INTRODUCTION

The recent COVID-19 pandemic represents a public-health shock on an unprecedented scale that imposes long-term adverse effects on the global economy. To help understand these effects, existing economic research either propose scenario simulations via economic-epidemiology models or present empirical observations of how the interaction of infection rate and mobility restriction policies affect growth prospect. However, the more data become available, the more rapidly our understanding of the virus shifts and so do the estimates of these models, making their interpretation complicated.
A growing strand of research deviates from this mainstream and focuses instead on the specific role of trade policies, which are viewed as lower cost instruments in the policymaker toolkit complementing other policies such as mobility restriction and monetary and fiscal stimuli (González, 2020). Interestingly, the bulk of this strand addresses issues in food trade and security while few were dedicated to medical-product trade, arguably due to the more immediate effect of the former on welfare and livelihood. In the latter category, while some studies converge on the importance of lowering trade barriers to streamline access to essential medical supplies, to our best knowledge, no quantifiable effects of medical trade barriers on consumer welfare are analysed in detail. Without these insights, it is difficult to make a convincing case for trade policy reforms and coordination, especially during a time of heightened protectionism even prior to the crisis.

Our main motivation in this study is to understand the welfare effects of the trade for a particular medical product that is currently in high demand, namely the COVID-19 test kit. The importance of this product stems from the asymptomatic nature of the pandemic: Infected patients can contribute to the spread without even knowing they are infected or showing symptoms, making transmission limitation difficult. Since the time and location of infection may be unknown, mass testing is required at least until a spreading pattern of the virus can be documented. Accurate identification of cases via testing regardless of symptoms allows for efficient distribution of resources for surgical containment of the outbreak and provides much needed data for informed contact-tracing operations (ECDC, 2020). However, an apparent weakness of mass testing is its high cost, and rising test-kit shortage due both to demand and supply shocks could be detrimental to its effectiveness. For example, challenges to maintaining trade flow include export restrictions, rising transport costs, closure of shipping ports, delayed trade processes, and the need to impose safety measures at all levels of the supply chains all add to rising test-kit costs.

Research on the welfare effect of test-kit trade is therefore important, but is currently limited due to a lack of high-quality estimation of price sensitivity. In this paper, we fill in this gap by studying the demand for test-kit imports in a global sample of countries with different rates of infection. In particular, we are interested in examining that given the characteristics of the pre-pandemic test-kit consumption patterns, what is the impact on welfare if there is a sudden surge in demand during the pandemic. The pre-pandemic elasticities are estimated for a number of major test-kit exporters, including the United States, Germany, the Netherlands, the United Kingdom, and Singapore using data covering the period 1996–2018. Based on these demand-elasticity estimates, we evaluate the potential impact of current tariffs on test-kit trade flows. We show how import tariffs by leading producers could cause significant disruption in supplies, contribute to price increases, and significant welfare loss. Subsequently, using results from this analysis, as well as the test-kit consumption data during the pandemic, we perform a number of simulations designed to analyse the welfare effects of trade barriers.

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1See e.g., Baldwin & Evenett (2020), Baldwin & Tomiura (2020), Espitia, et al. (2020), Evenett (2020) and González (2020).

2Notwithstanding the role of large-scale testing, other testing strategies evolve quickly. Specifically, focusing on vulnerable and symptomatic patients or on neighbourhoods with known cases could be economical alternatives for low-income countries. For example, in light of the second COVID-19 outbreak at Da Nang, Vietnam, the local authorities adopted pool sampling in which five to six people can be tested jointly and will be individually tested only if the pooled result is positive. This approach significantly reduces cost while increasing the scale and speed of testing (WHO, 2020a).
Our study contributes to the broader literature on the effect of rising protectionism and other movements against globalisation and offers three important findings. First, similar to other medical markets, the test-kit supply is highly and persistently concentrated: There are a small number of high-income, technologically advanced producers (of which national and regional composition change little over time) while the majority of developing countries are dependent on imported products. Second, less-developed countries tend to exhibit larger price elasticities of demand and faster growth of demand, as measured by their positive test rates. Third, the increasing demand, in combination with these countries’ dependence on imports, results in larger adverse effects of trade barriers on consumer welfare. These findings suggest that to mitigate such effects in the current and future health crises, it is important for developing countries to develop long-term roadmaps that aim to reduce the dependency on imports from a small number of producers. This could be achieved via investment in domestic production capability and diversification of the medical supply chain by facilitating trade negotiations with new suppliers.

The remainder of this paper is organised as follows. Section 2 surveys the related literature. Sections 3 and 4 describe our methodology and data, respectively. These are followed by Section 5 in which empirical findings are presented. Section 6 provides summary comments and implications.

2 | LITERATURE REVIEW

In this section, we look at three strands of literature related to our subject matter. The first one addresses how critical rapid and large-scale testing is in combating the virus. The second focuses on the vital role of maintaining trade flows during the pandemic and the third discusses econometric approaches to estimating trade elasticities and welfare effects.

2.1 | The role of large-scale testing

There are three main public-health governance approaches in addressing the COVID-19 pandemic, the effectiveness, and appropriateness of which remain debatable. The first one is China’s
Wuhan-style lockdown, which is a strict measure amid fears of a deadly new virus, which seemed to be highly effective in the initial prevention and control of the diffusion of virus-induced pneumonia (Sun et al., 2020). The second style is that of the techno states which relies on comprehensive data collection and as well as transparency on the whereabouts of those with the illness such as in the case of South Korea (Balilla, 2020). The third approach involves democracies that embrace liberal principles of government and rely on a high level of social trust such as in Sweden (Klingler-Vidra et al., 2020). Indeed, transparency and public trust were found to be the key instruments in managing fear and uncertainty during health crises, such as that caused by the 2002–2004 severe acute respiratory syndrome (SARS) (Menon & Goh, 2005) and in the current one (Spalluto et al., 2020).

Regardless of the governance styles, rapid large-scale testing is proven to be crucial for the effective containment of an infectious outbreak. Recent experiences show that the key to this goal is a quick detection of people with COVID-19 in the community (especially those without clinical symptoms) and promptly implemented control, localisation and suppression measures. For instance, mass testing in the city of Daegu allowed the South Korean government to minimise community transmission within 1 month after a ‘superspreader’ incident (Balilla, 2020; Gollier & Gossner, 2020). In line with this observation, Gandhi et al. (2020) documented that mass testing in U.S nursing facilities is critical for detecting infected residents so that they can isolate themselves and be provided with necessary medical treatment. Due to reliable testing, people who have tested negative for COVID-19 could return to work in strategic sectors of the economy (Gollier & Gossner, 2020). Consider also Vietnam—a developing economy where large-scale testing has been growing but not on the same scale as compared to the United States or South Korea. Communities close to confirmed infection cases (sometimes an entire street or village) were swiftly tested and isolated (Klingler-Vidra & Tran, 2020).

