CESifo WORKING PAPERS

8294
2020

May 2020

Supply Chain Reliability and International Economic Growth:

Impacts of Disruptions like COVID-19

Rajeev K. Goel, James W. Saunoris, Srishti S. Goel

CESifo

Impressum:

CESifo Working Papers
ISSN 2364-1428 (electronic version)
Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH
The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute
Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
Editor: Clemens Fuest
https://www.cesifo.org/en/wp

An electronic version of the paper may be downloaded
· from the SSRN website: www.SSRN.com
· from the RePEc website: www.RePEc.org
· from the CESifo website: https://www.cesifo.org/en/wp

CESifo *Working Paper No. 8294*

Supply Chain Reliability and International Economic Growth: Impacts of Disruptions like COVID-19

Abstract

Reliable supply chains are crucial to the productivity and economic growth of nations. Despite the recognition of its importance, formal research on the contribution of supply chain logistics, including the relative impacts across different logistics dimensions, is less. The importance of supply chains has been recently been brought to the forefront in the wake of the challenges posed by the coronavirus crisis. This paper uses data over a recent decade for more than 130 nations to examine the relative effects of the different aspects of supply chain logistics on economic growth. Placing the empirical framework in a standard growth model, results show that improvements in the aggregate supply chain logistics performance yield positive growth dividends. These dividends are also present in most disaggregated dimensions of logistics, with the performance of the timeliness of shipments having the greatest positive impact on growth. The growth impacts of investment, labor growth, labor quality, are positive and in line with the extant literature. A simulation exercise discussed some supply chain disruption scenarios and their growth implications that could provide useful for nations in planning for the challenges posed by the COVID-19 crisis.

JEL-Codes: O400, L800, L910.

Keywords: economic growth, supply chain, logistics, infrastructure, disruptions, coronavirus.

*Rajeev K. Goel**
Department of Economics
Illinois State University
USA – Normal, IL 61790-4200
rkgoel@ilstu.edu

James W. Saunoris
Eastern Michigan University
USA - Ypsilanti, MI, 48197
jsaunori@emich.edu

Srishti S. Goel
School of Medicine
Southern Illinois University
Carbondale / IL / USA
rsvpgoel2023@gmail.com

*corresponding author

Rajeev Goel thanks the Katie School of Insurance for research support.

1. Introduction

Economic growth remains the main driver of the well-being of nations and even for the viability of their political systems. However, nations' growth trajectories are facing unexpected challenges in the wake of the recent coronavirus crisis. This calls for a renewed examination of the drivers of economic growth, especially with regard to factors pertinent to the present situation.

Individual nations, depending upon their comparative advantages and focus, are beginning to recognize the supply chain challenges posed by lockdowns in the wake of the coronavirus spread (see, for example, a related news report from U.S.-Mexico: https://www.bloomberg.com/news/articles/2020-04-28/lowly-water-heaters-get-ensnarled-in-cross-border-covid-19-fight; https://www.businessinsider.com/how-long-grocery-store-shortages-supply-chain-disruptions-could-last-2020-4). Not only are the supply chain disruptions making lives difficult for residents and firms, such disruptions, especially related to the medical and safety equipment, can prolong the current crisis, thus having a compound effect.[1] Even more challenging (and unknown) would be the ability of supply chains to run smoothly and in a coordinated and timely fashion when the lockdowns are finally lifted. Thus, ascertaining the possible impacts of disruptions under alternative scenarios should help planning and recovery, once the uncertainty is resolved. With increased globalization and specialization of production across nations, disruptions even in a single nation that is the source of crucial inputs can have adverse impacts on global supply chains (see https://www.weforum.org/agenda/2020/04/covid-19-pandemic-disrupts-global-value-chains/).

The global supply chain has been undoubtedly disrupted in the past, most recently during the 2008-2009 financial crash (Baldwin and Weder di Mauro (2020)). However, while lessons from the past would be instructive in present times, there are some qualitative differences this time around. At that time, it was more a factor of demand than supply, whereas the current crisis has impacted both supply and demand significantly. Baldwin and Weber di Mauro mention global value chains (GVCs) that require parts of products to be manufactured in different countries before being assembled in another nation.

COVID-19 initially impacted China, which is at the center of many GVCs, disrupting the supply chain. On the demand side, as the lockdown continues and consumers' physical spending is decreasing, global demand continues to fall. Global oil prices are already showing the impact COVID-19 has on supply and demand (Fernandes (2020)). Worldwide oil demand has decreased due to the global lockdown and other variables related to COVID-19, the oil prices have fallen over 50% from the start of 2020, due in part to a surplus of supply. Many companies (https://www.bbc.com/news/business-52226236) are planning to cut back production, to raise and keep prices up as demand continues to fall. This may have long term impacts when the lockdown lifts and supply shortage issues continue. However, the end period if the current crisis is uncertain, which makes planning all the more challenging.

Supply chain performance is crucial to the smooth functioning of economies, and glitches can create bottlenecks with adverse implications for economic productivity and growth. However,

[1] An informative collection of health care-related supply chain issues in the current pandemic can be found at https://www.cidrap.umn.edu/covid-19/supply-chain-issues.

there are many dimensions to supply chains and their coordinated, often sequential, functioning is crucial in the smooth on-time delivery of products to consumers and inputs to businesses.

Whereas realization of the reliability and performance of the supply chain is not new,[2] supply chain reliability has attracted renewed attention in the wake of the recent COVID-19 crisis. Governments around the world have been scrambling to ensure adequate supplies of medical equipment, avoid excessive transport disruptions and ensure reliable food supplies. Besides short run inconveniences, supply chain disruptions have longer-term effects on economic growth. For example, when tires are not delivered to manufacturers on time, trucks do not get built or are not usable, so the investment in the other dimensions of truck production (chassis, instrumentation, etc.) become unproductive.

Key questions addressed in this research are the following:

- What is the impact of supply chain disruptions on economic growth?
- Is the impact of the different dimensions of supply chain performance on economic growth similar?
- What is the projected impact of supply chain disruptions—e.g. to those related to COVID-19—on economic growth?

