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Abstract

The COVID-19 pandemic significantly disrupted trade flows between countries, thereby 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 2019-20. 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 a quantitative analysis. For each product, we consider: (1) the market concentration of Tunisia's suppliers, (2) the intensity of imports, and (3) COVID-19 products – that we call 'essential products' – as a potential source of import vulnerability, the impact of which we assess separately. These factors are country-specific product characteristics. Then, we identify a model based on a 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.

JEL Classification: I1

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

الملخص

عطلت جائحة كوفيد -19 بشكل كبير التدفقات التجارية بين البلدان، وبالتالي كشفت عن ضعف سلاسل القيمة العالمية. أثار هذا الحدث غير المتوقع نقاشًا عامًا حول وضع سياسات جديدة لزيادة مرونة سلاسل القيمة. تحدد هذه الدراسة نقاط الضعف المتعلقة بسلاسل التوريد مع التركيز بشكل خاص على الواردات التونسية خلال الفترة 2019-20. تحقيقًا لهذه الغاية، نختار ثلاثة محركات محتملة لضعف الواردات استنادًا إلى تقارير ومناقشات ما بعد الجائحة وتقييم تأثيرها على إجمالي واردات تونس باستخدام التحليل الكمي. لكل منتج، نعتبر: (1) تركيز السوق لموردي تونس، (2) كثافة الواردات، و (3) منتجات كوفيد -19 - التي نسميها "المنتجات الأساسية" - كمصدر محتمل لضعف الاستيراد، التأثير الذي نقوم بتقييمه بشكل منفصل. هذه العوامل هي خصائص المنتج الخاصة بكل بلد. بعد ذلك، نحدد نموذجًا بناءً على مقدر الفروق الأول لتقييم تأثير التغيير في الواردات المعرضة للخطر على التغيير في إجمالي الواردات على مستوى البلد والشهر والربع باستخدام بيانات الاستيراد للفترة 2019-20. أخيرًا، نستخدم روابط المدخلات والمخرجات لتقييم مستوى تعرض الصناعات المحلية في تونس للإمدادات الضعيفة من البلدان الشريكة من خلال نهج الانتشار المصب. سيساعدنا هذا الإطار في الحصول على نظرة ثاقبة للواردات والصناعات الأكثر حساسية في تونس.

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 percent in 2020.[5] Supply chain disruptions might have uneven effects on countries. The WTO forecasts a larger decline of 14 percent in 2020 imports for Africa, the Middle East, and the Commonwealth of Independent States (CIS), including associate and former member states, compared to a drop of 8.4 percent in imports for North America. Its consequences could be larger for developing and emerging countries participating in Global Value Chains (GVCs), such as Tunisia.

For instance, the 2020 United Nations Conference on Trade and Development Report shows that Tunisia is among the top 20 countries most impacted by Chinese supply disruption. The analysis is based on an assessment of each country and industry's integration with the Chinese economy using the Grubel-Lloyd Index (GLI) of intra-industry trade. The report underlines that a two percent reduction of Chinese exports of intermediate products in the electrical machinery sector, for example, will cost the Tunisian economy USD 27 million. 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 the top exposed countries to Chinese supply disruption together with South American countries, the Democratic Republic of Congo, France, 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 the most disrupted and 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 of 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 longer imported? Three options are available. 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 the methodologies used in the literature. Korniyenko et al. (2017) identify risky products based on three product 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, first taking into account the concentration of imports of

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

each product followed by 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 the diversification of partners results in higher resilience. The reliance on a limited number of suppliers exposes a country to the risk of policy changes. 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 the COVID-19 pandemic are a recent example.

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 non-manufacturing industries to imports from China. Acemoglu et al. (2016b) study the propagation of different shocks along the different local US 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 for 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 two provides the background of our research. It describes the development of Tunisia's trade post-pandemic with a focus on imports. Section three outlines our methodology and data and provides details of the vulnerability measures, econometric specification, and IO approach. We present our results in section four. Conclusions are drawn in section five.

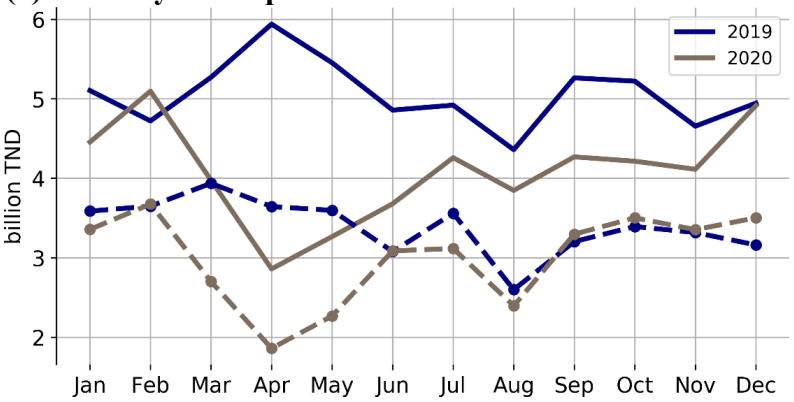
2. Research background

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 TND 11.8 billion (a 19.4 percent change). On the other hand, exports fell by TND 4.6 billion, a decrease of 11.3 percent. 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 steady growth for two years, and then started declining again. Figure 1c details the development of Tunisia's

imports by sector. The machinery, electronics, and transport equipment sector, which is Tunisia's largest import sector, declined by USD one billion 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.

