Received: 17 April 2022 | Revised: 3 July 2023 | Accepted: 15 July 2023

DOI: 10.1111/roie.12701

ORIGINAL ARTICLE

WILEY

How did GVC-trade respond to previous health shocks? Evidence from SARS and MERS

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Abstract

A health crisis can impact GVCs adversely by raising bilateral trade costs and via supply- and demand-side shocks in the exporting and importing countries. Focusing on trade in select GVC-intensive sectors, we disentangle the effects of these different channels in the context of SARS and MERS in a structural gravity framework. The estimated effects are found to be small in magnitude and show significant heterogeneity by sector, channel and disease outbreak. SARS-induced rise in bilateral trade costs is found to reduce the export value and number of products traded of both intermediate and final goods, while similar adverse effects from MERS are only observed on intermediate goods export value. There is more evidence for the adverse effects of supply-shocks from both SARS and MERS in our results, while the expected negative effects of the demand-shock are only observed for MERS. The SARS effects are found to diminish over time, pointing to resilience of the associated value-chains. We also find suggestive evidence for SARS in particular being associated with geographical diversification and widening of value-chains.

KEYWORDS

COVID-19, diversification, GVC-trade, MERS, SARS

JEL CLASSIFICATION

F1, F14

1 | INTRODUCTION

COVID-19 has proved to be an unprecedented health and economic crisis with long-term implications for countries across the world. According to WHO data, it has infected over 650 million lives as of May 31, 2023 since its outbreak in Wuhan, China in December 2019. A burgeoning literature has developed around analysing the epidemiological and macroeconomic impact of this pandemic (Baldwin & di Mauro, 2020; Djankov & Panizza, 2020; Eichenbaum et al., 2020; Guerrieri et al., 2020; McKibbin & Fernando, 2020). The crisis also has significant implications for trade and investment due to disruption of global value chains (GVCs). These disruptions emanate from the demand shock that lockdowns and stalled economic activity have caused as well as the supply shock resulting from temporary or permanent breaks in supply networks. Additionally, there is the GVC contagion effect (Baldwin & Freeman, 2020; Friedt & Zhang, 2020)—the pandemic has affected many locations simultaneously and the high level of interconnectedness of the global economy has amplified the impact.

Former health epidemics might offer examples regarding the nature and channels through which these disruptions affect trade using data currently available. We thus aim to inform the discussion on geographical/supplier diversification and disruption of value-chains by studying the response of trade in select GVC-based products[1] to two past health epidemics, SARS and MERS, both to understand how value-chains may have responded to those crises and to draw implications, if at all, for the COVID-19 outbreak. We focus on SARS and MERS for reasons that are common to the current pandemic—both outbreaks originated at an epicenter but spread around quickly; the diseases are characterized by flu-like symptoms; and manufacturing value-chains were likely disrupted by both episodes.[2] Besides, these outbreaks are separated by a decade, and the share of GVC-trade in total trade was rising and falling, respectively, at these points in time (World Bank, 2020), which also makes it interesting to examine the impact of both epidemics from a GVC-trade perspective.

Infectious disease outbreaks have a profound impact on GVCs, simultaneously affecting multiple countries and industries, with the fear of contagion resulting in unanticipated changes in demand and supply of products (Sheffi, 2015). This fear can lead to under-reporting of an outbreak, especially if the country fears an ex-post application of trade sanctions against it by non-outbreak countries (Brahmbhatt & Dutta, 2008). It is believed that epidemic outbreaks are a unique type of supply-chain risk characterized by long-term disruption in demand, supply and logistics as well as unpredictable ripple effects. The location of supply bases in severely affected regions creates disruptions in supply networks; suppliers may close their plants or may be unable to deliver their products (Ivanov, 2020; Miroudot, 2020). For example, a supply-side contagion in East Asia's (China, Japan, Korea, and Taiwan) manufacturing sectors may hurt manufacturing sectors of other countries as well due to supply linkages, especially in automobile, textiles and ICT goods sectors (Baldwin & Tomiura, 2020). Similarly, the decrease in domestic output in Thailand due to COVID-19 is attributed to increasing trade costs and under-utilization of capital, especially in the ICT goods industry that has the highest level of fragmentation of production in that country (Maliszewska et al., 2020). Moreover, the scope and timing of disruptions play a vital role in determining the impact of an epidemic outbreak on supply chains; the asynchronous opening and closing of facilities creates uncertainty at the firm-level, necessitating a guided framework for better decision-making (Ivanov, 2020).

Building resilience during a pandemic is thus the topmost priority for firms integrated in supply chains. Brandon-Jones et al. (2014) and Miroudot (2020) distinguish between building robustness and resilience in supply chains—the ability to recover in the postcrisis period is resilience, while the ability to continue firm operations during a crisis is robustness. Extant literature proposes two opposing solutions to build resilience. One, insurance against a disruption by diversifying the supplier base, albeit at an additional cost, to reduce excess dependence on one country and compensate loss from a few supplier breakdowns (Baldwin & Henriet et al., 2012; Tomiura, 2020); and two, isolation from any disruption through reshoring manufacturing firms back home (di Mauro, 2020; Henriet et al., 2012).

Exclusive reliance on suppliers from one or a few countries can be detrimental by exposing importers to localized risks from health crises or natural disasters. Hence diversifying to alternative suppliers or locations of production during a crisis is more of a robustness strategy compared to reshoring manufacturing back home to a localized setting (Miroudot, 2020). However, long-term firm-to-firm relationship with a single supplier can assist in an easy bounce-back in the postcrisis period (Antràs, 2020), besides avoiding sunk costs from diversification at the eleventh-hour. Hence, there is an apparent downside to diversification vis-à-vis recovery, as supplier diversification is associated with slower recovery from interruptions (Jain et al., 2016). Strange (2020) recommends diversification over reshoring citing increased firm costs, reduced competitiveness and foreign sale of goods due to reshoring of firms closer home. Bonadio et al. (2020) and Eppinger et al. (2020) also find reshoring to be suboptimal from an economic welfare perspective. The negative sentiment around reshoring is also corroborated by firms: 32% of executives interviewed in an UNCTAD survey associated reshoring of manufacturing functions with a significant decline in global FDI (UNCTAD, 2015). Similarly, Hassan et al. (2020) show that discussions about diversifying supply chains in firm-level conference calls on corporate sector resilience during epidemics peaked during the first quarter of 2003, clashing with the SARS outbreak.

Existing literature has studied the macroeconomic consequences of natural disasters, including health crises (Noy, 2009; Raddatz, 2009; Toya & Skidmore, 2007). Previous research suggests that economic development and institutional quality may provide implicit insurance against natural disasters (Kahn, 2005). Recent work provides both historical evidence (Ceylan et al., 2020) and empirical analysis (Fernandes & Tang, 2020; Friedt & Zhang, 2020; Hayakwa & Mukunoki, 2021; Liu et al., 2021), including on the role of GVCs in the propagation of the COVID-19-induced shock (Bonadio et al., 2020; Eppinger et al., 2020; Espitia et al., 2021; Kejzar & Velic, 2020; Sforza & Steininger, 2020).

We contribute to this literature by studying GVC responses to SARS and MERS as observed in actual trade data[3] and thus focus our analysis on select merchandize sectors regarded as the most GVC-intensive in applied work (Sturgeon and Memedovic,2010; OECD and World Bank WITS classifications). A health crisis can impact GVCs adversely by raising bilateral trade costs and via supply- and demand-side shocks in the exporting and importing countries[4]. In a departure from most existing studies, we disentangle the effects of these different channels in a structural gravity framework. Moreover, we consider both the value of bilateral trade in intermediate and final goods across GVC-intensive sectors and the number of such products traded in our empirical analysis.

Our results show small magnitudes of the estimated effects and significant heterogeneity in them by sector, channel and disease outbreak. There is more evidence for the adverse effects of supply-shocks from both SARS and MERS in our results, while the expected negative effects of the demand-shock are only observed for MERS. Meanwhile, SARS-induced rise in bilateral trade costs is found to reduce the export value and number of products traded of both intermediate and final goods in the electronics, apparel and textile sectors, while similar adverse effects from MERS are only observed on the value of intermediate goods exports in apparel and electronics. While our SARS results are consistent with firm-level findings on the impact of that outbreak on Chinese trade in Fernandes and Tang (2020), to the best of our knowledge, we are the first to document the adverse effects of MERS on international trade along the extensive and intensive margin using rigorous empirical analysis.