The findings will be instructive, especially with the worldwide supply chain challenges faced in the wake of unexpected developments posed by the coronavirus crises.

This paper uses data over a recent decade for over 130 nations to examine the relative effects of the different aspects of supply chain logistics on economic growth. Placing the empirical framework in a standard growth model, results show that improvements in the aggregate supply chain logistics performance yield positive growth dividends. These dividends are also present in most of the disaggregated dimensions of logistics, with the performance of the timeliness of shipments having the greatest positive impact on growth. A simulation exercise discussed some supply chain disruption scenarios and their growth implications that could provide useful in nations planning for the challenges posed by the COVID-19 and other unexpected crises.

The structure of the rest of the paper includes the literature and the model in the next section, followed by data and estimation, results, and conclusions.

2. Literature and model

2.1 Literature

Broadly speaking, this research can be seen as merging the growth literature with that on performance logistics (see Arvis et al. (2007, 2018), Eyob and Kahsai (2019), Hausman et al. (2005), Nordås et al. (2006)).

The importance of economic growth has garnered a lot of interest by economic scholars over the years, with different studies examining the effectiveness of various drivers of growth across

[2] In fact, in 1950 the United States government enacted The Defense Production Act (https://www.fema.gov/media-library/assets/documents/15666) to ensure smooth functioning of supply lines and prevent hoarding in times of national emergencies.

countries (see Barro and Sala-i-Martin (2003), Gollop et al. (1987), Jones (2016), Levine and Renelt (1992), Mankiw et al. (1992)). However, within this body of research, the impact of supply chain performance, especially along its various dimensions, on economic growth has not been considered. The present research aims to fill this gap. Equally important, we provide some estimates of the impacts of unexpected supply chain disruptions on economic growth. This exercise gains added importance in the wake of the current COVID-19 crisis that has strained supply chains worldwide.

Given the recent (and unexpected) nature of the COVID-19 crisis, there are very few papers discussing its economic implications- see Baldwin and Weder di Mauro (2020) and Eichelberger et al. (2020). Due to the relatively recent nature of the coronavirus crisis, almost all of the related research is qualitative in nature (due to a lack of access to relevant data). The present study adds by bringing hard evidence to bear in the context of international economic growth.

The consideration of the different supply chain dimensions also enables us to take account of the sequential nature of some of the aspects of the supply chain. If it turns out that the individual aspects of logistics performance have differing growth consequences, i.e., with some positive and others negative growth impacts, then overall economic growth would not go up (and in fact could go down), unless all supply chain dimensions improve in a coordinated and timely manner. Viewed from a different angle, the individual stages of the supply chain can potentially pose hold-up issues, where individual bottlenecks could detail a nation's growth. The potential for hold-up would depend upon related technical and logistical complementarities (Goel (2009)). Therefore, an identification of such potential bottlenecks would be instructive for policymakers.

Beyond the technical dimensions of logistical bottlenecks, there may be political obstacles related to the will and financing to remove such obstacles trajectory (see Werlin (1991)). The logistics performance literature notes the importance of lower international trade frictions brought on by better logistics performance (Hausman et al. (2005), Nordås et al. (2006)). The multilateral coordination challenges across nations have also been discussed in the context of China's Belt and Road (B&R) initiative (https://www.cfr.org/backgrounder/chinas-massive-belt-and-road-initiative). The B&R initiative is a massive multi-country initiative aimed at streamlining transportation and improving logistical bottlenecks in global supply chains. The present work can also be tied to decision-making under uncertainty – how do the uncertainties related to timely delivery or the quality of shipments impact economic growth?

An overview of the different bodies of work shows that the aspect studied is somewhat unique and the tie to the coronavirus emergency adds special importance. Our formal estimation model follows.

2.2 Model

The general form of the estimated growth model, with subscripts i and t, respectively denoting a country and a year, is the following:

$$EconGR_{it} = f(\text{Supply chain logistics}_{itm}, Z_{itg}, \text{Infrastructure}_{its}, \text{Land locked}_{i}, COLONY_{i}) \quad \ldots(1)$$

$i = 1,\ldots,136$

$t = 2007,\ldots,2017$

m = SClogistics, SCcustoms, SCinfrastructure, SCshipments, SCquality, SCtracking, SCtimeliness

g = GDP, INVEST, EmpGR, HumanCap

s = RAIL, AIR, INTERNET, ShippingINDX

The dependent variable is the real per capita annual GDP growth rate across the 130-odd nations in our sample. As Table 1 shows, the average per capita growth rate over 2007-2017 was 1.5 percent, with substantial variation across individual nations.

Using insights from the growth literature, we include a number of regressors to explain economic growth, with the main focus (and novelty) lying in the consideration of various aspects of supply chain logistics. How does supply chain performance impact economic growth?

Turning to the main focus then, we first consider an aggregate index of supply chain logistics performance (SClogistics). Improved logistics performance, ceteris paribus, would lead to higher economic growth. However, individual dimensions of logistics might impact growth differently. Accordingly, we consider six sub-components or aspects, dealing with customs performance (SCcustoms), infrastructure (SCinfrastructure), shipments (SCshipments), logistics quality (SCquality), the tracking of shipments (SCtracking), and the timeliness of delivery (SCtimeliness) – see Table 1 details about how these were specifically measured.

As alluded to above, the impact of COVID-19 on global supply chains has also directly impacted the very system treating it. Before the pandemic, about half of the global face masks were produced in China (Ranney et al. (2020)). Due to the virus, the production was halted for a time, resulting in decreased exports and global face mask (and ventilators) shortages. Other supply chain disruptions have resulted in a shortage of other Personal Protective Equipment (PPE) such as gloves, gowns, and hand sanitizer for healthcare workers on the frontline (see Rowan and Laffey (2020) for evidence from Ireland). This decreased supply and increased demand has led to increased infections and deaths among healthcare workers when they are severely needed. To help increase the supply, governments are looking towards other industries using similar equipment, such as artists and construction workers and non-essential services (such as elective surgeries) have been suspended.

Not only are the individual aspects of supply chain logistics qualitatively different, many of those are sequentially dependent. For instance, a good infrastructure would be an important precursor to the performance of subsequent shipments, tracking and timely delivery. On the other hand, the performance of customs might not matter very much for nations that are largely self-reliant.

