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Supply chains in times of crisis:

Evidence from Kenya's production network

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Abstract

Trading relationships between suppliers and buyers play a key role in transmitting both local and international shocks. We use rich transaction-level data from Kenya to study the relevance of a firm's domestic network position and links to international supply chains in determining its trajectory during the COVID-19 crisis. We document that firms with varying degrees of exposure to import and export markets differ substantially in terms of their size and age profile. The specialisation of direct importers, often intermediaries, on international markets made them very vulnerable to the initial COVID-19 shock. Exporters, one-third of which operate in primary sectors, experienced a less drastic downturn. We find that both importers and exporters adjust their domestic supply chains in response to international trade shocks. Sourcing from international markets crowds in domestic purchases, while sales abroad and at home are substitutes. Diversified domestic networks further helped to mitigate the impact of severe shocks like the COVID-19 crisis and contributed to a stronger recovery.

JEL Classification: F15, F43; L25

Keywords: trade; production networks; COVID-19; resilience; intermediation; heterogeneous firms; firm-to-firm relationships

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1 Introduction

The COVID-19 pandemic threw a new spotlight on the role of supply chain structures for firm dynamics. Previous research has documented the key role of interdependencies that arise through firm-to-firm trade in the transmission and amplification of shocks.¹ The present paper relies on a rich set of administrative firm- and transaction-level data from Kenya, East Africa’s largest economy, to document the firm dynamics in response to the COVID-19 crisis. The setting enables us to study the role of a firm’s supply chain position in determining its trajectory during times of heightened uncertainty and the recovery from a severe aggregate shock. We focus on three aspects of the firm’s network position: the degree of exposure to international supply chains, the diversification, and the complexity of its domestic network.

While only a small share of firms worldwide participates in international supply chains, non-participants are indirectly linked to them via domestic buyers and suppliers ([Ahn et al., 2011](#); [Bernard et al., 2015](#); [Dhyne et al., 2021](#); [Grant and Startz, 2022](#)). Customs data, the most popular sources with which to trace global supply chains at the firm-and transaction-level, typically only capture firms that directly import and export. Hence, firms with indirect exposure remain understudied compared to their relative importance in many low- and middle-income economies. Therefore, a key contribution of our paper, is its ability to combine domestic firm-to-firm transaction level data with customs data, allowing us to trace indirect exposure of Kenyan private sector firms to global value chains.

The purpose of this paper is three-fold: First, we document the degree to which formal firms in Kenya’s private sector are directly or indirectly embedded in international supply chains. We find that only a few large firms have strong direct or indirect linkages to international supply chains. These firms are key to the Kenyan economy, both in terms of their share of total sales and employment. On the export side, the linkage is dominated by primary sectors while imports

¹See, among others, [Acemoglu et al. \(2012\)](#); [Gabaix \(2011\)](#); [Barrot and Sauvagnat \(2016\)](#); [Huneus \(2018\)](#); [Bernard and Moxnes \(2018\)](#); [Carvalho and Tahbaz-Salehi \(2019\)](#); [Korovkin and Makarin \(2021\)](#); [Carvalho et al. \(2021\)](#); [Arkolakis et al. \(2021\)](#); [Kashiwagi et al. \(2021\)](#).

are dominated by the wholesale and retail sectors.

Second, we provide evidence on the response of firms to international shocks, both during the years immediately prior to the COVID-19 crisis and during the crisis itself. We find that the COVID-19 crisis had an almost universal negative effect on major firm outcomes. Average firm-level sales dropped by 56 percent in April 2020 relative to January 2020, taking seasonal fluctuations into account.² However, the downturn was much smaller for exporters, which experienced a drop of 47 percent during the peak of the crisis. On the other hand, firms with indirect linkages to import markets saw a decline of less than 20 percent during the peak of the crisis. We then combine the data with information on global trade flows to study how firms respond to international trade shocks. We are able to study how firms with indirect linkages to international supply chains respond to the shocks, but also how firms adjust their domestic supply chain in response to changes in world demand and supply. We find that sourcing from international markets and domestic markets act as complements for Kenyan firms but also that Sales to domestic versus international markets act as substitutes.

Finally, we show how firm dynamics during the crisis differed for firms with highly diversified supply chains relative to those with less diversification. Diversification of the firm's domestic network also mattered for its trajectory during the crisis. Firms with a highly diversified domestic buyer base lost, on average, 4 percent less of their sales relative to their less diversified peers, while upstream diversification enabled a stronger recovery.

This paper is related to and contributes to several strands of literature. First, we contribute to a large literature that sprung up in the 1990s examining the relationship between firms' export decisions and their characteristics ([Bernard et al., 1995](#); [Bernard and Jensen, 1999, 2004](#); [Greenaway and Kneller, 2007](#); [Wagner, 2007](#)) - a precursor to the modern theory of international trade and firm heterogeneity ([Pavcnik, 2002](#); [Melitz, 2003](#); [Bernard et al., 2003](#)). Many of these studies show that exporting is a rare undertaking among firms, with only a small proportion participating in international trade. Furthermore, exporters are different from non-exporters in virtually all performance measures, even before entering export markets. Nevertheless, in

²Including the hospitality sector, the average drop was as much as 67 percent.

many contexts a larger pool of firms imports or exports indirectly via wholesalers (Ahn et al., 2011; Bernard et al., 2015) or even longer chains of intermediation (Dhyne et al., 2021; Grant and Startz, 2022). A distinct and rich set of administrative data allows us to cleanly identify firms with indirect links for the Kenyan context. We contribute to the literature providing vital descriptive evidence on key characteristics of firms with indirect linkages and their firm dynamics during a global crisis, the COVID-19 pandemic.

Within Kenya, a number of studies have examined exporting at the firm level (Rankin et al., 2006; Granér and Isaksson, 2009; Abala, 2013; Abala et al., 2013), relying heavily on survey data and comparing attributes of Kenyan firms with the findings from the rest of the world. A limited number of papers have recently deployed transaction-level customs data (Türkcan et al., 2022; Majune et al., 2020; Chacha and Edwards, 2019; Chacha et al., 2018, 2017) to examine dynamics of firm-level exports, including survival of trade relationships, and adjustment along extensive and intensive margins in international trade. Due to data constraints, the existing stock of papers focuses exclusively on direct exporters and their international trade relationships, neglecting potential adjustments of domestic supply chains. The present paper contributes to filling this gap by analysing the full supply chain network, encompassing both domestic and international transactions. This allows us to measure both domestic and international sales and purchases, as well as the number of domestic buyers and suppliers. In doing so, we also complement a small set of papers that studies the response of domestic supply chains to international shocks (Huneus, 2018; Boehm et al., 2019; Arkolakis et al., 2021).

Our case study falls into the literature on trade and global supply chains in the transmission of the COVID-19 shock (Majune, 2020; Berthou and Stumpner, 2021; Fujiy et al., 2022; Lafrogne-Joussier et al., 2022). With the exception of Fujiy et al. (2022), the majority of the papers in this series rely on sector-level input-output tables (Barrot et al., 2021; Baqaee and Farhi, 2020) or focus exclusively on international trade flows and direct exporters and importers (Majune, 2020; Berthou and Stumpner, 2021; Lafrogne-Joussier et al., 2022).

Moreover, we speak to a small but growing literature that studies the relevance of supply chain diversification for firm dynamics in response to shocks (Freund et al., 2021; Kashiwagi et al., 2021; Lafrogne-Joussier et al., 2022; Boehm and Sonntag, 2022). In a paper closely related to

ours, [Lafrogne-Joussier et al. \(2022\)](#) looked at French exporters studying the pass-through of the initial import shock triggered by the first lockdown in China in February 2020. Firms with geographically diversified international supply chains were not able to better cope with the shock than firms that solely relied on imports from China. In our setting, we find that diversification helped firms to mitigate the impact of the COVID-19 shock and allowed for a stronger recovery. Our setting complements theirs, in that we to provide vital evidence on diversification of the domestic firm network and study a substantially broader set of firms with various degrees of exposure to international supply chains. Finally, our paper contributes to a mounting stock of evidence on the impact of the COVID-19 crisis on business outcomes, employment, and trade in Kenya ([Shupler et al., 2020](#); [Pape et al., 2020](#); [Majune, 2020](#); [Kansiime et al., 2021](#); [Egger et al., 2021](#); [Kinyanjui et al., 2021](#)).

2 Data and context

2.1 Data description

We combine information from five different data sets collected by the Kenya Revenue Authority: (i) transaction-level data on domestic firm-to-firm trade from Value-Added-Tax (VAT) records; (ii) import and export transactions from customs records; (iii) firm-level information on aggregate monthly sales, purchases, imports, and exports from VAT records; (iv) the monthly number of employees and payroll from pay-as-you-earn returns, and (v) information on basic firm characteristics from registration forms. The data sets cover the period 2015 to March 2021 and can be linked through unique anonymised firm identifiers. We restrict our analysis to private sector firms and firms with annual purchases greater than zero and annual sales of at least KES 5 million (approximately US\$46,500) in at least one year that we observe in the data.

We use the transaction-level firm-to-firm data to construct a monthly supplier-buyer panel, capturing the monthly transaction volume and the number of transactions between each supplier-buyer pair. We further compile a monthly firm panel detailing sales, purchases, imports, exports, number of employees, and total payroll. We complement this data with information on firm age,

firm headquarter location, and the sector of operation collected from registration forms. The sector classification corresponds to the 4-digit International Standard Industrial Classification of All Economic Activities (ISIC) code. The customs data yields information on the origin/destination of imports/exports, as well as, 8-digit Harmonized System (HS) product codes, quantity, and value of the goods traded. Due to the reporting system implemented as part of the East African Community’s (EAC) Single Customs Union, we are unable to map product-level details for trade with other EAC member states to the firm data. However, the information on total monthly imports and exports in the VAT data, still captures aggregate trade with the EAC.

We complement the administrative data with monthly product-level customs data from UNComtrade database to measure changes in world demand for products using 4-digit HS codes.³ A number of important trade partners of Kenya, including China, Vietnam, and South Africa, do not report to the monthly data base. Nevertheless, the export transactions that can be linked to the monthly UNComtrade database represent 78 percent of the observed export volume. All variables denoted in monetary terms are deflated using the monthly consumer price index.

The data set covers 57,482 firms considering all the years between 2015 to 2021. For instance, in 2019, 44,888 formal firms participate in the firm-to-firm network forming close to 1.5 million relationships among each other (see Table 4 in the appendix). Their domestic sales aggregate to 6,806 billion KES (about 62 billion USD) and their value added (sales-purchases) corresponds to approximately 30 percent of Kenya’s GDP. The largest sectors in terms of volume are wholesale and retail and manufacturing (see Table 3 in the appendix).