Figure 1. Development of Tunisia's trade flows

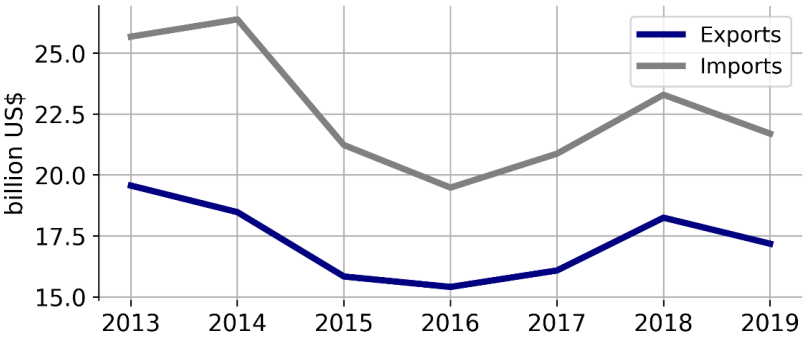
(a) Monthly development



Source: Authors' elaboration based on data from Tunisia's customs.

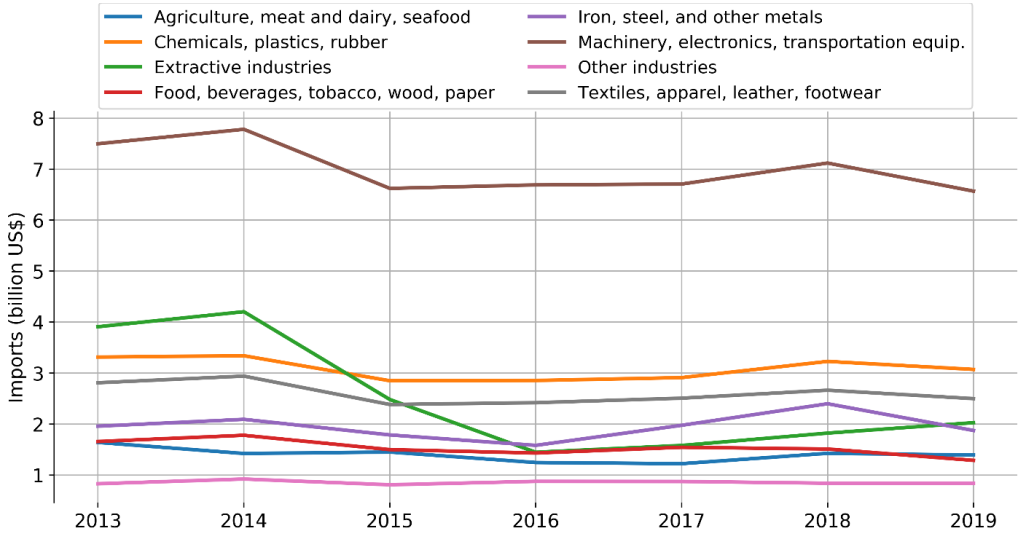
Notes: Continuous lines represent imports while dashed lines represent exports.

(b) Seven-year development



Source: Authors' elaboration based on data from CEPII-BACI.

(c) Seven-year development by sector[6]



Source: Authors' elaboration based on data from CEPII-BACI.

Tunisia's imports experienced a significant drop in 2020 in all sectors, except for agriculture. The agriculture, meat and dairy, and seafood sector shows a 13.6 percent increase in imports. Agricultural imports amounted to TND 4.1 billion in 2019 and reached TND 4.7 billion 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 percent in the second quarter of 2020 compared to 2019. However, its value increased by 13.6 percent, 54.8 percent, 15.5 percent in the first, third, and last quarters, respectively.

Sectors that participate in upstream GVCs, namely machinery, electronics, and transport equipment, textiles, clothing, leather, and 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 percent in the first quarter of 2020 compared to 2019. Then, it experienced a reduction of 39.6 percent in the second quarter. This difference was reduced to 18.5 percent and 13.4 percent 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. However, it remains largely vulnerable to shocks.

