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Impact of COVID-19 on Tunisian imports

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Abstract

COVID-19 pandemic caused significant disruption of trade flows between countries, revealing the vulnerability of global value chains. This unexpected event sparked a public debate on devising new policies to increase the resilience of value chains. This study identifies vulnerabilities related to supply chains with a specific focus on Tunisian imports during the period 2019-2020. To this end, we select three potential drivers of import vulnerability based on post-pandemic reports and discussions and assess their impact on Tunisia's overall imports using quantitative analysis. We consider, for each product, (1) the market concentration of Tunisia's suppliers, (2) the intensity of imports and (3) we also consider COVID-19 products – that we call 'essential products' – as potential source of import vulnerability and assess their impact separately. These factors are country-specific product characteristics. Then, we identify a model based on first differences estimator to assess the impact of the change in vulnerable imports on the change in total imports at the country-month and country-quarter levels using import data for the period 2019-20. Finally, we use input-output linkages to assess the level of exposure of Tunisia's local industries to vulnerable supplies from partner countries through a downstream propagation approach. This framework will help us get insights into Tunisia's most sensitive imports and industries.

Keywords: COVID-19, supply chain vulnerability, Tunisia, input-output linkages, downstream propagation.

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1. Introduction

The COVID-19 pandemic has significantly disrupted supply chains, affecting most economies. According to the World Trade Organization (WTO), the volume of world merchandise trade declined by 9.2% in 2020[5]. Supply chains disruptions might have uneven effects on countries. The WTO forecasts a larger decline of 14% in 2020 imports for Africa, Middle East and Commonwealth of Independent States (CIS), including associate and former member States compared to a drop of 8.4% in imports for North America. Its consequences could be larger for developing and emerging countries participating in Global Value Chains (GVC), such as Tunisia.

For instance, a recent United Nations Conference on Trade and Development Report (2020) shows that Tunisia is among the top twenty countries most impacted by Chinese supply disruption. The analysis is based on an assessment of each country's and industry's integration with the Chinese economy using the Grubel-Lloyd Index (GLI) of intra-industry trade. The report underlines that a reduction of two percent of Chinese exports of intermediate products in the electrical machinery sector as an example will cost the Tunisian economy 27 million of US dollars. Similarly, Friedt and Zhang (2020) study the overall impact of COVID-19 on Chinese exports and differentiate between the domestic supply shock, the international demand shock and the effects of GVC contagion. They show that Tunisia is among top exposed countries to Chinese supply disruption together with South American countries, the Democratic Republic of Congo, France and Poland, Zambia and several countries neighboring China (i.e. India, Pakistan, Thailand, Laos, and Vietnam, among others).

In this study, we aim to identify the sources of vulnerability in Tunisia's supply chain by unveiling which imported products – and sectors – are likely to be most disrupted, thus the most vulnerable. To this end, we identify vulnerable imports based on three conditions. We check if (1) the geographical concentration of suppliers is high as an indication to whether the country cannot easily substitute the sources of its imports, (2) the intensity of imports is high to verify if the product cannot be easily substituted with another – high intensity means high demand for substitutes which cannot be satisfied at least in the short run, (3) the imports are essential to fight the pandemic (COVID-19 products). The choice of these conditions is based on a simple reasoning: how do we replace a product that is no more imported? Three options are available.

[5]https://www.wto.org/english/news_e/pres20_e/pr862_e.htm#:~:text=The%20WTO%20now%20forecasts%20a,and%20government%20responses%20to%20it.

Either we import it from other suppliers, substitute it with a similar product, or produce it locally (although this last option is beyond our study). In the next step, we define a first differences model to evaluate the impact of the change in vulnerable imports on the change in total imports at the country-month and country-quarter levels for the period 2019-20.

Our approach is similar to methodologies used in the literature. Korniyenko et al. (2017) identify risky products based on three products' characteristics, namely, the presence of central players, the tendency to cluster, and international substitutability. Bonneau and Nakaa (2020) pin down "vulnerable" goods for France through the analysis of extra-European imports of around 5,000 categories of products taking into account first the concentration of imports of each product and second the international substitutability of the product, i.e. the existence of other alternatives for obtaining inputs from other countries. Todo, Nakajima and Matous (2015) and Huang (2019) show that diversification of partners results in higher resilience. The reliance on a limited number of suppliers exposes a country to the risk of policy changes. A recent example is the export restrictions that were imposed by many countries on essential products to address the domestic shortages that followed the sudden rise in demand in response to COVID-19 pandemic.

One novelty of our work is the use of the vulnerability indicators and Tunisia's input-output (IO) table to assess the level of exposure of Tunisia's local industries to the supply shock due to its downstream propagation. Many papers use IO linkages as a mechanism to investigate the propagation of shocks. Carvalho et al. (2016) use IO linkages to study the propagation of the shock resulting from the Great East Japan Earthquake of 2011 along the supply chain. Acemoglu et al. (2016a) use the US IO table to estimate the indirect effects of upstream and downstream exposure of employment in manufacturing and nonmanufacturing industries to imports from China. Acemoglu et al. (2016b) study the propagation of different shocks along the different US local industries using IO linkages. Our approach is close to Acemoglu et al. (2016b), specifically when they study the shock related to imports from China.

COVID-19 affected businesses in different ways. It resulted in the shutdown of some factories, difficulties for others in delivering their products due to disruptions in transportation and logistics, employees not getting to the factory because of illness or lockdown, etc. In other cases, demand was shifting. The pandemic proved that, like many countries, Tunisia did not show a high resilience to the trade shock that followed the unexpected disruption in GVCs and distribution channels. This work tries to explain the vulnerability of Tunisian imports to allow

the implementation of the right measures that could ease the impact of the shock in the future and secure essential national supplies.

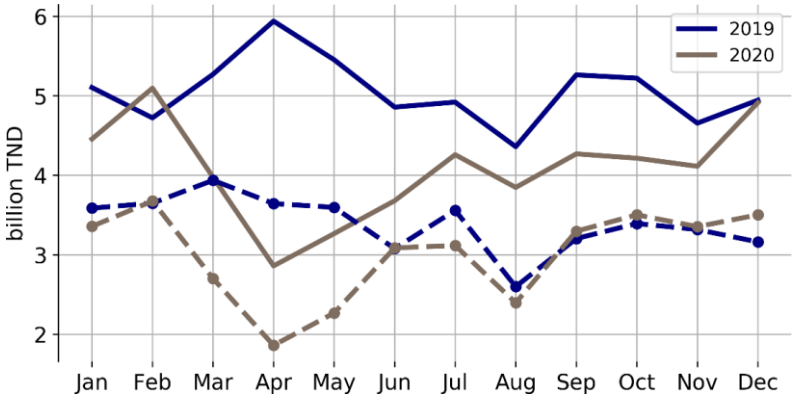
The paper is organized as follows. Section 2 provides the background of our research. It describes the development of Tunisia's trade post-pandemic with a focus on imports. Section 3 outlines our methodology and data and provides details of the vulnerability measures, econometric specification, and IO approach. We present our results in section 4. Conclusions are drawn in section 5.

2. Research background

The unexpected surge of COVID-19 has caused an unprecedented level of disruption in global trade flows affecting all countries, but with different degrees. Overall, Tunisia's trade has experienced a sharp decline in 2020 compared to 2019 although exports were less affected than imports. Imports fell by 11.8 billion TND, that is, a 19.4% change. On the other hand, exports fell by 4.6 billion TND, a decrease by 11.3%. The fall in both trade flows started in February 2020 and registered the sharpest negative picks in April (see figure 1a). It is noteworthy that Tunisia's trade flows have not been stable during the last decade. Figure 1b shows that exports and imports have been declining until 2016, then experienced a steady growth for two years, and then started declining again. Figure 1c details the development of Tunisia's imports by sector. 'Machinery, electronics, transport equipment', Tunisia's largest import sector declined by one billion US$ between 2013 and 2019. Extractive industries show the largest drop for the same period. They fell by more than half until 2016, then started to recover very slowly. The other sectors show less significant variations.