2.2 Key events during the COVID-19 pandemic in Kenya

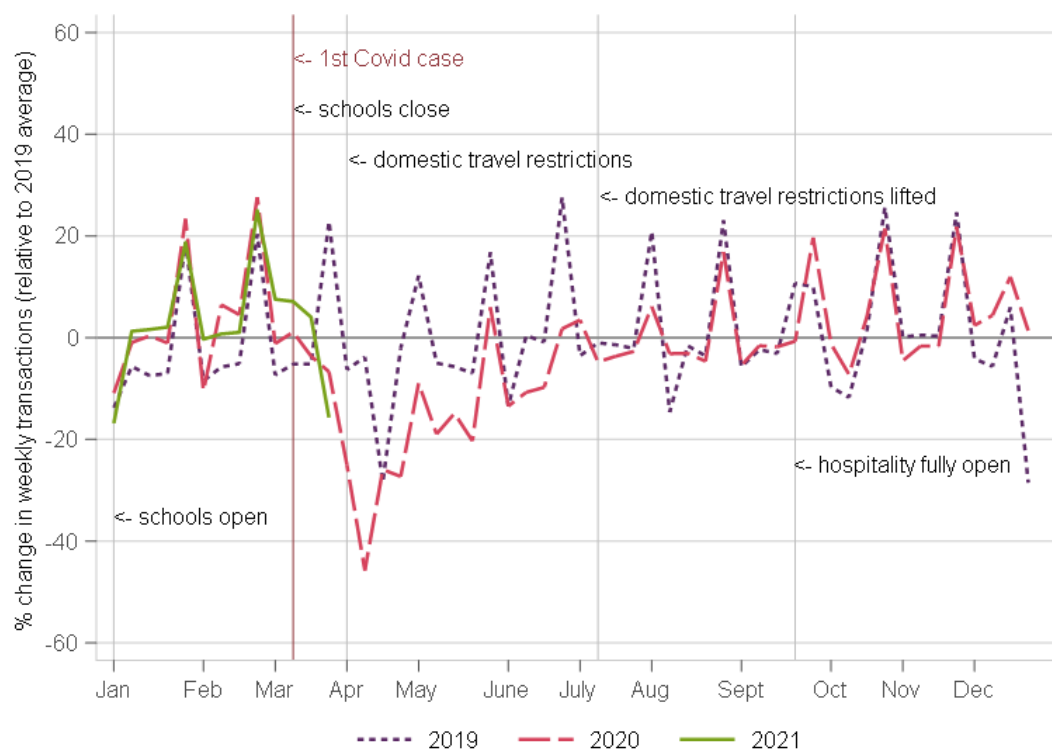
As a result of COVID-19-related shocks, Kenya faced its first recession in almost two decades.⁴ The private sector in Kenya was first impacted by disruptions of its trade with China in early 2020.⁵ The first domestic COVID-19 case was reported in early March and a series of measures

³<https://comtrade.un.org/Data/bulk>

⁴<https://citizentv.co.ke/business/kenyas-economy-slumped-into-recession-after-18-years-in-september-5068864/#:~:text=The%20Kenyan%20economy%20sunk%20to,cent%20in%20the%20third%20quarter.>

⁵See for example Majune (2020) on lockdown policies and trade flows in and out of Kenya.

Figure 1: Weekly firm-to-firm transactions



The figure shows the evolution of the percentage change in the number of purchase transactions relative to the weekly average number transactions in 2019. The data includes the universe of input VAT transactions reported by any tax filing entity.

to contain the spread of the virus was introduced.⁶ Figure 1 depicts key events of the COVID-19 crisis in Kenya alongside the count of firm-to-firm transactions in 2019, 2020 and the first quarter of 2021.

Starting in mid-March the Government of Kenya closed national borders, restricted domestic travel, banned public gatherings, closed schools, and later imposed a night-time curfew. The number of firm-to-firm transactions started to fall substantially in the second half of March 2020 before the recovery process starts to kick in around mid-April. By early July, major domestic travel restrictions had been lifted and by September, the evolution of inter-firm transactions had largely caught up with the regular fluctuations experienced in 2019. In March 2021, Kenya experienced its third and till that date largest wave of COVID-19 cases. Another round of containment measures was imposed.⁷ Overall, the transaction-level records suggest both a sharp

⁶<https://www.health.go.ke/wp-content/uploads/2020/03/1584711987736-Press-statement-20th-March-2020.pdf>

⁷For a summary of key policy responses see, for example: <https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19#K>.

initial downturn between March and April 2020, as well as a relatively swift recovery. Going forward, we define April to June 2020 as the peak months of the COVID-19 crisis and any of the subsequent months as the recovery phase.

2.3 Fluctuations in major firm-level outcomes during the COVID-19 crisis

To examine the evolution of key firm-level outcomes during the COVID-19 pandemic in Kenya, we first regress firm-level outcomes on a series of time dummies, firm, and 2-digit sector-month fixed effects.⁸ The coefficient for January 2020 is normalised to zero. The results plotted in Figure 2 show that domestic sales of the average firm dropped by 67 percent in April relative to January 2020. We further compare the trends in key firm-level outcomes to 2019 trends during the same window in Figure 8 in the appendix. The bottom two panels of Figure 8 show that the number of buyers and suppliers dropped by as much as 20 percent at the peak of the crisis relative to January 2020, but also that domestic firm-to-firm relationships rebounded relatively swiftly. Exports and imports took a much smaller hit than domestic trade flows and even rose to above pre-pandemic levels by the second half of 2020. It is important to bear in mind that the, on average, smaller dip in imports and exports is also driven by the fact that very few firms import and export directly. Therefore, we use a more nuanced measure of exposure to international supply chains in the following sections of the paper to obtain a better understanding of the trajectory of firms linked to international markets.

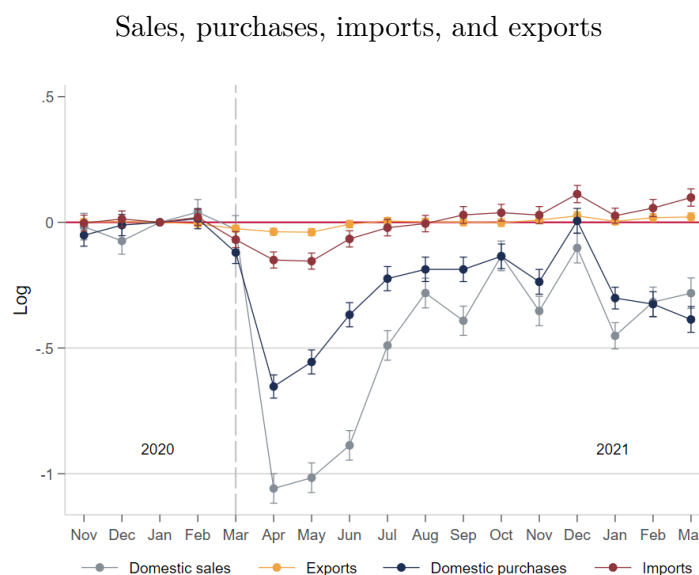
We then exclude firms from the hospitality sector, which has been disproportionately affected by the pandemic, to address concerns regarding the impact of outliers in the hospitality sector being the key driver of results. Much of the subsequent analysis further relies on being able to observe a firm’s links with other firms in the domestic network. Therefore, we exclude firms that do not have at least one up- or downstream linkage to another domestic firm.

8

$$y_{it} = \beta preC19 + \sum_{k=1}^2 \tau_{-k} jan2020_{t-k} + \sum_{k=1}^{14} \tau_{+k} jan2020_{t+k} + \phi_i + \eta_{sm} + \varepsilon_{it}$$

where y_{it} denotes the firm-level outcome, ϕ_i firm FEs, η_{sm} 2-digit sector-month FE, and ε_{it} the error term, which is clustered at the firm-level.

Figure 2: The evolution of major firm-level outcomes during the COVID-19 crisis:



Regression of firm-level outcomes on a series of monthly time dummies. All outcomes are in $\log(+1)$ terms. Standard errors are clustered at the firm-level and the error bars show the 95 percent confidence intervals. The regressions include data from April 2015 to March 2021.

3 Links to international supply chains and firm dynamics during the COVID-19 crisis

In this section we take a closer at characteristics of Kenyan firms with strong direct and indirect linkages to international supply chains, their trajectory during the COVID-19 crisis, and their response to international shocks.

3.1 Measuring direct and indirect exposure to international supply chains

In 2018, only 11 percent of the firms import directly. However, as many as 90 percent of the firms buy from a firm that is importing. While virtually all firms in the network are linked to at least one importer or one exporter, these links tend to be very weak. To get a more complete picture of the extent of indirect exposure to international supply chains, following [Dhyne et al. \(2021\)](#), we computed each firm's total exposure to foreign demand r_{iX}^{total} and foreign inputs r_{iM}^{total} .⁹ As an example, a firm's full exposure to foreign demand is characterised by its own share of total output that is directly exported r_{iX}^{direct} , as well as the export share of its buyers, the buyers'

⁹In other words, the share of the firm's sales and purchases that are ultimately sold to or sourced from international markets.

buyers and so on. Thus the firm’s full exposure to foreign demand becomes:

$$r_{iX}^{total} = r_{iX}^{direct} + r_{iX}^{indirect} = \sum_j \tilde{H}_{ij} r_{jX}$$

A key element of the above equation is \tilde{H}_{t-1} , which corresponds to $(I - A)^{-1}$. A is the adjacency matrix of the domestic firm-to-firm network.¹⁰ By subtracting it from the identity matrix and inverting it, we obtain the matrix \tilde{H}_{t-1} , which captures the share of output from i to j both directly and indirectly and thus serves as a weight for i ’s total exposure to j .

3.2 Firm characteristics and links to international supply chains

5 percent of the average firm’s sales was ultimately absorbed by foreign demand in 2018, while 8 percent of its inputs were sourced abroad. In the following we distinguish among:

(i) Firms with high direct exposure to exports and imports,

- i.e. $r_{iX}^{direct} \geq 0.25$ and $r_{iM}^{direct} \geq 0.25$

(ii) Firms with high total exposure (direct plus indirect),

- i.e. $r_{iX}^{total} \geq 0.25$ and $r_{iM}^{total} \geq 0.25$, but $r_{iX}^{direct}, r_{iM}^{direct} < 0.25$

(iii) Firms that export (import) less than 25 percent.¹¹

- i.e. $r_{iX}^{total} < 0.25$ and $r_{iM}^{total} < 0.25$

The key firm characteristics of the firms in each group are summarised in Table 1. While as little as 9 percent of all firms are highly exposed to import markets, these firms capture more than half of the total sales volume reported in 2018. Notably, the 657 firms with high indirect imports account for 28 percent of the total sales across all firms in that year. Likewise on the downstream side, only 5 percent of the firms are highly exposed to export markets, but account for 13 percent of total sales. Importantly, firms with strong linkages to international supply chains also employ substantially more workers on average and tend to be older.