The usual controls as drivers of economic growth include physical capital investment (INVEST), labor force growth (EmpGR), and labor quality (HumanCap), (see Romer (1990)).[3] The consideration of capital and labor inputs can be viewed in the context of an aggregate production function of nations. These are expected to have a positive impact on growth and are routinely used in the related literature (see Barro and Sala-i-Martin (2003), Jones (2016)). In addition, to consider the possibility that the level (or base) of economic prosperity dictates how fast a nation might grow economically, we include lagged GDP as a regressor. It is generally the case that

[3] Kapataidakis et al. (2001) suggest that the relation between human capital and economic growth may be nonlinear.

after a certain level of prosperity, nations find it hard to maintain high rates of economic growth (so-called convergence).

Furthermore, land locked nations like Austria, Mongolia, Nepal, Switzerland, etc. face special logistical challenges (see Arvis et al. (2007), Eyob and Kahsai (2019)), and we include a dummy variable, LandLocked, to identify such nations. Landlocked nations have to rely on their neighbors for access to sea routes, and, depending on a landlocked nation's geography, even building airfields in some landlocked nations might be challenging (e.g., Bhutan, Bolivia).

Whereas aspects of the infrastructure are included in the SCinfrastructure index, we also consider direct measures of the infrastructure, including the rail and air networks (RAIL and AIR, respectively), internet diffusion (INTERNET) and shipping connectivity of a nation (ShippingINDX), (Table 5). A greater diffusion of the internet in a nation, for example, should facilitate the tracking of shipments.[4]

Finally, a nation's colonial past might dictate the development of logistics and their impacts of growth and this is accounted for by including a dummy variable for nations with colonial past (COLONY), (Table 6). For instance, the colonizers were instrumental in the early development of railroads and the postal system in nations like India; yet, they favored the dismantling of native cottage (textile) industries in favor of mass-produced goods from the industrial revolution that could be imported. Thus, the overall impacts on growth are unclear a priori.

The following section discusses the data used and the estimation procedure(s) employed to estimate equation (1).

3. Data and estimation

3.1 Data

The data used to estimate the model is an unbalanced panel of 136 countries observed from 2007 to 2017—Table 1 includes variable definitions, summary statistics, and sources. The time frame of our sample is constrained by the logistics variables that are available biannually from 2007 to 2018. The main dependent variable is a measure of total annual economic growth calculated as the log difference of real GDP per capita. The average growth rate (from 2007 to 2017) in the sample is 1.5%, ranging from a low of -9.5% (Yemen) to a high of 7.6% (Zimbabwe).

The main explanatory variable is an index capturing the overall supply chain logistics performance. This index is constructed using several dimensions of supply-chain logistics based on timeliness, tracking and tracing, logistics quality and competence, international shipments, infrastructure and customs (see https://lpi.worldbank.org/about for details; also see Arvis et al. (2018)).

The average supply-chain logistics index (SClogistics) is 2.85 (on a five-point scale; higher values denoting better performance), with Germany showing the highest supply-chain performance (4.23) and Afghanistan (1.21) the lowest. Likewise, supply-chain performance varies across each individual dimension. For example, in terms of the timeliness dimension of supply chain performance (SCtimeliness), Luxembourg (4.8) scores the highest while

[4] Hsieh and Goel (2019) examine the impact of internet diffusion on labor productivity in OECD countries.

Afghanistan and Somalia (1.4) both score the lowest. Strategic, political, and geographic factors, along with the degree of globalization will dictate how the supply chains in individual nations would fare in the wake of the coronavirus crisis – even in nations that are largely unaffected directly by the disease. However, the unknown scope and end times of the virus spread make decisions, especially related to long term investments, challenging.

Figure 1 shows the relation between EconGR and SClogistics across the sample countries. This figure provides an exposition of the correlation (-0.06 and statistically insignificant) between the two variables given in Table 2. Interestingly, improvements in supply chain performance precede improvements in economic growth and this is clearly evident around the time following the recent financial crises. The econometric analysis below will formally test this relationship.

Details about the data used, including summary statistics, variable definitions and data sources are provided in Table 1. Table 2 provide pairwise correlations between the key variables of interest. Notably, not all aspects of logistics performance share a positive and significant correlation with economic growth and the formal analysis below will test the strength of these relations in the context of other potential influences on economic growth.

3.2 Estimation

To estimate the baseline models for the overall and each dimension of supply-chain logistics performance we use OLS and control for regional specific effects and time effects. Furthermore, we gauge the statistical significance of individual coefficient estimates using robust standard errors. However, there is the potential for simultaneity between economic growth and supply-chain logistics performance, thus we account for this endogeneity using two-stage least squares (2SLS) estimation in Table 4; also see Section 4.2. The results section follows.

4. Results

4.1 Baseline models

Table 3 reports results from our baseline regressions, with both the aggregate logistics index and its different components highlighted.

The results show that improvements in overall logistics performance boost economic growth – the resulting coefficient on SClogistics is positive and statistically significant. In terms of economic significance, the elasticity estimate suggests that economic growth would increase by approximately 14.4% following a 10% improvement in supply chain performance.

Upon disaggregating, supply chain logistics across different, qualitatively distinct and somewhat sequential, dimensions show that not all have positive and statistically effects on economic growth. Specifically, infrastructure (SCinfrastructure) and shipments (SCshipments) dimensions are positive but statistically insignificant. This may be due to the longer-term payoffs from infrastructure improvements, while shipments could be in inventory. On the other hand, the timeliness of shipments turns out be strongly statistically significant. This makes sense, since the timeliness of shipments enables planning for delivery and use, and that does have positive growth dividends. Also, if deliveries are delayed and not on time, consequent payments for goods and services are delayed, then workers and suppliers are not paid on time and so on. This ripple effect understandably would have adverse growth consequences. Quantitatively, a ten percent increase in the performance of supply chain timeliness would boost economic growth by about 17.6%.

