-border trades as two different channels for shock propagation, though the domestic channel has a stronger impact than the cross-border one. In the case, supply chain finance programs that allow upstream suppliers to receive cash before trade credit maturity could be a valuable instrument that helps decompose such correlation, and possibly lower systemic risk.

Our results also imply that in the past two decades, the influence of these two channels on sectoral co-movements both reduce, possibly due to a higher level of risk diversification. Combining these results together, governments can encourage diversifying cross-border trades among firms in the manufacturing industries. Second, our final comparison between the use of trade credit and bank credit also suggests the needs for credit redistribution from financial institutions to manufacturing sector in Asia so as to reduce the degree of shock propagation.

This research can be extended along different directions. First, there is no existing theory that rationalizes the difference of credit chain impact between domestic and international trade. Further development in this direction could be promising. Second, as in Raddatz (2010), our results are not based on causal identifications. When adopting exogenous shocks for identifications, one could potentially identify how different types of shocks (e.g., natural disaster, financial crisis, global
pandemic) are propagated differently through both physical and credit channels. Further study that using a specific shock on certain sector/geographic regions could be explored. Finally, due to data limitation, this work focus mainly on financial variables, such as payables and bank credit. Should reliable data become available, we could examine the impact of other factors, such as inventory, on sectoral co-movement.

References

Babich V, Tang CS (2012) Managing opportunistic supplier product adulteration: Deferred payments, inspection, and combined mechanisms. *Manufacturing & Service Operations Management* 14(2):301–314.

Barrot JN (2016) Trade credit and industry dynamics: Evidence from trucking firms. *The Journal of Finance* 71(5):1975–2016, ISSN 1540-6261.

Boissay F (2006) Credit chains and the propagation of financial distress. *Review of Finance* 10:1853–1894.

Boissay F, Gropp R (2013) Payment defaults and interfirm liquidity provision. *Review of Finance* 17:1853–1894.

Brennan M, Miksimovic V, Zechner J (1988) Vendor financing. *Journal of Finance* 43(5):1127–1141.

Breza E, Liberman A (2017) Financial contracting and organizational form: Evidence from the regulation of trade credit. *Journal of Finance* 72(1):291–324.

Burkart M, Ellingsen T (2004) In-kind finance: A theory of trade credit. *American Economic Review* 94(3):569–590.

Cardoso-Lecourtois M (2004) Chain reactions, trade credit and the business cycle. *Econometric Society*. Available at SSRN 3375922.

Chen C, Jain N, Yang SA (2020) The impact of trade credit provision on retail inventory: An empirical investigation using synthetic controls. Available at SSRN 3375922.

Chod J, Lyandres E, Yang SA (2019) Trade credit and supplier competition. *Journal of Financial Economics* 131(2):484–505.

Cooper R, Haltiwanger J (1990) Inventories and the propagation of sectoral shocks. *The American Economic Review* 170–190.

Cuñat V (2007) Trade credit: suppliers as debt collectors and insurance providers. *Review of Financial Studies* 20(2):491–527.

Fisman R, Love I (2003) Trade credit, financial intermediary development, and industry growth. *Journal of Finance* 58(1):353–374.

Giannetti M, Burkart M, Ellingsen T (2011) What you sell is what you lend? explaining trade credit contracts. *Review of Financial Studies* 24(4):1261–1298.

Irvine O, Schuh SD (2005) The roles of comovement and inventory investment in the reduction of output volatility. *Federal Reserve Bank of Boston Working Paper No. 05-9*. Electronic copy available at: https://ssrn.com/abstract=3897212
Jacobson T, Von Schedvin E (2015) Trade credit and the propagation of corporate failure: an empirical analysis. *Econometrica* 83(4):1315–1371.

Kiyotaki N, Moore J (1998) Credit chains. *unpublished paper (London School of Economics)*.

Kouvelis P, Zhao W (2012) Financing the newsvendor: Supplier vs. bank, and the structure of optimal trade credit contracts. *Oper. Res.* 60(3):566–580.