It can be seen that the ability to test individuals is crucial in reducing the economic and health consequences of the COVID-19 pandemic regardless of countries’ affluence, given the asymptomatic nature of the disease. However, the cost of testing plays a critical role in the efficacy of the testing strategy. This is particularly relevant for emerging and developing countries, which rely heavily on the imported supply of medical products, an issue we shall discuss below.

2.2 Medical-product trade amidst the pandemic

Severe economic consequences of an unprecedented global health crisis seem inevitable, particularly for developing countries. With limited access to medical resources and technologies, many least-developed economies are unprepared for dealing with the devastating effects of the coronavirus pandemic (Vickers & Ali, 2020). It has been argued that preserving the operation of key supply chains of essential goods for the crisis, such as food and medical supplies and information and communication technology goods and services, becomes a critical priority. Alternatively, to overcome trade barriers and mobility restrictions, the adoption of new digital technologies and electronic cross-border health services such as telemedicine and telehealth checks become

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3Initially, targeted testing was recommended for nursing facilities located in areas with high transmission rates only. However, the overwhelming socioeconomic and health consequences of the outbreaks prompted the extension of testing to all U.S nursing facilities. Given the incomplete information on spreading patterns, there seems to be no immediate alternative strategy to mass testing (Gandhi, et al., 2020).
immediately important support mechanisms. Allowing greater freedom of movement for doctors and health professionals could also alleviate critical capacity constraints in domestic health systems (Gillson & Muramatsu, 2020).

Using a new database on restrictive and liberalising measures imposed on exports and imports of food and medical products (Evenett et al., 2021), Shingal and Agarwal (2021) find that richer, more globally integrated economies with high levels of government effectiveness exhibited higher trade policy effectiveness during the first 9 months of the pandemic, and that policy activism is more idiosyncratic for food than for medical products. Espitia et al. (2020) present another new database on trade in COVID-19 relevant medical products and show that export restrictions by leading producers could result in significant disruption in global supply chains and lead to higher prices, particularly in developing countries where domestic healthcare capacity is overwhelmed by the pandemic has urged the need for the movement of healthcare resources across international borders. However, relatively heavy tariffs are still levied on imports of COVID-19 test kits/testing instruments—in some cases at a level of more than 10% (Vickers & Ali, 2020). Other import restrictions that significantly discourage imports of medical consumables and other medical devices include are also put in place, resulting in a ‘sickening thy neighbour’ situation where trade flows are hindered by national protectionism (Evenett, 2020a, 2020b). Key products in the prevention and control of the COVID-19 outbreak such as test kits, diagnostic equipment, and vaccines should be and made universally available with unilateral and regional, rather than global, trade negotiations (Evenett & Vines, 2012).

The recent surge in test-kit and medical product demand in combination with trade restrictions has led to rising prices of medical products and thus hinders the countries’ ability to address the health crisis and affect consumer welfare. The magnitude of the welfare effect depends both on the degree of trade restriction measures imposed and the price elasticity of demand, which can be evaluated by a number of econometric approaches discussed in the following.

2.3 | **Estimating trade demand elasticities**

As will be shown in Section 4, since the number of countries that are dependent on imported test kits is high and is on the rise, understanding the demand for source-differentiated test kits and the effects of prices from different suppliers would be of interest to policymakers, producers, and consumers. The theory of demand for products distinguished by place of production was first proposed by Armington (1969), who studied the substitutability between broadly defined goods from domestic and foreign sources. This substitutability directly governs the strength of the demand response to relative international prices, and therefore is central to understanding many features of the global economy. However, empirical estimations of import demand elasticities for disaggregated products are still limited (Kadjo & Seale, 2014).

In this paper, we adopt the Rotterdam model developed by Theil (1965) to analyse the demand for test-kit imported from different countries. Compared with other demand models such as the Almost Ideal Demand System (Deaton & Muellbauer, 1980) or the translog system (Christensen et al., 1975), the Rotterdam is superior at recovering the true elasticities when we implement an exact aggregation within weakly separable branches of a utility tree (Barnett & Seck, 2008) and is also robust to alternative separability assumptions (Moschini et al., 1994). Other advantages of this approach include its consistency with demand theory (Barnett, 1979), comparable flexibility to any other local approximating form (Mountain,
and most importantly, simplicity and transparency in parameterisation (Clements & Gao, 2015).

3 | METHODOLOGY

3.1 | Import-demand model

Consider the $n$ sources of test kit imported at time $t$ in quantities $q_{1t}, \ldots, q_{nt}$, at prices $p_{1t}, \ldots, p_{nt}$. The share of consumer income devoted to source $i$ in year $t$ is $w_{it} = \frac{p_{it}q_{it}}{M_t}$ ($i = 1, \ldots, n$) where $M_t = \sum_{i=1}^{n} p_{it}q_{it}$ is the total import expenditure. The Rotterdam demand model can be specified as

$$
\overline{w}_{it}Dq_{it} = \theta DQ_t + \sum_{j=1}^{n} \pi_{ij}Dp_{jt} + \epsilon_{it},
$$

where $\overline{w}_{it} = 1/2(w_{it} + w_{i,t-1})$ is the arithmetic average of the $i$th budget share in years $t$ and $t - 1$, $DX_{it} = \log X_{it} - \log X_{i, t-1}$ denotes the finite log-change of variable $X$ ($X = p, q$) and $DQ_t = \sum_{i=1}^{n} \overline{w}_{it}Dq_{it}$ is a measure of real income change (a budget-share weighted average of the change in imported quantities). Note that quantity is simply import value divided by price, and its growth represents the growth of both ‘real’ consumption and affluence (Clements et al., 2021).

In terms of the model’s coefficients, $\theta_t$ denotes the marginal share (or the budget share devoted to imported goods from country $i$ when domestic income rises by one unit), $\pi_{ij}$ is the Slutsky price coefficient and $\epsilon_{it}$ is a disturbance term. The income elasticity can be evaluated at the mean budget share as $\eta_i = \theta_i/\overline{w}_i$ where $\overline{w}_i = \frac{1}{T-1} \sum_{t=1}^{T} w_{it}$. The corresponding Slutsky price elasticity is $S_{ij} = \pi_{ij}/\overline{w}_i$ and the Marshallian elasticity is $\lambda_{ij} = S_{ij} - \eta_i/\overline{w}_i$.

We estimate model (1) by applying an iterative seemingly-unrelated-regression estimator (SURE) (Zellner, 1962). This estimator is the equivalence of a generalised least squares estimator in a panel setting, and is unbiased and efficient under the assumption that the disturbance term is independent over time and across equations, with $E(\epsilon_{it}) = 0$ and $E(\epsilon_{it}, \epsilon_{jt})$ a constant. Our main interest lies in estimates of Marshallian own-price elasticities, $\lambda_{ii}$, which captures both income and substitution effects, and reflect the degree to which test-kit demand reacts to price changes. These form the basis of our subsequent welfare analyses.