Regarding the usual drivers of growth, the results are in line with the literature – higher investment, and both the quantity and quality of labor boost economic growth. The complementarity between the quantity and the quality of labor has obvious public policy implications. As expected, more prosperous nations grow somewhat slowly, suggesting convergence in the rates of growth. Finally, economic growth in landlocked nations was no different from other nations.[5]

4.2 Robustness check accounting for potential simultaneity

There is the possibility that there might be reverse feedbacks from growth to logistics performance – higher growth nations have greater resources devoted to logistics and infrastructure, and thus would likely have better performance. Accordingly, Table 4 considers the different aspects of supply chain logistics to be endogenous, thus we instrument each logistics measure using a weighted average of neighboring countries' supply-chain logistics performance (averaged from 2007 to 2010).[6] This spatial lag is constructed by calculating the inverse distance between each country i and j, $1/d_{ij}$, where d is the geographic distance between country i and country j's centroid. The spatial lag thus is able to consider a nation's relations beyond its immediate neighbors. In addition, we consider the length of a country's land border (in kilometers) as an additional instrument.

Both instruments (assumed to be exogenous) are highly correlated with supply-chain logistics performance as evidenced by the rejection of the underidentification and weak identification tests reported in Table 4. Furthermore, the Hansen J test for overidentification fails to reject the validity of the instruments—instrument diagnostic tests and results are reported at the bottom of Table 4.

The results show that the baseline results are valid. Importantly, the aggregate and (most) individual dimensions of supply chain performance contribute positively to economic growth. Indeed, the impact is more than twice as much as the baseline estimates, however, less precisely estimated. Again, the growth dividends from improvements in the timeliness performance are substantial (as is also the case with the performance of shipments (SCshipments)).

The results for investment and labor and lagged GDP are qualitatively similar to Table 3. Further support of the baseline models is shown by the endogeneity test results that suggest that supply-chain logistics is exogenous. Additionally, there seems somewhat greater support for higher

[5] Some landlocked nations, depending upon their trade relations with their immediate neighbors and the nature of their exports and imports, might be able to overcome significant drawbacks that being landlocked might pose. Anecdotally, Austria and Switzerland seem to fit that bill.

[6] Bergh and Nilsson (2014) and Berggren and Nilsson (2015) also use information from neighboring countries as instruments.

growth in landlocked nations.[7] We now consider some further dimensions to shed additional light.

4.3 Additional consideration 1: Impact of infrastructure dimensions

Infrastructure is an important cog in the logistics wheel, and it is considered in the indices considered in Tables 3-4. As an alternative consideration and as a robustness check, in Table 5, we consider direct measures of infrastructure, including a nation's rail network (RAIL), air network (AIR), internet (INTERNET), and shipping (ShippingINDX). These direct measures of infrastructure and logistics capabilities might capture impacts on growth that the aggregate indices are unable to uncover.

The results show that the coefficients on RAIL, AIR, and INTERNET are statistically insignificant, but better shipping connectivity had positive growth effects. This suggests that the logistics measures are considering broader dimensions of logistics that these individual measures are not capturing. Interestingly, growth was higher in landlocked nations, even though shipping connectivity for them (at least directly) did not matter. The other findings were supportive of earlier results.

4.4 Additional consideration 2: Impact of colonial legacy

As a further consideration, we consider the effect of colonial legacy. A nation's colonial past shapes the institutional legacy, which would impact growth and also shape the development of infrastructure (Goel and Saunoris (2016)). Accordingly, in Table 6 we consider a variation of Table 3 with a dummy variable (COLONY) identifying nations that were former colonies. A little more than four-fifths of the sample nations were former colonies (Table 1).

The resulting coefficient on COLONY was statistically insignificant in all cases, and the other results support those reported in Table 3. Thus, economic growth in former colonies was no different from that in other nations.[8]

The importance of aggregate supply chain performance (SClogistics) and the relative superiority of timeliness (SCtimeliness) is reinforced (as in Table 3). Next, we consider some simulated scenarios to see how unexpected supply chain disruptions might impact economic growth.

5. Simulated impact of supply chain disruptions

In this section we conduct simulations of supply-chain disruptions and their impact on economic growth (see Ivanov (2020) also). To carry-out these simulations we consider five somewhat heterogeneous countries for a basis of comparison. We then consider a 10%, 20%, and 30%

[7] It could be the case that the nature of outputs of the landlocked nations is such that their geography is less of an issue (e.g., computer software).
[8] One reason for the lack of significance of colonial effect might be that nations became free from colonial rules in the past and the years of independence enabled them to overcome some of the drawbacks from colonial rule.

decline in supply-chain logistics performance.[9] For each scenario, we trace out their corresponding impact on economic growth based on the elasticity 1.44 estimated in Model 3.1 of Table 3.

The results show a significant impact on economic growth. For example, in Germany a 30% shock or disruption in supply-chain logistics performance (4.12 to 2.88) would yield a decline in economic growth from the sample average of 1.3% to 0.8%. On the other hand, a smaller disruption of 10% would lower the German growth to 1.1%. Indeed, these are likely to underestimate the true effect given the obvious spillovers from supply chain disruptions from one country to another (see Hausman et al. (2005)).

The corresponding drops for the other nations are shown in Table 7.[10] Overall, we see that supply chain disruptions have significant adverse growth effects and these disruptions have become significant in many cases with the current pandemic.[11] Supply chain performance is a crucial cog in the growth wheel. The concluding section follows.

6. Conclusions

Reliable supply chains are crucial to productivity and economic growth of nations. The reliance of nations on global supply networks has increased with greater globalization (Arvis et al. (2018)). The performance and reliability of global supply chains have gained greater recognition in the face of the challenges posed by the COVID-19 pandemic (see https://www.weforum.org/agenda/2020/04/covid-19-pandemic-disrupts-global-value-chains/).

Despite the recognition of its importance, formal research on the contribution of supply chain logistics, including the relative impacts across different logistics dimensions, is less. This paper uses data over a recent decade for over 130 nations to examine the relative effects of the different aspects of supply chain logistics on economic growth. Figure 1 shows no clear pattern of a relation between the aggregate logistics performance and cross-country economic growth.