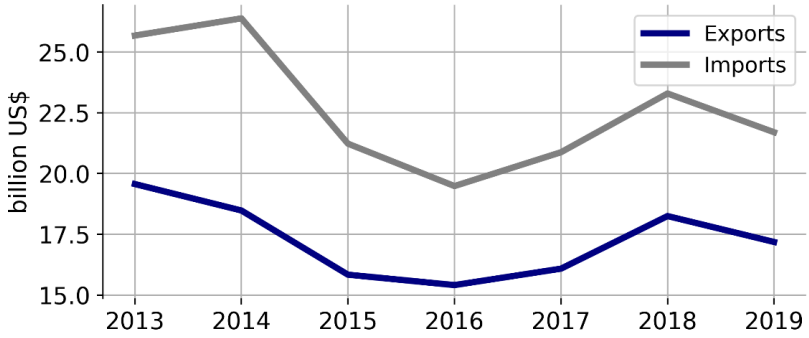
Fig. 1 Development of Tunisia's trade flows

(a) Monthly development



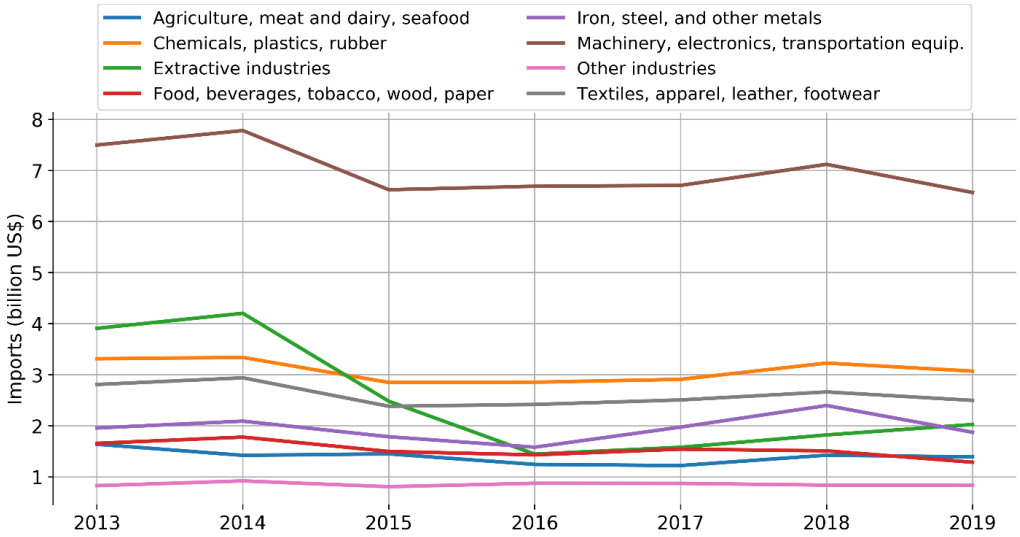
Source: authors' elaboration based on data from Tunisia's customs
Notes: continuous lines represent imports while dashed lines represent exports

(b) 7-years development



Source: authors' elaboration based on data from CEPII-BACI

(c) 7-years development by sector[6]



Source: authors' elaboration based on data from CEPII-BACI

[6] The classification of sectors we use throughout the analysis is based on Hanson (2010) unless otherwise specified.

Tunisia's imports experienced a significant drop in 2020 in all sectors except agriculture. The sector ‘agriculture, meat and dairy, seafood’ shows a 13.6% increase in imports. Agricultural imports amounted to 4.1 billion TND in 2019 and reached 4.7 billion TND in 2020. Figure 2a shows the change in import values by sector. Going further into details, we find that the agricultural sector imports recorded a single drop of 21% in the second quarter of 2020 compared to 2019. However, their value increased by 13.6%, 54.8%, 15.5% in the first, third, and last quarters respectively.

Sectors that participate in upstream GVCs, namely, "machinery, electronics, transport equipment", "textiles, clothing, leather, footwear", and "chemical industries" (Baghdadi, 2018) were heavily impacted in terms of their supplies since the first quarter of 2020. As an example, the “machinery, electronics and transport equipment” sector suffered a reduction of 21.6% in the first quarter of 2020 compared to 2019. Then, a reduction of 39.6% in the second quarter. This difference was reduced to 18.5% and 13.4% in the third and fourth quarters, respectively, showing that this sector was relatively able to secure its sources of supply starting from the second quarter. But it remains largely vulnerable to the shock.

The “machinery, electronics and transport equipment” sector is dependent on the growth of the automobile sector and other means of transport, a sector whose demand has been severely hit globally. The textiles sector follows the same trend as the machinery sector. Nevertheless, it shows a certain resilience as it was able to return in the fourth quarter to import levels that are only 4.3% lower than 2019. “Chemicals, plastics, rubber” sector follows a trend similar to textiles, clothing, leather and footwear. It is noteworthy that all sectors have experienced their largest fall in imports in the second quarter of 2020.

The “machinery, electronics, transport equipment” sector is the most affected by the pandemic. In 2019, 98% of Tunisian imports belonging to this sector were made by offshore companies. The sector is highly integrated into value chains and being highly affected by the disruption of supply chain may suggest that it is part of “rigid production networks” as Boehm et al. (2019) call them. Boehm et al. (2019) provide evidence for the role of multinational firms in the cross-country transmission of shocks through trade of highly specialized inputs. Their results show that the elasticity of substitution with respect to domestic inputs is low. Similarly, Barrot and Sauvagnat (2016) show that input specificity is a key driver of the propagation of firm-level shocks.

The "textiles, apparel, leather, footwear" sector was also highly affected by the supply shock. However, despite the significant fall in imports, the sector proved resilient. According to a study made collaboratively by International Trade Centre (ITC), Tunisia's Ministry of Industry and Small and Medium Enterprises, the Tunisian Textile and Clothing Federation and the Technical Center for Textile, 87% of the sector continued to operate and 60% of companies have converted to the production of protective personal equipment (PPE). The same study shows that Tunisia was ranked 4th supplier of reusable masks to the European Union during the first half of 2020[7].

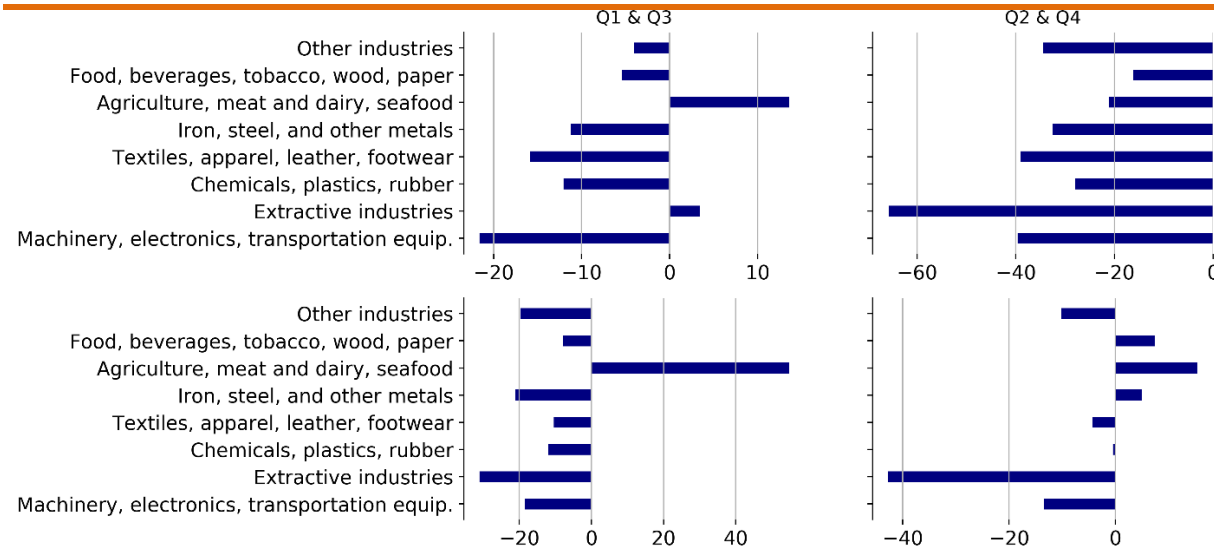
Extractive industries recorded the largest fall in imports (35.9%), followed by the machinery sector that registered a 23.5% decrease. Extractive industries also present in downstream GVCs (Baghdadi, 2018) were strongly impacted since the second quarter with a significant reduction of 65.7%. The sector's imports fell by 31% and 42.8% in the third and fourth quarters of 2020, respectively. This is evidence of the fragility of the sector and its inability to cope with the shock.

Results from the perspective of products' end use show that, overall, imports of intermediate and consumption products fell by 20.3% and 13.3% respectively. Imports of intermediates went from 52.4 billion TND in 2019 to 41.7 billion TND in 2020. Products imported for final consumption fell from 8.3 billion TND to 7.2 billion TND. Imports of both intermediate and consumption products experienced a decline in all quarters (see figure 2b).

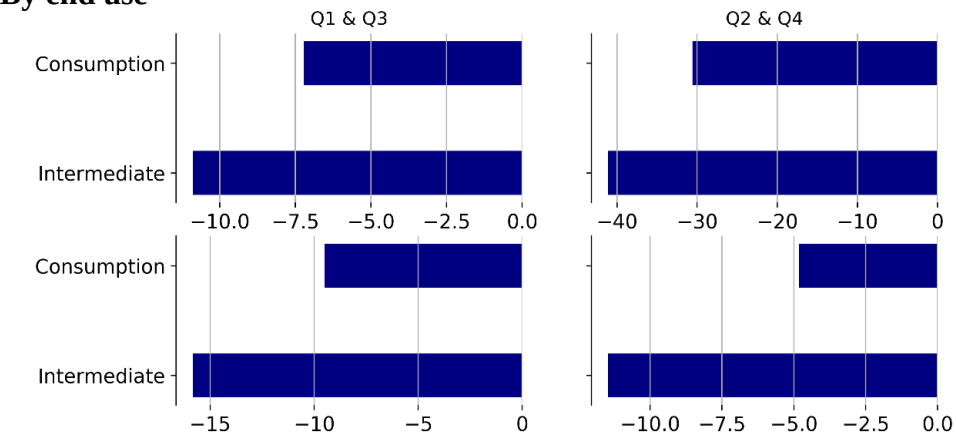
Fig. 2 Change in Tunisia's imports 2019-20 (%)

(a) By sector

[7]https://www.intracen.org/layouts/2coltemplate.aspx?pageid=47244640256&id=47244683322#:~:text=L%27%C3%A9tude%2C%20coordonn%C3%A9e%20par,r%C3%A9gionale%20et%20internationale.