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4This model is subject to a number of testable coefficient constraints including Slutsky symmetry ($\pi_{ij} = \pi_{ji}; i, j = 1, \ldots, n$), homogeneity ($\sum_{j=1}^{n} \pi_{ij} = \sum_{j=1}^{n} \pi_{ij} = S_y = 0$) and adding-up ($\sum_{j=1}^{n} \pi_{ij} = 0$). More details on the derivation of this model and results of the tests for these constraints are provided in Appendix A1.

5With respect to the SURE estimates, there is a potential concern of endogeneity bias if either income or price is endogenously determined, a situation commonly encountered in demand analyses of household expenditure. However, it is important to note that an underlying assumption in our model is that import price is determined exogenously from consumption decision (as importers are price takers) and unlike consumption of household items, the demand for test kits is unlikely to be influenced by tastes, but by exogenous health shocks such as the COVID-19 pandemic.
In the following discussion, we propose a simple analytical framework to analyse the welfare impact of a measurable type of trade restriction, that is, tariff, on the demand side of two small importers, the first has a more elastic demand curve than the second in a particular period. We denote these ‘country 1’ and ‘country 2’, respectively. We argue in Section 4 that this setting is appropriate when studying the market for test kits.

For each importer, the import demand curve ($MD$) is the difference between domestic demand and domestic supply, as illustrated by panel A of Figure 1. Additionally, the export supply curve is flat, implying that the world price ($P$) is taken as given. As illustrated in panel B of this figure, for the importer with an elastic demand curve ($D_1$), the quantity demanded by consumers before tariff imposition is $Q_0$ and afterwards is $Q_1$. For this importer, we can compute the total loss of consumer surplus as indicated by the area $EABC$ as:

$$\Delta CS_1 = EABC = \underbrace{BAFC + AFE} = \underbrace{\Delta P \left( Q_1 + \frac{1}{2} (Q_0 - Q_1) \right)} = \Delta P \left( Q + \frac{1}{2} \Delta Q_1 \right)$$

$$= Q_1 \Delta P \left[ 1 + \frac{1}{2} \left( \frac{\Delta Q_1}{Q_1} \frac{P}{\Delta P} \right) \left( \frac{\Delta P}{P} \right) \right] = (PQ_1) \Delta P \left( 1 + \frac{1}{2} \lambda_1 \frac{\Delta P}{P} \right) = M_1 \tau \left( 1 + \frac{1}{2} \tau \lambda_1 \right),$$

where $M_1 = PQ_1$ denotes the import demand after tariff, $\Delta Q_1 = Q_0 - Q_1$ is the change in consumption in country 1, $\Delta P$ is the price change due to tariff and $\tau = \frac{\Delta P}{P}$ denotes the ad-valorem tariff rate. $\lambda_1 = \frac{\Delta Q_1}{Q_1} \frac{P}{\Delta P}$ is the Marshallian own-price elasticity of import demand derived previously (note that here we remove the subscripts $ij$ for simplicity, as $i = j$ in the case of own-price elasticity).

The consumer loss for country 2, with a lower demand elasticity ($\lambda_2 < \lambda_1$), is represented by the area $EDBC$ and can be computed similarly as $\Delta CS_2 = M_2 \tau \left( 1 + \frac{1}{2} \tau \lambda_2 \right)$. Since $M_1 < M_2$ and $M_1 \lambda_1 = PQ_1 \left( \frac{\Delta Q_1}{Q_1} \frac{P}{\Delta P} \right) = P^2 (\Delta Q_1 / \Delta P) < P^2 (\Delta Q_2 / \Delta P) = M_2 \lambda_2$, it follows that $\Delta CS_1 < \Delta CS_2$. In other words, a country with higher demand and a less-elastic demand curve will incur a higher loss. The excess loss, or the difference between the losses of inelastic- and elastic-demand
economies, is highlighted by the triangle EAD. Equation (2) will be used to estimate the economic impact of the tariff on consumers of test kits in Section 5.

The above analysis refers to the potential economic impact of test-kit tariff under normal circumstances, that is, no health shock. Using Equation (2), we can also study the welfare loss given exogenous and unanticipated large changes in the import demand \( M \) when there is a health shock. Since the corresponding actual demand and tariff change data are not available to us at the time of this study, as discussed in Section 4, we use the log-change in positive test rate as a proxy for demand growth and the latest available tariff data. Specifically, we assume that 

\[
\log M_t - \log M_{t-1} = \log r_t - \log r_{t-1}
\]

where \( M_t \) and \( r_t \) denote the import value and the positive rate at day \( t \). We choose the starting value of import, \( M_0 \), to be the latest pre-pandemic data point available in our sample. Provided that tariff rates and price elasticities are unchanged in the short run, the simulated welfare loss is

\[
CSL_t = \bar{M}_t \tau \left( 1 + \frac{1}{2} \tau \lambda \right) = \left( \bar{M}_{t-1} \frac{r_t}{r_{t-1}} \right) \tau \left( 1 + \frac{1}{2} \tau \lambda \right) = \left( M_0 \prod_{s=1}^{t} \frac{r_s}{r_{s-1}} \right) \tau \left( 1 + \frac{1}{2} \tau \lambda \right),
\]

where \( \bar{M}_t = M_0 \prod_{s=1}^{t} \frac{r_s}{r_{s-1}} \) denotes the simulated daily import demand of test kits.

4 | DATA DESCRIPTION

This section describes our data, provides preliminary analyses and discusses the implications of data patterns.

4.1 | The international test-kit market

Table 1 lists the items designated as ‘COVID-19 test kits and instruments’ in the United Nations Statistics Division’s Commodity Trade (UNCOMTRADE, 2020) database provided via the World Integrated Trade Solution (WITS) data portal. These definitions are based on the 2017 Harmonised System (HS) of item classification employed by WITS. To obtain the longest data range coverage to ensure accuracies of the demand model estimates, we select only the standard, most popular tried-and-true polymerase chain reaction (PCR) tests that detect virulent genetic materials (WITS product ID 382200) for our analyses.\(^7\)

From Figure 2, we can see that the high-income exporter group accounts for the majority of the shares of imports in any region, and this dominance is very persistent over time.

As more detailed evidence of market concentration, columns (2), (3), (6), and (7) of Table 2 present the values and shares of top 10 importers and exporters as fractions of global trade in

\(^6\)It could be argued that a measure of welfare effect should account for producer surplus and government tariff revenue, i.e., the deadweight loss, which is computed as 

\[
DWL = \frac{1}{2} (\Delta P \times \Delta Q) = \frac{1}{2} \left( PQ \frac{\Delta P}{P} \right) \left( \frac{\Delta Q}{Q} \frac{P}{\Delta P} \right) = \frac{1}{2} (M \times r^2 \times \lambda).
\]

However, in this study, we counter this argument by considering that in the case of public health shock, consumer welfare should be placed a higher priority. It is also uncertain whether gains from producer surplus and tariff revenue would contribute directly to the effort against the pandemic.