Our results show that improvements in the aggregate supply chain logistics performance yield positive growth dividends. These dividends are also present in most of the disaggregated dimensions of logistics, with the performance of the timeliness of shipments have the greatest positive impact on growth. The importance of timeliness makes sense when one thinks that payments for transactions are fully made upon timely delivery. In the absence of timeliness, the subsequent production stages would be adversely affected, with negative growth consequences.

The growth impacts of investment, labor growth, labor quality, are positive and in line with the extant literature. The main findings of the paper are robust to the allowance for bi-directional causality between supply chain logistics and economic growth. However, nations' colonial legacy did not matter and the impacts of being landlocked were somewhat mixed.

---

[9] Admittedly, our choice of the three percentages is somewhat arbitrary, but they seem plausible under the current scenarios.

[10] Recall that following a growth setback, the recovery of individual nations would take different trajectories, dictating by numerous economic, political, geographic and strategic factors.

[11] Beyond the grown impacts, the human costs of COVID-19 are quite substantial. A formal study of that is beyond the scope of the current work.

Many of these drivers for economic growth are adversely impacted by COVID-19, resulting in negative growth dividends due to the disruption of supply chains. In addition to direct supply shortages (i.e. less exports), the less impacted countries will have greater difficulty obtaining supplies to manufacture goods (Baldwin and Weder di Mauro (2020)). The decreased demand (due to recession and caution by consumers) will further increase the economic decline. In other words, there will be a decrease in investment, labor growth, and other supply chain logistics. To combat this, countries may look to diversify their overseas suppliers as well as encourage return of business to national soil (although this is currently undermined by the travel restrictions), (Baldwin and Weder di Mauro (2020)). As the pandemic subsides, a close eye must be kept on the synchronous activity of multiple components of the supply chain because if, for example, if the shipments are on time but customs are still strict, there can still be continued disruption. Quantitatively, using the elasticities from Table 3, a ten percent improvement in, say logistics quality (SCquality) or logistics tracking (SCtracking), with a concurrent and corresponding decline in logistics timeliness (SCtimeliness), would result in an overall decline in the economic growth.

Governments around the world have been paying attention to improving supply chain performance. The coronavirus crisis has brought these issues to the forefront and added a sense of urgency to government intervention. In the United States, the government has implemented The Defense Production Act (https://www.fema.gov/media-library/assets/documents/15666) to deal with supply constrains related to COVID-19. However, the realization of where to focus limited government resources (in the United States and elsewhere) to ensure sufficient supplies of essentials and lower the impacts of economic growth does not seem to be there. In this regard, the results of this study can provide some guidance.

Implementation of improvements in logistics performance is difficult and time-consuming, given the complexities involved (see Arvis et al. (2018)).[12] In the case of the current pandemic, the supply chain performance would contingent on the opening and closing times (Ivanov (2020)), and with the closing time being uncertain. In addition to the shortages and on-time delivery of products, other impacts of COVID-19 could include less product diversity for consumers and greater monopoly for those companies that can continue to produce products (see Goel (2009) for a theoretical model regarding the impact of technological complementarities on market power). This would then pose challenges for antitrust regulators in the intermediate run. The impact of COVID-19 could be further extrapolated to other major supply disruptions in the future, resulting in readiness for future events.

[12] One multi-year initiative has been China's Belt and Road initiative (https://www.cfr.org/backgrounder/chinas-massive-belt-and-road-initiative).

References

Arvis, J-F., Raballand, G., Marteau, J-F., 2007. The cost of being landlocked: Logistics costs and supply chain reliability. World Bank Policy Research Working Paper #4258. World Bank, Washington, DC. https://openknowledge.worldbank.org/handle/10986/7420.

Arvis, J-F, Ojala, L, Wiederer, C., Shepherd, B., Raj, A., Dairabayeva, K, Kiiski, T., 2018. Connecting to Compete 2018: Trade Logistics in the Global Economy. World Bank, Washington, DC. https://openknowledge.worldbank.org/handle/10986/29971.

Baldwin, R., Weder di Mauro, B. (eds.), 2020. Economics in the Time of COVID-19. Centre for Economic Policy Research, London: CEPR Press.

Barro, R.J., Sala-i-Martin, X., 2003. Economic Growth. Cambridge, MA: MIT Press.

Berggren, N., Nilsson, T., 2015. Globalization and the transmission of social values: The case of tolerance. Journal of Comparative Economics, 43(2), 371-389.

Bergh, A., Nilsson, T., 2014. Is globalization reducing absolute poverty?. World Development, 62(C), 42-61.

Eichelberger, R., Hegselmann, R., Savage, D.A., Stadelmann, D., Torgler, B., 2020. Certified coronavirus immunity as a resource and strategy to cope with pandemic costs. Kyklos, https://onlinelibrary.wiley.com/doi/pdf/10.1111/kykl.12227

Eyob, E., Kahsai, M.S., 2019. Relationships of selected key logistics factors and logistics performance index of Sub-Saharan African countries. Journal of Applied Business and Economics, 21(6), 77-92.

Fernandes, N., 2020. Economic effects of coronavirus outbreak (COVID-19) on the world economy. IESE Business School, Spain. Preliminary version.

Goel, R.K., 2009. Technological complementarities, demand, and market power. Netnomics, 10, 161-170.

Goel, R.K., Saunoris, J.W., 2016. Institutional path dependence and international research intensity. Economic Modelling, 52, 851-858.

Gollop, F.M., Fraumeni, B.M., Jorgenson, D.W., 1987. Productivity and U.S. Economic Growth. Cambridge, MA: Harvard University Press.

Hausman, W.H., Lee, H.L., Subramanian, U., 2005. Global logistics indicators, supply chain metrics, and bilateral trade patterns. World Bank Policy Research Working Paper #3773. World Bank, Washington, DC. http://documents.worldbank.org/curated/en/313001468328178815/pdf/wps3773.pdf

Hsieh, E.W.-T., Goel, R.K., 2019. Internet use and labor productivity growth: Recent evidence from the U.S. and other OECD countries. Netnomics, 20(2), 195-210.

Ivanov, D., 2020. Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. Transportation Research Part E: Logistics and Transportation Review, 136, 101922.