Our results also provide suggestive evidence for geographical diversification of value-chains—the SARS outbreak in particular is found to be associated with a rise in the number of export destinations and a decline in partner concentration for both intermediates and final goods across GVC-intensive sectors. The value-chains also seem to have been resilient to the SARS outbreak—the adverse impact in affected sectors was found to diminish significantly over time. These results are consistent with SARS's medium term impact observed on Chinese firm-level trade in Fernandes and Tang (2020).

Our paper adds to existing literature on the impact of health epidemics. It is also related to different strands of the empirical literature examining the determinants and effects of (i) the global financial crisis (Ahn et al., 2011; Baldwin, 2009; Bems et al., 2010; Chor & Manova, 2012; Crowley & Luo, 2011; Levchenko et al., 2010) and (ii) natural disasters, especially the 2011 earthquake in Japan (Barrot & Sauvagnat, 2016; Boehm et al., 2019; Carvalho et al., 2021; Freund et al., 2022; Todo et al., 2015; Zhu et al., 2016). Finally, our diversification analysis adds value by departing from existing studies that focus on ex-ante diversification before the realization of shocks (Caselli et al., 2020; Esposito, 2020; Huang, 2017).

The rest of the article is organized as follows. Section 2 provides a brief background on the two virus outbreaks and studies examining their impact. Section 3 provides a conceptual discussion of the likely impact of exogenous crises on the extensive and intensive margins of trade and on partner concentration to motivate the empirical analysis. Section 4 provides stylized facts on the evolution of GVC-trade patterns in the aftermath of the two epidemics. Section 5 discusses the empirical methodology used to examine the impact of SARS and MERS on GVC-trade. Section 6 discusses results from estimation. Section 7 concludes with a discussion of the possible relevance of our findings for the COVID-19 pandemic.

2 | BACKGROUND: SARS, MERS, AND THEIR IMPACT

Severe Acute Respiratory Syndrome or SARS is a viral infectious disease caused by SARS-related coronavirus. It was first detected in China in November 2002, but spread rapidly to over thirty countries (including in neighboring Asia) by the first quarter of 2003. SARS was declared a global threat with 8437 cumulative cases, of which, 7452 reported recoveries (WHO, 2003), putting the mortality rate at 9.6%. Majority of the cases were concentrated in China (63.1%) and Hong Kong (20.8%) and these also accounted for 79.5% of the total SARS-reported deaths (WHO, 2003). As the virus spread through contact with the infected individual, controlling measures consisted of an early warning system, isolation of suspected cases, and contact tracing. SARS had costs beyond immediate health concerns; it created widespread panic, halted tourist activity in the region as well as greatly impacted trade and the overall far-eastern economy with losses worth US$ 30 billion by May 2003 (Demmler & Ligon, 2003). The disruption to international travel also impacted business meetings, leading to cancelation of factory orders and adding to the medium-term impact of the disease (Fernandes & Tang, 2020).

Several studies have examined the economic cost of SARS (Hai et al., 2004; Hanna & Huang, 2004; Lee & McKibbin, 2004; Smith et al., 2019). The overall impact was felt across sectors, as diverse as seafood to microchips (ADB, 2003; IMF, 2004; NIC, 2003). SARS deterred global FDI in industrial production in China (Fan, 2003; Hanna & Huang, 2004) and in Hong Kong and

Japan (Keogh-Brown & Smith, 2008). The threat to manufacturing sectors in China was to the extent that new orders were placed on hold and investors halted expansion plans for the year. Lee and McKibbin (2004) show that Hong Kong and China experienced the largest shocks to their GDPs from the SARS outbreak compared to Taiwan and Singapore, primarily due to their greater reliance on trade. In fact, Taiwan may have faced a wave of delayed shocks to its trade and investment due to linkages with mainland China (Chou et al., 2004). Fernandes and Tang (2020) show that firms in the affected regions of China experienced a year-on-year (YoY) decline in export and imports for three consecutive quarters during the outbreak. Moreover, they continued to experience unfavorable growth even during the last quarter of 2005, supporting the claim that the SARS outbreak had a medium-term impact on Chinese trade.[5]

A similar contagion fear was felt soon after the outbreak of the Middle East Respiratory Syndrome, identified as a high-risk pathogen by the WHO (Memish et al., 2020). MERS is a viral respiratory disease caused by the novel coronavirus that was first detected in Jeddah, Saudi Arabia on June 13, 2012 (WHO, 2019). Outbreaks were reported in 27 countries including Saudi Arabia, UAE, Jordan, Oman, Qatar, Germany, and South Korea, though the incidence of cases was concentrated in Saudi Arabia over 2013–2017; the UAE in 2014 and in South Korea in 2015. Notably, 84.2% of the reported cases of infection in Saudi Arabia were acquired mostly from hospitals and health workers treating infected patients; 65.7% of these cases were identified in the period 2014-2016 alone. The next highest number of cases was reported outside of the Middle-east in South Korea with 158 cases and 38 fatalities that resulted in an economic loss of US$ 8.5 billion in that country (Myoung-don et al., 2018) and contracted overall export activity (Smith et al., 2019). Of the 2499 global cumulative cases reported, 858 died due to compromised immunity and severe co-morbidities, taking the case-fatality rate to 34.3% (Memish et al., 2020; WHO, 2019).

3 | CONCEPTUAL DISCUSSION

Firms participating in GVCs exchange highly customized inputs on a repeated basis (Antràs, 2020); our empirical strategy can thus be explained using the theoretical framework in Acemoglu and Tahbaz-Salehi (2020). The virus outbreaks result in negative shocks to the economy (observed as lower productivity or higher fixed costs of operation for some firms, sectors, or in aggregate) that alter the distribution of surplus throughout the production network, causing customized firms to fail either due to the direct negative shock to their production technology or indirectly from a break in their supplier network; reduced demand from their customers; or other increases in the bilateral costs of doing business along their network. This firm failure also leads to a decline in trade, which is more likely to be pronounced for firms and clients located in countries more severely affected by the disease outbreaks, a fact that we exploit in our empirical strategy that focuses on both the supply and demand shocks emanating from these health crises.

Bernard et al. (2007) use firm-product data to distinguish between two extensive margins for exporting firms (the number of products that firms trade and the number of export destinations) and an intensive margin (the value they trade per product per country). Their analysis shows that both the number of exporting firms and the number of exported products increase in importer income and sharply decrease with the distance to the destination country, which is a proxy for bilateral trade costs. In a standard heterogeneous-firm model of trade with CES preferences, where trade costs include both fixed entry and variable (iceberg) costs of exporting, any imposition or increase in trade costs has a negative impact on the extensive margin of trade (Chaney, 2008; Crozet & Koenig, 2010; Lawless, 2010; Melitz, 2003). Fixed costs can emanate from bureaucratic paperwork associated with exporting, marketing costs, or from the costs of running a wholesale and retail distribution chain (Lawless, 2010). In contrast, variable costs relate to transport costs, tariffs, and the variable costs associated with marketing and distribution.

An exogenous health crisis affecting a particular destination is a negative shock on importer income together with a likely increase in both the fixed and variable costs of trading; each of these changes will reduce the number of exporting firms and the number of products exported. Fixed costs of exporting to each market (Romer, 1994) imply that only varieties with sufficiently low marginal costs of production (relative to quality) will be profitable to export to a given market (Hummels & Klenow, 2005). Crises-induced increases in the marginal costs of production (emanating inter alia from domestic supply shocks, reduced/no availability and/or a rise in prices of imported intermediates) will render some varieties unprofitable to export to a given destination, resulting in a fall in the number of products exported. Similarly, some destination markets are likely to have lower thresholds for profitable entry by exporting firms. As these thresholds fall further across destination markets due to crises-induced shocks, they become even more profitable for exporting firms, resulting in a rise in the number of export destinations.

Meanwhile, export sales depend positively on productivity and on the exporting country's GDP and price level, and negatively on variable trade costs. Once a firm becomes an exporter, fixed costs do not have any impact on the level of sales. In this framework (for instance see Lawless, 2010), total exports to a destination are affected by an exogenous shock through two channels—the change in sales of above-(productivity)threshold firms and the change in the (productivity) threshold itself. An increase in crisis-induced variable trade costs affects both channels, by reducing the sales of current exporters and by increasing the productivity levels needed to export. While a rise in crisis-induced fixed costs does not affect the sales of current exporters, it still impacts total sales as these costs are included in determining the threshold productivity, an increase in which results in some firms exiting the market, resulting in lower total export sales. These adverse trade cost effects are compounded by a fall in productivity and GDP of the exporting country emanating from the health crisis.