\(^7\)For descriptions of the PCR and other types of tests and their effectiveness, see Guglielmi (2020). As our data coverage extends to as early as 1996, a synchronisation of item classifications between HS 2017 and HS 1992 is needed. Analyses for other types of test kits can be implemented in a manner similar to those outlined in this paper.
TABLE 1  COVID-19 test-kit product description

| Product name | Description | Product ID |
|--------------|-------------|------------|
| (1)          | (2)         | (3)        | (4)        |
| 1. COVID-19 test kit | Diagnostic reagents based on immunological reactions | 300215 | 300290 |
| 2. Swab and viral transport medium set | A vial containing a culture media for the maintenance of a viral sample and a cotton tipped swab to collect the sample put up together | 382100 | 382100 |
| 3. COVID-19 test kit | Diagnostic reagents based on polymerase chain reaction (PCR) nucleic acid test | 382200 | 382200 |
| 4. Diagnostic test instruments and apparatus | Instruments used in clinical laboratories for In Vitro Diagnosis. Colorimetric end tidal CO2 detector, sizes compatible with child and adult endotracheal tube | 902780 | 902780 |

Note: This table provides description and identification of products designated as 'test kits' in the WITS database. The emboldened item is selected for our main analyses.

Data source: Item classification is from https://wits.worldbank.org/trade/covid-19-medical-products.aspx.

FIGURE 2  Regional test-kit import-share decomposition, 1996–2018.
Note: This table presents the time series of import shares by importers in 4 regions from each of the other regions.
| Rank | A. Import values, in $mil. (shares, in %) | B. Export values, in $mil. (shares, in %) |
|------|-----------------------------------------|------------------------------------------|
|      | Country 2018 (3) | Country 1996–2018 Mean (5) | Country 2018 (7) | Country 1996–2018 Mean (9) |
| 1    | U.S 3882 (13.32) | U.S 29 (9.75) | U.S 6690 (25.18) | U.S 21 (21.26) |
| 2    | Germany 3001 (10.30) | Germany 23 (7.84) | Germany 4386 (16.50) | Germany 11 (11.41) |
| 3    | China 1780 (6.11) | Italy 16 (5.43) | Netherlands 2291 (8.62) | U.K 7 (7.28) |
| 4    | Netherlands 1677 (5.75) | France 14 (4.62) | U.K 1876 (7.06) | Ireland 6 (5.55) |
| 5    | France 1432 (4.92) | U.K 13 (4.38) | Singapore 1465 (5.51) | France 6 (5.49) |
| 6    | Italy 1229 (4.22) | China 11 (3.84) | Ireland 1413 (5.32) | Singapore 5 (5.15) |
| 7    | U.K 1225 (4.20) | Japan 11 (3.77) | France 1349 (5.07) | Netherlands 5 (5.00) |
| 8    | Spain 784 (2.69) | Netherlands 9 (3.17) | Sweden 705 (2.65) | Belgium 5 (4.67) |
| 9    | Canada 731 (2.51) | Spain 9 (2.87) | Belgium 665 (2.50) | Sweden 3 (3.07) |
| 10   | Korea, Rep. 678 (2.33) | Belgium 8 (2.79) | Japan 638 (2.40) | Japan 3 (2.69) |
| 11   | R.O.W 12720 (43.65) | R.O.W 154 (51.54) | R.O.W 5097 (19.18) | R.O.W 29 (28.42) |

Note: This table presents the values ($mil.) and corresponding shares (%, in parentheses) of the top 10 test-kit importers and exporters, together with those of the rest of the world ("R.O.W"). Columns (5) and (9) provide the sample averages. The emboldened countries in column (6) (top 5 exporters in 2018) are selected for the subsequent demand model estimations.

Data source: UNCOMTRADE.
2018. As can be seen, the compositions of these top traders do not vary substantially between imports and exports, resonating with the dominance of the Europe-North America-East Asia trade network (see also Appendix A3). Additionally, this pattern is also captured by the sample mean trade values presented in columns (4), (5), (8), and (9) of Table 2, which again points to persistence over time. Based on this finding, we use data from the top 5 exporters in 2018, that is, the United States, Germany, The Netherlands, United Kingdom, and Singapore, to study import demand from differentiated sources in our empirical analyses. Subsequently, available data from 1996 to 2018 are used to estimate the demand model (1).

How did import and export values and prices of traded test-kits vary over the last three decades? We show in Appendix A3 that there is a rising trend of both import and export values, while the trends are not as strong for corresponding prices. This could be a result of a significant reduction of trade barriers over time. In particular, the cross-country average of trade-weighted tariffs fell from a height of 16.7% in 1996 to 1.64% in 2018, a reduction by a factor of 10. In addition, there is no clear association between tariffs and income: Low and high tariff rates are implemented by both rich and poor countries in all regions. The potential impact of the tariff is discussed further in Section 5, which shows that in low-income countries, the heavy dependence on a small number of exporters would have a more profound impact on consumer welfare relative to countries that are affluent.

4.2 Demand shortages

The epidemiology data are obtained from multiple public sources. Testing data are provided by John Hopkins University (Dong et al., 2020), while confirmed cases data are from the European Centre for Disease Prevention and Control (ECDC). Panel (a) of Figure 3 plots the total number of tests performed per 1000 people against income per capita. Note that throughout this paper, the GDP per capita data are those adjusted for spatial and temporal price differences (i.e., it is expressed in constant international PPP dollars). It is apparent countries that are more affluent perform more daily tests, regardless of population sizes. A fitted linear regression line reveals that a 1% increase in per capita income is associated with a 1% increase in the number of tests, and the relationship is statistically significant.

Another important measure of the prevalence of the outbreak is the positive test rate, which is the ratio of daily new cases and new tests performed. We argue that this rate captures the extent of testing relative to the scale of the outbreak in different countries and can be used as an indicator of test-kit demand. Whenever the number of confirmed cases is high relative to the extent of testing, there may not be enough tests being carried out to properly monitor the outbreak, that is, a demand shortage. The shortage is expected to be larger for poorer countries with less-developed healthcare systems. Panel B of Figure 3 plots the positive rate against income, and indeed shows that poorer countries tend to have greater positive rates. In particular, a 1% rise in income is accompanied by a 0.4% fall in positive rate, however, this

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8As with all recent studies on COVID-19, in our analyses, comparisons of testing data across countries are influenced by differences in the way data are collected and reported.