(b) By end use[8]



Source: authors' elaboration based on data from Tunisia's customs

The market shares of Tunisia's top partners have varied between 2019 and 2020. We note a 13% increase in imports from China in 2020. Unlike the case with its other top partners, the trade balance of Tunisia with China is not balanced. In 2019, 9.8% of Tunisia's imports came from China, while only 0.3% of its exports went to it. China is ranked 140 in Tunisia's export partners (out of 168). Imports from Algeria experienced a sharp decrease (25%) while exports decreased by 19.5%.

Despite the variations, the ranking of Tunisia's top 5 partners remains unchanged for the two years. A small exception is noticed: Algeria ranked Tunisia's sixth largest partner in 2019, but in 2020, during the pandemic, it ranked seventh after Turkey. However, the difference in the

[8] We distinguish between consumption and intermediary products using Broad Economic Categories (BEC) which classifies products based on their primary end use. See UN Publication (2002) for further details. We eliminate category 7 'Goods not elsewhere specified' and consider category 51 'Transport equipment, passenger motor cars' as consumption goods.

market shares of the two countries is not significant, as 5.22% and 5.20% of Tunisia's imports came from Turkey and Algeria respectively, in 2020.

3. Methodology and data

Our framework is built on three parts. First, we identify vulnerable and essential imports. Second, we define an econometric model based on first differences estimator to assess the impact of importing vulnerable and essential products on overall import growth. Finally, we explore IO linkages to see how an import shock affecting vulnerable and essential products propagates to other industries. This framework will help us get insights into Tunisia's most sensitive imports and industries.

3.1. Drivers of vulnerability

We consider three factors as drivers of vulnerability and then, we assess their role in the variations of imports during the pre- and post-COVID-19 period (2019-20) and how they affect Tunisia's local industries. These factors are (1) the diversity of suppliers that we call "concentration", (2) the intensity of imports, and (3) essential products to fight COVID-19. The selection of these factors is based on the ongoing discussion about the way governments and businesses should respond to the vulnerabilities of supply chains and the way they should plan the post-pandemic period when it comes to production and trade. In what follows we provide details of the drivers of vulnerability and the data used.

1. We define diversity of suppliers as the number of countries exporting to Tunisia. We use the market concentration measure Herfindahl-Hirschman Index (HHI) to characterize each of the 4,699 HS6-digits products imported by Tunisia in 2019 and 2020. This measure allows us to assess whether Tunisia's imports depend on a limited number of suppliers.

HHI is defined by equation (1):

$$(1)\ HHI_p = \sum_n s_n^2$$

HHI is the concentration index of product p; s_n is the partner country's market share; and n is the number of partner countries exporting product p to Tunisia. For each product, we determine the sum of squares of market shares corresponding to each supplier. The index lies between 0 and 1. A value of 1 indicates the highest concentration, thus, the lowest diversification of suppliers. Products imported from a limited number of countries are the most vulnerable. HHI is a popular measure of market concentration for the information it embeds. Throughout the

paper we consider 'concentrated imports' those with HHI exceeding the 75th percentile[9]. We use import data from CEPII-BACI database. For each product, we use the average HHI for the period 2013-2019 to avoid biased results that may arise due the variations in Tunisia's imports during the last decade.

2. We define the intensity of Tunisia's imports as the import share of each product compared to the world import of the same product. We measure it using the revealed comparative advantage for imports (import-RCA). Import-RCA compares a product's share in a country's imports to its share in world imports. It indicates whether Tunisia imports products in high quantity relative to its size, compared to imports of other countries. A value greater than 1 indicates that the product is intensively imported. We characterize products by the level of their intensity to see if 'intensive imports' are more vulnerable to supply shocks. Data from CEPII-BACI database is used. Similar to HHI, we compute averages for the period 2013-2019. We use Balassa (1965) definition of RCA, with X_{cp} as the import value of country c in product p.

$$(2)\ RCA_{cp} = \frac{X_{cp}}{\sum_p X_{cp}} \Big/ \frac{\sum_c X_{cp}}{\sum_{c,p} X_{cp}}$$

3. The final factor of vulnerability we consider in this study is related to the use of the product, specifically if it is essential or not to fight COVID-19. We define 'essential imports' as medical supplies required to cure COVID-19 patients or to prevent the propagation of the pandemic. We merge two lists of products to get a consolidated list of essential products. The first list is provided by the World Bank[10]. The second is jointly prepared by World Customs Organization and World Health Organization[11].

3.2. Econometric specification

We define an econometric model to assess the impact of each of the vulnerability indicators on overall imports in 2020, during the spread of the pandemic. We use monthly bilateral data of Tunisia's imports for the years 2019 and 2020, provided by Tunisian customs. Our regression model is based on first differences estimator. We run it using country-month data and country-quarter data. We define different model specifications to check the behaviors of the different

[9] The choice of this threshold is justified by Productivity Commission (2021).
[10] https://www.worldbank.org/en/data/interactive/2020/04/02/database-on-coronavirus-covid-19-trade-flows-and-policies
[11] http://www.wcoomd.org/en/media/newsroom/2020/june/new-edition-of-the-wco-who-hs-classification-list-for-covid-19-medical-supplies-now-available.aspx

variables separately, then globally. We also interact some variables to check the level of dependency between them. In what follows we detail our specifications.

Equation (3) represents the first specification. It only considers the core regressors.

$$(3)\ \Delta IMP_{it} = \beta_1 \Delta VIMP_{it} + \beta_2 \Delta MED\_COVID19_{it}$$

ΔIMP_{it} is the change in Tunisia's total imports from partner country i in the period 2019-2020. $\Delta VIMP_{it}$is the change in imports of vulnerable products including both 'concentrated' and 'intensive' products that we identify using a filtering process. $\Delta \text{MED\_COVID19}_{it}$ is the change in imports of medical products required to fight COVID-19.

Equation (4) represents the second specification. We add to equation (3) the number of restrictions imposed by Tunisia's supplier countries due to COVID-19 as an interaction variable. We use data provided by ITC Market Access Map to estimate the number of restrictions[12].

$$(4)\ \Delta IMP_{it} = \beta_1 \Delta VIMP_{it} + \beta_2 \Delta MED\_COVID19_{it} + \beta_3(\Delta VIMP_{it} * Num\_restrictions_i) + \beta_4(\Delta MED\_COVID19_{it} * Num\_restrictions_i)$$

We also run the two specifications while considering 'concentrated' and 'intensive' imports separately to check the impact of each factor of vulnerability on Tunisia's overall imports. Results are presented in the next section.

3.3. Input-Output linkages

This part of the analysis allows us to answer the following question: How does the effect of vulnerable and essential imports propagates through Tunisia's local industries? We quantify the downstream propagation of the shock affecting vulnerable and essential imports by adapting the work of Acemoglu et al. (2016b) to our specific case. Based on the work of Ben abderrahmen, Marouani and Baghdadi (2022, forthcoming)[13], we use Tunisia's IO table for the year 2015 provided by Tunisia's National Institute of Statistics (INS) to estimate the downstream propagation of the shock on inputs of eleven manufacturing and non-manufacturing industries.

[12] https://www.macmap.org/covid19

[13] The work is titled 'The Unobserved Effects of COVID-19 Related Shocks: The Role of Production Networks'.

Downstream propagation is defined such as customer industries are hit much more significantly by the shock than supplier industries, the reverse being an upstream propagation. We limit our analysis to downstream propagation as we are interested in quantifying the effect of the supply shock caused by the pandemic on the production of Tunisia's local industries. In this study downstream effects are those arising from the shock to vulnerable and essential imports belonging to each industry that flow up the IO linkages.

We determine each industry's own direct shock and its downstream propagation (indirect shock). An industry's own direct shock is computed as the change in imports of vulnerable or essential products relative to 2019 Tunisia's market size. We do the analysis with time periods corresponding to years then to quarters. Equation (6) is an adaptation of China Trade shock defined in Acemoglu et al. (2016b) to capture an industry's exposure to rising trade with China.

$$(6)\ Shock_{j,t} = \frac{Vulnerable\ or\ Essential\ Imports_{j,t}}{Value\ Added_{j,2019} + Imports_{j,2019} - Exports_{j,2019}}$$

The downstream shock is "the interaction of the vector of shocks hitting other industries and a vector representing the interlinkages between the focal industry and the rest" (Acemoglu et al., 2016b). Equation (7) does not include the direct effect of the shock of industry i.

$$(7)\ Downstream_{i,t} = \sum_j (Input\%_{j \to i}^{2015} - 1_{j=i}) \cdot \Delta Shock_{j,t}$$

$Input\%_{j \to i}^{2015}$ represents the elements of the Leontief inverse of the IO matrix. $1_{j=i}$ is an indicator function for j = i. Given a data availability constraint, we use IO matrix for the year 2015 as we do not expect major changes relative to IO matrix of 2019.