Thus, a health crisis can adversely impact GVC-trade along both margins by increasing the bilateral costs of doing business and via supply- and demand-side shocks in the exporting and importing countries.

In contrast, the likely impact of health shocks on diversification decisions are more ambiguous. A firm may decide to diversify its import sources if the marginal benefit from doing so outweighs the marginal cost (Freund et al., 2022). Tweaking their simple model, the marginal benefit from diversification depends on the cost (c) and risk differentials (r) between two alternative sources and the value of imports (M). The marginal cost, in turn, depends on the search costs (fixed, F) of finding an alternative supplier and on operating costs (variable, V) that include the cost of establishing new relationships (or beaking existing ones). In this simple model, looking for alternative suppliers is a rational decision if $(c + r)M > (F + V)$. If an existing source of imports is at a greater risk of a macroeconomic or health crisis, then the risk differential vis-à-vis an alternative supplier increases, making diversification attractive. However, if the search costs of looking for alternative suppliers or the cost of breaking existing relationships is high (as is the case with customized inputs used in value-chains, for instance see Antràs, 2020), then the status-quo may be more appealing. The impact of a macroeconomic or health shock on diversification of suppliers (GVC-widening) is thus ambiguous, depending on the relative magnitudes of these opposing mechanisms.

4 | STYLIZED FACTS

In this section, we use disaggregated HS6-digit-level data to look at the pattern of import shares of intermediate goods in select GVC-intensive sectors from the SARS- and MERS-worst-affected countries, before, during and after the incidence of these outbreaks to motivate the empirical analysis. We also see if these episodes were associated with a fall in the number of intermediate products exported by the worst-affected countries or with a fall in the number of their export destinations. Our analysis covers GVC-based intermediates in the apparel, automobiles, electronics, footwear and pharmaceuticals sectors; note that a few HS6-digit products are classified as intermediates common to the automobiles and electronics sectors.

Figures 1 and 2 show the intensive (mean share in total imports by value in the top panel) and extensive margin (mean number of importers and mean number of products imported in the middle and bottom panels, respectively) trends of GVC-based intermediate imports from SARS-worst-affected suppliers (China, Hong Kong, and Singapore); and from MERS-worst-affected suppliers (Saudi Arabia, the UAE, and South Korea), respectively[6].

Figure 1 (top panel) shows a decline in the share of intermediate imports by value in the auto & electronics sectors from Hong Kong and in footwear from Singapore in the wake of the SARS outbreak. These declines seem to have been arrested by 2005–2006, which suggests that SARS may have had a medium-term impact on exporters of these intermediate products in the

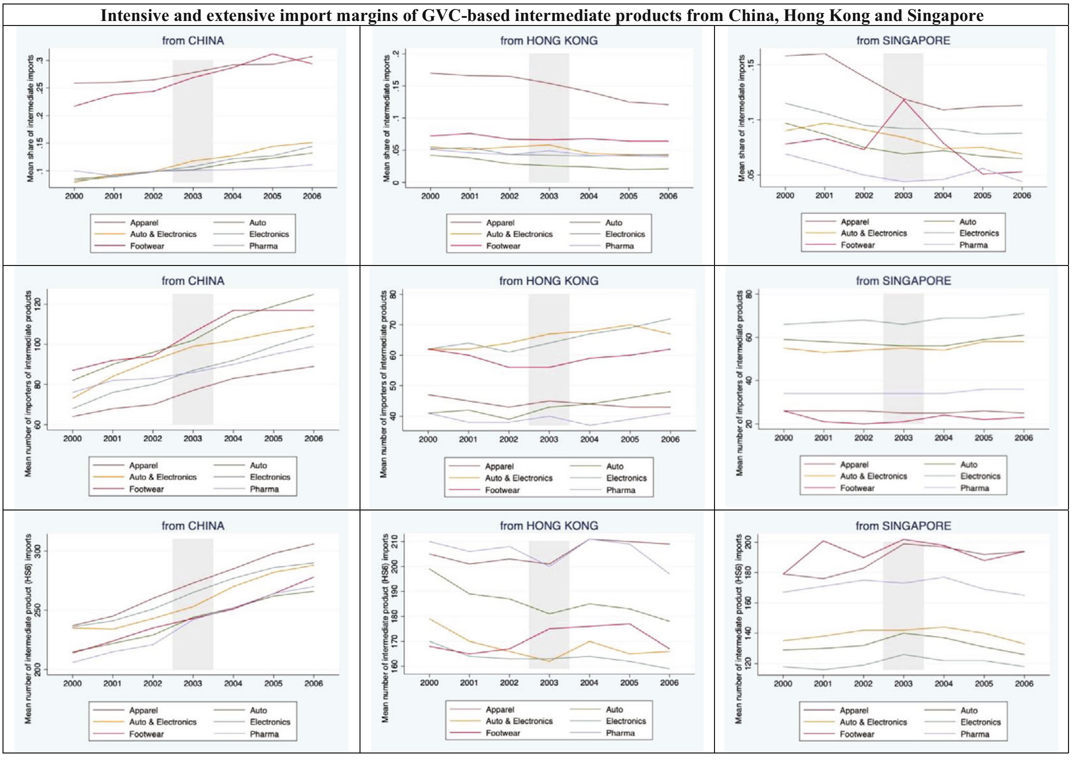

FIGURE 1 Intensive and extensive import margins of GVC-based intermediate products from China, Hong Kong and Singapore. *Source*: BACI dataset; own calculations. [Colour figure can be viewed at wileyonlinelibrary.com]

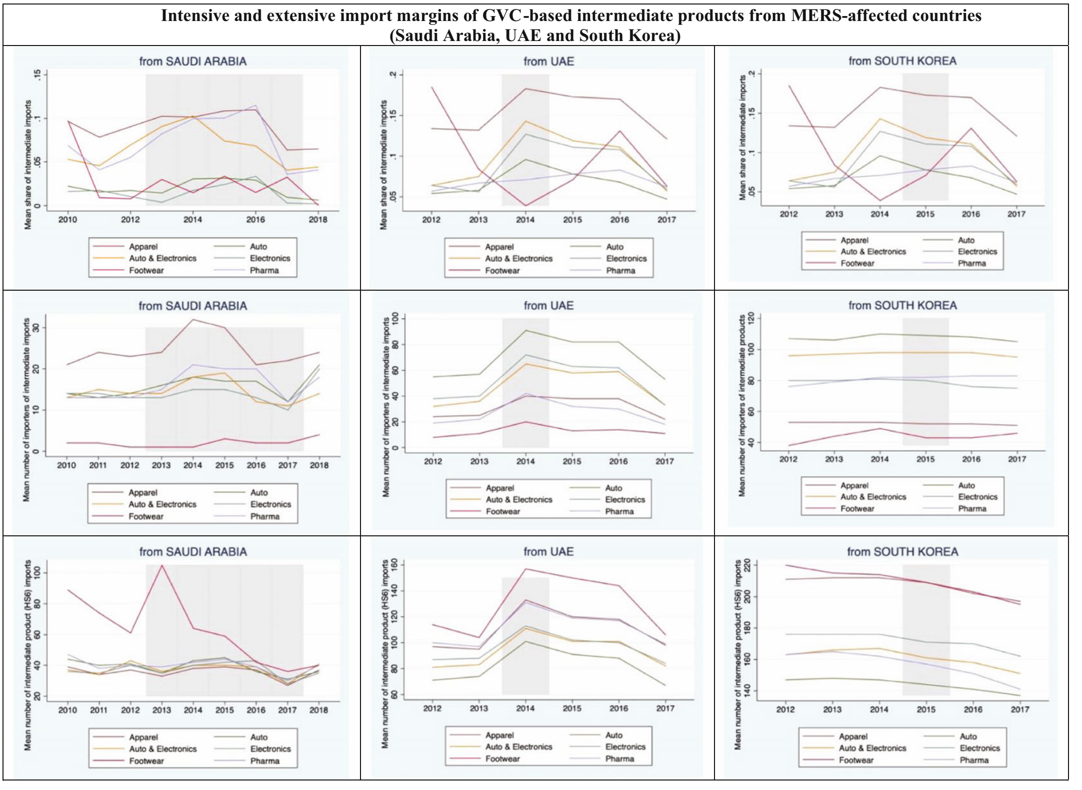

FIGURE 2 Intensive and extensive import margins of GVC-based intermediate products from MERS-affected countries (Saudi Arabia, UAE, and South Korea). *Source*: BACI dataset; own calculations. [Colour figure can be viewed at wileyonlinelibrary.com]

two countries. The decline in import value shares in all other sectors from both Hong Kong and Singapore seems to have predated the SARS outbreak. Hong Kong also seems to have exported intermediate products to fewer destinations in the apparel and pharma sectors (middle panel) in the wake of this disease episode, while Singapore seems to have exported fewer number of intermediate products in the auto, electronics, apparel and footwear sectors (bottom panel) during this health crisis. In contrast, intermediate imports from China, the disease epicenter, seem to have been unaffected by SARS at both the intensive and extensive margins. These stylized facts thus provide mixed and only some sector-specific evidence for the adverse effects of SARS on GVC-trade.