¹⁰Element i, j of the adjacency matrix A corresponds to the share of i ’s output that is sold to j .

¹¹Looking at the distribution of the share of total exports r_{iX}^{total} across all firms, the measure is roughly 0.25 or larger for firms in the 95th percentile. For imports (r_{iM}^{total}), firms in the 90th percentile import 25 percent or more of their imports.

Table 1: Summary statistics for firms directly and indirectly linked to international supply chains in 2018

Exports

export group	# firms	% of sales	Age	Sales		Employment		# buyers	# suppliers	% sales to HH
			avg	avg	sd	avg	sd	avg	avg	avg
No/low exports	46,193	87	9	115	1,773	15	149	28	25	40
25%+ total exports	1,456	2	11	98	438	25	120	24	32	1
25%+ direct exports	863	11	15	717	2,122	147	636	19	60	28

Imports

import group	# firms	% of sales	Age	Sales		Employment		# buyers	# suppliers	% sales to HH
			avg	avg	sd	avg	sd	avg	avg	avg
No/low imports	44,002	43	9	60	368	12	124	16	23	40
25%+ total imports	657	28	18	2,497	11,816	277	966	354	118	3
25%+ direct imports	3,853	29	11	436	3,311	34	131	94	45	26

The table groups firms by their exposure to international supply chains. Total export and total import exposure is the sum of both direct and indirect exposure. The category for 25%+ total exposure excludes any firms that are part of the 25%+ direct exposure group. The number of buyers and suppliers refers to domestic suppliers and buyers only. % sales to HH capture the share of domestic sales that is sold outside the network - mostly to consumers.

Primary sectors dominate Kenya’s exposure to export markets. Of the large formal agricultural firms captured in the administrative data, over 70 percent of their sales are destined for export markets, mostly through direct exports, but in some cases also indirectly (see top panel of Figure 3). Close to half of the output of mining and quarrying firms is exported. This is followed by 20 percent of manufacturing output and the transportation sector respectively. Jointly those two sectors capture a relatively larger share of the formal economy (see Table 3), while sourcing most of their inputs from international markets (see bottom of Figure 3). Figure 3 further highlights that exposure to import markets is less concentrated in specific sectors and that indirect linkages to import markets play a much bigger role for upstream supply chains than exports do for downstream supply chains.

Figure 3: Output share of firms by strength of links to international supply chains

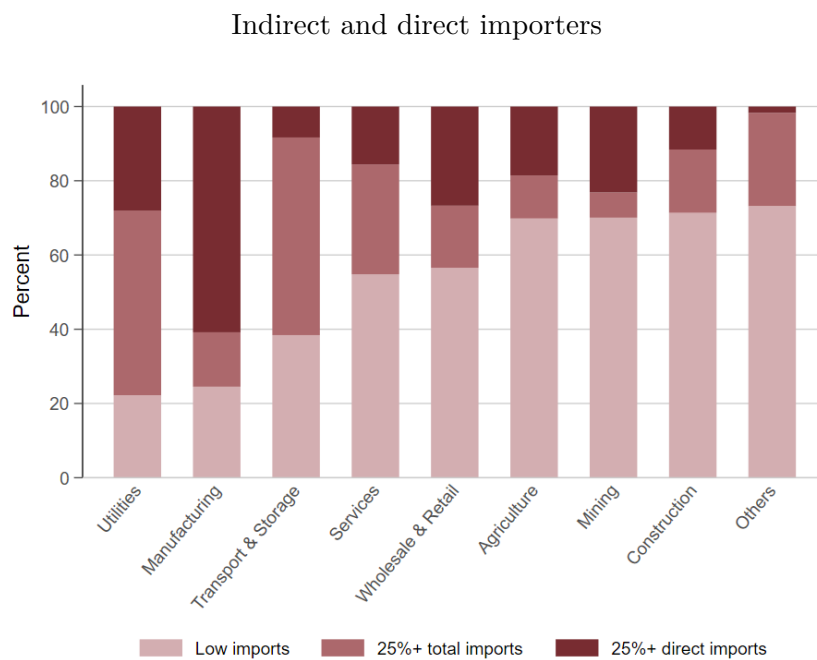
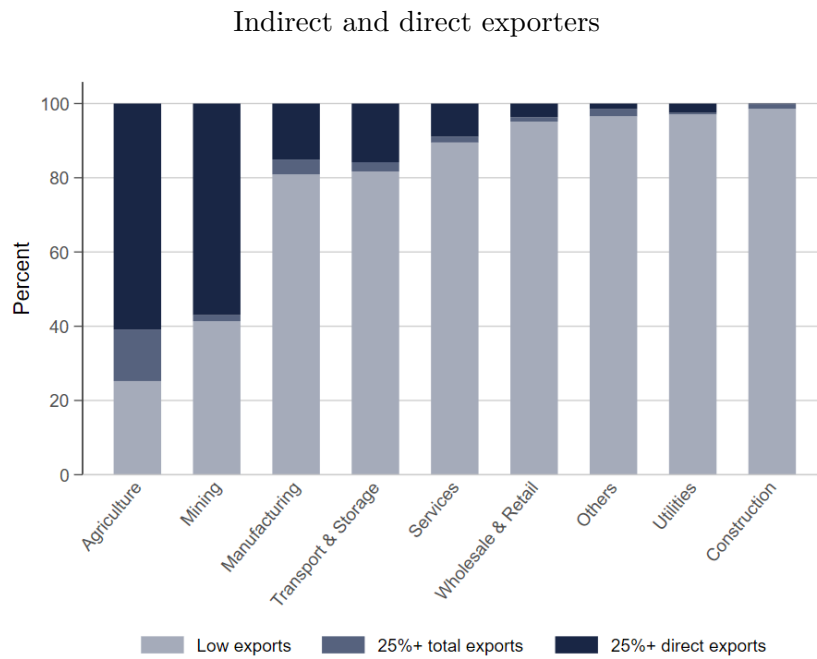


Figure 3 categorises firms by their degree of exposure to international supply chains and plots their sales (exports)/input (imports) share by sector in 2018. Total export and total import exposure is the sum of both direct and indirect exposure. The category for 25%+ total exposure excludes any firms that are part of the 25%+ direct exposure group.

3.3 The trajectory of firms with strong linkages to international supply chains during the COVID-19 crisis

Next, we examine the trajectory of firms with different degrees of exposure to international supply chains during the crisis. We start with the simple categorisation of firms into importers and exporters¹² and plot the evolution of their sales relative to those with no direct prior links to international supply chains in Figure 4a.¹³ We have three main findings. First, the downturn for direct importers already starts in February 2020 when the lockdowns in China were at their height. Second, sales of direct importers dropped by a similar margin compared to sales of firms without any direct links to international supply chains. They initially recovered more swiftly, but stagnated in the second half of 2020. Third, sales of exporters only dropped by 47 percent relative to January 2020 at the lowest point of their trajectory in May 2020 and bounced back quickly.

In Figures 4b (exports) and 4c (imports) we now draw on the more nuanced measure to distinguish between firms that face a high direct versus high indirect exposure to international supply chains respectively. For the case of exports, direct exporters which specialise on international markets hit their lowest point in May, which coincides with Mother’s Day in many European export destinations for Kenya’s flower exporters. By July, these firms reach their pre-pandemic level of sales. However, firms with indirect links to export markets, only reach their January sales level by the end of 2020. The dominating factor for these differential trends are driven by the sectors in which direct and indirect exporters operate. Direct exports are dominated by firms exporting agricultural products, the demand for which was barely affected by the pandemic or even increased (that is, the demand for vegetable exports). Indirect exporters operate in a wider range of sectors, with a substantial proportion in transport and logistics as well as manufacturing.

Turning to indirect importers, we find a relatively small initial downturn of less than 20 percent on average, but sustained below January-2020 levels of sales until the end of our data set, March

¹²We classify a firm as an importer or exporter if more than 10% of their inputs (sales) are directly sourced from (sold) abroad.

¹³We again rely on the same event study specification as above including firm and sector-month fixed effects as well as normalising the coefficient for January 2020 to zero.

2021. The descriptive statistics in Section 3.2 highlight the older age profile and larger size of firms with high indirect exposure to import markets. These characteristics often coincide with greater firm resilience. In addition, larger firms often have a more diversified demand profile that helped them to buffer the initial shock (also see Section 4 below).

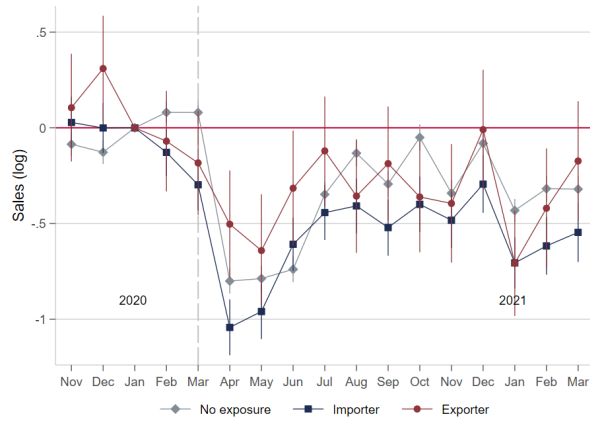
Direct importers, many of which act as intermediaries, were hit the hardest by the initial downturn. Their sales started declining substantially from February 2020 onward, reaching a level of 20 percent below the January average by March, and ultimately dropped to 60 percent in April and May. While their downturn was even more pronounced than for the average firm without any or weak linkages to import markets, their initial recovery was swifter. However, their imports again stalled in the last quarter of 2020 and remained well below pre-pandemic levels up until March 2021. Domestic sales of these firms largely trail their imports, which underlies their role as intermediaries.¹⁴ Section 3.4 shows that the pass-through of direct import shocks to firm sales is particularly high during both the crisis peak and the recovery. These results seemingly contradict those of Figure 2, which shows that imports start to rise above January 2020 levels by August for the average firm (and also import volumes overall).¹⁵ However, this increase is driven less by firms that previously specialised on imports, but rather by firms that have high direct exports at the same time and firms that have not imported before or only to a limited extent.

¹⁴Graph available on request.