4. Results

4.1. Filtering process and results

In our analysis we consider the factors of vulnerability – concentration and intensity – both separately and merged to get a global view of their impact on overall imports. Products that are both concentrated and intensively imported favor the exposure to shortages resulting from a disruption of supply. The filtering process is applied as follows.

The first filter is applied to Tunisian imports to select the products that Tunisia imports from a limited number of suppliers. Highly concentrated products are determined by a HHI greater than 3100 points (or 75th percentile). This filter indicates that 2,454 products out of 4,435, that

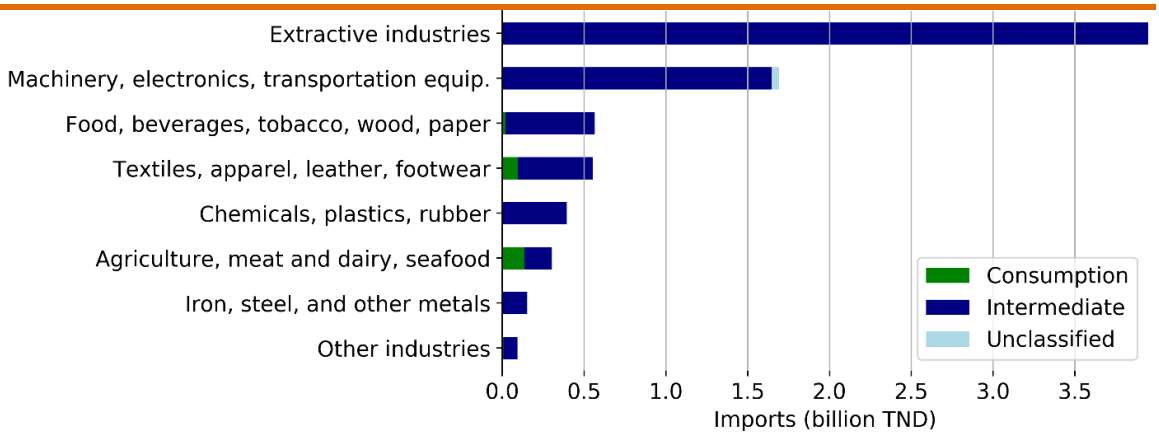
is 20 billion TND out of 61 billion TND, represent highly concentrated imports in 2019. The second filter includes the products that are imported by Tunisia in high quantities compared to other countries. This filter reduces the number of vulnerable products from 2,454 to 776. Intensive products represent 1,574 products and 42 billion TND out of total imports.

The final list of vulnerable products (776) represents 17% and 17 billion TND of overall imports. Essential products represent 132 products and more than 5 billion TND of total Tunisian imports in the same period. Vulnerable imports are less likely to be replaced, at least in the short run, and thus, more likely to disrupt production processes if they are intermediary inputs, and to not match the demand if they are consumption goods. Figure 3 shows the characteristics of the vulnerable imports.

Vulnerable imports are mainly intermediates that belong to extractive industries (by value of imports). However, extractive industries include the lowest number of vulnerable products (less than 20 products). The second major group of vulnerable products includes intermediates that belong to the sector "machinery, electronics, transportation equipment" based on import value (35 products). The food sector ranks third (more than 30 products) followed by the textiles sector. The textiles sector ranks first based on the number of vulnerable products which exceeds 80, from which around 15 are consumption products. The largest number of vulnerable consumption products belong to the textiles sector, followed by the agriculture and food sectors (13 and 11 products respectively). Chemicals and iron sectors include large numbers of vulnerable products (46 and 22 respectively) but with lower values of imports. The agriculture sector includes 13 consumption products out of 30 vulnerable products with low value of imports.

Fig. 3 Characteristics of vulnerable imports (2019)

(a) By value of imports



(b) By number of products

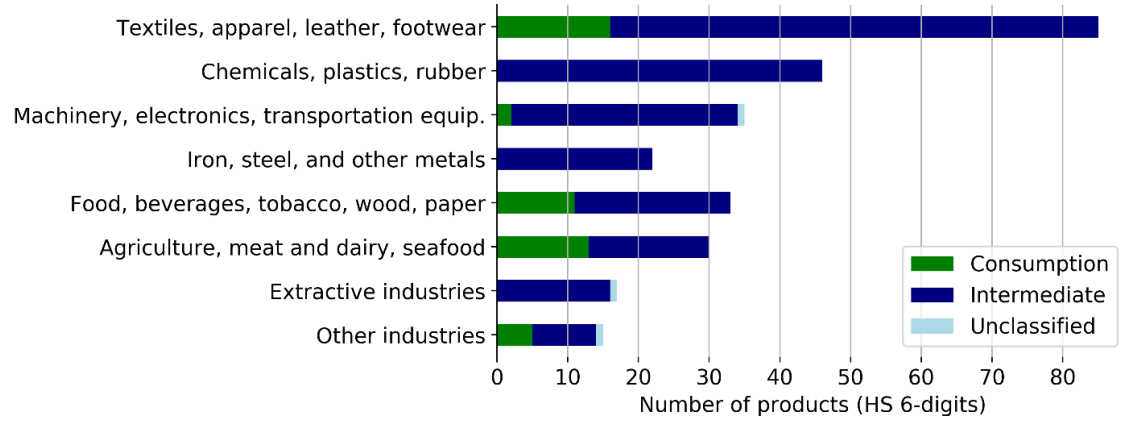
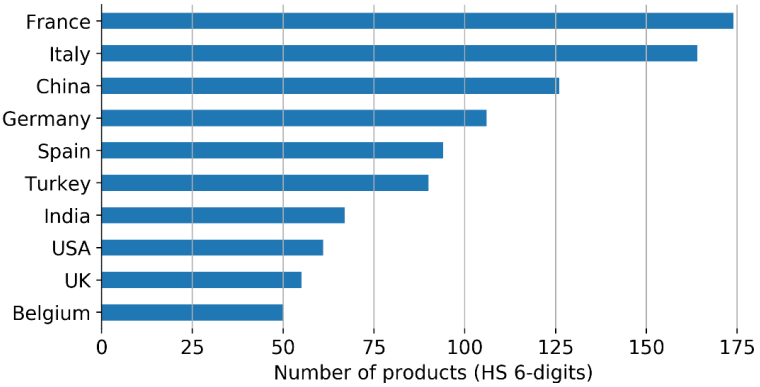


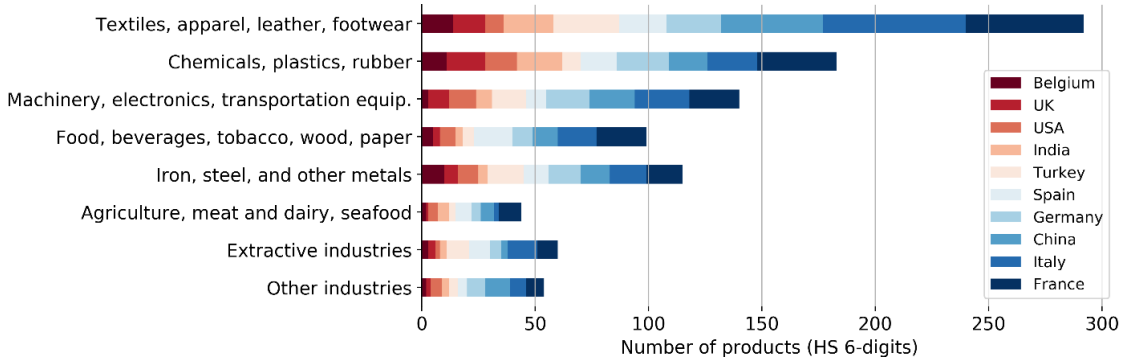
Figure 4 shows the top suppliers of Tunisia's vulnerable imports. Tunisia imports more than 100 of vulnerable products from France, Italy, China, and Germany. Figures 4a and 4b show the distribution of vulnerable imports across sectors and partner countries. For most sectors, France, Italy, and China are the main suppliers. Figures 4c and 4d show the same data by value of imports. Algeria is the main supplier as all of its supplies belong to extractive industries, the most important sector in terms of value. France ranks second with most of its supplies belonging to the machinery sector. Italy is third ranked with vulnerable supplies belonging mainly to textiles, machinery, and extractive industries.