In contrast, suggestive evidence for the adverse impact of MERS on GVC-trade is relatively stronger, especially in the case of UAE (Figure 2). The top panel shows that intermediate import value shares of auto & electronics, and apparel and pharma from Saudi Arabia reported a decline during 2014–2017 and 2016–2017, respectively; a similar decline was observed in the share of intermediate imports by value across sectors (barring footwear and pharma) from the UAE. Both countries, with the UAE in particular, also seem to have witnessed a decline in the number of their trading partners (middle panel) and in the number of GVC-based intermediates (bottom panel) exported across sectors in the wake of this outbreak. In contrast, any extensive and intensive margin decline in intermediate imports from South Korea observed in Figure 2 seems to have predated the MERS outbreak.

While these stylized facts are suggestive of some sector-specific reconfiguration of GVCs in response to these disease outbreaks, the patterns are mixed and do not provide conclusive evidence of the "impact" of these health crises on GVC-trade. The identification of these effects requires more rigorous causal inference, which is the subject of the following section.

5 | EMPIRICAL STRATEGY

Our empirical strategy is embedded in a structural gravity framework. Following Anderson and van Wincoop (2004), the value of exports of product p from country i to country j at time t can be written as follows:

$$X_{ijt}^{p} = \frac{E_{jt}^{p} Y_{it}^{p}}{Y_{t}^{p}} \left(\frac{\phi_{ijt}^{p}}{P_{it}^{p} \Pi_{jt}^{p}} \right)^{(1-\sigma^{p})}, \tag{1}$$

where X_{ijt} denotes the value of exports of product p from country i to j at time t, E_j is the expenditure on product p in the destination country j, Y_i denotes the total sales of product p of exporter i toward all destinations, Y is the total world output of product p, ϕ_{ij}^{p} are the product-specific bilateral trade costs and σ^p is the elasticity of substitution across products. P_{it}^{p} and Π_{jt}^{p} are the product-specific outward and inward Multilateral Resistance Terms (MRTs) as defined in the literature.

Trade costs in ϕ_{ijt}^{p} can arise from different sources such as product-specific import tariffs (τ_{ijt}^{p}); geographical distance between trading partners [$ln(DIST_{ij})$]; cultural distance proxied by dummy variables identifying whether the trading partners share a common border ($CNTG_{ij}$), had a colonial relationship ($CLNY_{ij}$) and share a common language ($LANG_{ij}$); and membership of preferential trade agreements (PTA_{ijt}). Recent advancements in the estimation of structural gravity advocate the use of three-way fixed effects to mitigate endogeneity-induced biases in estimation (for instance see Baier & Bergstrand, 2007; Piermartini & Yotov, 2016)[7]. The dyadic trade cost variables ($lnDIST_{ij}$, $CNTG_{ij}$, $CLNY_{ij}$ and $LANG_{ij}$) are thus subsumed in product-specific bilateral pair-wise fixed effects.

5.1 | Intensive margin analysis

SARS and MERS could have impacted country i's exports to country j via multiple channels. For instance, country j could have changed the share of expenditure allocated to sector k (such as pharmaceuticals) emanating from changes in disease-induced consumption patterns. The viral outbreaks could have also reduced consumption and investment in country j, leading to a general slump in demand. They could have hurt firm productivity (through factory shutdowns and reduced labor supply due to absence of infected workers) and supplier networks (leading to shortage or unavailability of intermediate inputs) in country i, generating a supply-side shock. The reduction in domestic demand in country i could have also forced firms to leave some productive capacity idle, further decreasing productivity. The health crises could have also increased the bilateral costs of merchandize trade emanating from reduced availability and frequency of freight transport.

Departing from most existing studies, we consider the effects of both increases in bilateral trade costs and supply and demand-side shocks emanating from the disease episodes in our empirical analysis. Following recent literature (Friedt & Zhang, 2020; Liu et al., 2021), the shocks are measured on the supply and demand-side by the share of the number of cases of each outbreak in the population of the exporting ($SARS_{it}/MERS_{it}$) and importing ($SARS_{it}/MERS_{it}$) countries, respectively. Any rise in bilateral trade costs due to the viral outbreaks is measured by the interaction terms $SARS_{it} * SARS_{jt}$ and $MERS_{it} * MERS_{jt}$.

The baseline equation takes the following form[8]:

$$X_{ijpt}^{I/F,k} = exp(\beta_1 SARS_{it} + \beta_2 SARS_{jt} + \beta_3 SARS_{it} * SARS_{jt} + \beta_4 MERS_{it} + \beta_5 MERS_{jt} + \beta_6 MERS_{it} * MERS_{jt} + \beta_7 ln(1 + \tau_{ijpt}) + \beta_8 PTA_{ijt} + \alpha_{ijp} + \mu_{ipt} + \gamma_{jpt} + \rho_t) + \epsilon_{ijpt}, \quad (2)$$

where $X_{ijpt}^{I/F,k}$ is the value of country i's exports of GVC-based intermediate/final (I/F) products (p) in sector k in destination country j at time t; τ_{ijpt} are the applied tariffs in country j on HS6-digit product p exported by country i; PTA_{ijt} denotes membership of preferential trade agreements between countries i and j; μ_{ipt} and γ_{jpt} are the product- and time-varying exporter and importer fixed effects; α_{ijp} are the product-specific dyadic fixed effects; ρ_t are the year fixed-effects to control for the confounding influence of the global financial crisis in 2008–2009; and ϵ_{ijpt} is the error term.

One challenge in estimating equation (2) is that the supply and demand-shocks cannot be directly estimated as the product- and time-varying exporter and importer fixed effects are completely collinear with $SARS_{it}/MERS_{it}$ and $SARS_{jt}/MERS_{jt}$, respectively. To enable identification of the supply and demand-side shocks, we therefore deploy an alternative estimation strategy based on "shift-share" regressions. The $SARS_{it}/MERS_{it}$ and $SARS_{jt}/MERS_{jt}$ variables are weighted, respectively, by the exposure of each importing country to a particular exporter ($w_{jip} = \frac{X_{ijp}}{M_{jp}}$; where M is imports) and the exposure of each exporting country to a particular importer ($w_{ijp} = \frac{X_{ijp}}{X_{ip}}$) in the year 2000. The exposure variables are constructed using bilateral trade values at the HS6-digit level and for intermediate and final goods separately and in a precrisis year to assuage endogeneity-related concerns. The use of the exposure variables makes intuitive sense as the incidence of disease cases in any supplier (destination) would matter more if that supplier (destination) was important in the importer's (exporter's) partner distribution. Econometrically, the interaction of the exposure weights with the $SARS_{it}/MERS_{it}$ and $SARS_{jt}/MERS_{jt}$ variables enables identification of the supply and demand-side shocks as the interacted terms are no longer collinear with the product- and time-varying exporter and importer fixed effects.

