

International Trade Policy During a Pandemic

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Abstract

This paper studies international trade policy during a pandemic. We consider a multi-sector small open economy model with essential and non-essential goods. Essential goods provide utility relative to a reference consumption level, and a pandemic consists of an increase in this reference level along with higher import and export prices of these goods. The economy produces domestic varieties of both types of goods subject to sectoral adjustment costs, and varieties are traded internationally subject to trade barriers. We find that trade provides limited relief to the increased demand for essential goods: import prices increase, limiting access, while domestic producers reallocate domestic sales toward exports. We find that international trade policy changes can mitigate these effects. The optimal unilateral trade policy response to the pandemic is to subsidize imports of essential goods while taxing exports, leading to increased consumption of essential goods in the short-run. These findings are consistent with evidence on changes in trade barriers across countries during the COVID-19 pandemic.

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1 Introduction

International trade policy has often been used to respond to economic downturns, such as the Great Depression or the Great Recession. These policy interventions have been typically protectionist and found to be detrimental to the subsequent recovery (Irwin 2017).

Similar policy interventions have been observed across countries during the COVID-19 pandemic, with a focus on essential medical goods that have been critical to combating and preventing the disease. In this paper, we ask: Did countries introduce such policies as a panic-driven response to the pandemic, or were these measures unilaterally helpful to alleviate supply shortages and increase access to such critical goods, at least in the short-term? Is this time different? We examine these questions through the lens of a quantitative small open economy model with international trade of essential goods.

The current pandemic led to a massive increase in the demand for essential medical equipment (e.g., gowns, masks, gloves and, more recently, vaccines) to combat it and prevent the spread of the disease. While supply has increased gradually in an attempt to satisfy the high demand for these goods, countries have faced supply shortages, being forced to ration these goods and face exorbitant prices. As a result, many countries resorted to trade policy.¹ Countries have lowered import barriers to ease access to essential medical goods, while restricting their exports of these goods, making it harder for domestic firms to sell them internationally. Similar policy changes have been recently introduced in several countries on vaccines and vaccine-related goods, suggesting international trade has played a fundamental role during COVID-19. Yet, these observed trade policy changes have puzzled policymakers and academics alike.

In this paper we investigate the extent to which these trade policy responses have been unilaterally optimal, or whether they reflect failures in policy design. To do so, we set up a quantitative dynamic general equilibrium model of international trade with multiple sectors and estimate it to match salient features of the data. We use the model to examine the trade policy changes on essential goods introduced during COVID-19. In particular, we ask: To what extent should countries unilaterally adjust trade policy in response to a pandemic?

We begin by documenting salient features of the dynamics of demand, supply, and prices of essential medical goods during the COVID-19 pandemic. Because of data limitations, we

¹See Baldwin and Evenett (2020) for a detailed analysis of trade policy changes during COVID-19.

restrict our analysis to the U.S. and to the following types of personal protective equipment (PPE): N95 respirators, surgical masks, gloves, and face shields. We document four key patterns in the data. First, the demand for PPE experienced a significant increase at the onset of the pandemic, remaining high through February 2021. Second, changes in the supply of these goods were not sufficient to meet the increased demand for these goods, leading to supply shortages. By April of 2020, only 27 percent of the N95 respirators needed had been met by supply, whereas this was the case for only 37 percent of the face shields needed. Third, prices of essential medical goods increased significantly throughout the pandemic, reflecting the supply shortages of these goods during the pandemic. For instance, the price increase of surgical masks and nitrile gloves peaked at 104% and 95%, respectively. Finally, we show that trade plays a critical role to access these goods: most of PPE supply was accounted for by imports, suggesting the importance of trade of essential medical goods during the pandemic.

Alongside these developments, we document that countries resorted to widespread temporary trade policy changes on essential medical goods. Data on trade policy interventions for several COVID-related products from Global Trade Alert (GTA) show that by April 2020, 70 countries had imposed export restrictions, whereas 64 countries had liberalized imports of these goods. These features of the data suggest that international trade might have played a key role on the dynamics throughout the pandemic as well as in the response of policy. We investigate the role of international trade policy on essential medical goods during a pandemic using a quantitative general equilibrium model of international trade.