Fig. 4 Tunisia's top suppliers of vulnerable products (2019)

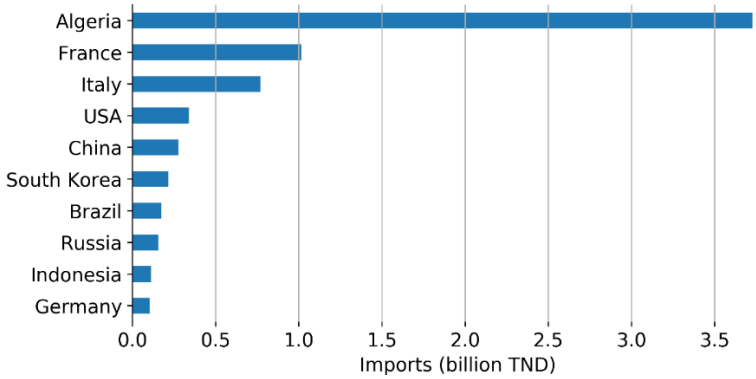
(a) By number of products



(b) By number of products and sectors



(c) By value of imports



(d) By value of imports and sectors

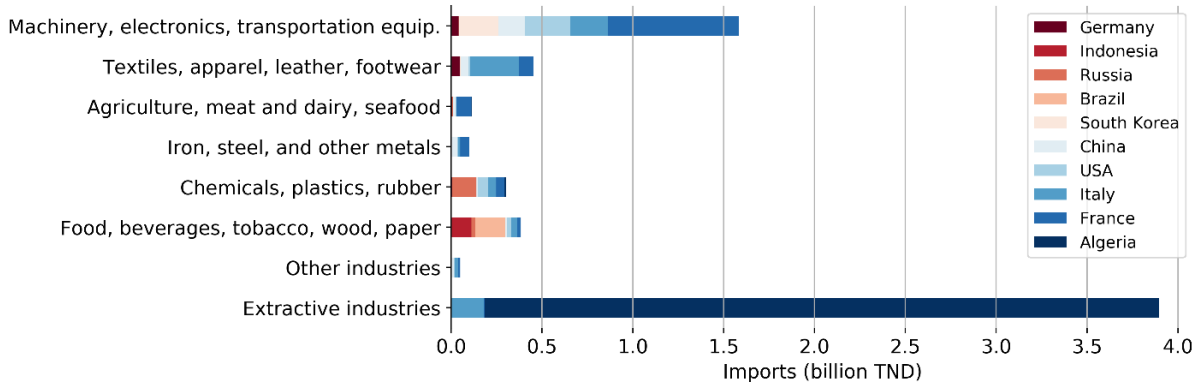


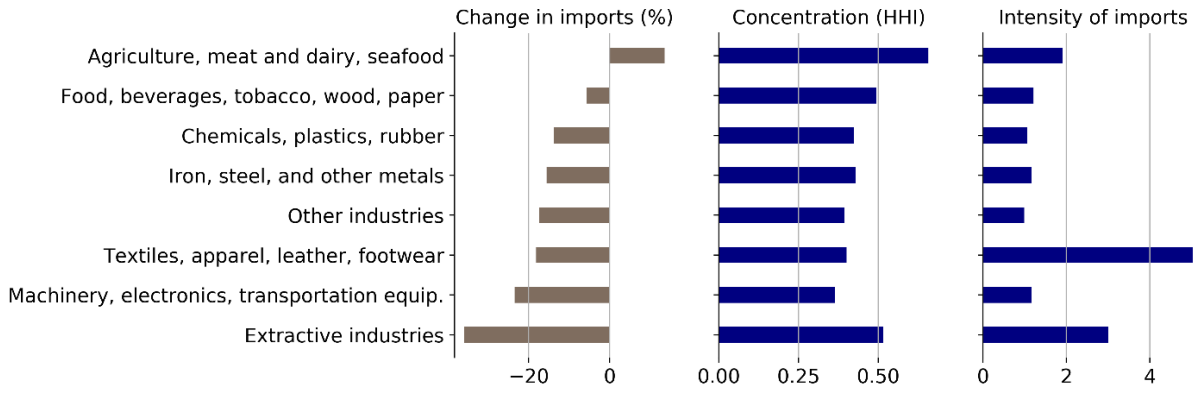
Figure 5a compares the sectoral change in import values between 2019 and 2020 to the sectoral distribution of the scores of vulnerability measures (averages). The distribution of vulnerability measures among sectors provides some insights as to the characteristics of these sectors. The concentration measure HHI shows that the agricultural sector includes the less diversified products, that is, products which are imported from a limited number of countries. At the same time, the sector recorded the only positive change in imports between 2019 and 2020, which is in part due to an increase in prices. The sector has the third high score in import intensity.

The "textiles, apparel, leather, and footwear" sector shows the highest score for import intensity. The products belonging to the textiles sector have low concentration of suppliers. The "machinery, electronics and transport equipment" sector has been severely affected by the pandemic despite that its imports are the least concentrated and have low import intensity. This may be due to the high integration of this sector into GVCs. Imports of extractive industries are highly concentrated, they rank second after the agricultural sector. In terms of import intensity, it is ranked second.

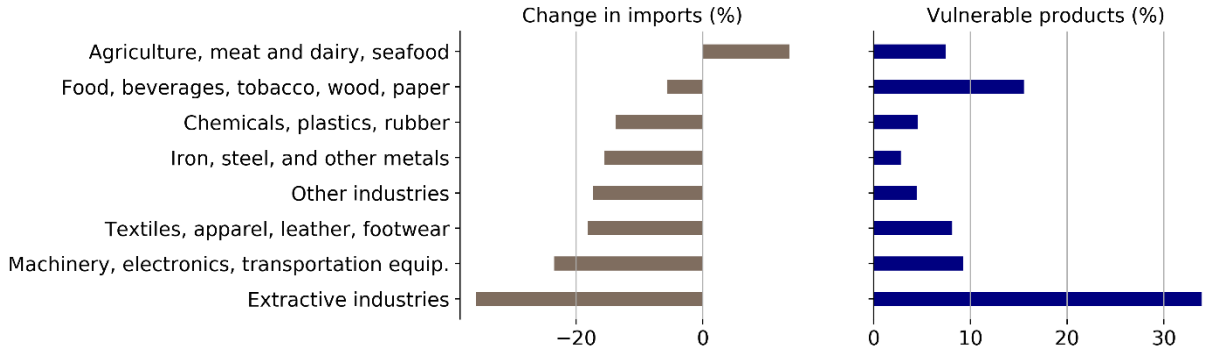
Figure 5b shows that the food sector experienced a small negative change in imports between 2019 and 2020 despite the high percentage of vulnerable products belonging to the sector. This is due to the nature of the sector as it is critical for survival and may also suggest that local production increased to satisfy the rise in retail and food spending. In what follows we present some cases of essential products where Tunisia has shown resilience despite the high sudden rise in demand.

Fig. 5 Variation in Tunisia's imports 2019-20 vs. vulnerability

(a) Imports vs. vulnerability indicators



(b) Imports vs. vulnerable products



Despite the disruption of trade, Tunisia succeeded in producing and even exporting essential products related to COVID-19 in response to the pandemic. Our results show that the country increased its exports of some COVID-19 products significantly. This suggests that Tunisia has the potential and the resources needed to produce new products, or to increase the volume of its current production following an increased demand. Table A1 in annex 1 shows examples of COVID-19 related products that experienced a high rise and a high fall in both trade flows.

At the same time, some products were subject to an important fall in imports. This could have two explanations. First, the restrictions that countries around the world have imposed on the export of some products related to COVID-19. Second, Tunisia managed to substitute some imports, relying on its own resources. As an example, hand sanitizers (HS 382499) experienced 100% fall in imports, while its export value increased by 139%. Tunisia stopped importing certain goods and started exporting them, at the same time, satisfying both local and foreign demand. The country has shown certain resilience when it comes to COVID-19 related goods. Tunisia also showed resilience in some other activities e.g. production of face masks, that emerged in response to the pandemic.

Some COVID-19 products showed a high increase in imports and high decrease in exports due to their critical use. As an example, imports of protective garments (HS 621030) multiplied by more than five, while exports experienced almost a hundred percent decrease. This indicates that Tunisia couldn't meet the rising demand for some essential products locally and had to import them which shows the vulnerability of the country to these products.

4.2. Regression analysis

We present the estimations of the first differences model and try to assess the relationship between the one-period changes in our dependent variable – overall imports – and the explanatory variables. Table 1 summarizes the results of the different specifications.

Our results show that the coefficients associated with vulnerable and essential imports are significant and positive in all specifications, with essential imports impacting overall imports much more. The coefficients associated with essential imports are higher than the coefficients of vulnerable imports. Quarterly specifications have higher coefficients than monthly specifications, but overall conclusions are the same.

The coefficient associated with the number of restrictions imposed by Tunisia's partner countries is significant but low for all specifications. The interaction term of vulnerable imports and the number of restrictions (column (5)) shows that an increase in the number of restrictions increases the impact of vulnerable imports on overall imports by 0.13. However, when interacted with essential imports, we find that an increase in the number of restrictions reduces the impact of essential imports on overall imports by 0.7 (rounded). The two interaction terms are statistically significant, showing there is a significant dependency between the number of restrictions on one side and vulnerable and essential imports on the other side, although the signs are different.

We run two other models for robustness. The results are presented in table A1 in annex 2. In the first model we exclude intensive imports as they have a correlation of 0.9 with the dependent variable. The results are robust. In the second model we consider concentrated and intensive imports separately to see the impact of each vulnerable cluster apart. Column (5) shows that the interaction term between the number of restrictions and concentrated imports is not significant (although positively significant at 10% significance level for quarterly data), positively significant for intensive imports and negatively significant for essential imports.