Lee H, Zhou J, Wang J (2018) Trade credit financing under competition and its impact on firm performance in supply chains. *Manufacturing & Service Operations Management* 20(1):36–52.

Lilien D (1982) Sectoral shifts and cyclical unemployment. *Journal of Political Economy* 90(4):777–793.

Long M, Malitz I, Ravid S (1993) Trade credit, quality guarantees, and product marketability. *Financial Management* 117–127.

Long Jr JB, Plosser CI (1983) Real business cycles. *Journal of political Economy* 91(1):39–69.

Lucas RE (1995) Understanding business cycles. *Essential readings in economics*, 306–327 (Springer).

McMillan J, Woodruff C (1999) Interfirm relationships and informal Credit in Vietnam. *Quarterly Journal of Economics* 114(4):1285–1320.

Miller RE, Blair PD (2009) *Input-Output Analysis: Foundations and Extensions*.

Ng C, Smith J, Smith R (1999) Evidence on the determinants of credit terms used in interfirm trade. *Journal of Finance* 54(3):1109–1129.

Petersen M, Rajan R (1997) Trade credit: theories and evidence. *Review of Financial Studies* 10(3):661–691.

Peura H, Yang S, Lai G (2017) Trade credit in competition: A horizontal benefit. *Manufacturing Service Oper. Management* 19(2):263–289.

Raddatz CE (2010) Credit chains and sectoral comovement: Does the use of trade credit amplify sectoral shocks? *The Review of Economics and Statistics* 92(4):985–1003.

Rajan R, Zingales L (1995) What do we know about capital structure? Some evidence from international data. *Journal of Finance* 50(5):1421–1460.

Schwartz R (1974) An economic model of trade credit. *Journal of Financial and Quantitative Analysis* 9(4):643–657.

Shea J (2002) Complementarities and comovements. *Journal of Money, Credit and Banking* 34(2):412–433.

Yang S, Birge J (2018) Trade credit, risk sharing, and inventory financing portfolios. *Management Sci.* 64(8):3667–3689.
## Appendix: Tables and Figures

### Table 22: MRIO Country List

| Asia (25)                      | Europe (32)                   |
|-------------------------------|-------------------------------|
| China                         | Austria                       |
| Indonesia                     | Belgium                       |
| India                         | Bulgaria                      |
| Japan                         | Switzerland                  |
| Korea, Republic of (Korea (South)) | Cyprus               |
| Bangladesh                    | Czechia                       |
| Malaysia                      | Germany                       |
| Philippines (Philippines)     | Denmark                       |
| Thailand                      | Spain                         |
| Viet Nam (Vietnam)            | Estonia                       |
| Kazakhstan                    | Finland                       |
| Mongolia                      | France                        |
| Sri Lanka                     | United Kingdom of Great Britain and Northern Ireland (United Kingdom) |
| Pakistan                      | Greece                        |
| Fiji                          | Croatia                       |
| Lao People’s Democratic Republic | Hungary              |
| Brunei Darussalam             | Ireland                       |
| Bhutan                        | Italy                         |
| Kyrgyzstan                    | Lithuania                     |
| Cambodia                      | Luxembourg                    |
| Maldives                      | Latvia                        |
| Nepal                         | Malta                         |
| Singapore                     | Netherlands                   |
| Hong Kong                     | Norway                        |
| Taipei, China                 | Poland                        |
| **South America (1)**         |                               |
| Brazil                        | Portugal                      |
|                               | Romania                       |
| **North America (3)**         |                               |
| Canada                        | Russian Federation            |
| Mexico                        | Slovakia                      |
| United States of America (United States) | Sweden |
| **Oceania (1)**               |                               |
| Australia                     | Turkey                        |

*Notes. Countries in red are not included in Worldscope database. Countries in blue are not considered due to Worldscope data limitation. Country names are listed as in MRIO, if their names are different in Worldscope, we show them in brackets. Countries in red and blue are not included in the current analysis.*