The machinery, electronics, and transport equipment sector is dependent on the growth of the automobile sector and other means of transport, the demand for which 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 percent lower than 2019. The chemicals, plastics, and rubber sector follows a trend

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

similar to the textiles, clothing, leather, and footwear sector. It is noteworthy that all sectors have experienced their largest fall in imports in the second quarter of 2020.

The machinery, electronics, and transport equipment sector is the most affected by the pandemic. In 2019, 98 percent of Tunisian imports belonging to this sector were made by offshore companies. The sector is highly integrated into value chains and highly affected by the supply chain disruption, which may suggest that it is part of what Boehm et al. (2019) refer to as "rigid production networks." Boehm et al. (2019) provide evidence for the role of multinational firms in the cross-country transmission of shocks through the 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, clothing, leather, and 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 the 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 percent of the sector continued to operate and 60 percent of companies have converted to the production of protective personal equipment (PPE). The same study shows that Tunisia was ranked as the fourth supplier of reusable masks to the European Union during the first half of 2020.[7]

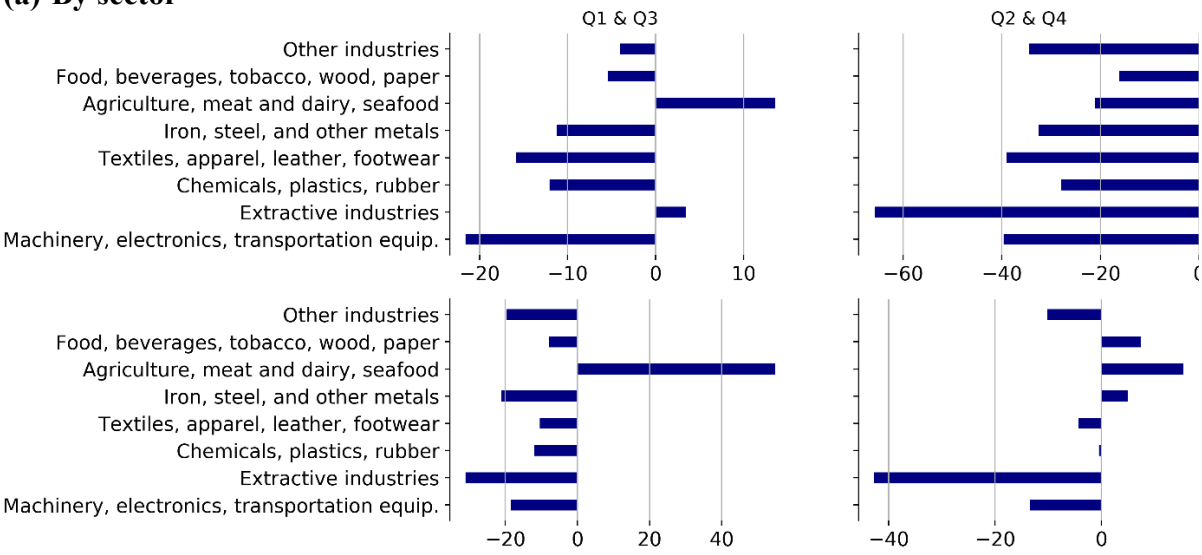
Extractive industries recorded the largest fall in imports (35.9 percent), followed by the machinery sector, which registered a 23.5 percent decrease. Extractive industries also present in downstream GVCs (Baghdadi, 2018) were strongly impacted since the second quarter with a significant reduction of 65.7 percent. The sector's imports fell by 31 percent and 42.8 percent 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 percent and 13.3 percent, respectively. Imports of intermediates went from TND 52.4 billion in 2019 to TND 41.7 billion in 2020. Products imported for final consumption fell from TND 8.3 billion to TND 7.2 billion. Imports of both intermediate and consumption products experienced a decline in all quarters (see Figure 2b).

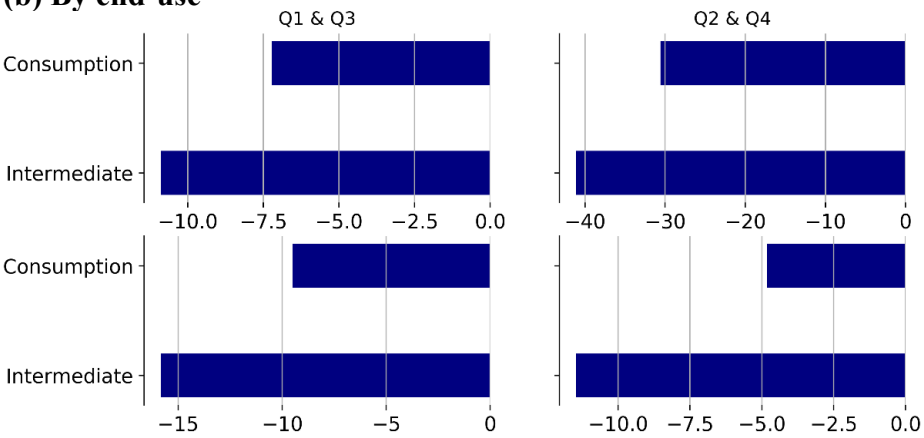
[7]https://www.intracen.org/layouts/2coltemplate.aspx?pageid=47244640256&id=47244683322#:~:text=L%27%C3%A9tude%2C%20coordonn%C3%A9e%20par,r%C3%A9gionale%20et%20internationale.