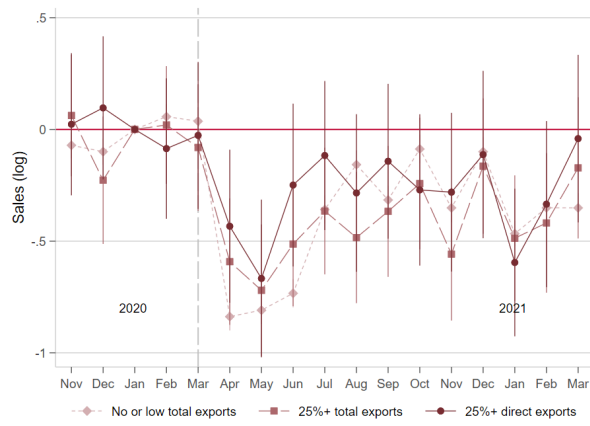
¹⁵See <https://pedl.cepr.org/publications/domestic-and-international-trade-flows-during-covid-19-pandemic-evidence-kenya%E2%80%99s>

Figure 4: Firm-level exposure to international supply chains

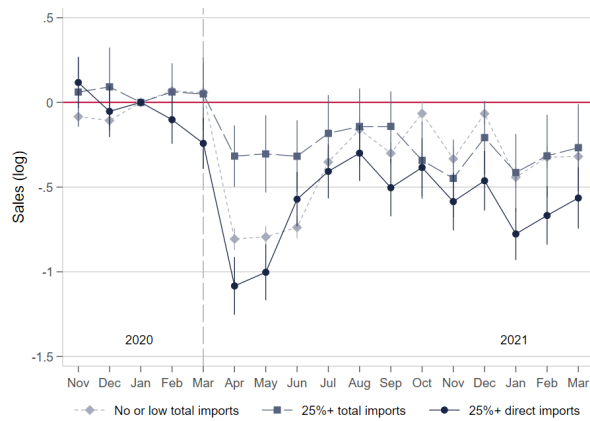
a) Importers and exporters



b) Indirect and direct exporters



c) Indirect and direct importers



Regression of firm-level outcomes on a series of monthly time dummies and include firm fixed effects and cluster standard errors at the firm level. The error bars show the 95 percent confidence intervals. The regressions for the COVID-19 period include data between November 2019 and March 2021.

3.4 Pass-through of shocks to import and export markets and domestic supply chains

So far we have focused on differences in firm dynamics based on their pre-COVID links to supply chains. To get a better understanding of the response of domestic supply chains to international shocks, we further exploit the fact that the COVID-19 shock was nowhere near universal.¹⁶ More specifically, we exploit the heterogeneity in supply and demand to and from worldwide markets across countries and product categories.

Empirical strategy

We deploy a popular shift-share design approach popularised by [Hummels et al. \(2014\)](#) and subsequently applied in similar settings to ours, such as [Huneus \(2018\)](#); [Dhyne et al. \(2021\)](#); [Arkolakis et al. \(2021\)](#). The measure consists of two components. The first is, the shares $\omega_{i,c,p,t-12}$,¹⁷ which capture a firm i 's exports of product p to country c as a share of the firm's total revenues of the last 12 months at time $t - 12$.¹⁸ The second is, the change in demand WID for (supply WES of) product p by country c from all other countries, excluding Kenya.¹⁹ In a nutshell firm-level changes in foreign demand FD and foreign supply FS are defined as:

$$\Delta \log FD_t = \sum_{c,p} \omega_{i,c,p,t-12} \Delta \log WID_{c,p,t}, \text{ and}$$

$$\Delta \log FS_t = \sum_{c,p} \omega_{i,c,p,t-12} \Delta \log WES_{c,p,t}.$$

Crucially, here we do not assume exogeneity of the exposure to international shocks (that is, the shares), but instead seek to exploit variation in changes in demand and supply at the country-product level. For the shocks, we consider the month-over-month changes between the current

¹⁶Our analysis complements a growing literature that has focused largely on localised shocks ([Carvalho et al., 2021](#)) or the transmission of firm-level micro shocks ([Acemoglu et al., 2012](#)). A key exception is [Huneus \(2018\)](#), who studied the pass-through of terms of trade shocks during the 2008 financial crisis.

¹⁷For the computation of the shares we hold the country-product shares fixed in the same month of the previous year. I.e. for April 2020 we compute the shares based on import and export transactions between May 2018 and April 2019.

¹⁸Or the share of total inputs (intermediate inputs plus payroll) in the case of imports.

¹⁹The data to construct the shock measure is retrieved from the UNComtrade database. Products p are defined by 4-digit HS codes (see Section 2.1). <https://comtrade.un.org/Data/bulk>

and the same months in the previous year (for example, April 2020 vs April 2019). We follow [Dhyne et al. \(2021\)](#)'s estimation strategy to simultaneously estimate the pass-through of both direct and indirect import and export shocks. However, being able to rely on more granular monthly data instead of annual data, we define the relevant adjacency matrix as the network observed in the same months of the previous year taking into account all firm-to-firm relations in the 12 months leading up to it (that is, to compute the indirect exposure for April 2020, we consider all firm-to-firm relationship between May 2018 and April 2019). While this approach is computationally intensive and involves inverting the adjacency matrix for every single month in the data set, it is crucial for holding the predictive power of the foreign demand and supply measure constant at any point. The full exposure measure for exports then becomes:²⁰

$$Z_{it}^X = \sum_j \tilde{H}_{ij,t-1} r_{jF,t-1} \Delta \log FD_t$$

We split Z_{it}^X into its direct and indirect component and ultimately estimate the following specification:

$$\Delta y_{it} = \beta_1 Z_{it}^{X_{direct}} + \beta_2 Z_{it}^{X_{indirect}} + \gamma_1 Z_{it}^{M_{direct}} + \gamma_2 Z_{it}^{M_{indirect}} + \eta_s + \phi_{sy} + \varepsilon_{it} \quad (1)$$

y_{it} denotes the change in (log) firm-level outcomes of firm i in month t relative to the same month in the previous year. We further controlled for two-digit sector-date fixed effects. The first-difference approach is crucial to isolate the shock variation from the variation in exposure shares in the case of panel data with time variation in the exposure to shocks ([Borusyak et al., forthcoming](#)). While the month-over-month first difference introduces more noise on the left hand side, the shock measure gains in predictive power. We controlled for firm age to address the fact that younger firms typically experience more pronounced growth patterns. Finally, we controlled for the contemporaneous sum of shares and their interaction with the control variable (log) firm age, a crucial addition for contexts where the shares do not sum to 1 ([Borusyak et al., forthcoming](#)). In our case the sum is not 1 because we do not capture imports and exports of all relevant countries in the UN Comtrade data base and miss out on product level trade with EAC

²⁰Following the notation introduced in Section 3.1.

member countries in the customs data. Relying on the 12-month difference for firm outcomes comes with the caveat of losing observations at the extensive margin where either the current or lagged observation is zero. This issue is particularly prevalent for the count of buyers and suppliers, where using $\log+1$ as the outcome greatly distorts the results. We therefore restrict the sample to firms which have at least one supplier in both periods in order to hold the sample of firms constant. Only when looking at the number of buyers and employment will the sample size again drop due to fewer firms having domestic buyers and formal employees.

Results

The results show that international supply and demand shocks not only impact firm-level exports and imports, but are also passed on through domestic supply chain linkages. Moreover, they are associated with changes in the domestic production network (see Table 2). Unsurprisingly, direct import and export shocks have the strongest effects on firm-level imports and exports. A 10 percent increase²¹ in world demand results in a 3.7 percent increase of exports by Kenyan firms. A positive export shock also increases the firm's upstream participation in international supply chains, leading to more imports. On average, the increase in imports does not crowd out domestic inputs. Rather, there is a crowding-in effect, with firms increasing their domestic purchase volume and the number of suppliers. The effect size is, however, much smaller with a 10 percent increase in foreign demand leading to an increase of domestic purchases of only 0.5 percent. However, the picture would be incomplete without considering the impact of indirect export shocks. A positive indirect export shock corresponds with an increase in domestic sales and thus supports the interpretation that shocks to foreign demand pass through to domestic suppliers. These firms in turn increase their domestic purchases and the number of suppliers.

We observe the same crowding-in effect for import shocks, a finding that is in line with [Arkolakis et al. \(2021\)](#) using data from Chile. However, the magnitude of our estimates is substantially smaller with a 10 percent increase in imports only corresponding to a 0.3 percent increase in

²¹Note that most export shocks are much smaller and only firms in the 1st and 99th percentiles experienced shocks of a magnitude well above 10 percent during our sample period. During the peak of the COVID-19 crisis some firms saw a decline in demand for their products by as much as 82 percent, while other firms experienced a 76 percent boost.

the number of suppliers. This might be partly explained by the fact that [Arkolakis et al. \(2021\)](#) focused on the two-year difference of annual rather than monthly outcomes and relied on a slightly different specification.

Interestingly, international shocks seem to coincide with a shift in downstream supply chains.

Table 2: Firm response to international supply and demand shocks

	Imports	Exports	Domestic sales	Domestic purch.	# of suppliers	# of buyers	No. employees
export direct	0.266* (0.147)	0.387* (0.205)	0.154 (0.138)	0.053* (0.030)	0.035* (0.019)	-0.074** (0.030)	0.008 (0.019)
export indirect	0.007 (0.250)	0.037 (0.227)	0.735* (0.429)	0.177 (0.132)	0.125* (0.068)	0.047 (0.056)	0.006 (0.073)
import direct	0.870*** (0.162)	0.002 (0.074)	0.248** (0.105)	0.105*** (0.029)	0.034** (0.014)	0.055*** (0.017)	0.023* (0.012)
import indirect	0.083 (0.113)	0.278*** (0.087)	-0.166*** (0.039)	-0.001 (0.017)	-0.021*** (0.008)	-0.001 (0.010)	0.002 (0.011)
No. observations	950,713	950,713	950,713	950,713	950,713	594,342	607,403
No. of firms	40243	40243	40243	40243	40243	27597	23711
R2	0.076	0.107	0.150	0.157	0.197	0.256	0.361
Firm FE	✓	✓	✓	✓	✓	✓	✓
Sector-date FE	✓	✓	✓	✓	✓	✓	✓

The results present the estimation of Equation 1 regressing the respective shock measures on the change in logged firm-level outcomes relative to same month in previous year as well as firm and sector-date fixed effects. Standard errors are clustered at the firm-level. We further control for the sum of shares and firm age (log)

weighted by the sum of shares. The regressions include data from April 2018 to March 2021.

While we do not detect a statistically significant response of domestic sales to foreign demand shocks, the number of domestic buyers declines as a result of an increase in foreign demand. We observe a similar pattern for the case of indirect import shocks, where firms start to export more, but sell less domestically as a result of a positive import shock. Jointly, these results suggest a perhaps surprising, substitution effect between sales to international supply chains and domestic supply chains, at least for the average firm.

To test whether these results are driven by substitution patterns during the COVID-19 crisis, a rather exceptional period, or whether these are patterns that pre-date the pandemic, we re-estimate Equation 1 interacting each of the shock measures with two dummy variables for the crisis peak and the recovery phase (see Figure 9). We find that both of the downstream substitution and upstream complementary patterns between foreign and domestic markets pre-date the pandemic. At the same time, however, indirect import shocks have a strong positive effect on domestic sales during the recovery period from the crisis (top left panel of Figure 9).