The results show that vulnerable and essential imports impact overall imports positively and significantly but to a different extent (coefficients are 4.7 and 1.2 for essential and vulnerable imports respectively). Vulnerable imports have an effect on overall imports that is about 4 times less than essential imports. We **s**how that the way vulnerable and essential imports influence overall imports depends significantly on the number of restrictions imposed by partner countries. Our results show that as more restrictions are set, an increase in vulnerable imports increases overall imports even more (0.13), and an increase in essential imports still increases

overall imports but to a lower extent (-0.67). Restrictions mainly affected essential products, consequently the coefficient is more significant for the interaction term of the two variables.

Hayakawa and Imai (2021) show that an increase in COVID-19 burden leads to lower exports of medical products. They show that the decrease is less significant when exports are going to countries with closer political, economic, or geographical ties. However, in the case of Tunisia – and other developing countries – foreign aid played a key role in providing essential products during the pandemic, which may not be reflected in trade data.

Table 1 First differences estimations

	Data by month/country			Data by quarter/country		
	(1)	(2)	(3)	(1)	(2)	(3)
ΔVIMP	1.211***	1.196***	1.010***	1.290***	1.268***	0.819***
	(0.038)	(0.038)	(0.060)	(0.065)	(0.064)	(0.105)
ΔMED_COVID19	4.712***	4.606***	6.729***	5.733***	5.579***	8.432***
	(0.174)	(0.172)	(0.349)	(0.281)	(0.278)	(0.618)
Num_restrictions		-0.002***	-0.002***		-0.005***	-0.006***
		(0.000)	(0.000)		(0.001)	(0.001)
ΔVIMP:Num_restrictions			0.133***			0.329***
			(0.037)			(0.067)
ΔMED_COVID19:Num_restrictions			-0.671***			-0.996***
			(0.094)			(0.180)
R-squared	0.528	0.540	0.557	0.585	0.599	0.632
R-squared Adj.	0.528	0.540	0.556	0.584	0.598	0.629
No. Observations	1708	1708	1708	674	674	674

Notes: ΔVIMP is the change in vulnerable imports, it includes products that are both concentrated and intensively imported. ΔMED_COVID19 is the change in imports of essential products. Num_restrictions is the number of restrictions imposed by partner countries due to COVID-19.
Standard errors in parentheses. * p<.1, ** p<.05, ***p<.01.

4.3. Exposure of Tunisia's local industries to supply shocks

The last part of our study is to quantify the propagation of shocks on imports through IO linkages. We focus on three supply shocks: (1) supply of concentrated products, (2) supply of intensive products, and (3) supply of essential products. First, we identify the direct shock, which is related to the lack of inputs in each industry (change in imports of concentrated, intensive and essential products). Second, we quantify the indirect shock running through downstream linkages, as outputs of an industry are inputs to another. Sectors in this section are based on the Tunisian Classification of Activities (NAT)[14]. We present the results of each shock

[14] The conversion between HS products and NAT sectors is made manually.

separately. Figures 7 and 8 in Annex 3 show quarter data for Tunisian industries' exposure to supply shock.

Industries' exposure to the different supply shocks is most significant in the second quarter of 2020. We note that Tunisia experienced the largest disruption of its imports during this period. Thus, we are particularly interested in analyzing how, during this time span, the three import shocks propagated through the IO linkages and disrupted the different sectors. We conclude with a brief analysis of the annual variation (2020 relative to 2019) of these direct and indirect import shocks to see which shocks have persisted during this year and which sectors have been most affected.

The existence of input-output linkages leads input supply shocks to affect not only sectors that import vulnerable products but also their customers (downstream sectors) that do not necessarily import these products. For example, the "building materials, ceramics and glass" sector faces an indirect shock of approximately -2% in the second quarter of 2020 while not being exposed to a decrease in vulnerable imports – no direct shock – (figure A2 in annex 3). On the other hand, the "oil refining" sector, despite a very large direct shock of around -25%, faces almost a null indirect shock. In fact, this could be explained by a negligible negative import shock of vulnerable products to its suppliers. We decompose the vulnerable imports into its two components, namely intensive and concentrated imports. We find similar results.

For concentrated imports, the direct shocks are important for the oil refining, agro-food, and chemicals, while the indirect shocks were of low magnitude. However, there were positive indirect effects for the electricity and gas, and the oil refining sectors. These results could be explained by the increase in imports from the oil and natural gas sector, which is an important supplier of the former ones, highlighting the downstream propagation of supply shocks.

Intensive import shocks were negative and important for both manufacturing and non-manufacturing sectors, with direct shocks more important in most cases than the indirect shocks. The oil refining, chemicals and textiles sectors showed the strongest contraction of intensive imports with 28%, 25% and 24% respectively. These shocks propagated through downstream linkages and disrupted sectors that were not directly concerned with intensive imports like the "electricity and gas" and "mining" sectors.

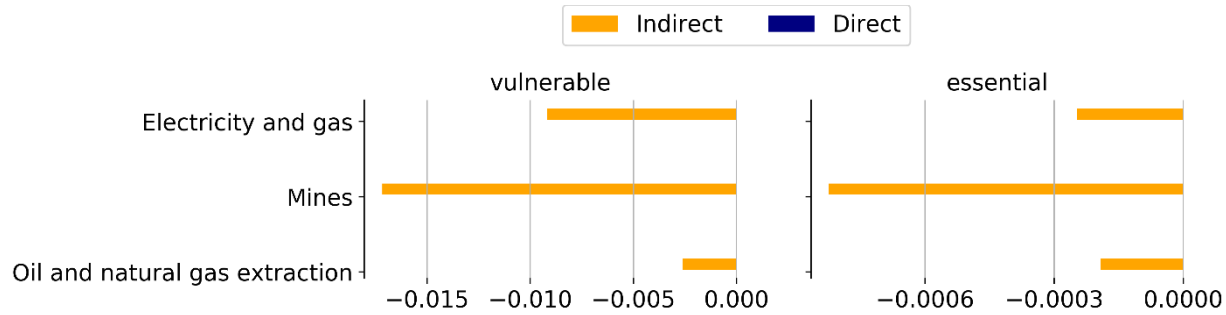
For essential imports, which are mainly consumption goods that belong to machinery, chemicals, and textiles sectors, the indirect shocks are low for all sectors. Direct shocks for chemicals and textiles sectors are relatively high (approximately -2% and 2% respectively).

By evaluating the annual variation in imports (2020 compared to 2019), we note that results are comparable to those of the quarterly variations. Supply shocks caused by concentrated imports are of higher magnitude than the two other types of shock. Indirect exposure is of a lesser magnitude than direct exposure for three shocks. The sectors most affected directly by negative supply shocks are the oil refining, chemicals, and textiles.

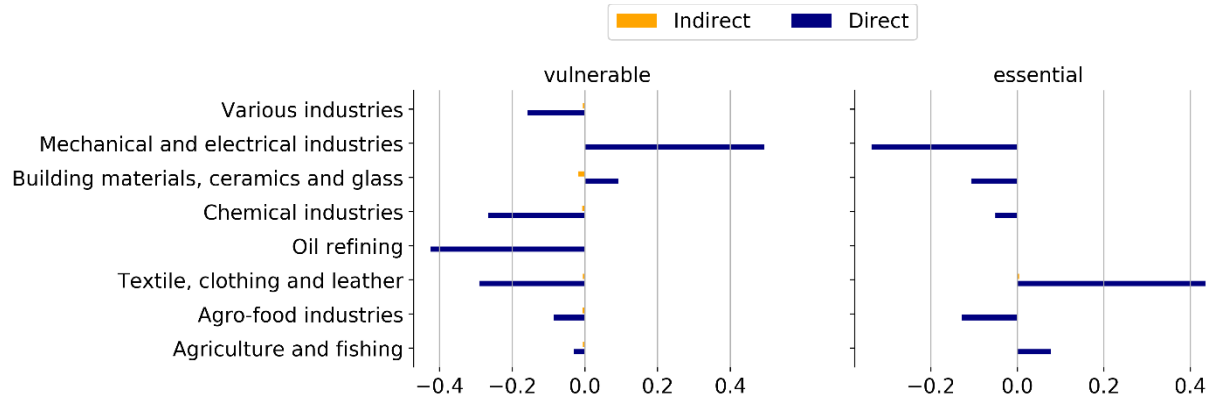
We conclude that sectors' direct and indirect exposure to essential imports shock are far lower than their exposure to shocks from intensive and concentrated imports, except for 'mechanical and electrical' and 'textiles' sectors that show a high direct exposure. Moreover, results regarding the importance of direct shocks relative to indirect shocks are in line with the findings in Ben abderrahmen, Marouani and Baghdadi (2022, forthcoming) where the indirect COVID-19 related shocks in Tunisia are less important than direct ones.