9It follows that in these countries, the true number of infections may be far higher than the number of reported cases. Countries that do very few tests per confirmed case are unlikely to be testing in a sufficient number to find all cases. The WHO, for example, has recommended around 10–30 tests per confirmed case as a general benchmark of adequate testing rate (WHO, 2020b).
relationship is not statistically significant. This figure reveals that the countries from South America and Asia as well as the United States are among those with the highest positive rates. Recently, demand shortages tend to increase in correspondence with the second wave of the outbreak in many countries (see also Appendix A2).

5 | RESULTS

5.1 | Import-demand analyses

Table 3 presents our first set of results, which are parameter estimates of the demand model (1) for 26 countries in different geographic and income categories. These countries are selected subject to the availability of data on actual testings and confirmed cases from our data sources (Dong et al., 2020; ECDC, 2020). As can be seen from this table, our estimates support the fundamental predictions of demand theories (i.e., positive marginal shares, positive income elasticities and negative price elasticities) (see e.g. Barnett & Seck, 2008; Clements, 2019; Deaton, 1974). It can also be seen that both the income and price effects are statistically significant for the majority of country pairs examined.

The own-price elasticities are reported in panel B: The higher the price elasticity (in absolute terms), the more price-elastic an importer is to export goods. On average, test kits imported from all top exporters are more price-elastic than from the R.O.W source. However, average elasticities

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10 The joint tests of the homogeneity and symmetry constraints for these countries yield evidence in favour of null hypotheses and also support demand theories. The test results are provided in Appendix A1.

11 Appendix A3 provides additional information on the estimates of the demand model, including the marginal shares.
TABLE 3 Income and own-price elasticity estimates

| Importer       | USA       | DEU       | NLD      | GBR      | SGP      | R.O.W    | USA       | DEU       | NLD      | GBR      | SGP      | R.O.W    |
|----------------|-----------|-----------|----------|----------|----------|----------|-----------|-----------|----------|----------|----------|----------|
| (1)            | (2)       | (3)       | (4)      | (5)      | (6)      | (7)      | (8)       | (9)       | (10)     | (11)     | (12)     | (13)     |
| 1. Bangladesh  | 0.881***  | 1.035***  | 1.931*** | 1.391*** | 1.137*** | 0.836*** | −0.43     | −0.658*** | −0.802*** | −1.49***  | −0.502*** | −0.487***|
| 2. Cambodia    | 1.398***  | 0.771**   | 0.74     | 2.541*   | 0.679*   | 0.978*** | −0.696*** | −0.479**  | −0.08     | −0.772**  | −0.488**  | 0.12     |
| 3. India       | 1.051***  | 0.947***  | 0.27     | 1.198*** | 0.887*** | 0.988*** | −0.624*** | −0.702*** | −0.734**  | −1.152*** | −1.364*** | −0.699***|
| 4. Pakistan    | 1.204***  | 1.012***  | 0.22     | 0.90     | 0.815*   | 0.941*** | −0.963*** | −0.28     | −0.99     | 0.18      | −0.71     | 0.246*** |
| 5. Philippines | 0.821***  | 0.32      | 0.14     | 0.41     | 0.885*** | 1.533*** | −0.418*** | −0.07     | −0.637*** | −0.719*** | −0.489*** | −0.443***|
| 6. China       | 0.845***  | 0.857***  | 0.15     | 0.646*** | 0.63     | 1.466*** | −0.391*** | −0.705*** | −0.702*** | −0.459*** | −0.518**  | −0.531***|
| 7. Indonesia   | 1.052***  | 0.382***  | 0.27     | 0.704*** | 0.877*** | 1.584*** | −0.558*** | −0.279*** | −0.969*** | −0.807*** | −0.591*** | −0.49*** |
| 8. Sri Lanka   | 1.249***  | 1.274***  | 2.354*   | 0.897*** | 0.828*** | 0.879*** | −0.665*** | −0.17     | −0.10     | −1.113*** | 0.19      | −0.355***|
| 9. South Africa| 0.939***  | 0.938***  | 1.137*** | 1.565*** | 4.027*** | 0.904*** | −0.563*** | −0.706*** | −0.603**  | −1.213*** | −1.883*** | −0.305***|
| 10. Brazil     | 0.963***  | 0.941***  | 1.235*** | 0.975*** | 0.46     | 1.086*** | −0.248*** | −0.489*** | −0.434*** | −0.448*** | −0.14     | −0.06    |
| 11. Thailand   | 0.851***  | 0.97***   | 1.377*** | 1.24***  | 0.70     | 1.186*** | −0.447*** | −0.497*** | −0.83***  | −0.877*** | −1.112*** | −0.517***|
| 12. Mauritius  | 0.949***  | 0.761***  | 0.42     | 1.278*** | 0.05     | 1.046*** | −0.793*** | −0.725*** | −0.603**  | −0.964*** | 0.06      | −0.22*** |
| 13. Mexico     | 1.04***   | 0.704***  | 0.62*    | 0.83***  | 1.06     | 1.136*** | −0.358*** | −0.479*** | −0.761**  | −0.532*** | −0.15     | −0.19    |
| 14. Chile      | 0.853***  | 0.989***  | 4.346*** | 0.904*** | 0.94     | 1.104*** | −0.569*** | −0.786*** | −0.967*** | −0.637*** | −0.31     | −0.513***|
| 15. Malaysia   | 0.938***  | 0.822***  | 0.741**  | 0.972*** | 1.436*** | 1.085*** | −0.555*** | −0.807*** | −0.593*** | −0.761*** | −0.729*** | −0.322***|
| 16. Argentina  | 1.06***   | 1.17***   | 0.65     | 0.533*   | 0.79     | 0.92***  | −0.272*** | −0.321*   | −1.079**  | −0.31    | −1.772*  | −0.182***|
| 17. Croatia    | 0.356***  | 1.536***  | 1.585*** | 0.374*** | 0.96**   | 1.063*** | −0.658*** | −0.698*** | −0.47     | −1.342*** | −1.153*** | −0.181** |
| 18. Oman       | 1.267***  | 0.833***  | 3.826*** | 1.123*** | 0.82     | 0.846*** | −0.533*** | −0.657*** | −2.393*** | −0.511*** | 0.40      | −0.15    |
| 19. Czech Republic | 0.924*** | 1.145***  | 0.814*** | 1.226*** | 0.42     | 0.879*** | −0.578*** | −0.572*** | −0.568*** | −0.75***  | −0.535*  | −0.227*  |
| 20. Spain      | 0.973***  | 1.084***  | 1.505*** | 0.676*** | 1.437*** | 0.91***  | −0.466*** | −0.457*** | −1.843*** | −0.634*** | −0.853*** | −0.234***|
| 21. Australia  | 1.038***  | 0.821***  | 0.38     | 0.706*** | 1.871*** | 1.147*** | −0.458*** | −0.644*** | −0.641*** | −0.825*** | −0.561*** | −0.139***|
| 22. Sweden     | 2.621***  | 0.831***  | 0.09     | 0.80     | 2.22     | 0.521*** | −0.893*** | −0.377*** | −0.589*** | −0.581*** | −9.037*** | −0.05    |