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

(a) By sector



(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 percent 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 percent of Tunisia's imports came from China, while only 0.3 percent 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 percent) while exports decreased by 19.5 percent.

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

[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 and passenger motor cars' as consumption goods.

in the market shares of the two countries is not significant, as 5.22 percent and 5.20 percent 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 a 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 provide insights into Tunisia's most sensitive imports and industries.

3.1. Drivers of vulnerability

We consider three factors as drivers of vulnerability and then 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 supply chain vulnerabilities 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 the diversity of suppliers as the number of countries exporting to Tunisia. We use a market concentration measure, the 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 the CEPII-BACI database. For each product, we use the average HHI for the period 2013-19 to avoid biased results that may arise due to the variations in Tunisia's imports during the last decade.

[9] The choice of this threshold is justified by Productivity Commission (2021).

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 the 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 the CEPII-BACI database are used. Similar to HHI, we compute averages for the period 2013-19. We use Balassa's (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] while the second is jointly prepared by the World Customs Organization and the 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 a 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 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.

[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

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 the 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 propagate 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 Baghadi (2021, forthcoming), 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 11 manufacturing and non-manufacturing industries.

Downstream propagation is defined as customer industries being hit much more significantly by the shock than supplier industries, with 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 conduct 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.

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

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

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 an HHI greater than 3,100 points (or 75th percentile). This filter indicates that 2,454 products out of 4,435 (TND 20 billion out of TND 61 billion) 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 TND 42 billion out of total imports.

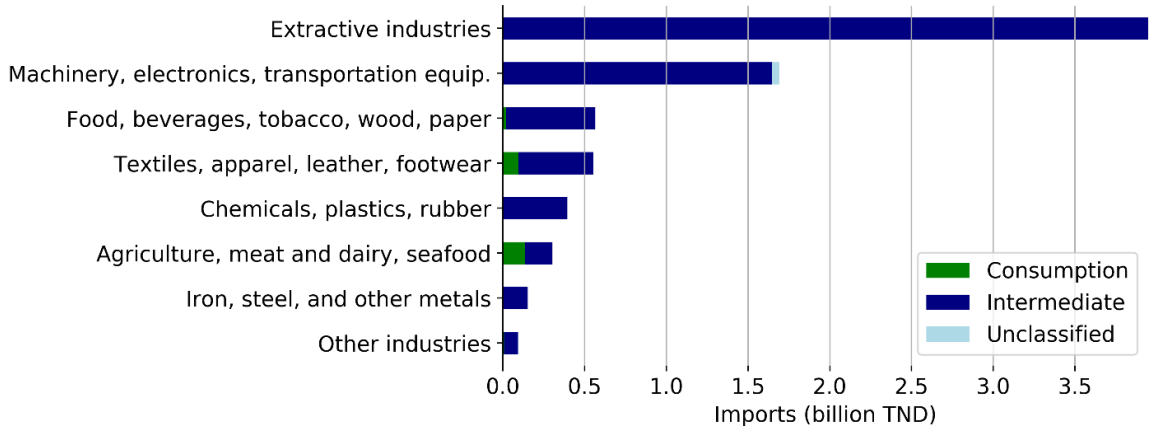
The final list of vulnerable products (776) represents 17 percent and TND 17 billion of the overall imports. Essential products represent 132 products and more than TND five billion of total Tunisian imports in the same period. Vulnerable imports are less likely to be replaced, at least in the short run. Thus, they are more likely to disrupt production processes if they are intermediary inputs, and they are more likely not to 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 machinery, electronics, and transportation equipment sector 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, around 15 of which 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). The 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 a low value of imports.