The final estimating equation takes the following form:

$$X_{ijpt}^{I/F,k} = exp(\beta_1 SARS_{it} * w_{jip} + \beta_2 SARS_{jt} * w_{ijp} + \beta_3 SARS_{it} * SARS_{jt} + \beta_4 MERS_{it} * w_{jip} + \beta_5 MERS_{jt} * w_{ijp} + \beta_6 MERS_{it} * MERS_{jt} + \beta_7 ln(1 + \tau_{ijpt}) + \beta_8 PTA_{ijt} + \alpha_{ijp} + \mu_{ipt} + \gamma_{jpt} + \rho_t) + \epsilon_{ijpt}. \quad (3)$$

Equation (3) is estimated separately for intermediate and final goods in each GVC-intensive sector in a panel over the time period 2001–2018. A priori, we expect the estimates of β_1 through β_6 to be negative in all results.

5.2 | Extensive margin analysis

A variant of equation (3) is also used to examine empirically if the epidemics were associated with a change in the number of HS6-digit products exported ($Prod_{ijt}$). Thus:

$$Prod_{ijt}^{I/F,k} = exp(\beta_1 SARS_{it} * w_{ji} + \beta_2 SARS_{jt} * w_{ij} + \beta_3 SARS_{it} * SARS_{jt} + \beta_4 MERS_{it} * w_{ji} + \beta_5 MERS_{jt} * w_{ij} + \beta_6 MERS_{it} * MERS_{jt} + \beta_7 PTA_{ijt} + \alpha_{ij} + \mu_{it} + \gamma_{jt} + \rho_t) + \epsilon_{ijt}. \quad (4)$$

Negative values of the estimated coefficients would provide evidence for the adverse effects of SARS and MERS at the extensive margin.

5.3 | Geographical diversification of value-chains

To examine if the supply-shocks emanating from the disease outbreaks were associated with a widening of value-chains, we depart from the gravity framework and estimate the following equation:

$$HHI_{ipt}^{I/F,k} = \varphi_1 SARS_{it} + \varphi_2 MERS_{it} + \mu_{pt} + \gamma_{ip} + \rho_t + \epsilon_{ipt}, \quad (5)$$

where $HHI_{ipt}^{I/F,k}$ is the Hirschmann–Herfindahl index of partner concentration[9] constructed for intermediate and final goods separately in each GVC-intensive sector at the HS6-digit level for country i at time t; μ_{pt} and γ_{ip} are the product-year and exporter-product fixed effects; and ϵ_{ipt} is the error term. Estimated $\varphi_1, \varphi_2 < 0$ would provide evidence for widening of value-chains from the outbreaks-induced supply-shocks. Conceptually, if reliance on imported products remains high despite the shock, then the importing country is likely to find new trading partners to source these imports from (at the expense of the disease-affected countries), whose shares would therefore rise, leading to GVC-widening.

Finally, to examine if the supply-shocks were associated with a change in the number of destination markets for the exported GVC-products, we estimate the following equation:

$$PAR_{ipt}^{I/F,k} = exp(\alpha_1 SARS_{it} + \alpha_2 MERS_{it} + \mu_{pt} + \gamma_{ip} + \rho_t) + \epsilon_{ipt}, \quad (6)$$

where $PAR_{ipt}^{I/F,k}$ is the number of destination markets for intermediate and final products in each GVC-intensive sector for country i at time t; and all other variables are as defined above. Estimated $\alpha_1, \alpha_2 > 0$ would provide evidence for a rise in the number of destination markets for the exported GVC-products from the outbreaks-induced supply-shocks. Note that our diversification analysis also adds value by departing from existing studies that focus on ex-ante diversification before the realization of shocks (Caselli et al., 2020; Esposito, 2020; Huang, 2017).

Equations (3), (4), and (6) are estimated using the Poisson Pseudo-Maximum Likelihood (PPML; Silva & Tenreyro, 2006), which accounts for both zero values of the dependent variable and for heteroskedasticity-related concerns in estimation; equation (5) is estimated using OLS. The time period for analysis is 2001–2018 as the exposure variables are constructed in the year 2000.

Summary statistics are reported in Appendix Table A2. Trade data are taken from BACI (Gaulier & Zignago, 2010) and those on bilateral applied HS6-digit tariffs from UNCTAD Trains. PTA_{ijt} is constructed using information from the WTO's RTA-IS database.

6 | RESULTS AND ANALYSIS

6.1 | Export value

Sector-specific results from estimating equation (3) are reported in Table 1 for GVC-based intermediate and final goods. All estimations include exporter-product-year, importer-product-year, product-specific dyadic and year fixed effects. The (unreported) standard errors are clustered by dyad-product-year in each case.

For ease of interpretation, the table reports the marginal effects (in percentage) emanating from a one standard deviation increase in the value of all SARS- and MERS-specific variables[10] except for $ln(1+\tau_{ijpt})$ and PTA_{ijt} for which the table reports point estimates. The SARS-induced supply-side shock is found to be associated with marginal effects of −1.4% on exports of footwear intermediates and those of −0.45% and −0.04% on final exports of auto and electrical products. Similar adverse effects are not observed for the remaining sectors on the supply-side and notably, on any sector on the demand side. SARS-induced bilateral trade costs rise is found to reduce the export value of electrical intermediates (marginal effect of −0.24%) and final textile products, though the latter effect is weakly estimated. MERS is found to be associated with adverse effects on export value from supply- (electrical and pharma intermediates; apparel and textiles final goods) and demand-side shocks (apparel and footwear final goods) as well as from the increase in bilateral trade costs (apparel and electrical intermediates), though some of these effects are also weakly estimated.

The magnitudes of the estimated marginal effects are small across sectors, which is consistent with the stylized facts observed in Figures 1 and 2. Also, there is more evidence for the adverse effects of supply-shocks from both SARS and MERS in these results, while the expected negative effects of the demand-shock are only observed for MERS.

In other results, the expected negative effect of applied bilateral tariffs on export value is observed across most sectors barring auto and footwear where the coefficient estimates lack statistical significance for both intermediate and final products. Moreover, PTA membership is found to increase the export value of GVC-based intermediate and final products across sectors with the exception of electrical and pharmaceutical intermediates.

6.2 | Number of products traded

Sector-specific results from estimating equation (4) are reported in Table 2. All estimations include exporter-year, importer-year, dyadic and year fixed effects. The (unreported) standard errors are clustered by dyad-year in each case. For ease of interpretation, the table again reports the percentage marginal effects emanating from a one standard deviation increase in the value of all SARS- and MERS-specific variables except for PTA_{ijt} for which the table reports point estimates.

There is more conclusive evidence for the adverse effects of MERS-induced supply- and demand-side shocks at the extensive margin for both GVC-based intermediates and final goods across sectors in the results reported in Table 2. The adverse effects are again more pronounced on the supply-side and for GVC-based final goods in particular. The marginal effects hover around −0.5% across the final goods sectors on the supply-side and range from −0.05% (electricals) to −0.12% (apparel and auto) on the demand-side. The adverse effects of MERS on both export value and number of products suggest that the outbreak resulted in a productivity shock as well as a rise in marginal production costs.

In contrast, supply and demand shocks emanating from SARS may not have been associated with a decline in the number of HS6 products exported in the results reported in Table 2,

TABLE 1 Impact of SARS and MERS on export value.

	PPML estimation; dependent variable = X_{ijpt}									
	Intermediate goods					**Final goods**				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
VARIABLES	**APP**	**AUTO**	**ELE**	**FOOT**	**PHARMA**	**APP**	**AUTO**	**ELE**	**FOOT**	**TEX**
$SARS_{it}$*W_{jip}	4.30%	−1.07%	−0.04%	−1.37%***	−0.07%	−0.05%	−0.45%***	−0.04%***	−0.06%	0.44%
$SARS_{jt}$*W_{ijp}	0.47%	0.02%	0.10%	11.59%	2.79%	1.02%	−0.10%	0.10%	1.49%	0.27%
$SARS_{it}$*$SARS_{jt}$	0.09%	0.00%	−0.24%***	0.09%	0.13%	0.06%	−0.42%	0.02%	0.04%	−0.06%*
$MERS_{it}$*W_{jip}	0.19%	0.04%	−1.45%**	0.32%	−1.91%*	−0.13%*	0.24%	−0.10%	−0.13%	−0.27%**
$MERS_{jt}$*W_{ijp}	0.06%	−0.17%	−0.04%	−0.78%	−0.59%	−0.37%***	−0.02%	0.49%	−1.59%***	0.04%
$MERS_{it}$*$MERS_{jt}$	−0.01%**	0.00%	−0.05%**		0.34%	0.01%	0.00%	0.00%	0.02%	0.01%
$\ln(1+\tau_{ijpt})$	−0.2301***	0.0106	−0.1181*	−0.0128	−0.2112***	−0.1994***	−0.0748	−0.0874*	−0.0135	−0.1781**
PTA_{ijt}	0.1886***	0.1049**	−0.0515	0.6061**	−0.6004***	0.1502***	0.9167***	0.3143***	0.1799***	0.3498***
Observations	638,540	310,844	117,311	14,186	38,678	1,635,326	126,661	514,763	167,378	399,693
Pseudo R2	0.988	0.995	0.987	0.983	0.992	0.986	0.995	0.990	0.988	0.987

Note: Table reports marginal effects in % from a one standard deviation rise in the values of all variables except for $\ln(1+\tau_{ijpt})$ and PTA_{ijt} for which it reports point estimates. All estimations include exporter-product-year, importer-product-year, product-specific dyadic and year fixed effects. Values of standard errors, clustered by dyad-product- year, are not reported.
Levels of significance: *10%, **5%, ***1%.