We study a small open economy that produces domestic varieties of both essential and non-essential goods using capital and labor. These goods are traded internationally vis-a-vis the rest of the world. Capital and labor can be reallocated across sectors in response to shocks, but this reallocation is subject to adjustment costs. Moreover, we assume that firms are myopic and do not internalize the impact of their production decisions on the welfare of households; this assumption allows us to capture that producers of essential goods might not fully internalize the critical nature of the goods produced for social welfare.

We assume that the fundamental difference between essential and non-essential goods is accounted for by differences in household preferences for these goods. In particular, we assume that utility from essential goods is derived from the consumption of these goods

relative to a time-varying *reference level*.² While analogous to the subsistence level featured by Stone-Geary preferences, we allow households to consume below the reference level.

In addition, we capture the critical nature of essential goods by assuming that consumption of essential goods is complementary both intra-temporally and inter-temporally. That is, households find it hard to substitute essential goods within periods by shifting consumption toward non-essential goods, as well as across periods by substituting consumption today by future consumption.

We use this model as a laboratory to investigate the role of international trade on the impact of a global pandemic. Thus, throughout our analysis we interpret essential goods as consisting solely of essential medical goods. We then model a global pandemic as consisting of a combination of domestic and foreign shocks that hit the steady-state of the economy. On the domestic front, the economy experiences a shock to the reference level of essential goods. On the foreign front, the economy experiences a shock to the price of imports and a shock to the price of exports of essential goods. We assume the pandemic lasts for one year, is unexpected, and that the full path of shocks back to steady-state is observed once the pandemic is realized. Thus, our analysis abstracts from other multifaceted effects of a pandemic (e.g., social distancing policies, infection and death rates, increased unemployment), isolating the impact of increased domestic and foreign demand for essential goods.

We estimate the model to match salient features of the U.S. economy prior to COVID-19 as well as during the pandemic. We begin our analysis by investigating the role of international trade on the impact of a pandemic. We find that, while the higher reference level of essential goods increases the demand for these goods, consumption of essential goods increases gradually due to several factors, while remaining below the reference level throughout the pandemic. Domestically, adjustment costs prevent producers of essential goods from rapidly adjusting their production scale. Internationally, the price of imports increases substantially, making it more costly to alleviate the increased needs via imports. Additionally, the increase in the price of exports leads domestic producers of essential goods to reallocate domestic sales towards exports.

International trade, thus, plays an important role on the impact of a pandemic. On the one hand, while imports help domestic consumers to ease the increase need for essential

²In the context of essential medical goods, one might interpret this reference level as the healthcare consumption recommended by healthcare professionals. A pandemic such as COVID-19 can then be interpreted as an increase in this reference level.

goods, the substantial price increase limits the extent to which they are able to do so. On the other hand, the higher price of exports of essential goods induces domestic producers to increase their foreign sales relatively more than their domestic ones. Thus, total domestic production increases, but many of these goods are shipped abroad.

We then investigate the potential of international trade policy to mitigate the impact of a pandemic. We ask: To what extent is it optimal in our model to unilaterally adjust international trade policy on essential goods during the pandemic? We answer this question by evaluating the optimal design of international trade policy during a pandemic, endowing the government with two trade policy instruments that apply only to essential goods: import tariffs/subsidies, and export taxes/subsidies. The government's problem consists of choosing the value of each of these instruments during the pandemic to maximize the household's lifetime expected utility starting from the period in which the pandemic arrives. To simplify the analysis, we restrict attention to one-time transitory changes to these instruments that are only active during the pandemic.

Consistent with the cross-country trade policy changes documented in the data, we find it is unilaterally optimal to introduce taxes on exports of essential goods during the pandemic, along with subsidies on imports of these goods. We find that these policies allow consumers to speed up their consumption of essential goods, leading to substantial gains in welfare. On the one hand, the export tax discourages foreign sales and increases domestic access to domestically-produced essential goods. On the other hand, the import subsidy allows consumers to increase their imports of essential goods at a lower price. Welfare gains in consumption-equivalent-units imply that households in an economy without optimal trade policy changes would need their consumption bundle to increase by 4.07% every period forever to remain indifferent to living in the economy that implements the optimal trade policy during the 12-month pandemic.