This suggests that the bouncing back of international supply chains was of great relevance for the recovery trajectory of Kenyan firms. While indirect import shocks seem to have led to a concentration in supply chains prior to the pandemic, they result in more domestic supplier relationships during the recovery. Further, at the peak of the crisis, firms exposed to less severe negative import and export shocks maintain more domestic relationships with suppliers (bottom right panel of Figure 9).

4 Network position and firm resilience

Finally, we take a closer look at the relevance of the firm’s domestic network position for its trajectory during the COVID-19 crisis and for the pass-through of foreign demand and supply shocks. Here we considered diversification of domestic up- and downstream supply chains on both the extensive and the intensive margin and the number of up- and downstream sectors, a proxy for the complexity of the supply chain. We find that downstream diversification is beneficial during times of severe economic downturn. Meanwhile, upstream diversification of suppliers improved firm recovery as demand picked up but stories of supply chain backlogs started to make headlines worldwide.

4.1 Measuring diversification and complexity of domestic supply chains

In the following, we again fix the firm’s network in the same month of the previous year and consider all suppliers (or buyers) the firm has interacted with during the past 12 months (rolling network).

Diversification

Diversification can take place along both the extensive and the intensive margins.

On the extensive margin, we looked at the number of suppliers (buyers) the firm has within each 4-digit sector it purchases from (sells to). For firms purchasing (or selling to) more than one 4-digit sector, we considered the weighted average number of suppliers (buyers). To account for differences across sectors, age cohorts and firm size, we first grouped firms based on their 2-digit

sector, age cohort²² and sales quartile.²³ We then defined a firm as highly diversified if the number of suppliers (or buyers) within the sector-cohort-size bin lies above its peers in the same 4-digit sector. Even within each sector-age-sales bin, we still see sizeable differences between firms that are highly diversified on the extensive margin versus those with little diversification (see Table 6 for downstream diversification and Table 5 for upstream supply chains). Firms with higher downstream diversification, for example, have more employees, are more likely to be direct importers and have larger sales. Many of the noted differences like firm age are statistically significant but not sizable. For firms with a high degree of upstream diversification the sales and age gap to less diversified firms is even smaller, while the gap is similar for purchases (about 5 million KES in each case). While the results below are robust to alternatively grouping firms into sales tertiles or deciles, we cannot fully rule out any size effects that correlate with our measure of diversification to drive some of the results.

On the intensive margin, diversification essentially corresponds to the concentration of sales and purchases. We use the Herfindahl–Hirschman Index (HHI), which can take a value between 0 (least concentrated) and 1 (highly concentrated).

Number of up- and downstream sectors

The delay or failure of a small input can often result in the break down of an entire product (Kremer, 1993). Thus, supply chains with a large number of inputs might be particularly fragile during times of crisis when the probability of delays or shortages increases steeply. We look at the number of 4-digit sectors a firm sources from/sells to as a proxy for the complexity of its supply chain. Firms sourcing from an above median number of industries within their 4-digit sector are categorised as having complex supply chains.

Empirical strategy

With those measures at hand, we estimate an adapted version of the event study specification in Section 2.3. In our preferred specification we pool the months dummies into pre-COVID

²²The respective cohorts are < 5 years, 5-10 years, 11-20 years and 20+ years.

²³Conditioning on 4-digit sectors would come with the caveat of having too few firms in some of the age cohort bins.

(November 2019 to March 2020), COVID peak (April to June 2020), and recovery phase (July 2020 to March 2021) and interact them with the respective diversification and complexity measure N_{it} :

$$\begin{aligned}
 y_{it} = & \beta_1 N_{it} + \beta_2 C19_{pre} + \beta_3 C19_{pre} * N_{it} + \beta_4 C19_{peak} + \beta_5 C19_{peak} * N_{it} \\
 & + \beta_6 C19_{recov} + \beta_7 C19_{recov} * N_{it} + \beta_8 X_i + \delta_{st} + \phi_i + \varepsilon_{it}
 \end{aligned} \tag{2}$$

y_{it} denotes firm-level outcomes of firm i in month t in log (+1) terms. We further control for 2-digit sector-month FE (δ_{st}) and firm FE (ϕ_i). To ensure the firm's network position is not primarily driven by its proximity to final demand and/or international markets, we controlled for the whether or not the firm is an importer or exporter and its shares for sales to domestic entities outside the network in the following analysis. We further controlled for firm age (log) and the average N_{it} for the firm's 4-digit sector to capture sector level shocks; for example, due to the exit of a key supplier for the sector.

β_1 (for N_{it}) is identified by firms moving in and out of respective diversification and complexity categories over time. $\beta_2, \beta_4, \beta_6$ are identified by within firm and calendar month variation relative to the pre-COVID years 2015-2019. β_3, β_5 and β_7 rely on the same source of variation, but are interpreted as interaction terms. Figure 5 plots the respective point estimates and confidence intervals.

As an alternative specification, we again start out from the same event study approach, but this time normalise the coefficients for each group of firms to January 2020. While the interpretation of this specification is more straight-forward and exactly mirrors the specification in Section 2.3, it relies heavily on the firm's relative performance in the anchor month January 2020 (see Figures 10 for the results).

Finally, we are interested in the network position's relevance for the pass-through of shocks to import and export markets. Here we run the specification from Section 3.4, but interact the shock measures with the respective network position measure of choice N_{it} . The results are presented in Figure 11.

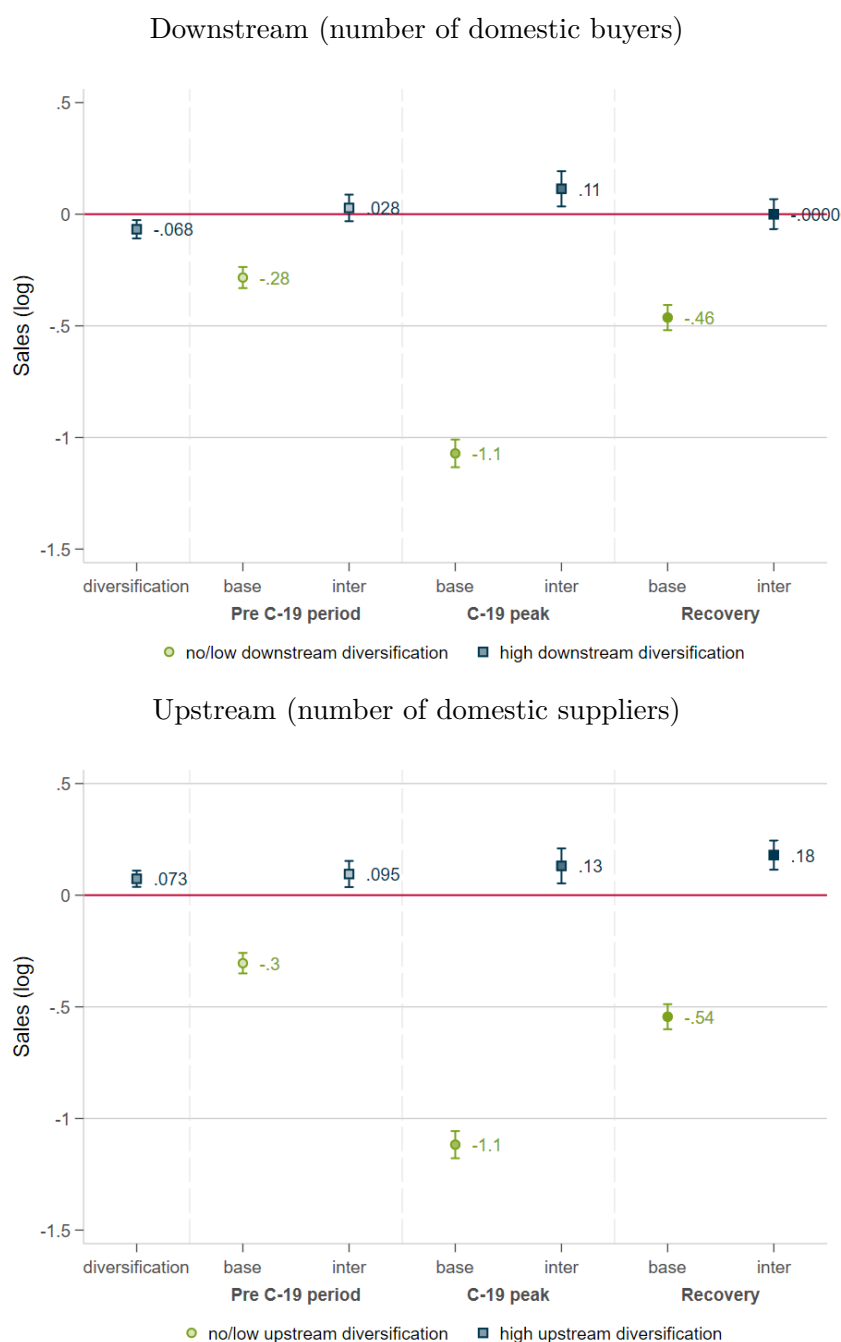
4.2 Results

Diversification

We find that firms with a greater degree of downstream diversification face a less drastic downturn during the peak of the crisis (top panel of Figure 5). Firms with below median diversification see their sales drop by an average of 67 percent during the peak months, while the sales of firms with a high degree of diversification drop by an average of 63 percent. Firms with more upstream diversification recover more strongly (bottom panel of Figure 5). The strong positive effects are primarily driven by the firm trajectory in the last quarter of 2020 and the first quarter of 2021 (see dashed blue line in right top row panel of Figure 10), when stories of supply chain backlogs started to make headlines worldwide. Average sales of firms with high upstream diversification are only down by 30 percent relative to the pre-COVID period in comparison to a 42 percent loss of sales for the less diversified firms.

Both estimates hinge on the assumption that the outcomes of highly and less diversified firms followed a parallel trend prior to the COVID-19 crisis. We did not see any meaningful diverging pre-trends in the event study plots of Figure 10 for both upstream and downstream diversification and we cannot reject the null that the coefficient for downstream diversified firms is zero. However, when we estimate specification 2 for firms with a high degree of upstream diversification, the pre-COVID coefficient is significantly different from zero at the 5 percent level. While the effect size is almost double during the recovery phase and quite substantial in economic terms, we cannot entirely rule out the possibility of differential pre-trends driving the upstream results.