Jones, C.I., 2016. The facts of economic growth. In: Handbook of Macroeconomics, Vol. 2, Chapter 1, edited by J.B. Taylor and H. Uhlig. Amsterdam: Elsevier, pp. 3-69.

Kapataidakis, P., Mamuneas, T.P., Savvides, A., Stengos, T., 2001. Measures of human capital and nonlinearities in economic growth. Journal of Economic Growth, 6(3), 229-254.

Levine, R., Renelt. D., 1992. A sensitivity analysis of cross-country growth regressions. American Economic Review, 82(4), 942-963.

Mankiw, N., Romer, D., Weil, D., 1992. A contribution to the empirics of economic growth. Quarterly Journal of Economics, 107(2), 407-437.

Mayer, T., Zignago, S., 2011. Notes on CEPII's distance measures (GeoDist). CEPII Working Paper #2011-25.

Nordås, H., Pinali, E., Grosso, G.M., 2006. Logistics and time as a trade barrier. OECD Trade Policy Papers, No. 35, OECD Publishing, Paris.

Ranney, M.L., Griffeth, V., Jha, A.K., 2020. Critical supply shortages — The need for ventilators and personal protective equipment during the Covid-19 pandemic. New England Journal of Medicine, 382, e41. https://www.nejm.org/doi/full/10.1056/NEJMp2006141

Romer, P.M., 1990. Human capital and growth: Theory and evidence. Carnegie-Rochester Conference Series on Public Policy, 32, 251-286.

Rowan, N.J., Laffey, J.G., 2020. Challenges and solutions for addressing critical shortage of supply chain for personal and protective equipment (PPE) arising from Coronavirus disease (COVID19) pandemic – Case study from the Republic of Ireland. Science of The Total Environment, 725, Article 138532.

Treisman, D., 2000. The causes of corruption: A cross-national study. Journal of Public Economics, 76, 399-457.

Werlin, H., 1991. Understanding administrative bottlenecks. Public Administration and Development, 11(3), 193-206.

Table 1: Variable definitions, sources and summary statistics

Variable	Description [observations; mean; standard deviation]	Source
EconGR	Economic growth measured as the log difference in real GDP per capita (at constant 2011 national prices in millions of 2011 US dollars. [1820; 0.015; 0.046]	PWT9.1
SClogistics	Overall supply chain logistics performance index (LPI) measured as an unweighted average of the six sub-indicators including timeliness, tracking and tracing, logistics quality and competence, international shipments, infrastructure, and customs. The index is rated from 1 = “very low” to 5 = “very high”. [780; 2.852; 0.590]	LPI (2018)
SCcustoms	Customers sub-index of LPI measures the efficiency of customs and border management clearance, rated from 1 = “very low” to 5 = “very high”. [780; 2.649; 0.611]	LPI (2018)
SCinfrastructure	Infrastructure sub-index of LPI measures the quality of trade and transport infrastructure, rated from 1 = “very low” to 5 = “very high”. [780; 2.702; 0.703]	LPI (2018)
SCshipments	International shipments sub-index of LPI measures the ease of arranging competitively priced shipments, rated from 1 = “very difficult” to 5 = “very easy”. [780; 2.825; 0.533]	LPI (2018)
SCquality	Supply chain logistics quality and competence sub-index of LPI measures the competence and quality of logistics services, rated from 1 = “very low” to 5 = “very high”. [780; 2.793; 0.626]	LPI (2018)
SCtracking	Tracking and tracing sub-index of LPI measures the ability to track and trace consignment, rated from 1 = “very low” to 5 = “very high” [780; 2.858; 0.651]	LPI (2018)
SCtimeliness	Timeliness sub-index of LPI measures the frequency with which shipments reach consignee within scheduled or expected delivery times, rated from 1 = “hardly ever” to 5 = “nearly always”. [780; 3.272; 0.602]	LPI (2018)
GDP	Log of real GDP per capita (at constant 2011 national prices in millions of 2011 US dollars. [2002; 9.279; 1.179]	PWT9.1
INVEST	Log of the share of real GPD per capita that is gross capital formation, at current PPP. [2002;-1.502; 0.435]	PWT9.1
EmpGR	The log difference in the number of persons engaged in the labor force (in millions) defined as anyone age 15 years and over that was employed during the reference week or had a job in which they were temporarily absent. [1718; 0.019; 0.027]	PWT9.1
HumanCap	Human capital index, which is based on years of schooling and an assumed rate of return to education, higher values imply greater human capital [1584; 2.554; 0.691]	PWT9.1
LandLocked	Dummy variable equal to 1 for landlocked countries, and zero otherwise.	Mayer and Zignago (2011)
ShippingINDX	Linear shipping connectively index (2006 = 100) measures how well countries are connected to global shipping networks based on five components of the maritime transport sector including number of ships, their container-carrying capacity, maximum vessel size, number of services, and number of companies that deploy containerships in a country’s port. [1809; 22.607; 23.631]	UNCTAD
RAIL	Total rail lines (route-km) per million population. [408; 362.534; 314.402]	The World Bank
AIR	Air transport freight (million ton-km) per million population. [652; 154.911; 1054.186]	The World Bank
INTERNET	Individuals using the internet as a percent of population. [2017; 38.444; 28.949]	The World Bank
COLONY	Dummy variable equal to one if the country is a former colony and zero otherwise. [2135; 0.856; 0.351]	Treisman (2000)
BorderLength	The length of the country’s land border measured in kilometers. [1759; 3158.155, 3464.317]	http://chartsbin.com/view/mp2

Notes: Summary statistics based on all available data for 147 countries for years 2007 to 2017. The number of countries included in the estimated models is somewhat smaller due to missing observations.
UNCTAD = United Nationals Conference on Trade and Development -
http://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=92
LPI = Logistics Performance Index - https://lpi.worldbank.org/about
PWT – Penn World Tables 9.1

Table 2: Correlation matrix of key variables

	1.	*2.*	*3.*	*4.*	*5.*	*6.*	*7.*	*8.*
EconGR	1.000							
SClogistics	-0.064	1.000						
	[0.120]							
SCtimeliness	-0.021	0.926	1.000					
	[0.620]	[0.000]						
SCtracking	-0.055	0.962	0.889	1.000				
	[0.184]	[0.000]	[0.000]					
SCquality	-0.068	0.977	0.881	0.937	1.000			
	[0.101]	[0.000]	[0.000]	[0.000]				
SCshipments	-0.050	0.927	0.830	0.868	0.880	1.000		
	[0.230]	[0.000]	[0.000]	[0.000]	[0.000]			
SCinfrastructure	0.111	0.969	0.859	0.915	0.953	0.868	1.000	
	[0.007]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]		
SCcustoms	0.063	0.957	0.840	0.891	0.934	0.860	0.942	1.000
	[0.128]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	

Notes: See Table 1 for variable definitions. N=587. Probability values are in brackets.