Figure 3. Characteristics of vulnerable imports (2019)

(a) By value of imports



(b) By number of products

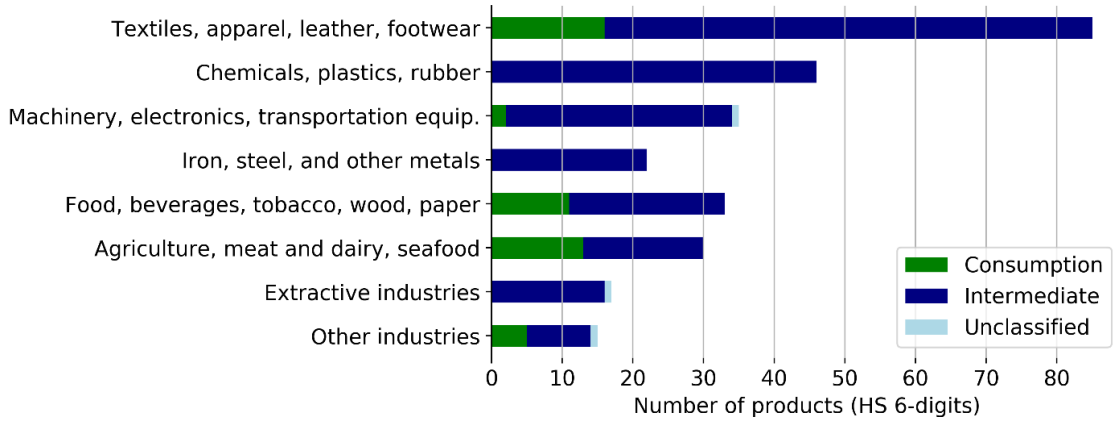
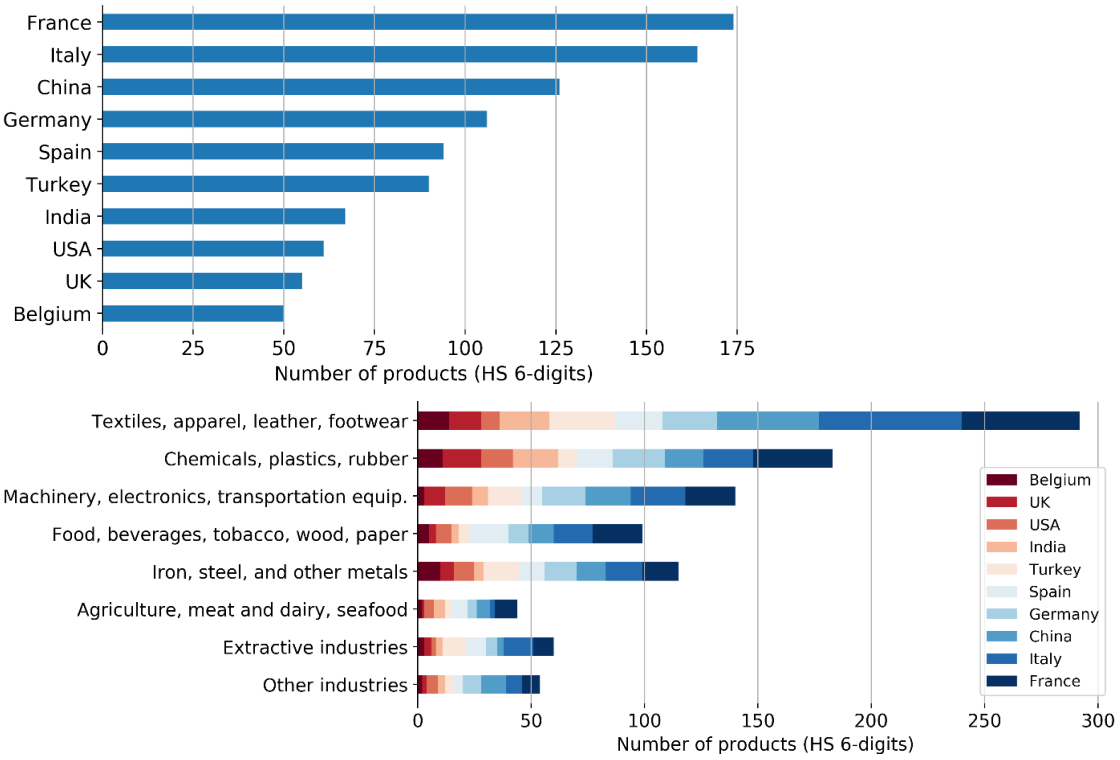


Figure 4 shows the top suppliers of Tunisia's vulnerable imports. Tunisia imports more than 100 of its vulnerable products from France, Italy, China, and Germany. Figure 4a shows the distribution of vulnerable imports across sectors and partner countries. For most sectors, France, Italy, and China are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