Figure 5: Supply chain diversification and firm sales during the crisis and recovery phase



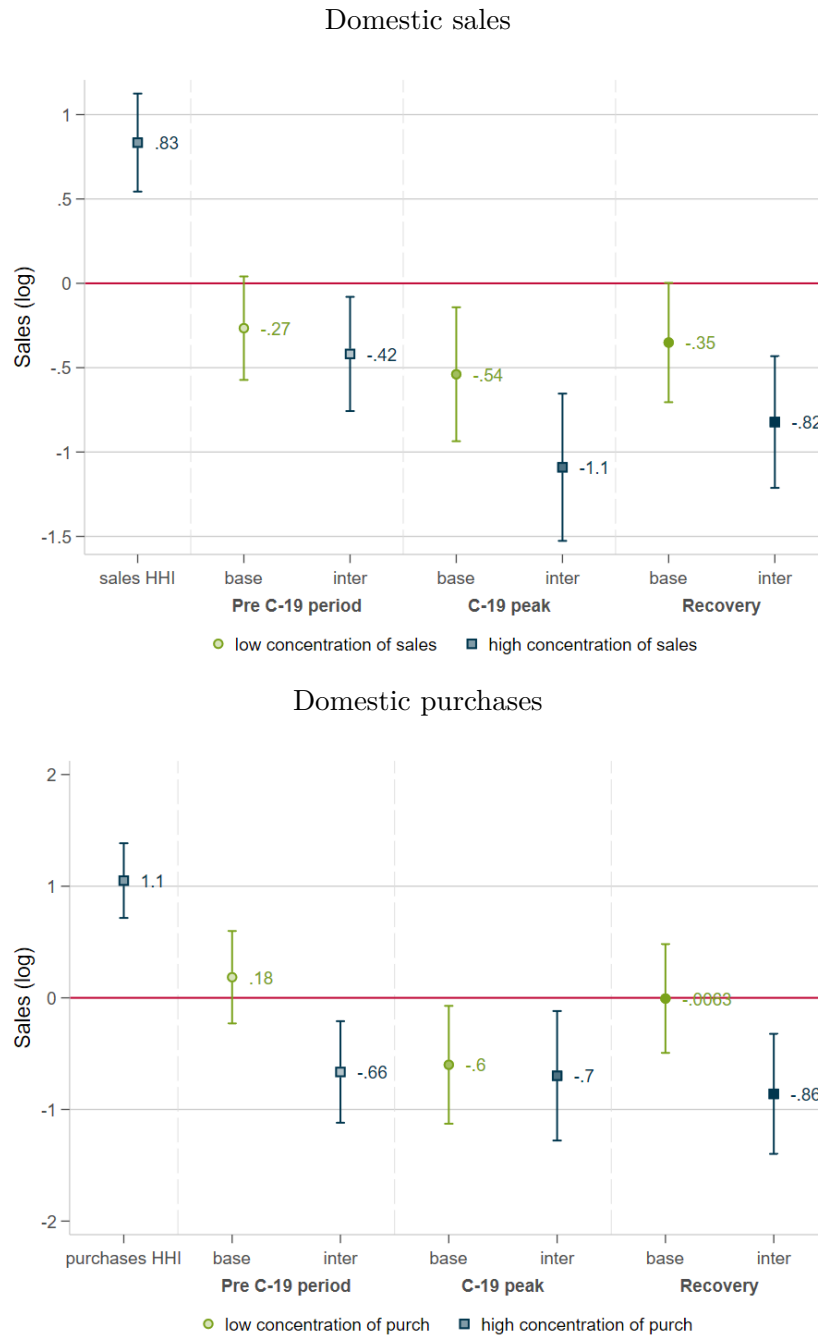
The above graphs present the results from estimating Equation 2. We control for firm age, share of sales to final domestic demand, share of highly diversified firms the firm's own 4-digit sector, import and export status. The pre-COVID-19 (C-19) phase corresponds to November 2019 to March 2020, the COVID-19 peak is April to June 2020, and the recovery July 2020 to March 2021.

Figure 6 plots the results for diversification on the intensive margin. While we again struggle to rule out differential pre-trends, the results largely mirror those for diversification on the extensive margin. Conditional on the number of buyers, firms with a larger concentration of sales among their buyers faced a more drastic decline in their sales during the crisis peak.

Finally, we interacted our proposed measures for supply chain diversification with the firm's direct and indirect exposure to international shocks (see Section 3.4). Unsurprisingly, the response of firm sales to international shocks is more pronounced for less diversified firms than for their highly diversified peers.²⁴ Assuming a linear relationship, this implies that firms can equally benefit more from positive shocks, but are also more exposed to negative ones. Note that the proposed specification following (Borusyak et al., forthcoming) controls for the firm's total exposure (the shares) to the shock at any given point (see Section 3.4). However, we are unable to provide clear insights as to whether the results are primarily driven by (i) a change in the composition of the sources of exposure (a firm's total import share might remain constant, but now purchases it from two suppliers instead of one) or (ii) the firm's ability to respond better to the shock as a result of having a more diversified network.

²⁴Unfortunately, we lack the power to detect meaningful effects when interact all of the shock measures and network measures with COVID-period dummies.

Figure 6: Concentration of sales and purchases (HHI) and firm sales during the crisis and recovery phase



The above graphs present the results from estimating Equation 2. We controlled for firm age, share of sales to final domestic demand, the average concentration of sales/purchases in the firm's own 4-digit sector, and import and export status. The pre C-19 phase corresponds to November 2019 to March 2020, the C-19 peak is April to June 2020, and the recovery July 2020 to March 2021. We further control for diversification along the extensive margin.

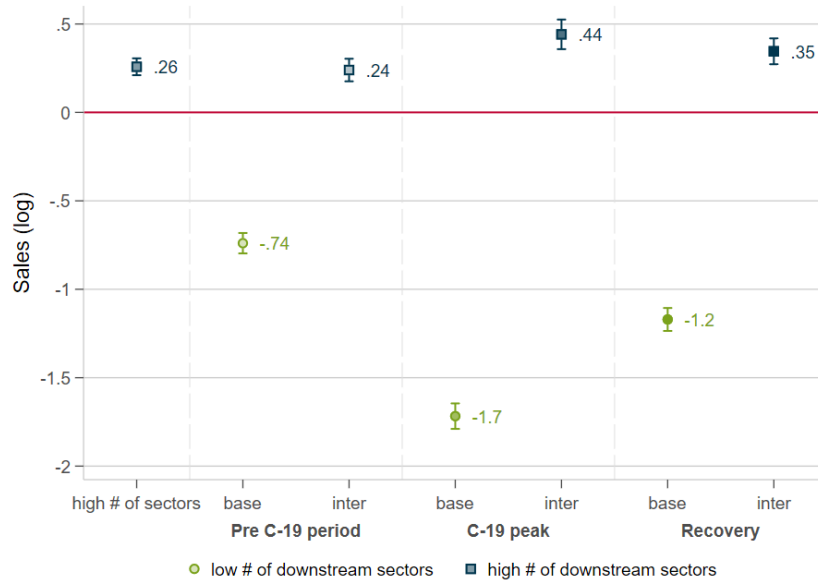
Number of upstream and downstream sectors (complexity)

Looking at the number of sectors the firm purchases from or supplies to, the coefficients plotted in Figure 7 suggest a very similar story for complexity relative to diversification. Firms with

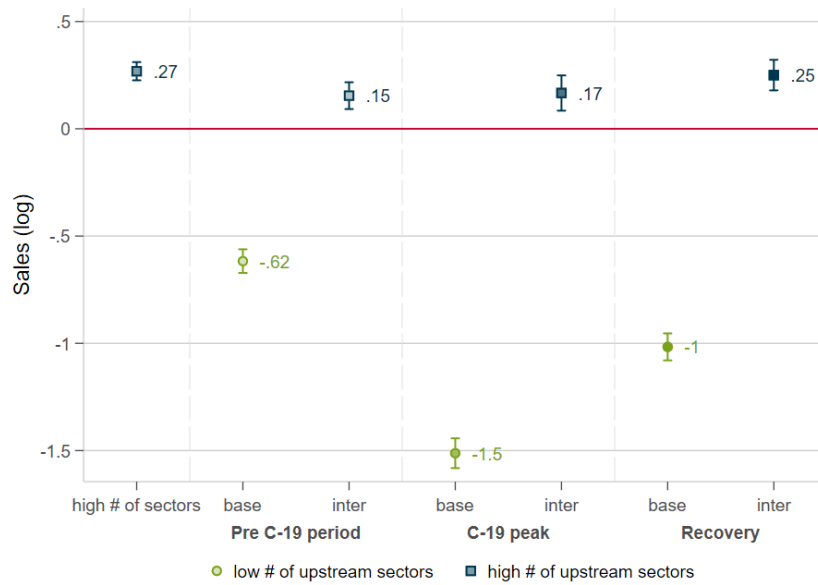
above median complexity relative to their peers in the same 4-digit sector fared better during the pandemic. Crucially, however, they were already on a favourable trend in the pre-pandemic period. Therefore, the results suggest that the observed patterns are, if anything, indicative of complex supplier network serving as a proxy for a number of relevant firm characteristics, such as high productivity and managerial capital. To test for the robustness of the results, we again draw on the event study specification and normalise all coefficients to January 2020. Using this approach the results suggest a parallel pre-trend for firms with above and below median supply chain complexity. The bottom left panel of Figure 10 suggests that, especially during the peak of the crisis, firms selling to a larger number of 4-digit sectors faced a smaller loss in their sales. One potential explanation is that selling to more downstream sectors serves as a form of diversification, which helped firms smooth the shock in times of a severe demand shock. While the results leave room for different interpretations, they also highlight the need to test the sensitivity of the results using different base periods.

Figure 7: Supply chain complexity and resilience

Downstream (number of downstream 4-digit sectors)



Upstream (number of upstream 4-digit sectors)



The above graphs present the results from estimating Equation 2. We controlled for firm age, share of sales to final domestic demand, share of firms with above median supply chain complexity in the firm's own 4-digit sector, and import and export status. The pre C-19 phase corresponds to November 2019 to March 2020, the C-19 peak is April to June 2020, and the recovery July 2020 to March 2021.

5 Conclusion

This paper links customs and domestic transaction-level data on buyer and supplier relationships of over 57,000 private sector firms in Kenya. The data enabled us to study several dimensions of a firm's network position, namely its embeddedness in global value chains, degree of diversification, and the complexity of its supply chains. Providing evidence on the relevance of each dimension can play a crucial role in informing policies to promote the post-crisis recovery and long-run resilience of firms in East Africa. The findings in this paper are particularly relevant for countries with similar supply chain structures, where a large proportion of exporters operates in primary sectors (agriculture and mining) and a lot of importing takes place through intermediaries.