Fig. 6 Tunisian industries' downstream exposure to supply shocks (total)

(a) Nonmanufacturing industries



(b) Manufacturing industries & agriculture and fishing



5. Conclusion

Trade between countries has been challenged by the spread of COVID-19 pandemic resulting in the disruption of supply chains. These disruptions raised concerns worldwide about the possible ways to ensure the continuity of value chains in times of disruption. To this end, we

identify the most vulnerable (less diversified suppliers and intensively imported) products imported by Tunisia in a first step. The final list includes 776 vulnerable products that represent 17% and 17 billion TND of overall imports. Essential products represent 132 and more than 5 billion TND of total Tunisian imports in 2019. Our findings show that the highest value of vulnerable products belongs to the extractives sector, followed by the machinery and food sectors. The imports of the extractives and the machinery sectors are the most impacted by the pandemic with a drop of 35,85% for the former and 23,45% for the latter.

Next, we define a first differences model to evaluate the impact of the change in the imports of vulnerable and essential products on the change in total imports at the country-month and country-quarter levels between 2019 and 2020. Our estimations show that a change in imports of vulnerable and essential products significantly explain the change in overall imports. We show that vulnerable and essential imports have a significant and positive impact on overall imports in all specifications with the impact of essential imports approximately four times that of vulnerable imports. Some limitations of our work is that we do not consider the demand or the change in prices.

Finally, we study the direct and indirect exposure to supply shocks. Our results show that overall, direct exposure is more significant for manufacturing industries and agriculture and fishing, for which the second quarter was the most effected. For nonmanufacturing industries, the supply shocks related to intensive and essential imports have no direct effect as these industries include mainly concentrated products. Accordingly, the supply shock related to concentrated imports have a significant direct effect, especially on oil and natural gas extraction industry which was highly exposed to the shock in the first quarter.

Unveiling supply chain vulnerabilities is important to address them properly. First, government intervention is needed to quickly address problems encountered by impacted sectors with a permanent dialogue between public and private representatives to alleviate sources of vulnerability such as warehousing, diversifying sources of inputs and implementing sectoral policies to produce feasible and strategic products. Second, at the bilateral and regional level, it is important to explore ways to reduce vulnerabilities with partner countries within trade agreements. Third, at the multilateral level, COVID-19 products are among vulnerable products and Tunisia was not able to access to many of them because of supply chains disruptions, increasing export restrictions and behind the border procedures. The WTO trade facilitation agreement and more generally WTO mechanisms, through alleviating new and potentially cost increasing border controls and export restrictions that emerged during the pandemic, offer an

important framework to help low- and middle-income countries to access to essential products such as COVID-19 products.

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Annex 1

Table A1 Examples of affected COVID-19 products

Product	Change in imports/exports (%)	+ imports	+ exports	- imports	- exports
Protective garments - 621030	559,7	1	0	0	0
Medical Masks - 630790	228,7	1	0	0	0
Raw Materials to produce masks - 391610	198,2	1	0	0	0
Gloves, examination, non-sterile - 401511	161,4	1	0	0	0
Textile raw material for masks and coveralls – 560391	131,8	1	0	0	0
Raw Materials to produce masks - 600240	126,4	1	0	0	0
Gloves – 621020	100,7	1	0	0	0
Ventilators, oxygen mask and nebulizer, nasal cannula and CPAP machines - 901920	89,4	1	0	0	0
Textile raw material for masks and coveralls – 560394	81,5	1	0	0	0
Textile raw material for masks and coveralls – 560312	80,6	1	0	0	0
Nitrile and Sterile gloves - 401519	5046,1	0	1	0	0
Disinfectant - 380894	1012,8	0	1	0	0
Gloves – 621020	821,3	0	1	0	0
Gloves – 401590	480,5	0	1	0	0
Raw Materials to produce masks - 760410	194,8	0	1	0	0
Textile raw material for masks and coveralls – 560311	177	0	1	0	0
Raw Materials to produce masks - 721790	172,6	0	1	0	0
Protective garments - 621050	168,4	0	1	0	0
Hand sanitizers - 382499	139,1	0	1	0	0
Medical Masks - 630790	122,7	0	1	0	0
Hand sanitizers - 382499	-100	0	0	1	0
Protective garments - 611300	-93,7	0	0	1	0
CT systems - 902212	-71,7	0	0	1	0
Raw Materials to produce masks - 600290	-61,7	0	0	1	0
Protective garments - 621040	-60,3	0	0	1	0
Bougies, catheters, drains and sondes, and parts – 901839	-57,3	0	0	1	0
Raw Materials to produce masks - 760429	-48,9	0	0	1	0
Raw Materials to produce masks - 391620	-47,9	0	0	1	0
Other medical headwear - 650610	-47,9	0	0	1	0
Protective garments - 621149	-47,8	0	0	1	0
Protective garments - 621030	-99,9	0	0	0	1
Sharps container boxes - 392329	-87,5	0	0	0	1
Textile raw material for masks and coveralls – 560312	-86,4	0	0	0	1
Raw Materials to produce masks - 391690	-76,2	0	0	0	1
Liquid Soap - 340130	-72,3	0	0	0	1
Ventilators, oxygen mask and nebulizer, nasal cannula and CPAP machines - 901920	-66,1	0	0	0	1
Chlorine – 390421	-66	0	0	0	1
Patient monitors and pulse oximeters - 901819	-65,5	0	0	0	1
Full face mask filters anti-aerosol FFP3 - 842199	-63,8	0	0	0	1
Other medical headwear - 650610	-50	0	0	0	1

Annex 2

Table A1 First difference estimations including concentrated and intensive imports separately

(a) Without intensive imports

	Data by month/country			Data by quarter/country		
	(1)	(2)	(3)	(1)	(2)	(3)
ΔVIMP	1.203***	1.191***	0.958***	1.266***	1.248***	0.744***
	(0.033)	(0.033)	(0.054)	(0.055)	(0.054)	(0.092)
ΔMED_COVID19	4.723***	4.613***	6.701***	5.734***	5.572***	8.248***
	(0.165)	(0.163)	(0.329)	(0.265)	(0.261)	(0.574)
Num_restrictions		-0.002***	-0.002***		-0.005***	-0.006***
		(0.000)	(0.000)		(0.001)	(0.001)
ΔVIMP:Num_restrictions			0.171***			0.384***
			(0.034)			(0.061)
ΔMED_COVID19:Num_restrictions			-0.664***			-0.948***
			(0.089)			(0.167)
R-squared	0.574	0.586	0.606	0.630	0.645	0.683
R-squared Adj.	0.573	0.586	0.605	0.629	0.643	0.681
No. observations	1708	1708	1708	674	674	674

Notes: ΔVIMP is the change in vulnerable imports, it only includes concentrated imports.

(b) With intensive imports

	Data by month/country			Data by quarter/country		
	(1)	(2)	(3)	(1)	(2)	(3)
ΔVIMP_HHI	0.146***	0.152***	0.216***	0.152***	0.160***	0.173**
	(0.029)	(0.029)	(0.050)	(0.047)	(0.046)	(0.081)
ΔMED_COVID19	1.301***	1.283***	2.310***	1.432***	1.412***	3.225***
	(0.123)	(0.122)	(0.233)	(0.204)	(0.201)	(0.422)
ΔVIMP_INTENS	1.086***	1.073***	0.850***	1.124***	1.107***	0.856***
	(0.021)	(0.021)	(0.044)	(0.033)	(0.033)	(0.070)
Num_restrictions		-0.001***	-0.001***		-0.003***	-0.003***
		(0.000)	(0.000)		(0.001)	(0.001)
ΔVIMP_HHI :Num_restrictions			0.033			0.086*
			(0.024)			(0.044)
ΔMED_COVID19 :Num_restrictions			-0.335***			-0.597***
			(0.060)			(0.120)
ΔVIMP_INTENS :Num_restrictions			0.081***			0.083***
			(0.015)			(0.025)
R-squared	0.832	0.836	0.842	0.864	0.869	0.877
R-squared Adj.	0.832	0.835	0.841	0.864	0.868	0.876
No. Observations	1708	1708	1708	674	674	674

Notes: ΔVIMP_HHI is the change in concentrated imports; ΔVIMP_INTENS, the change in intensive imports. ΔMED_COVID19 is the change in imports of essential goods; Num_restrictions, the number of restrictions imposed by partner countries due to COVID-19. Missing values are set to null.
Standard errors in parentheses. * p<.1, ** p<.05, ***p<.01.