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

(a) By number of products



(b) By value of imports

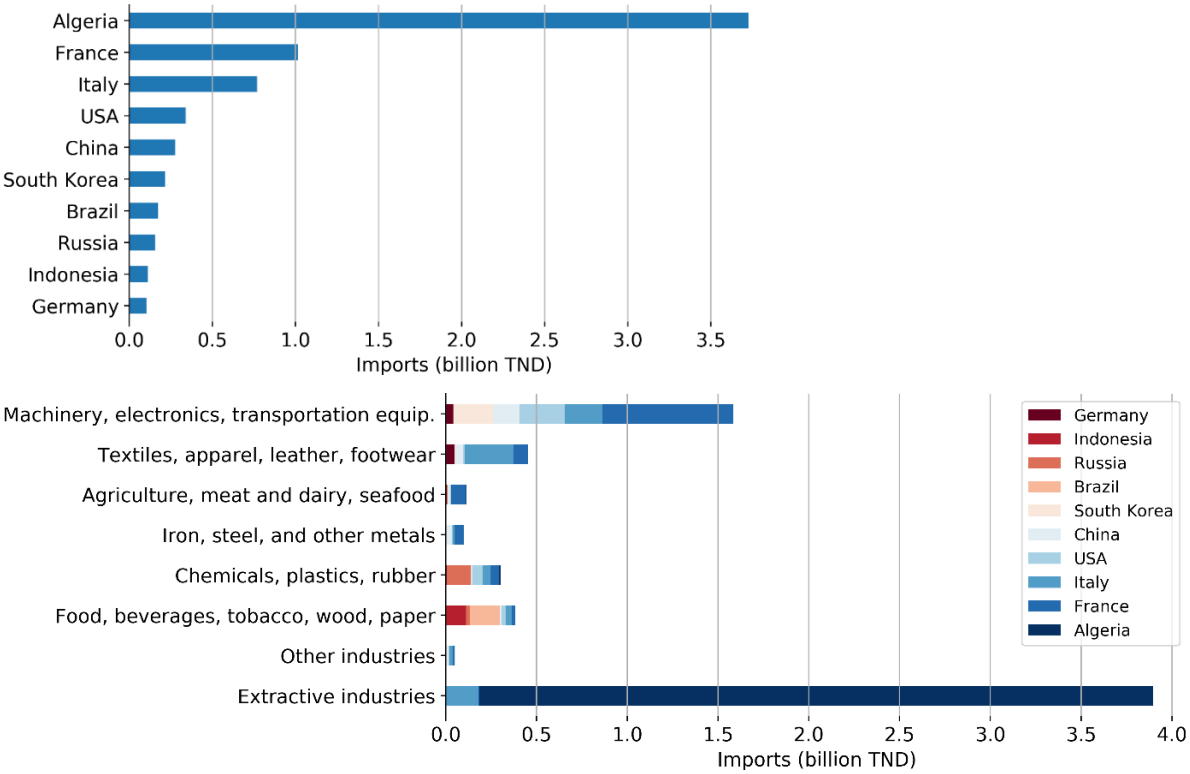


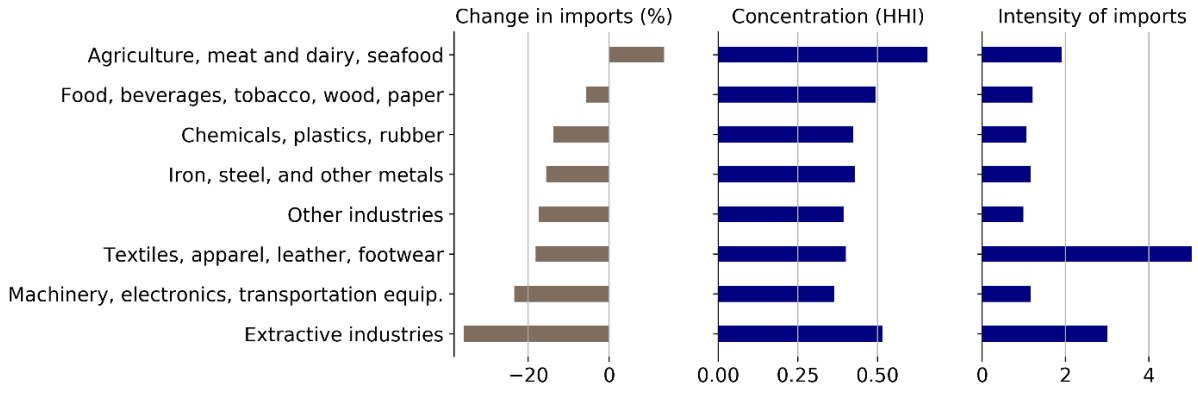
Figure 5a compares the sectoral change in import values between 2019 and 2020 to the sectoral distribution of the scores of vulnerability measures (averages). The distribution of vulnerability measures among sectors provides some insights about the characteristics of these sectors. The concentration measure HHI shows that the agricultural sector includes the less diversified products, i.e. products 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 highest score in import intensity.