TABLE 2 Impact of SARS and MERS on the number of HS6-digit products exported.

	PPML estimation; dependent variable = $Prod_{ijt}$								
	Intermediate goods					**Final goods**			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
VARIABLES	**APP**	**AUTO**	**ELE**	**PHARMA**	**APP**	**AUTO**	**ELE**	**FOOT**	**TEX**
$SARS_{it}$*W_{jip}	0.006%	0.059%	0.019%	0.009%	0.095%	0.061%	0.080%	0.086%	0.096%
$SARS_{jt}$*W_{ijp}	0.019%	0.022%	0.020%	0.011%	0.037%	0.044%	0.031%	0.051%	0.028%
$SARS_{it}$*$SARS_{jt}$	0.001%	0.001%	0.001%	0.001%	−0.001%***	0.0002%	0.0003%	−0.0003%*	0.00001%
$MERS_{it}$*W_{jip}	−0.17%***	−0.056%	−0.154%	−0.193%*	−0.53%***	−0.134%	−0.50%***	−0.556%***	−0.515%***
$MERS_{jt}$*W_{ijp}	0.035%	0.014%	−0.001%	−0.028%*	−0.117%***	−0.11%***	−0.054%**	−0.085%	−0.079%*
$MERS_{it}$*$MERS_{jt}$	0.004%	−0.001%	−0.001%	−0.001%	0.005%	−0.001%	−0.001%	0.002%	0.002%
PTA_{ijt}	−0.0136***	−0.0306***	−0.0492***	0.0211***	−0.0039	−0.0214***	−0.0314***	0.0482***	−0.0035
Observations	200,634	187,846	190,942	164,017	216,086	174,769	251,879	138,228	172,235
Pseudo R2	0.921	0.728	0.762	0.597	0.889	0.672	0.897	0.555	0.851

Note: Table reports marginal effects in % from a one standard deviation rise in the values of all variables except for PTA_{ijt} for which it reports point estimates. All estimations include exporter-year, importer-year, dyadic and year fixed effects. Values of standard errors, clustered by dyad-year, not reported.

Levels of significance: *10%, **5%, ***1%.

which is again consistent with the stylized facts in Figures 1 and 2. However, the SARS-induced bilateral trade costs increase may have reduced final goods exports in apparel and footwear, though the estimated marginal effect is found to be very small in magnitude. These results suggest that the adverse effect of SARS observed on export value may have been primarily via the productivity-shock channel.

6.3 | GVC-diversification

Sector-specific results from estimating equations (5) and (6), reported in Table 3, provide evidence for geographical diversification in the form of an increase in the number of export destinations and widening of value-chains in response to the supply-shock emanating from the SARS outbreak in particular. All estimations include product-year, exporter-product, and year fixed effects. The (unreported) standard errors are clustered by exporter-year in each case. As above, the table reports the percentage marginal effects emanating from a one standard deviation increase in the value of the exporter-specific SARS and MERS case-share variables and point estimates for the two control variables, $ln(GDP_{it})$ and GE_{it}.

Marginal effects reported in Table 3 suggest that a one standard deviation rise in the value of the SARS variable is associated with 0.02-0.03% declines[11] in the Hirschmann–Herfindahl index of partner concentration (top panel) and a 0.4-1.2% increase in the number of export destinations (bottom panel) across sectors. These results suggest that the SARS outbreak may have lowered the thresholds for profitable entry by exporting firms across destination markets. Meanwhile, evidence for geographical diversification from the MERS-induced supply-shock is limited and only observed in apparel and pharma intermediates.

For most countries, the import reliance on China is greater than that on the MERS-worst-affected countries across GVC-based products; given the conceptual discussion in Section 3, this raises the marginal benefit from geographical diversification in the wake of SARS, resulting in a decline in partner concentration. Meanwhile, nominal GDP and government effectiveness are found to be strongly correlated with both our measures of GVC-diversification, justifying their choice as control variables in the analysis.

6.4 | GVC-resilience

We focus on examining resilience of value-chains to the SARS epidemic given that the confounding influence of the COVID-19 pandemic would render such an assessment challenging in the context of MERS. In particular, we examine the resilience of value-chains to the SARS-induced supply-side shock in two distinct intermediate and final goods sectors where this shock was found to have an adverse effect on exports in the results reported in Table 1. To do so, we estimate the following equation:

$$X_{ijpt}^{I/F,k} = exp\left(\sum_{z=0}^{4} \beta_z (SARS_{it} * w_{jip} * Year_{t+z}) + \beta_5 ln(1+\tau_{ijpt}) + \beta_6 PTA_{ijt} + \alpha_{ijp} + \mu_{ipt} + \gamma_{jpt} + \rho_t\right) + \epsilon_{ijpt}, \tag{7}$$

where $Year_{t+z}$ is a binary dummy that takes the value one in each of 2003 (corresponding to $t+0$) to 2007 and all other variables are as defined previously. The estimated coefficients of the $SARS_{it}$ $*$

TABLE 3 SARS, MERS and geographical diversification.

	Intermediate goods					Final goods				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	APP	AUTO	ELE	FOOT	PHARMA	APP	AUTO	ELE	FOOT	TEX
OLS estimation; dependent variable = HHI_{ipt}										
$SARS_{it}$	−0.024%***	−0.013%	−0.028%**	−0.025%**	−0.027%***	−0.028%***	0.002%	−0.033%***	−0.035%***	−0.023%***
$MERS_{it}$	−0.083%**	0.023%	−0.009%	0.077%	−0.084%***	−0.015%	0.012%	−0.016%	−0.020%	0.004%
$\ln(GDP_{it})$	−0.0041***	−0.0088***	−0.0099***	−0.0070***	−0.0023**	−0.0048***	−0.0032**	−0.0119***	−0.0032**	−0.0025*
GE_{it}	−0.0045***	−0.0062***	−0.0054***	−0.0094***	−0.0065***	−0.0025	−0.0055***	−0.0057***	−0.0055***	−0.0053***
Observations	5,562,835	2,363,887	2,182,764	108,244	1,076,252	8,658,196	1,455,258	7,223,126	1,008,040	2,919,657
R-squared	0.206	0.282	0.247	0.366	0.222	0.249	0.271	0.262	0.295	0.262
PPML estiomation; dependent variable = PAR_{ipt}										
$SARS_{it}$	0.66%***	−0.17%	0.31%	0.44%***	0.43%***	1.22%***	0.16%	0.50%***	1.01%***	0.54%***
$MERS_{it}$	0.36%	0.11%	0.40%	0.00%	0.54%**	0.21%	0.21%	0.37%	0.19%	0.09%
$\ln(GDP_{it})$	0.1630***	0.1496***	0.1781***	0.0941***	0.1050***	0.0466*	0.1124***	0.1482***	−0.0753***	0.0431**
GE_{it}	0.0737***	0.0906***	0.1015***	0.1177***	0.1141***	0.0322	0.0841***	0.0572**	0.1044***	0.0656***
Observations	412,285	91,519	98,647	6,444	49,573	438,982	81,803	343,930	48,105	195,813
Pseudo R2	0.481	0.695	0.569	0.676	0.591	0.592	0.688	0.591	0.667	0.583

Note: Table reports marginal effects in % from a one standard deviation rise in the values of $SARS_{it}$ and MERSit and point estimates for $\ln(GDP_{it})$ and GE_{it}. All estimations include product-year, exporter-product and year fixed effects. Values of standard errors, clustered by exporter-year, are not reported.
Significance levels: *10%, **5%, ***1%.