Table 3
Supply chain reliability and economic growth: Baseline models
Dependent variable: *EconGR*

	(3.1)	(3.2)	(3.3)	(3.4)	(3.5)	(3.6)	(3.7)
SClogistics	0.010**						
	(0.004)						
SCcustoms		0.009**					
		(0.004)					
SCinfrastructure			0.003				
			(0.003)				
SCshipments				0.007			
				(0.004)			
SCquality					0.009**		
					(0.004)		
SCtracking						0.008**	
						(0.004)	
SCtimeliness							0.011***
							(0.004)
GDP(t-1)	-0.009***	-0.009***	-0.009***	-0.009***	-0.009***	-0.009***	-0.009***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
INVEST	0.018***	0.018***	0.018***	0.018***	0.018***	0.018***	0.018***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
EmpGR	0.271***	0.271***	0.273***	0.269***	0.270***	0.279***	0.268***
	(0.087)	(0.087)	(0.088)	(0.088)	(0.087)	(0.088)	(0.087)
HumanCap	0.010**	0.010**	0.011***	0.011***	0.010**	0.010***	0.010**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
LandLocked	0.005	0.005	0.004	0.005	0.005	0.005	0.005
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
<u>Elasticity</u>							
SClogistics measure	1.439**	1.234**	0.471	0.945	1.236**	1.217**	1.760**
	(0.672)	(0.587)	(0.489)	(0.635)	(0.588)	(0.577)	(0.695)
Observations	513	513	513	513	513	513	513
R-squared	0.226	0.227	0.220	0.222	0.226	0.226	0.230

*Notes: See Table 1 for variable details. Each model is estimated using OLS controlling for regional and time specific effects. Robust standard errors are in parentheses. Standard errors of elasticities are based on the delta method. Asterisks denote the following significance levels: *** p<0.01, ** p<0.05, and * p<0.1*

Table 4
Supply chain reliability and economic growth: Accounting for simultaneity
Dependent variable: *EconGR*

	(4.1)	(4.2)	(4.3)	(4.4)	(4.5)	(4.6)	(4.7)
SClogistics	0.024*						
	(0.013)						
SCcustoms		0.018*					
		(0.010)					
SCinfrastructure			0.021*				
			(0.012)				
SCshipments				0.034*			
				(0.018)			
SCquality					0.019		
					(0.012)		
SCtracking						0.025*	
						(0.014)	
SCtimeliness							0.029*
							(0.017)
GDP(t-1)	-0.013***	-0.011***	-0.013***	-0.012***	-0.012***	-0.013***	-0.013***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
INVEST	0.017***	0.017***	0.017***	0.016**	0.017***	0.018***	0.016***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
EmpGR	0.260***	0.261***	0.261***	0.249***	0.257***	0.280***	0.253***
	(0.093)	(0.093)	(0.094)	(0.097)	(0.092)	(0.092)	(0.093)
HumanCap	0.006	0.008*	0.006	0.006	0.007	0.007	0.006
	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
LandLocked	0.007*	0.005	0.007*	0.009**	0.007*	0.008**	0.008*
	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Observations	451	451	451	451	451	451	451
Endogeneity test	1.517	0.709	2.817*	2.663	1.137	2.125	1.154
	[0.218]	[0.400]	[0.093]	[0.103]	[0.286]	[0.145]	[0.283]
Weak Identification test	29.18	34.06	24.01	12.63	29.06	19.58	11.45
Underidentification test	33.41***	36.83***	30.83***	19.83***	37.27***	28.90***	17.33***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Overidentification test	0.121	0.822	0.016	0.575	0.016	0.032	0.216
	[0.728]	[0.365]	[0.899]	[0.448]	[0.899]	[0.859]	[0.642]

*Notes: See Table 1 for variable details. Each equation is estimated using two-stage least squares controlling for regional and time specific effects. Robust standard errors are in parentheses. For each potentially endogenous logistics variables we used BorderLength and their own spatial lag (averaged from 2007-2010). Asterisks denote the following significance levels: *** p<0.01, ** p<0.05, and * p<0.1.*

Table 5
Supply chain reliability and economic growth:
Impact of infrastructure dimensions
Dependent variable: *EconGR*

	(5.1)	(5.2)	(5.3)
ShippingINDX	0.0001***	0.0002**	0.0001**
	(0.000)	(0.000)	(0.000)
RAIL		0.000	
		(0.000)	
AIR		0.000	
		(0.000)	
INTERNET			0.0001
			(0.000)
GDP(t-1)	-0.012***	-0.030***	-0.013***
	(0.002)	(0.005)	(0.002)
INVEST	0.029***	0.043***	0.031***
	(0.007)	(0.008)	(0.008)
EmpGR	0.283***	0.549***	0.274***
	(0.070)	(0.083)	(0.071)
HumanCap	0.015***	0.017**	0.013***
	(0.003)	(0.007)	(0.004)
LandLocked	0.030**		0.031*
	(0.014)		(0.016)
Observations	1,096	211	986
R-squared	0.261	0.642	0.270

*Notes: See Table 1 for variable details. Each model is estimated using OLS with regional and time effects. Robust standard errors are in parentheses. Asterisks denote the following significance levels: *** p<0.01, ** p<0.05, and * p<0.1*

Table 6
Supply chain reliability and economic growth: Impact of colonial legacy
Dependent variable: *EconGR*