(Continues)
### A. Income elasticities

| Importer    | USA | DEU | NLD | GBR | SGP | R.O.W |
|-------------|-----|-----|-----|-----|-----|-------|
| 23. Iceland | 1.043*** | 0.487** | 1.22 | 1.06*** | 5.314** | 0.903*** |
| 24. Belgium  | 1.171*** | 0.802*** | 0.91*** | 1.052** | 4.53 | 0.891*** |
| 25. Austria  | 0.72*** | 0.948*** | 1.02*** | 0.7*** | 0.46 | 1.3*** |
| 26. Switzerland | 1.936*** | 0.646*** | 1.705*** | 0.865*** | 11.11 | 0.618*** |
| Mean        | 1.08 | 0.89 | 1.14 | 0.98 | 1.74 | 1.03 |
| SD          | 0.41 | 0.26 | 1.04 | 0.42 | 2.26 | 0.24 |

### B. Own-price elasticities

| Importer    | USA | DEU | NLD | GBR | SGP | R.O.W |
|-------------|-----|-----|-----|-----|-----|-------|
| 23. Iceland | 0.11 | −0.258*** | 0.55 | −0.414*** | 0.59 | −0.14 |
| 24. Belgium  | −0.574*** | −0.704*** | −0.647*** | −0.199** | −0.31 | −0.319*** |
| 25. Austria  | −0.623*** | −0.514*** | −0.521*** | −0.916*** | −0.473*** | −0.565*** |
| 26. Switzerland | −0.766*** | −0.315*** | −0.508*** | −0.613*** | −3.622** | −0.07* |
| Mean        | −0.54 | −0.51 | −0.71 | −0.73 | −1.00 | −0.28 |
| SD          | 0.21 | 0.20 | 0.52 | 0.36 | 1.80 | 0.21 |

**Note:** This table reports the income and Marshallian own-price elasticities estimated from the demand model (1). Countries are ordered from top to bottom by increasing income. Statistical significance notations: ***: 1%, **: 5%, *: 10%.
tend to be less than unity in absolute terms (except for Singapore’s, which is close to 1), implying that importer’s demand falls by less than 1% in general when price rises by 1%.12

Compared with previous research that provides price elasticity estimates of import demand, our estimates are at the middle or lower end (in absolute values). For example, Kee et al. (2008) use a modified-GDP-function approach and find average price elasticities in 117 countries to be in the range of −4.05 (Japan) to −1.04 (Gambia) for about 4,600 traded products. Recently, Clements and Vo (2021) utilise a demand model similar to ours and found that price elasticities across 176 countries ranges from −4.72 (Luxembourg) to −0.20 (Niger) for 9 broad commodity aggregates.13 In general, our results agree with those of previous research which shows that elasticities are lower when income falls. This important stylised fact implies that changes in the prices of test-kit could impose a stronger negative impact on consumer surplus in poorer countries, as discussed subsequently.

5.2 The welfare effects of trade restrictions

Based on the price elasticity estimates described above, we compute the potential impact on consumer surplus given the current values of relevant tariffs. Specifically, using Equation (2) and information from panels A and B of Table 4, we compute the loss of consumer welfare and present the results in panel C. The average loss ranges from $0.4 million for goods sold by the Netherlands to $7.2 million for those from the United States. It should be noted that larger countries tend to import more, and the welfare loss could be proportionally higher. To account for the scaling effect, we also measure welfare losses in terms of shares of import values, which are put in squared brackets. Column (18), which gives the loss aggregated across sources, indicates that in poorer countries where medical supply is scarcity (such as Bangladesh, India, and Pakistan), the loss can be as high as accounting for a quarter of total trade value. High-income countries (such as Australia or Switzerland), either have insignificant trade barriers or are more price-inelastic, experience a much smaller loss in consumer welfare. Many countries with high estimated losses are also experiencing demand shortages, especially those in Latin America (Brazil, Argentina, and Mexico).

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12This finding is in strong agreement with previous surveys such as Goldstein & Khan (1985), Heathcote & Perri (2002), Bergin (2006). Goldstein & Khan (1985) also endorse an earlier judgment by Harberger (1957) that for a typical country, the price elasticity of import demand “lies in or above the range of −0.5 to −1.0” (p. 1076). To check for robustness, in Appendix A4 we re-estimate our model by removing the data corresponding to the period of emerging trade tensions between the US and China (2017–2018) and find that our results do not change qualitatively from those presented in Table 3.