We conclude our analysis by investigating the key determinants underlying the role for international trade policy changes in our economy. First, we find that firm myopia plays a key role in accounting for our findings: In an economy in which firms internalize the impact of their production decisions on household welfare, the optimal policy response is to keep import tariffs and export taxes unchanged at their zero steady-state values. Second, we find that the complementarities of essential goods are also critical. Relaxing these complementarities create a weaker motive for optimal trade policy interventions, as households can overcome

the increased needs for essential goods during the pandemic with increased consumption of non-essential goods (weak intra-temporal complementarity), or with increased consumption of essential goods after the pandemic is over (weak inter-temporal complementarity). Finally, we find that high trade dependence is also important for our findings: If our economy has a trade surplus in essential goods, then the costs of the pandemic are lower and the optimal response of trade policy is also milder. In all these cases, the welfare gains from adjusting trade policy in response of a pandemic are significantly lower than in the baseline model.

Our findings provide a rationale for the cross-country response of international trade policy observed during the COVID-19 pandemic. From the lens of our model, the observed trade policy changes are a unilaterally optimal response to a pandemic that increases the demand for essential goods. While these trade policy responses might have looked like a panic-driven increase of protectionism, our findings show that they can be interpreted as the optimal unilateral policy response of a welfare-maximizing government. Thus, we conclude that indeed, this time is different to the rise of protectionism in the aftermath of the Great Depression and Great Recession.

Note, however, that our optimal policy analysis restricts attention to unilateral optimal policies, abstracting from investigating potential multilateral policies that may improve these outcomes further. In particular, our analysis does not imply that these trade policy responses achieve any desirable world-level outcomes. Thus, our findings should not be interpreted normatively as prescriptive of what policies should countries necessarily implement during a pandemic; rather, they provide a lens to interpret what actually happened during the pandemic.

Our modeling framework builds on a large literature that studies international business cycles. In particular, we combine the multi-country framework of Backus, Kehoe, and Kydland (1992) with the multi-sector setups of Mendoza (1995), Schmitt-Grohé and Uribe (2018), and Kohn, Leibovici, and Tretvoll (2021). As in the latter, our model features sectoral adjustment costs in both labor and capital. We extend these setups to model essential goods as different from non-essential goods via differences in their contribution to household utility.

The paper is also related to a recent trade literature that studies the role of capital accumulation on the welfare gains from trade along both the short- and long-run. In particular, Ravikumar, Santacreu, and Sposi (2019) develop a multi-country two-sector model

with endogenous capital accumulation and trade imbalances to evaluate the dynamic gains from trade. Anderson, Larch, and Yotov (2020) develop a structural gravity model with capital accumulation to evaluate the dynamic welfare gains from trade. Finally, Alvarez (2017) studies the effect of tariffs on welfare in a model of trade with capital accumulation.

The paper contributes to a literature on optimal trade policy. Costinot, Rodríguez-Clare, and Werning (2020) and Demidova and Rodríguez-Clare (2009) study optimal unilateral trade policy in a small open economy model with heterogeneous firms. Felbermayr, Jung, and Larch (2013) extend these papers to large economies. Finally, Ossa (2011) studies the gains from WTO/GATT negotiations.

Our analysis is also related to recent studies on the aggregate importance of small but systemic sectors, such as essential medical goods in our economy. Baqaee and Farhi (2019b) show in a static economy that small sectors can be systemically important if the elasticity of substitution between them and other production inputs is low and factors of production are fixed. Baqaee and Farhi (2019a) extend this analysis model to a standard static model of international trade. We study related forces using a dynamic environment with goods that are important for consumption rather than production, with frictions on production factors, and evaluating the implications for optimal policy.

Several authors have also emphasized the need for greater international coordination. An influential paper on this issue is Olson and Zeckhauser (1966) who develop a model of international cooperation on the basis that countries want to participate in these organizations to provide a public good. The model is applied to the case of NATO, hence focusing on defense as a global public good. More recently, Evenett (2020) has proposed an international agreement with export incentives to the main suppliers of essential goods and low import tariffs by the main importers.