Table A2 Descriptive Statistics (monthly data)

(a) Summary statistics

	ΔIMP	ΔVIMP	ΔVIMP_HHI	ΔVIMP_INTENS	ΔMED_COVID19	Num_restrictions
Number of observations	1708	1708	1708	1708	1708	1708
Average	-6,885	-1,699	-1,337	-4,47	-0,356	1,672
Standard deviation	43,364	19,175	20,844	32,152	4,202	1,711
minimum	-611,938	-576,772	-577,146	-602,853	-76,303	0
25%	-2,178	-0,003	-0,037	-1,472	-0,023	0
50%	-0,021	0	0	-0,001	0	1
75%	0,207	0	0,003	0,092	0,001	3
maximum	248,644	71,109	189,612	247,924	27,956	10

(b) Correlations

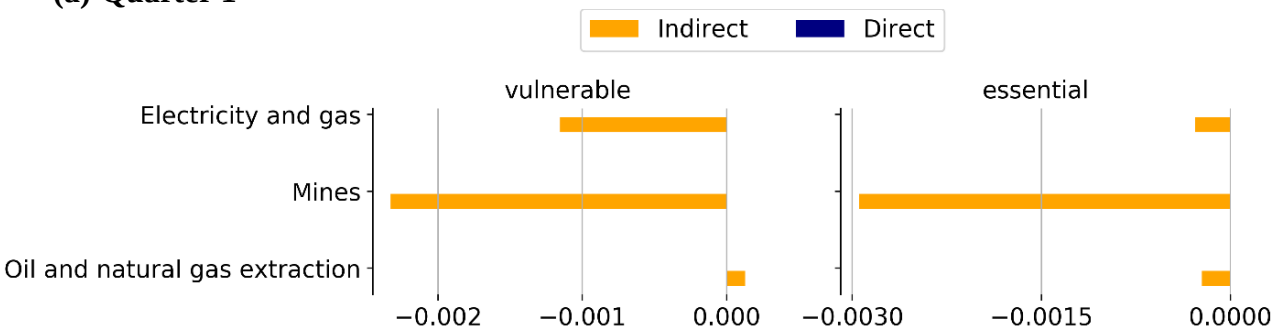
	ΔIMP	ΔVIMP	ΔVIMP_HHI	ΔVIMP_INTENS	ΔMED_COVID19	Num_restrictions
ΔIMP	1	0,566	0,607	0,904	0,493	-0,111
ΔVIMP	0,566	1	0,928	0,694	0,08	-0,006
ΔVIMP_HHI	0,607	0,928	1	0,657	0,074	-0,017
ΔVIMP_INTENS	0,904	0,694	0,657	1	0,453	-0,063
ΔMED_COVID19	0,493	0,08	0,074	0,453	1	-0,054
Num_restrictions	-0,111	-0,006	-0,017	-0,063	-0,054	1

Notes: import values are in million TND. ΔIMP is the change in total imports; ΔVIMP is the change in vulnerable imports, it includes products that are both concentrated and intensively imported; ΔVIMP_HHI is the change in concentrated imports; ΔVIMP_INTENS, the change in intensive imports; ΔMED_COVID19, the change in imports of essential goods; Num_restrictions, the number of restrictions imposed by partner countries due to COVID-19. Values are rounded to the nearest thousandths.

Annex 3

Fig. 7 Tunisian nonmanufacturing industries' downstream exposure to supply shocks

(a) Quarter 1



(b) Quarter 2

(c) Quarter 3

(d) Quarter 4

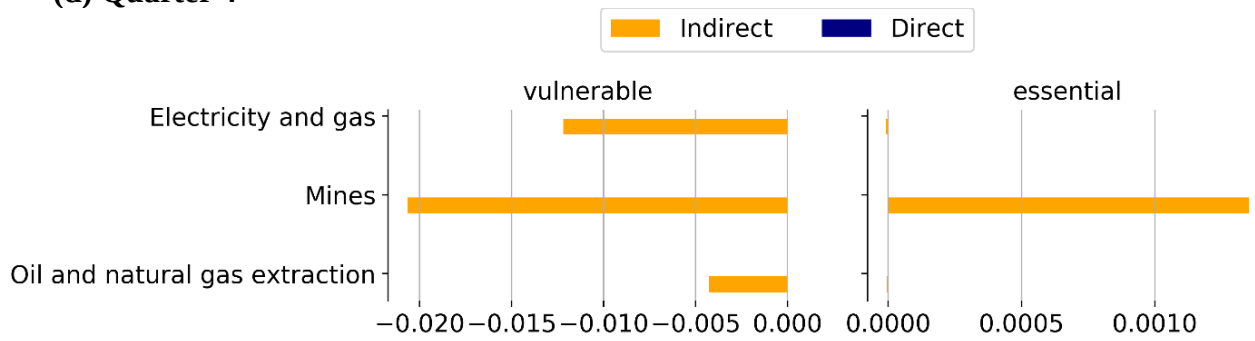
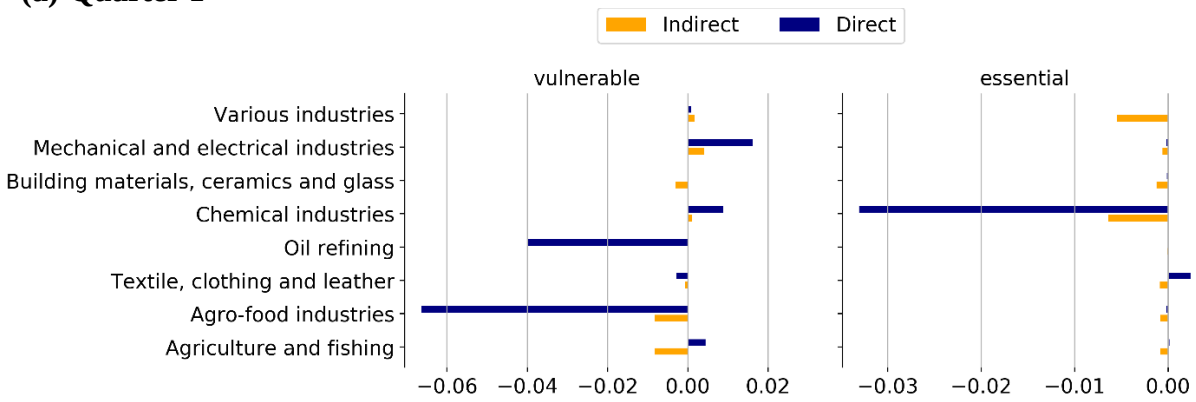
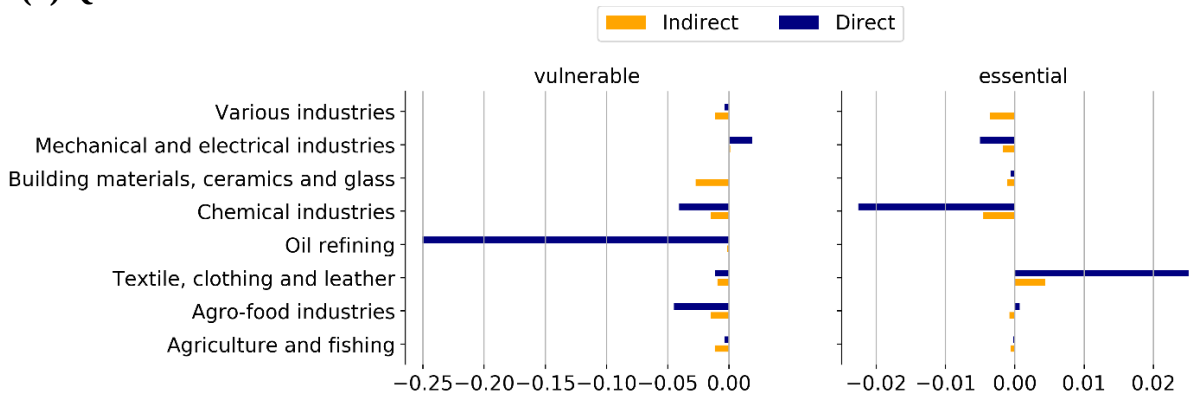


Fig. 8 Tunisian manufacturing industries & agriculture and fishing' downstream exposure to supply shocks

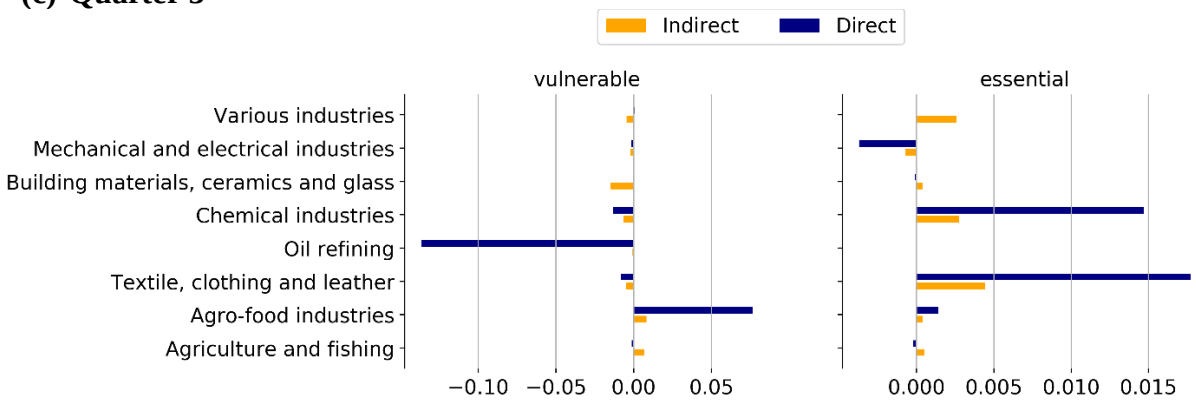
(a) Quarter 1



(b) Quarter 2



(c) Quarter 3



(d) Quarter 4