13In terms of income elasticities, for 109 goods traded by the U.S, Feenstra et al. (2018) find a median value of 1.54 to 4.05 using different estimators, while our (statistically significant) income elasticities range from 5.31 (Iceland) to 0.35 (Croatia).
| Reporter Name | A. Import value ($mil.) | B. Tariff (%) | C. Consumer welfare loss (Smil.) [% of import value] | USA | DEU | NLD | GBR | SGP | Total |
|---------------|------------------------|--------------|---------------------------------------------------|-----|-----|-----|-----|-----|-------|
| 1. Bangladesh | 3 6 0 1 1 11 13.0 13.0 11.0 13.0 13.0 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 |
| 2. Cambodia   | 4 1 0 0 0 5 7.0 7.0 6.8 6.8 6.8 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 7.0 | 7.0 | 6.8 | 6.8 | 6.8 | 6.8 |
| 3. India      | 189 71 22 16 42 339 22.6 22.6 20.3 20.3 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 22.6 | 22.6 | 20.3 | 20.3 | 20.3 | 20.3 |
| 4. Pakistan   | 25 32 1 0 2 63 24.0 24.0 24.0 24.0 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 |
| 5. Philippines | 842 244 6 108 117 1,316 8.5 8.5 8.5 8.5 8.5 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |
| 6. China      | 482 244 6 108 117 1,316 8.5 8.5 8.5 8.5 8.5 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |
| 7. India      | 34 30 1 6 19 89 7.7 7.7 7.7 7.7 7.7 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 |
| 8. Sri Lanka  | 9 3 0 3 1 16 2.5 2.5 2.5 2.5 2.5 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| 9. South Africa | 125 27 2 14 1 169 4.4 4.4 4.4 4.4 4.4 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 |
| 10. Brazil    | 142 76 3 23 3 247 9.4 9.4 9.4 9.4 9.4 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 9.4 | 9.4 | 9.4 | 9.4 | 9.4 | 9.4 |
| 11. Thailand  | 127 43 2 12 10 195 1.1 1.1 1.1 1.1 1.1 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |
| 12. Mauritius | 153 35 1 22 2 212 3.0 3.0 3.0 3.0 3.0 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 13. Mexico    | 60 34 1 11 0 106 5.4 5.4 5.4 5.4 5.4 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 |
| 14. Chile     | 47 19 2 7 13 88 0.9 0.9 0.9 0.9 0.9 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| 15. Malaysia  | 51 25 0 8 0 84 0.9 0.9 0.9 0.9 0.9 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| 16. Argentina | 19 3 0 3 0 26 0.3 0.3 0.3 0.3 0.3 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| 17. Croatia   | 2 3 0 2 0 7 0.9 0.9 0.9 0.9 0.9 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| 18. Oman      | 60 34 1 11 0 106 5.4 5.4 5.4 5.4 5.4 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 |
| 19. Czech     | 51 25 0 8 0 84 0.9 0.9 0.9 0.9 0.9 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| 20. Spain     | 48 43 5 9 0 105 1.7 1.7 1.7 1.7 1.7 | 0 0 0 0 0 0 | 0 0 0 0 0 0 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 |
| Reporter Name | A. Import value ($ mil.) | B. Tariff (%) | C. Consumer welfare loss ($mil.) [% of import value] |
|---------------|--------------------------|---------------|---------------------------------------------------|
|               | USA | DEU | NLD | GBR | SGP | Total | USA | DEU | NLD | GBR | SGP | Total | USA | DEU | NLD | GBR | SGP | Total |
| 21. Australia | 195 | 61  | 2   | 26  | 17  | 301   | 2.2 | 3.4 | 3.4 | 3.4 | 1.7 | -4.2 [2.2] | -2.1 [3.4] | -0.1 [3.4] | -0.9 [3.4] | -0.3 [1.7] | -7.6 [2.5] |
| 22. Sweden   | 53  | 62  | 49  | 32  | 0   | 197   | 0.9 | 4.5 | 4.5 | 4.5 | 0.0 | -0.5 [0.9] | -2.8 [4.5] | -2.2 [4.6] | -1.5 [4.6] | 0.0 [0.0] | -7.0 [3.6] |
| 23. Iceland  | 34  | 4   | 7   | 2   | 1   | 48    | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 [0.0] | 0.0 [0.0] | 0.0 [0.0] | 0.0 [0.0] | 0.0 [0.0] | 0.0 [0.0] |
| 24. Belgium  | 202 | 78  | 114 | 20  | 0   | 415   | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 [0.0] | 0.0 [0.0] | 0.0 [0.0] | 0.0 [0.0] | 0.0 [0.0] | 0.0 [0.0] |
| 25. Austria  | 77  | 111 | 13  | 17  | 1   | 218   | 0.3 | 5.0 | 5.0 | 5.0 | 0.1 | -0.2 [0.3] | -5.6 [5.1] | -0.7 [5.1] | -0.8 [5.1] | 0.0 [0.1] | -7.3 [3.4] |
| 26. Switzerland | 129 | 116 | 34  | 29  | 11  | 318   | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 [0.0] | 0.0 [0.0] | 0.0 [0.0] | 0.0 [0.0] | 0.0 [0.0] | 0.0 [0.0] |
| Mean         | 105 | 53  | 14  | 16  | 10  | 198   | 6.5 | 6.0 | 6.0 | 6.0 | 5.1 | -7.2 [5.8] | -3.1 [6.1] | -0.4 [6.3] | -1.0 [6.3] | -0.9 [5.3] | -12.6 [6.0] |
| SD           | 161 | 60  | 29  | 21  | 23  | 259   | 6.5 | 6.0 | 6.2 | 6.3 | 6.3 | 16.0 [7.0] | 5.0 [6.3] | 1.1 [6.8] | 1.9 [6.6] | 2.4 [6.9] | 25.6 [6.6] |

Note: 1. Columns 2–7: The 2018 value of imports of country $i$ (rows) from country $j$ (columns). Denote this as $M_{ij} (i = 1, \ldots, 32; j = 1, \ldots, 6)$. 2. Columns 8–12: The 1996–2018 bilateral trade-weighted-average tariff rates extracted from WITS database. Denote this as $\tau_{ij}$. 3. Columns 13–17: The loss of consumer surplus is computed as $\Delta_{CS}^i = \sum_{j=1}^{6} M_{ij}(1 + \frac{1}{2} \tau_{ij} \lambda_{ij})$ where $\lambda_{ij}$ denote the Marshallian own-price elasticity sourced from Table A5.1. 4. Column 18: Total consumer welfare change for $i$ is computed as $\Delta_{CS}^i = \sum_{j=1}^{6} \Delta_{CS}^j$ Countries with a welfare loss share exceeding 8% of the total import value are emboldened. 5. Countries are ordered from top to bottom by increasing income.
We conclude our analyses by discussing the main implications of the simulation experiment described at the end of Section 3. Using Equation (3) (assuming that tariffs and price elasticities are kept constant) and the actual changes in positive rates, we are able to produce simulated

14 According to the latest data from the World Bank (2020), both developed and developing countries continue to impose restrictive tariffs on a number of medical products during the pandemic. However, the detailed tariff-rate data and list of affected products are not available. See also Espitia et al. (2020) for a discussion of the potential health and economic consequences of these measures.

5.3 Counterfactual demand and welfare-loss simulations

FIGURE 4 Simulated excess consumer welfare loss.

Note: This figure presents the differences between the simulated consumer welfare loss [computed using Equation (3)] and the baseline loss value (measured at the beginning of the period). In each panel, the blue solid line indicates the mean and the shaded areas indicate the one-standard-deviation cross-country confidence band.
consumer welfare loss for each country in our sample, from all import sources, for the period from February to August 2020. The difference between this value and the welfare loss corresponding to the baseline no-pandemic scenario (presented in Table 4) provides us with a measure of the effect of the shock induced by exogenous surges in test-kit demand. We compute this ‘excess loss’ in absolute terms: The higher this value, the larger the impact of the shock.

The left-hand plot in panel (a) of Figure 4 presents the average excess loss (across all import sources and all importers) from the high-income group. The shaded area represents the corresponding one-standard-deviation confidence band. Results for lower-middle income and upper-middle income groups are shown in the middle and right-hand plots. These reveal a striking picture: The excess loss of the poorest country group is the highest, with a sample average of $19.6 million, followed by the loss of the upper-middle-income consumers ($6.48 mil.), while that of the high-income consumers is mere $0.87 million. Additionally, as demand rises, excess loss tends to increase steadily over time and follow a similar path in both lower-middle and upper-middle-income groups. But for affluent consumers, the loss increases only during the first wave of the pandemic (from Feb to May 2020) then falls back to near-zero levels. Even though high-income countries also experienced strong demand pressure, their much smaller welfare loss points to the resilience of their healthcare system and a lesser degree of dependence on imported test kits. The fact the richer countries felt more pressure during the first wave but not much in the second might be explained in terms of a greater initial shock due to greater integration and subsequent better adaptation of domestic production of test kits, compared to developing ones.