Our paper also raises questions related to a recent and growing literature on the role of international trade of essential medical equipment during a pandemic. In particular, the shortage of essential medical equipment in countries that depend on imports of these goods during the ongoing COVID-19 pandemic has led to a surge of papers proposing international coordination mechanisms to avoid future shortages. Many of these recent papers are contributions to the recent VoxEU eBook on COVID-19 and trade policy (Baldwin and Evenett 2020). For instance, Stelling, Berglund, and Isakson (2020) and others advocate for the role of international trade as an insurance device for those countries that rely on imports

of essential goods, and hence are specialized in the production of other types of goods. A broader set of papers has also recently studied the role of international trade as transmission channel for pandemic-related shocks across countries (Çakmaklı, Demiralp, Kalemli-Ozcan, Yeşiltaş, and Yıldırım 2021; Bonadio, Huo, Levchenko, and Pandalai-Nayar 2020; LaBelle, Leibovici, and Santacreu 2021).

Finally, while the paper is certainly applied to the COVID-19 pandemic, the implications of our analysis extend well beyond the specific case of trade in essential medical goods during a pandemic. Our approach allows us to investigate the role of trade in any type of essential good that might be subject to shocks. For instance, to the extent that agricultural goods are essential for the survival of a country’s population, our analysis can be extended to examine the impact of a global pest that might destroy agricultural production.

The rest of the paper is organized as follows. Section 2 documents key features of the data on the pattern of production and trade barriers on essential goods. Section 3 presents the model. Section 4 examines the quantitative impact of a pandemic and investigates the optimal design of trade policy. Section 5 examines the key determinants of optimal trade policy. Section 6 concludes.

2 Evidence on international trade of essential goods

In this section, we document key features informative about the role played by essential medical goods during the COVID-19 pandemic.

Our starting point is the observation that the demand for goods required to prevent COVID-19 increased sharply during this period. However, the increased demand for these goods often went unfulfilled, leading to shortages, as production increased gradually. Thus, we begin by documenting salient features of the dynamics of demand and supply across these goods. Given data limitations, we restrict attention to U.S. data on personal protective equipment (PPE) from the White House COVID-19 Supply Chain Task Force.

Next, we document the price changes associated with these movements of demand and supply. While data on prices for such disaggregate product categories has been sparse, we exploit information on unit values across U.S. imports of PPE.

In parallel to the increased demand and prices of these goods, countries rapidly adjusted trade policy during this period, making it harder to export these goods while easing import

restrictions. Thus, we conclude this section by documenting the response of international trade policy on essential medical goods across countries during the pandemic.

In the rest of the paper, we investigate the extent to which the dynamics of demand, supply, and prices of essential goods during the COVID-19 pandemic account for the trade policy developments documented during this period.

2.1 Demand vs. supply of personal protective equipment

We begin by documenting the evolution of demand and supply of personal protective equipment that is critical to prevent the transmission of COVID-19. To do so, we restrict attention to four key products identified by the White House COVID-19 Supply Chain Task Force: N95 respirators, surgical masks, face shields and nitrile gloves. In particular, our analysis is based on estimates of the demand and supply of these goods reported in June 2020 and January 2021 by the task force. We interpret the evidence on these four types of goods as representative of the broader set of personal protective equipment (PPE) required to prevent the spread of COVID-19.