	(6.1)	(6.2)	(6.3)	(6.4)	(6.5)	(6.6)	(6.7)
SClogistics	0.009*						
	(0.005)						
SCcustoms		0.008*					
		(0.004)					
SCinfrastructure			0.003				
			(0.004)				
SCshipments				0.006			
				(0.004)			
SCquality					0.008*		
					(0.004)		
SCtracking						0.008*	
						(0.004)	
SCtimeliness							0.010**
							(0.004)
GDP(t-1)	-0.009***	-0.009***	-0.009***	-0.009***	-0.009***	-0.009***	-0.009***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
INVEST	0.017***	0.017***	0.017***	0.017***	0.017***	0.018***	0.017***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
EmpGR	0.251***	0.252***	0.251***	0.248***	0.249***	0.258***	0.246***
	(0.091)	(0.091)	(0.091)	(0.091)	(0.091)	(0.092)	(0.091)
HumanCap	0.010**	0.010**	0.011***	0.010**	0.010**	0.010**	0.009**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
LandLocked	0.004	0.004	0.004	0.004	0.004	0.004	0.004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
COLONY	0.000	-0.000	-0.001	-0.001	0.000	-0.000	-0.000
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Observations	497	497	497	497	497	497	497
R-squared	0.221	0.222	0.216	0.218	0.221	0.221	0.225

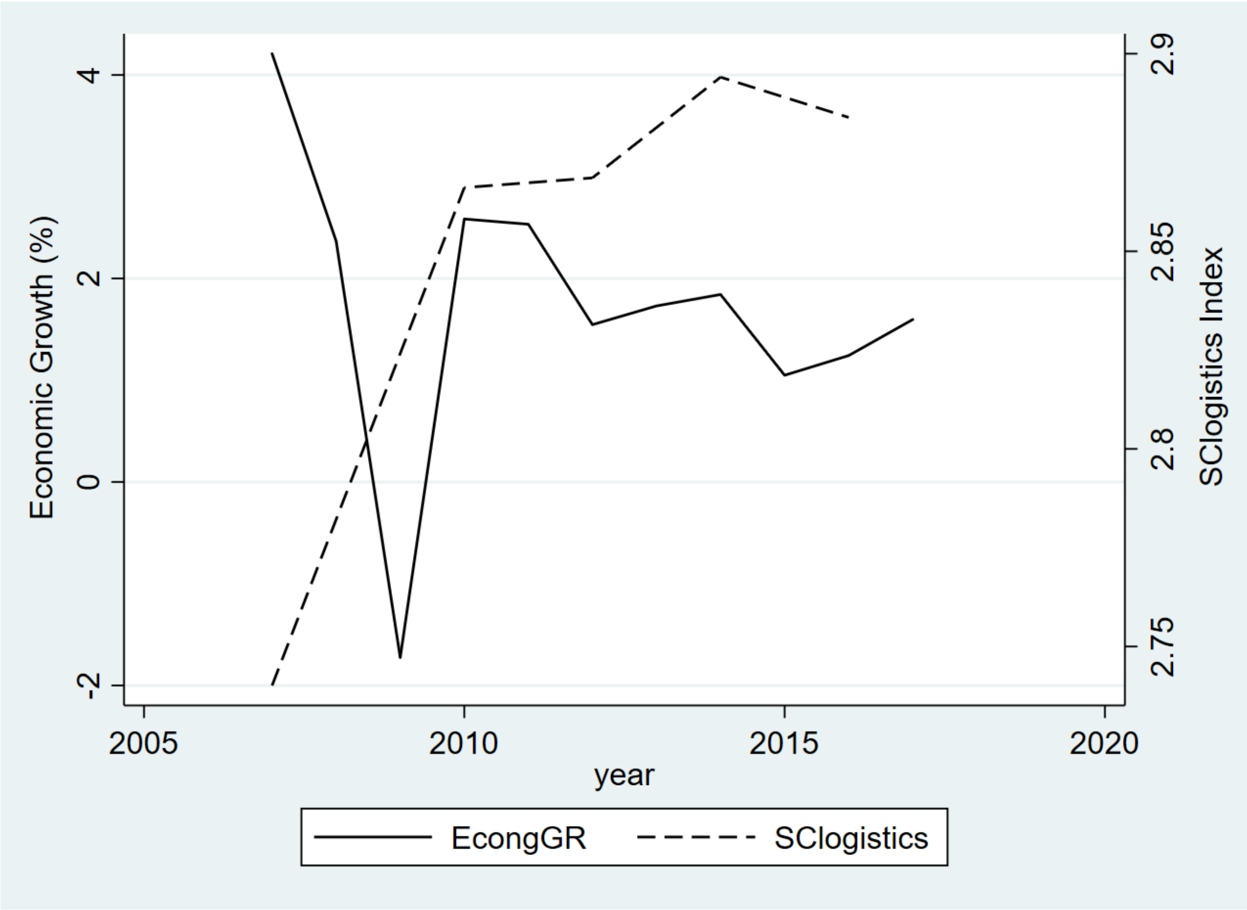
*Notes: See Table 1 for variable details. Each model is estimated using OLS controlling for regional and time specific effects. Robust standard errors are in parentheses. Asterisks denote the following significance levels: *** p<0.01, ** p<0.05, and * p<0.1*

Table 7
Simulated impacts of supply-chain disruptions

Magnitude of disruption→			10%	20%	30%	10%	20%	30%
Country	*EconGR*	*SClogistics*	*SClogistics disruption*			*Corresponding EconGR*		
	(sample values)							
China	6.4%	3.50	3.15	2.80	2.45	5.5%	4.6%	3.7%
USA	0.7%	3.91	3.52	3.13	2.74	0.6%	0.5%	0.4%
Sierra Leone	2.4%	2.01	1.81	1.61	1.41	2.0%	1.7%	1.4%
Germany	1.3%	4.12	3.71	3.29	2.88	1.1%	0.9%	0.8%
Nepal	3.2%	2.27	2.04	1.82	1.59	2.7%	2.3%	1.8%

Notes: Simulations are based off the elasticity estimate 1.44 reported in Model 3.1 of Table 3.

Figure 1
Economic growth and supply-chain logistics



Note: Data based on averages of all countries – see Table 1 for details.