These results should be interpreted with due care, however, given that the volatility of our estimates appears to change in the same direction as the mean, as indicated by the widening (shrinking) confidence bands of the poor (rich) group. This partly reflects the high degree of uncertainty involved in testing data reported by poor countries. Furthermore, it is important to note that as we do not include pandemic-related import data in our estimation period, because we aim to ‘isolate’ the effect of the sudden increase in demand by restricting the estimation to the pre-pandemic period and obtaining ex-ante estimates. As demand and/or trade policies are adjusted to the pandemic situation, the value of welfare effect evaluation is reduced if the ‘shock’ becomes ex-post information. However, this also means that if price elasticity is lower (in absolute value) during the pandemic, the welfare loss of price increases would be undoubtedly higher, which implies that our simulation results can be considered conservative.

In Panel (b) of Figure 4, we examine the excess loss from the regional perspective. It is apparent that the pattern observed previously in the high-income group is driven by that of European consumers. Africa, Asia, and North America all exhibited persistent increasing excess losses over time due to rising positive test rates. The rising trend in South America is not as clear with much more fluctuations, especially during the first wave and second wave periods. Interestingly, the only region that exhibits negative excess loss (that is, lower simulated levels than the initial loss level) is Oceania. This is due to the steadily decreasing positive rates in this region, implying a high degree of success in containing the outbreak. The minor rise near the end of the sample period coincides with the resurgence of cases in major Australian cities in the states of Victoria and New South Wales.

Due to the former two groups having larger populations, on a per capita basis, the average loss for an individual consumer is lower for the lower-middle ($0.0157) and upper-middle-income groups ($0.0604) and higher for the high-income group ($0.103). However, per capita comparison may not reflect the full impact of welfare loss, as while the loss is small for individuals, in aggregation this cost can be substantial (Rodrik, 1995).
CONCLUDING COMMENTS

One of the key determinants of the success in the fight against the current COVID-19 pandemic is the timely provision of medical supplies for the purposes of active prevention and detection of virulent spreading. In particular, the availability of test kits has proved to be crucial in rapidly detecting and quarantining known cases, therefore significantly reducing the probability of infection. It follows that maintaining test-kit trade flows and minimising trade barriers is of utmost importance during this unprecedented health crisis. As the number of COVID-19 cases rises sharply following subsequent outbreak waves around the globe, trade protectionism will cost lives, not just livelihood (OECD, 2020). In spite of an increasingly polarised world, cooperation and trust at an international level are essential to de-escalate the current trade tensions and preserve openness. This proposal serves a two-fold aim in the fight against the virus: To ensure the adequate supply of essential products and to send a strong signal of confidence that supports global economic recovery.

In this study, we aim to provide insights regarding the potential economic impact of trade barriers on consumer welfare in a sample of importing countries. For this purpose, we first investigate the characteristics of the global test-kit markets and the current tariffs applied to this product. Using bilateral trade data, we estimate a system of simultaneous demand equations each corresponding to a competing import source. The elasticity estimates obtained from this model allow us to systematically analyse the impact of trade barriers on consumer welfare when there is no health shock. Then, based on these results, we simulate and study a number of counter-factual scenarios reflecting the effects of the pandemic-induced demand shocks.

We documented that, similar to other medical product markets, the test-kit market is dominated by a small number of high-income, technologically advanced producers. Trade among European, North American, and East Asian consumers accounted for the majority of global test-kit trade and these trade patterns are very persistent over time. In addition, as poorer countries tend to have lower price elasticities, they are less price-sensitive to imports than affluent countries. As a result, the adverse effects of tariffs on consumer welfare are also higher for poorer countries. Incidentally, these countries also experienced higher positive test rates, implying a higher demand shortage, which increases their losses.

On the basis of these findings, it is recommended that (i) lower-income exporters should diversify their sources of import; (ii) trade barriers need to be reduced (by both importers and exporters); and (ii) exporters should consider increasing production and/or lowering prices towards importers that are most dependent on their products and most vulnerable to health shocks. These suggestions, though useful to increase the efficiency of test-kits allocation, may not be simple to implement, considering the unusual scale of the pandemic (which also severely affected major test-kit exporters) and the political economics of governing international trade (i.e., rising protectionism). In these situations, production could be directed towards meeting domestic demand regardless of the developments in the world market.

We conclude this study by acknowledging its limitations and discussing future research directions. First, it is important to re-emphasise that our results refer strictly to the quantifiable economic effects of tariffs on the trade of a single medical product. As such, we have not covered aspects related to: (i) The non-economic effects such as the value of lives saved (which could arguably be much higher than just consumer welfare loss, but is otherwise difficult to measure); (ii) non-tariff trade barriers (which could be of a larger magnitude than tariffs, especially in light
of the increasing technical requirements for post-COVID trade flows (OECD, 2020)\(^\text{16}\) (iii) the trade of other essential medical supplies such as facial masks, hand sanitisers, ventilators and, more recently, vaccines. Extending our study to these areas when more trade data become available is straightforward and would be a valuable effort. Nevertheless, in light of the current crisis, providing timely estimates (such as those in our study) for the purpose of trade policy evaluations and reforms would be a priority.

Second, our analyses focus on the demand side of medical supplies, while taking prices and income as exogenous to the consumers’ decision. This approach can be enhanced, however, by accounting for the supply side with estimates of producer-price elasticities and the corresponding effects of demand shocks experienced by consumers in the exporting countries (especially those with divergent growth rates of infection, i.e., the United States and Germany). Such an extension would require data on the production of test kits in these countries. Finally, though within the scope of this article we have only examined a partial and direct equilibrium effect of test-kit price changes on consumer welfare, it would be interesting to consider broader effects on labour market, income, and aggregated demand and supply via general equilibrium approaches.

ACKNOWLEDGEMENTS
We thank Farhad Mohammad for assisting with data collection. All errors remain with the authors.

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\(^{16}\) Relatedly, due to limited data availability, our simulations do not consider the import facilitating policies implemented during and following the first wave, and the export restriction imposed by developing countries. Recently, Evenett et al. (2021) introduce a new European University Institute-Global Trade Alert-World Bank joint database that records the jurisdiction implementing trade policy changes, the direction of the measure, type of measure, the timeline of the measure, and products covered by the policy. However, the exact magnitudes of such measures are not provided at the country level, thus limiting the use of this new database in computing welfare effects.
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Additional supporting information may be found in the online version of the article at the publisher's website.

**How to cite this article:** Vo, L. H., & Le, T.-H. (2022). COVID-19 test-kit trade and trade policy: Implications for developing countries. *The World Economy*, 00, 1–23. https://doi.org/10.1111/twec.13276