A large share of private sector firms in Kenya are linked to international supply chains with one degree of separation. Going beyond the binary definition of a link to an importer or exporter, we show that only a few large firms rely strongly on import and export markets. However, these firms are key to the Kenyan economy, both in terms of their share of total sales and employment. The COVID-19 crisis had an almost universal negative effect on major firm outcomes. Average firm-level sales dropped by 56 percent in April 2020 relative to January 2020, taking seasonal fluctuations into account. However, the downturn was smaller for exporters, which only experienced a drop of 47 percent during the peak of the crisis. On the other hand, firms with indirect linkages to import markets saw a decline of less than 20 percent during the same period. Third, and lastly, firm dynamics during the COVID-19 crisis differed for firms with highly diversified supply chains relative to those with less diversification. Firms with a highly diversified domestic buyer base (downstream) lost, on average, 4 percent less of their sales than their less diversified peers, while upstream diversification (a large supply base) enabled a stronger recovery. When responding to shocks to world demand and supply, sourcing from international markets and domestic markets complement each other. Faced with an increase in the demand for their products on global markets, firms start to export more, at the expense of domestic sales.

Our findings contain important insights for policy making. First, policy makers will have to strike a good balance in terms of supporting both large and small firms during the crisis. We

have shown that while only few large firms have strong linkages to international supply chains, they are key actors in the economy with links to a large number of smaller, non-internationalised firms. Second, a diversified customer and supplier base helps to build resilience to shocks and supports the recovery from downturns. While lowering the fixed cost of entry into markets remains vital, it can be complemented by lowering the cost of establishing and maintaining buyer and supplier relationships as part of future strategies to address vulnerabilities of supply chains.

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Appendices

Appendix A Additional descriptive statistics

Table 3: Sector-level breakdown of total sales (2019)

Sectors	%
Wholesale & Retail	22.88
Manufacturing	21.44
Electricity & Gas	16.37
Information & Communication	8.20
Transportation & Storage	8.00
Construction	7.07
Hospitality	2.93
Administrative & Support Services	2.32
Agriculture, Forestry, & Fishing	2.20
Professional, Scientific & Technical	1.95
Total	93.37

This table shows the share of aggregate sales for the ten biggest sectors by their total domestic sales volume.

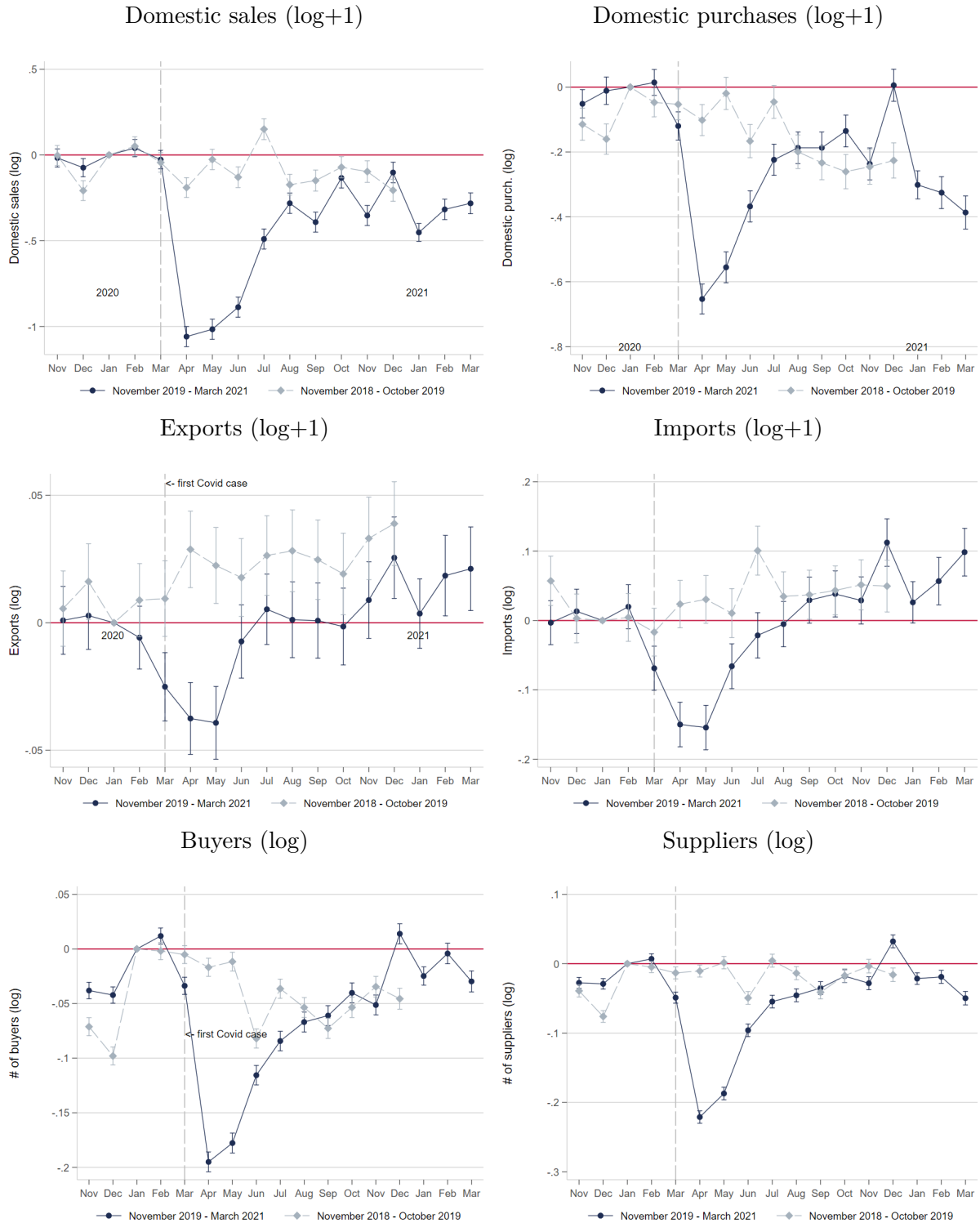
Table 4: Summary statistics on inter-firm relationships between 2015 and 2020

Year	Firms	Total sales (in bn. KES)	Relationships	Firm-to-firm sales (in % of total sales)
2015	31,684	4,857.5	886,940	49.3
2016	36,920	5,881.1	1,134,159	49.5
2017	40,677	6,218.8	1,204,754	50.6
2018	44,997	6,594.0	1,332,150	49.0
2019	48,697	6,828.3	1,528,410	56.3
2020	49,955	6,651.1	1,528,109	60.0

This table shows the number of firms in the production network, firm-to-firm relationships, the aggregate sales volume, as well as the share of aggregate domestic sales that is linked to transactions between registered entities.

Appendix B Comparison of firm dynamics during the COVID-19 crisis with previous year's trend

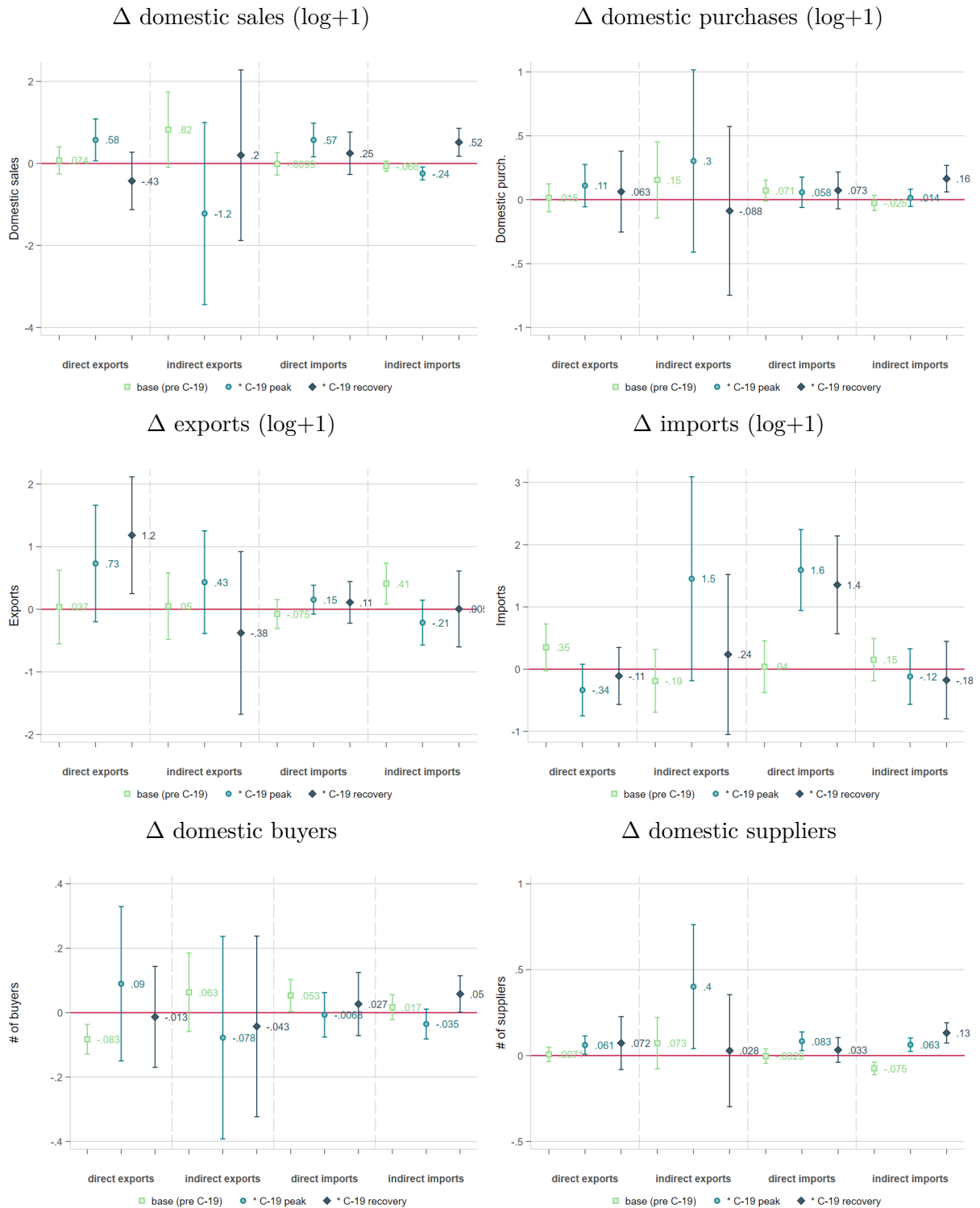
Figure 8: Major firm-level outcomes during the COVID-19 crisis vs 2019 trends



In the above graphs we regressed firm-level outcomes on a series of monthly time dummies. We further included firm and month fixed effects and normalised the coefficient for January 2020 to zero. Standard errors are clustered at the firm-level and the error bars show the 95 per cent confidence intervals. The regressions include data from April 2015 to March 2021.