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

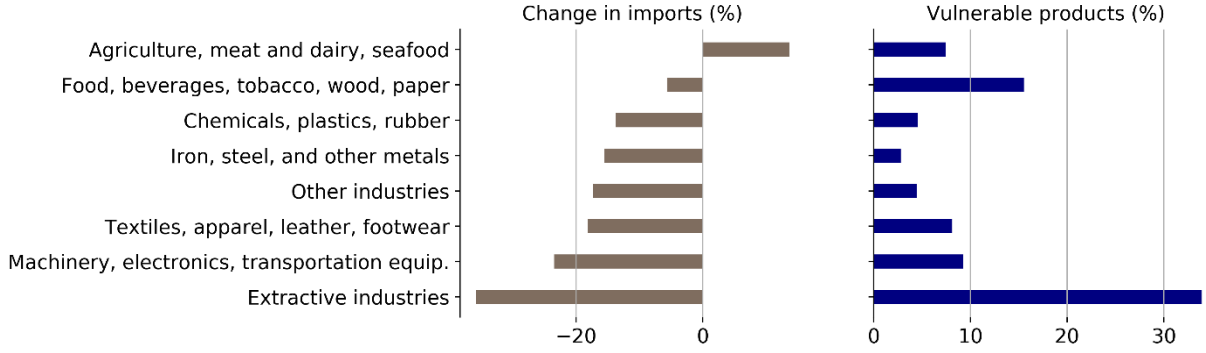
Figure 5b shows that the food sector experienced a small negative change in imports between 2019 and 2020 despite the high percentage of vulnerable products belonging to the sector. This is due to the nature of the sector, as it is critical for survival, and may also suggest that local production increased 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.

Figure 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 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 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 a 100 percent fall in imports, while its export value increased by 139 percent. 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, such as the 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 a decrease of almost one hundred percent. 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 the ten percent 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). The effect of vulnerable imports on overall imports is about four 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 the 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)
ΔNum_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).[13] We present the results of each shock separately. Figures A1 and A2 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.

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

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 percent in the second quarter of 2020 while not being exposed to a decrease in vulnerable imports (no direct shock) as shown in Figure A2 in Annex 3. On the other hand, the oil refining sector, despite facing a very large direct shock of around -25 percent, faces an almost 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 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 percent, 25 percent, and 24 percent, 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.

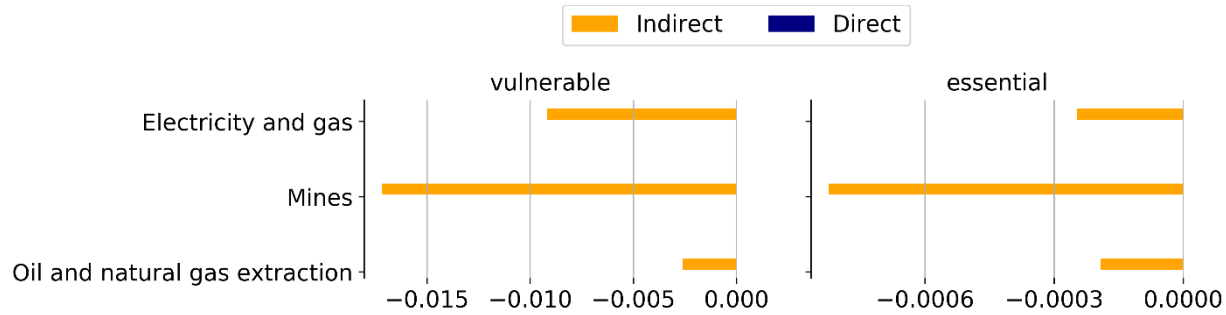
For essential imports, which are mainly consumption goods that belong to the machinery, chemicals, and textiles sectors, the indirect shocks are low for all sectors. Direct shocks for the chemicals and textiles sectors are relatively high (approximately -2 percent and two percent respectively).

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 directly affected by negative supply shocks are oil refining, chemicals, and textiles.

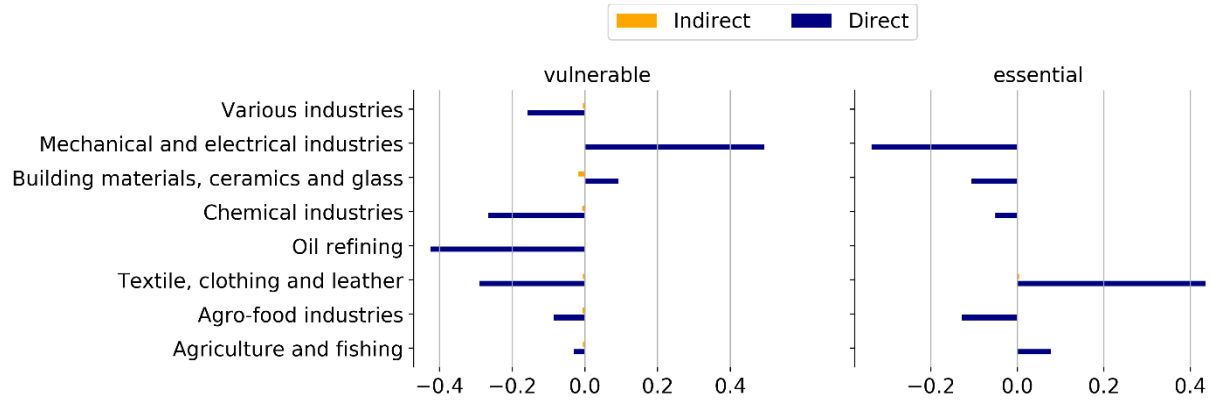
We conclude that sectors' direct and indirect exposure to essential imports shock are far lower than their exposure to shocks from intensive and concentrated imports, except for the mechanical and electrical and textiles sectors that show a high direct exposure. Moreover, results regarding the importance of direct shocks relative to indirect shocks are in line with the findings in Ben Abderrahmen, Marouani, and Baghdadi (2021), where the indirect COVID-19 related shocks in Tunisia are less important than direct ones.