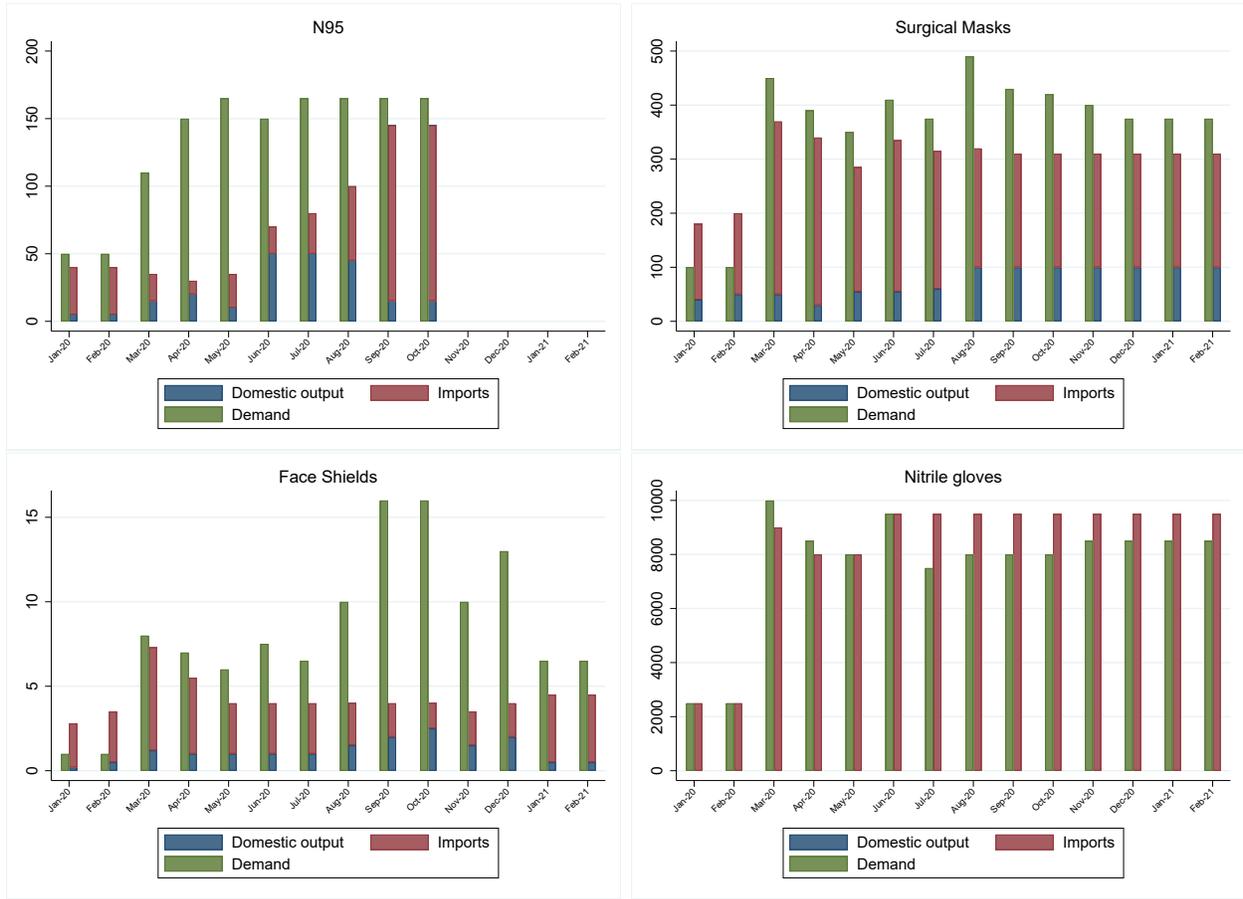
Figure 2.1 reports our findings, with green bars representing PPE demand, while the sum of the red (domestic output) and blue (imports) bars represent PPE supply. Therefore, observations with green bars (demand) higher than the red-blue bars (supply) reflect shortages of the given product.

First, we observe that PPE demand across these four types of goods experienced a significant increase between February and March 2020, at the onset of the pandemic, remaining high through February 2021. For instance, the estimated demand for N95 masks doubled between February and March, tripling by April; the demand for the rest of the goods increased even more sharply.

Second, changes in PPE supply were generally not sufficient to meet the increased demand for these goods. While domestic production and imports of all such goods increased during the pandemic, this increase was not sufficiently large to meet the spike in demand, leading to supply shortages. As reported in the first column of Table 1 based on this data, shortages of N95 respirators peaked in May 2020 with just 27% of the demand met with supply (either domestic or imported), while shortages of face shields peaked in September and October 2020, with about 37% of demand met with supply.