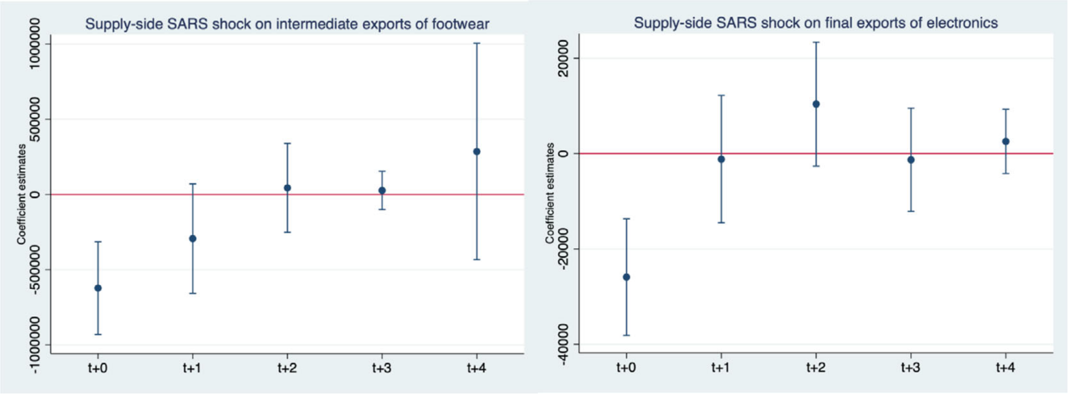

FIGURE 3 GVC-resilience to the supply-side SARS shock (The figure presents the estimation results for Equation (7). The dots represent the point estimates; the vertical bands are the 95% confidence intervals). [Colour figure can be viewed at wileyonlinelibrary.com]

w_{jip} variables interacted with the $Year_{t+z}$ dummies plotted in Figure 3 suggest that the adverse effects of the SARS-induced supply-side shock on the value of intermediate exports in footwear and final goods exports in the electronics sector diminished progressively over time. This suggests that GVC-trade in these sectors was resilient to that shock and that the associated value-chains returned to precrisis operations relatively quickly.

7 | CONCLUSION

We examine the response of trade in select GVC-intensive sectors to two previous health shocks to draw implications, if at all, for the COVID-19 pandemic. Our results reveal small adverse effects with considerable heterogeneity by sector, channel and disease outbreak. The SARS-induced rise in bilateral trade costs is found to reduce the export value and number of products traded of both intermediate and final goods, while similar adverse effects from MERS are only observed on intermediate goods export value. We also find more evidence for the adverse effects of supply-shocks from both SARS and MERS in our results, while the expected negative effects of the demand-shock are only observed for MERS. Empirical analysis also suggests geographical diversification of value chains and their non-resilience to SARS. While our SARS results are consistent with firm-level findings on the impact of that outbreak on Chinese trade in Fernandes and Tang (2020), to the best of our knowledge, we are the first to document the adverse effects of MERS on international trade along the extensive and intensive margin using rigorous empirical analysis.

It is tempting to compare SARS and COVID-19 given that both originated in China, but one must be mindful of the evolution of China's share in global GDP and trade over time, the inter-connectedness of the world economy and the severity of the current pandemic. During SARS, China accounted for 4% of global output; today, that number has quadrupled. Thus, any slowdown in China today will impact the world much more severely than in 2003. Moreover, GVC participation continues to be an important mechanism for international transmission of shocks (Berthou et al., 2020; Cigna & Quaglietti, 2020; Friedt & Zhang, 2020) though some early analysis suggests that it may have also been a source of resilience during the current pandemic (de Lucio et al., 2022; Giglioli et al., 2021; Simola, 2021).

The overall impact of COVID-19 is also worse than SARS because of three additional reasons. One, the scale of the pandemic is much larger than that of SARS both in terms of incidence of cases and geographical spread (less than 10,000 lives were affected by the relatively more localized-SARS versus over 650 million confirmed cases of COVID-19 worldwide between December 2019 and May 2023). Two, the state-mandated lockdowns in March 2020 resulted in immediate supply and demand shocks with lingering adverse effects on economies. Three, services trade has been hit more severely this time as upto 75% of international services transactions by value require physical proximity between buyers and sellers and the latter was the first casualty of travel bans and social-distancing practices in the wake of this pandemic (Shingal, 2020; WTO, 2020).

At the same time, the impact of COVID-19 also depends on the type of products being traded through supply networks. For instance, Fernandes and Tang (2020) found capital and skill-intensive products to have been more resilient to the export disruption caused by SARS. Similarly, Taiji et al. (2018) found sourcing of differentiated inputs to be less vulnerable to trade-shocks. Moreover, we find the adverse effects of SARS on GVC-trade in the affected sectors to have diminished significantly over time, suggesting that despite any partial re-configuration induced by the initial shock, value-chains tend to return to precrisis operations relatively quickly.

Finally, while prior epidemic experience may be significantly associated with a less negative sentiment toward COVID-19 (Hassan et al., 2020), anecdotal evidence[12] suggests that there may be a more conscious move toward geographical and supplier diversification following this pandemic. At the same time, the pandemic has spurred e-commerce and is also likely to accelerate the fourth industrial revolution through adoption of automation, 3D printing and extreme customization. It would be interesting to study these changes and their ramifications on GVCs in future research.

ACKNOWLEDGMENTS

We would like to thank the managing editor on this manuscript, Lisandra Flach, and two anonymous referees for their constructive comments and suggestions. Earlier versions of the paper have benefited from comments made by participants at ITSG, SPJIMR, OEET Turin, UNIDO Conference on Sustainability of GVCs Vienna, and XXXII Villa Mondragone International Economic Seminar Rome. We would also like to thank Bernard Hoekman, Sébastien Miroudot and Ben Shepherd for their useful comments and suggestions at various stages.

CONFLICT OF INTEREST STATEMENT

We have no conflict of interest to report.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request

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ENDNOTES

[1] Following Sturgeon and Memedovic (2010) and the World Bank WITS classification (available at https://wits.worldbank.org/referencedata.html), these are products classified as intermediate and final products in GVCs in the apparel, automobiles, electronics, footwear, pharmaceuticals and textiles sectors.

[2] We do not look at Zika (sporadic occurrence through 2000–2018), Ebola (localized in West Africa, with the region significantly less integrated in GVCs) and H1N1 (concurrence with the global financial crisis renders identification challenging).

[3] We use bilateral trade data from BACI (Gaulier & Zignago, 2010), disaggregated at the HS 6-digit level over the 2001–2018 period, for over 200 countries (see Appendix Table A1).

[4] Following recent literature (Friedt & Zhang, 2020; Liu et al., 2021), we measure the supply- and demand-side shocks of SARS and MERS using data on the number of cases of each outbreak in the exporting and importing countries, respectively.

[5] In contrast, Hong Kong returned to pre-SARS GDP levels by the end of 2003, while 2004 showed slight growth over the previous year (Keogh-Brown & Smith, 2008).

[6] These countries reported the largest number of cases and amongst the highest case fatality rates according to data from the WHO (https://www.who.int/csr/sars/country/table2004_04_21/en/; https://www.who.int/emergencies/mers-cov/en/). For instance, the number of SARS cases in China (the disease epicenter) and Hong Kong during January–June 2003 were 5327 and 1755, respectively, while the case fatality rate was 17% in Hong Kong and Canada (251 cases), 14% in Singapore (238 cases) and 7% in China. Vietnam reported 63 SARS cases and a case fatality rate of 8%. Similarly, Saudi Arabia, where MERS originated, had 158, 662, 454, 249, and 233 cases during each year of 2013–2017, followed by 185 cases in South Korea in 2015 and 86 cases in the UAE in 2014.

[7] The use of product-time-varying exporter and importer fixed effects additionally account for MRTs in estimation (Anderson & Yotov, 2012) and control for all observed and unobserved time- and product-varying exporter- and importer-specific determinants of bilateral trade.

[8] Note that the notation regarding the subscripts is slightly modified to accommodate the product dimension, p.

[9] $HHI_{ipt} = \checkmark \left[\sum_{j=1}^{N} \left(\frac{X_{ijpt}}{X_{ipt}}\right)^2\right]$. The value of the HHI lies between 0 (fully diversified) to 1 (unitary partner).