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

(a) Non-manufacturing industries



(b) Manufacturing industries and agriculture and fishing



5. Conclusion

Trade between countries has been challenged by the spread of the 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 percent and TND 17 billion of overall imports. Essential products represent 132 and more than TND five billion 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 machinery sectors are the most impacted by the pandemic, with a drop of 35.85 percent for the former and 23.45 percent 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 explains 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 are 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 affected. For non-manufacturing 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 has a significant direct effect, especially on the 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 the vulnerable products and Tunisia was not able to access many of them because of supply chain 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 access 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.

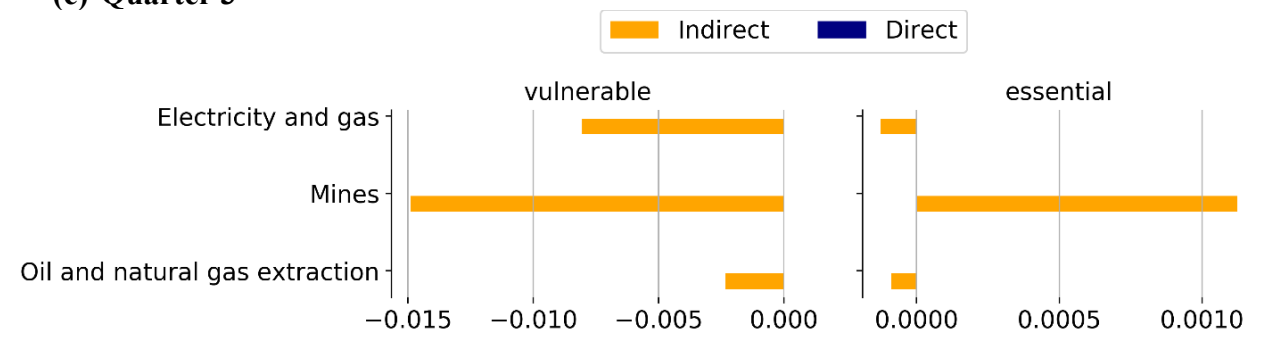
Annex 3

Figure A1. Tunisian nonmanufacturing industries' downstream exposure to supply shocks

(a) Quarter 1

(b) Quarter 2

(c) Quarter 3



(d) Quarter 4

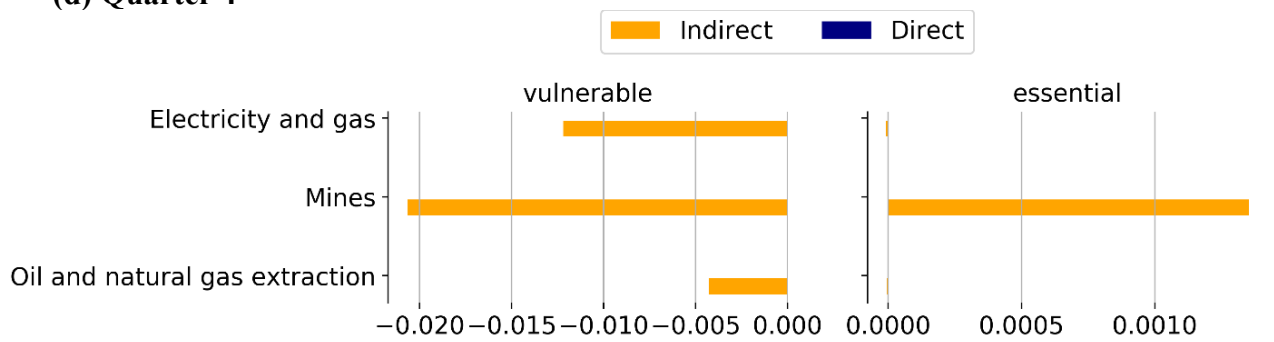


Figure A2. Tunisian manufacturing industries and agriculture and fishing sectors' downstream exposure to supply shocks