Appendix C Firm response to international shocks before the COVID-19 crisis, during its peak and the recovery phase

Figure 9: Major firm-level outcomes during the COVID-19 crisis vs 2019 trends



The results present the estimation of Equation 1 regressing the respective shock measures on the change in logged firm-level outcomes relative to same month in previous year as well as firm and sector-date fixed effects. Here we further interact the shock measures with dummies that are equal to one for the dates April to June 2020 (C-19 peak) and July 2020 to March 2021 (C-19 recovery). The coefficients for the interaction terms thus need to be interpreted relative to the coefficient estimated for the pre-COVID period. Standard errors are clustered at the firm-level. We further control for the firm's size (sum of shares and firm age (log) weighted by the sum of shares). The regressions include data from April 2018 to March 2021.

Table 5: Firm-level characteristics and 2019 outcomes by upstream diversification

Variable	(1)		(2)		T-test
	low diversification N	Mean/SE	high diversification N	Mean/SE	Difference (1)-(2)
Firm age	16828	11.745 (0.072)	10787	12.582 (0.093)	-0.837***
Nairobi or Mombasa based	16828	0.777 (0.003)	10787	0.786 (0.004)	-0.009*
Direct exporter	16828	0.042 (0.002)	10787	0.057 (0.002)	-0.015***
Direct importer	16828	0.141 (0.003)	10787	0.240 (0.004)	-0.099***
Share of dom. sales out. network	16828	0.288 (0.003)	10787	0.191 (0.003)	0.096***
Sales (log)	16828	16.355 (0.019)	10787	17.032 (0.022)	-0.677***
Purchases (log)	16828	14.977 (0.030)	10787	16.128 (0.030)	-1.150***
No. employees	16828	20.891 (1.371)	10787	37.054 (2.474)	-16.163***
Value added (log)	14208	15.837 (0.016)	9294	16.224 (0.021)	-0.386***
Value added per employee (log)	8579	14.578 (0.018)	7156	14.383 (0.017)	0.194***

Notes: The value displayed for t-tests are the differences in the means across the groups. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Table 6: firm-level characteristics and 2019 outcomes by downstream diversification

Variable	(1)		(2)		T-test
	low diversification N	Mean/SE	high diversification N	Mean/SE	Difference (1)-(2)
Firm age	17683	11.455 (0.070)	13905	11.764 (0.078)	-0.309***
Nairobi or Mombasa based	17683	0.773 (0.003)	13905	0.740 (0.004)	0.033***
Direct exporter	17683	0.037 (0.001)	13905	0.055 (0.002)	-0.017***
Direct importer	17683	0.167 (0.003)	13905	0.174 (0.003)	-0.007*
Share of dom. sales out. network	17683	0.325 (0.003)	13905	0.378 (0.004)	-0.053***
Sales (log)	17683	16.224 (0.019)	13905	16.851 (0.020)	-0.627***
Purchases (log)	17683	14.974 (0.027)	13905	16.187 (0.022)	-1.213***
No. employees	17683	13.565 (0.612)	13905	40.056 (2.531)	-26.490***
Value added (log)	14638	15.746 (0.016)	11720	16.124 (0.019)	-0.378***
Value added per employee (log)	8497	14.593 (0.018)	8600	14.403 (0.016)	0.190***

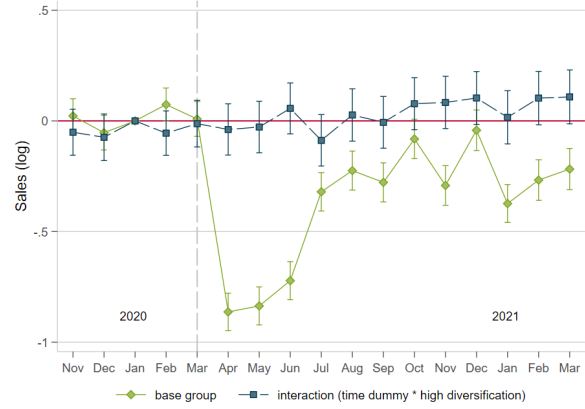
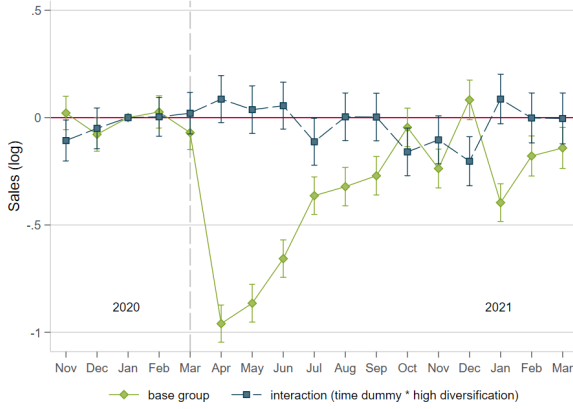
Notes: The value displayed for t-tests are the differences in the means across the groups. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Figure 10: Domestic network position and firm sales during the crisis and recovery phase

Extensive margin diversification

Downstream (number of domestic buyers)

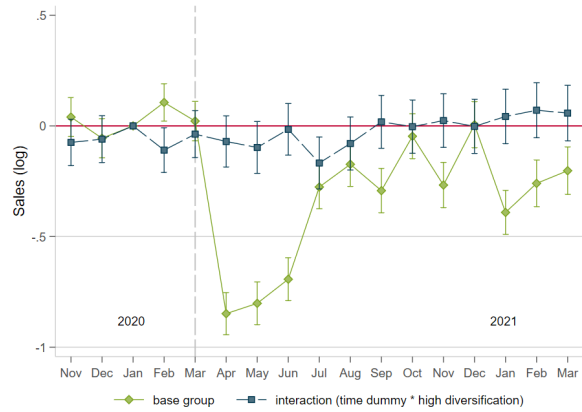
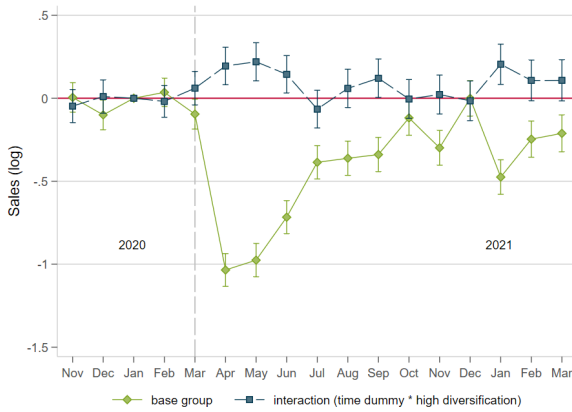
Upstream (number of domestic suppliers)



Complexity of the supply chain

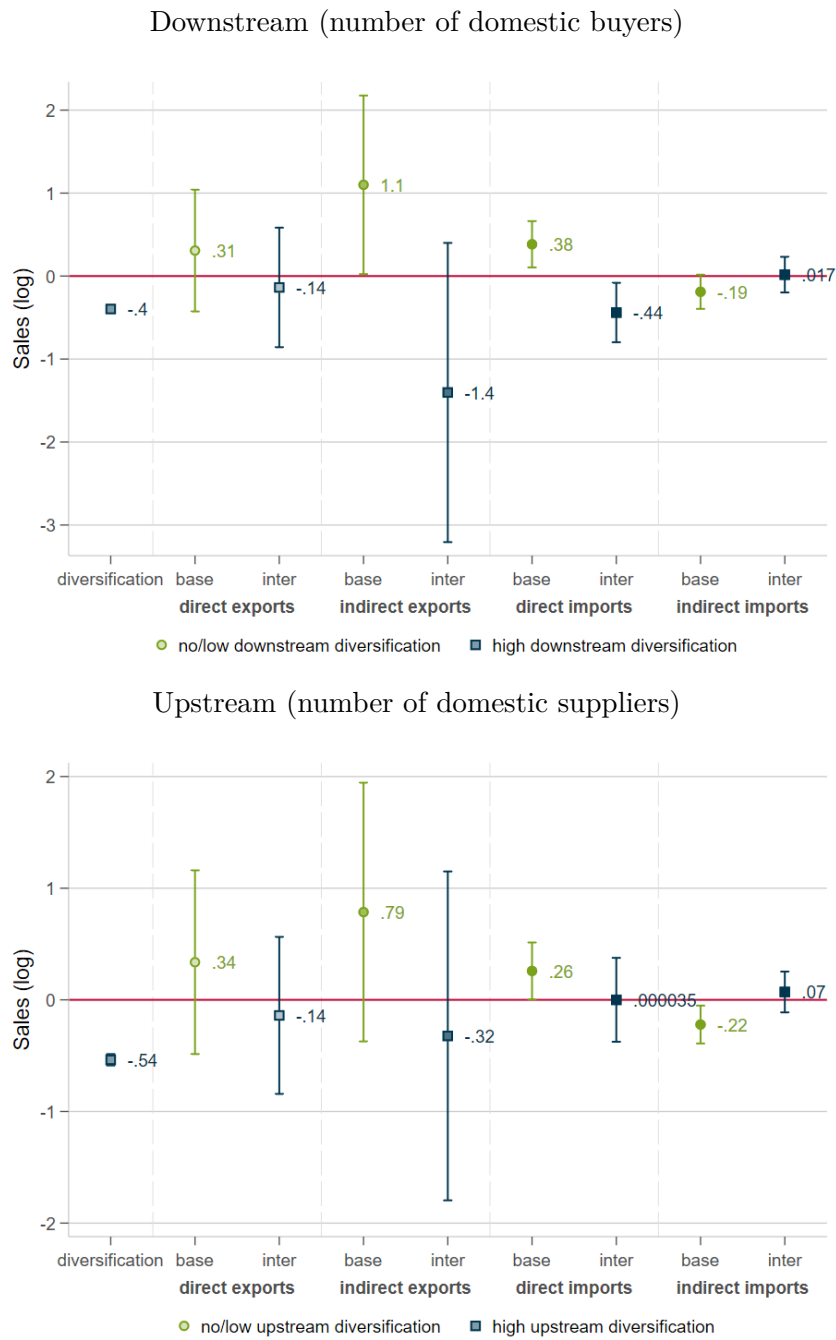
Number of domestic downstream sectors

Number of domestic upstream sectors



In the above graphs we regressed firm-level outcomes on a series of monthly time dummies (solid green line). We further interacted the time dummies with the respective measure for the firm's network position (dashed blue line). We included firm and month fixed effects and normalised the coefficient for January 2020 to zero. Standard errors are clustered at the firm-level and the error bars show the 95 per cent confidence intervals. The regressions included data from April 2015 to March 2021.

Figure 11: Supply chain diversification and the response of firm sales to international shocks



The above graphs present the results from estimating equation 1 while interacting the shock measures with dummies for above median diversification of the up- and downstream supply chain. The coefficients for control variables are not included.