[10] In the case of the SARS-induced supply-side shock measured by $SARS_{it} * W_{jip}$ for instance, the marginal effect is calculated as $[exp(Coefficient^{SARSit*Wjip} * s.d.^{SARSit} * Mean^{Wjip}) - 1] * 100$, using sector-specific values of $s.d.^{SARSit}$ and $Mean^{Wjip}$ reported for intermediate and final goods in Appendix Table A2.

[11] The marginal effects are calculated as $[exp(\widehat{SARS_{it}} * s.d.^{SARS_{it}}) - 1]$ using the sector-specific standard deviation of $SARS_{it}$ reported for the intermediate/final goods sample in Appendix Table A2.

[12] For example, Apple has shifted the manufacturing of some mobile phones to Vietnam, India, Taiwan and Mexico. Google smartphone unit is set to move to Northern Vietnam, while it has already chosen Thailand for its smart-home product unit. Microsoft is also expected to start manufacturing in Vietnam soon. Meanwhile, the Indonesian textiles industry witnessed a 10% rise in the number of orders, primarily from global brands looking to substitute trade with China. The Japanese megabrand UNIQLO has also moved sourcing from China to Vietnam.

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How to cite this article: Shingal, A., & Agarwal, P. (2023). How did GVC-trade respond to previous health shocks? Evidence from SARS and MERS. *Review of International Economics*, 1–25. https://doi.org/10.1111/roie.12701

APPENDIX

TABLE A1 Country coverage.

Afghanistan, Albania, Algeria, American Samoa, Andorra, Angola, Anguilla, Antarctica, Antigua and Barbuda, Argentina, Armenia, Aruba, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bermuda, Bhutan, Bolivia, Bonaire, Bosnia and Herzegovina, Botswana, British Indian Ocean Territory, British Virgin Islands, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cabo Verde, Cambodia, Cameroon, Canada, Cayman Islands, Central African Republic, Chad, Chile, China, Hong Kong, Macao, Christmas Islands, Cocos Islands, Colombia, Comoros, Congo, Cook Islands, Costa Rica, Croatia, Cuba, Curácao, Cyprus, Czech Republic, Cote d'Ivoire, Democratic People's Republic of Korea, Democratic Republic of the Congo, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Estonia, Ethiopia, FS Micronesia, Falkland Islands, Fiji, Finland, Fr. South Antarctic Terr., France, French Polynesia, Gabon, Gambia, Georgia, Germany, Ghana, Gibraltar, Greece, Greenland, Grenada, Guam, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kiribati, Kuwait, Kyrgyzstan, Lao People's Dem. Rep., Latvia, Lebanon, Liberia, Libya, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Marshall Islands, Mauritania, Mauritius, Mexico, Mongolia, Montenegro, Montserrat, Morocco, Mozambique, Myanmar, N. Mariana Islands, Namibia, Nauru, Nepal, Neth. Antilles, Netherlands, New Caledonia, New Zealand, Nicaragua, Niger, Nigeria, Niue, Norfolk Islands, Norway, Oman, Pakistan, Palau, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Pitcairn, Poland, Portugal, Qatar, South Korea, Republic of Moldova, Romania, Russia, Rwanda, Saint BarthÇlemy, Saint Helena, Saint Kitts and Nevis, Saint Lucia, Saint Maarten, Saint Pierre and Miquelon, Saint Vincent and the Grenadines. Samoa, San Marino, Sao Tome and Principe, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Slovakia, Slovenia, South Africa, Solomon Islands, Somalia, South Sudan, Spain, Sri Lanka, State of Palestine, Sudan, Suriname, Sweden, Switzerland, Syria, TFYR of Macedonia, Tajikistan, Thailand, Timor-Leste, Togo, Tokelau, Tonga, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Turks and Caicos Islands, Tuvalu, USA, Uganda, Ukraine, United Arab Emirates, United Kingdom, United Rep. of Tanzania, Uruguay, Uzbekistan, Vanuatu, Venezuela, Viet Nam, Wallis and Futuna Islands, Yemen, Zambia, and Zimbabwe.

TABLE A2 Summary statistics.

VAR	STAT	Intermediates APP	AUTO	ELE	FOOT	Final goods PHARMA	APP	AUTO	ELE	FOOT	TEX
X_{ijpt} ($ '000s)	Mean	750.9	3534.1	5683.0	1032.9	6045.0	693.7	9153.8	2629.6	1545.5	416.2
	Std. Dev.	10,506.6	50,719.6	179,161.3	6658.3	92,339.8	10,545.2	181,699.8	89,621.6	28,530.3	6995.4
$Prod_{ijt}$	Mean	27.6	12.5	11.4	2.0	6.4	39.6	8.1	28.7	7.1	16.7
	Std. Dev.	52.9	13.3	13.9	1.0	6.5	56.7	9.2	42.2	6.5	25.4
HHI_{ipt}	Mean	0.468	0.477	0.453	0.488	0.430	0.479	0.470	0.433	0.453	0.478
	Std. Dev.	0.190	0.180	0.174	0.188	0.180	0.183	0.194	0.178	0.178	0.185
PAR_{ipt}	Mean	47.5	86.4	70.8	51.5	81.6	55.3	77.5	76.4	67.0	49.6
	Std. Dev.	36.2	47.3	42.0	36.0	50.7	37.5	53.1	45.9	43.4	37.3
$SARS_{it}$	Mean	0.00000043	0.00000020	0.00000040	0.00000045	0.00000015	0.00000044	0.00000015	0.00000042	0.00000041	0.00000034
	Std. Dev.	0.00000997	0.00000631	0.00000914	0.00001027	0.00000541	0.00001023	0.00000533	0.00000949	0.00000971	0.00000886
$SARS_{jt}$	Mean	0.00000033	0.00000013	0.00000025	0.00000026	0.00000017	0.00000020	0.00000009	0.00000020	0.00000016	0.00000021
	Std. Dev.	0.00000866	0.00000514	0.00000721	0.00000759	0.00000599	0.00000641	0.00000435	0.00000648	0.00000572	0.00000667
$MERS_{it}$	Mean	0.00000002	0.00000003	0.00000002	0.00000001	0.00000002	0.00000002	0.00000003	0.00000002	0.00000002	0.00000003
	Std. Dev.	0.00000036	0.00000041	0.00000036	0.00000022	0.00000045	0.00000032	0.00000053	0.00000041	0.00000037	0.00000045

TABLE A2 (Continued)

		Intermediates				Final goods					
VAR	**STAT**	**APP**	**AUTO**	**ELE**	**FOOT**	**PHARMA**	**APP**	**AUTO**	**ELE**	**FOOT**	**TEX**
$MERS_{jt}$	Mean	0.00000004	0.00000004	0.00000004	0.00000003	0.00000005	0.00000005	0.00000005	0.00000004	0.00000005	0.00000005
	Std. Dev.	0.00000057	0.00000061	0.00000060	0.00000055	0.00000065	0.00000067	0.00000066	0.00000063	0.00000068	0.00000065
W_{jip}	Mean	0.074	0.046	0.046	0.060	0.059	0.047	0.063	0.054	0.051	0.068
	Std. Dev.	0.178	0.136	0.141	0.163	0.151	0.144	0.170	0.152	0.146	0.177
W_{ijp}	Mean	0.036	0.021	0.023	0.037	0.024	0.031	0.026	0.023	0.026	0.034
	Std. Dev.	0.122	0.095	0.095	0.129	0.096	0.118	0.111	0.096	0.104	0.122
$\ln(1+\tau_{ijpt})$	Mean	0.3	0.1	0.1	0.2	0.2	0.3	0.3	0.1	0.4	0.3
	Std. Dev.	0.5	0.4	0.3	0.4	0.4	0.5	0.5	0.3	0.5	0.5
PTA_{ijt}	Mean	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Std. Dev.	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
$\ln(GDP_{it})$	Mean	27.2	27.1	27.0	26.9	27.0	26.6	27.1	27.1	26.8	27.1
	Std. Dev.	1.7	1.7	1.7	1.8	1.8	1.9	1.9	1.7	1.9	1.7
GE_{it}	Mean	0.8	0.9	1.0	0.8	1.0	0.7	1.0	1.1	0.7	0.8
	Std. Dev.	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.8	0.9	0.9