Third, we observe that international trade is a crucial source of PPE. In particular, across

Figure 1: Demand and Supply Estimates of PPE, January 2020 – February 2021



Note: y-axes are expressed in millions of units.

all four of these goods, the average share of imports in total supply is higher than 70%. While nitrile gloves provide an extreme example, with virtually zero domestic production, domestic production plays a very minor role in the overall supply of all of these goods.³

2.2 Price changes on personal protective equipment

We now investigate the price implications of the shortages of essential goods documented in the previous section. To do so, we document the price changes experienced during the COVID-19 pandemic by the four PPE categories identified by the White House COVID-19 Supply Chain Task Force, as examined above. We report our findings in Table 1.

³N95 masks are the product with the lowest share of imports in total supply, accounting for over 40% at the peak.

Table 1: PPE Supply/Demand and Prices

	Supply/Demand	Price change
N95 respirators	0.27	1,513%
Surgical masks	0.85	104.8%
Face shields	0.37	21.01%
Nitrile gloves	0.90	95.35%

Note: For each product, supply/demand reports the minimum value of this ratio over the period Jan 2020 – Feb 2021. Price changes are computed as described in the text.

Data limitations prevent us from obtaining comprehensive information on the PPE prices that were prevalent in the U.S. during the pandemic. Thus, we combine data from various sources. For nitrile gloves, face shields, and surgical masks, we rely on international trade data from the United States International Trade Commission (USITC). In particular, we use monthly unit values of U.S. imports from the world reported across 10-digit HS product categories. We aggregate these categories into the various PPE products that we analyze as follows. First, for each 10-digit HS product and each month of 2020, we compute price changes relative to its average price in 2019. Then, for each product category under analysis, we compute the median price change across all 10-digit HS products that belong to such category.

Prices for N95 masks are not available in the USITC database before July 2020.⁴ Hence, we obtain the price data for this good from a study conducted by SHOPP (The Society for Healthcare Organization Procurement Professionals) in April 2020.⁵ The results of the study are based on current market pricing and Centers for Disease Control and Prevention guidelines on PPE costs incurred by skilled nursing facilities and assisted living centers treating COVID-19 patients.

Table 1 shows that the price of PPE increased substantially during the pandemic, likely reflecting the severe supply shortages documented in the previous section. The price of N95 respirators increased by 1,513%, while the price of surgical masks and nitrile gloves increased by 104% and 95%, respectively. Face shields experienced the lowest price increase, equal to

⁴The July 1st Revision of the U.S. Harmonized Tariff Schedule introduced a dedicated product category to identify N95 masks: 6307.90.9845. Prior to this revision, N95 were included under subheading 6307.90.9889.

⁵<https://shopp.org/>.

21%.⁶ These increases in prices may also reflect policy actions that were implemented around the world, such as trade policy as we document next.

2.3 International trade policy changes on essential medical goods

The worldwide supply shortages of essential medical goods and the associated price hikes documented above prompted several countries to resort to trade policy as a way to respond to COVID-19. On the one hand, some countries introduced export restrictions on medical supplies that were essential to fighting the pandemic. On the other hand, some countries implemented trade liberalization policies, mostly in the form of import tariff reductions, to make it easier to import these essential medical goods.

Next, we document the evolution in the number of countries that introduced these types of trade policy changes during the pandemic. To do so, we use trade policy data from Global Trade Alert for 122 countries between January and November 2020.⁷ We restrict our analysis to export restrictions and import liberalizations for 24 COVID-related products, as classified by the World Trade Organization (WTO).⁸ We find that 70 countries introduced export restrictions on COVID-related products during the period of analysis. Similarly, 64 countries imposed import liberalizations during this period.

Figure 2 shows the evolution over time in the number of countries with effective export restrictions (left panel) and import liberalizations (right panel) introduced during the COVID-19 pandemic on essential medical goods. The figure shows a big spike in the number of countries that resorted to trade policy after February 2020 to regulate trade of these goods. By April 2020, 64 countries had active export restrictions, whereas 61 countries had active import liberalizations. While these policies were largely temporary, several countries still had them in place at the end of 2020, nine months into the pandemic.

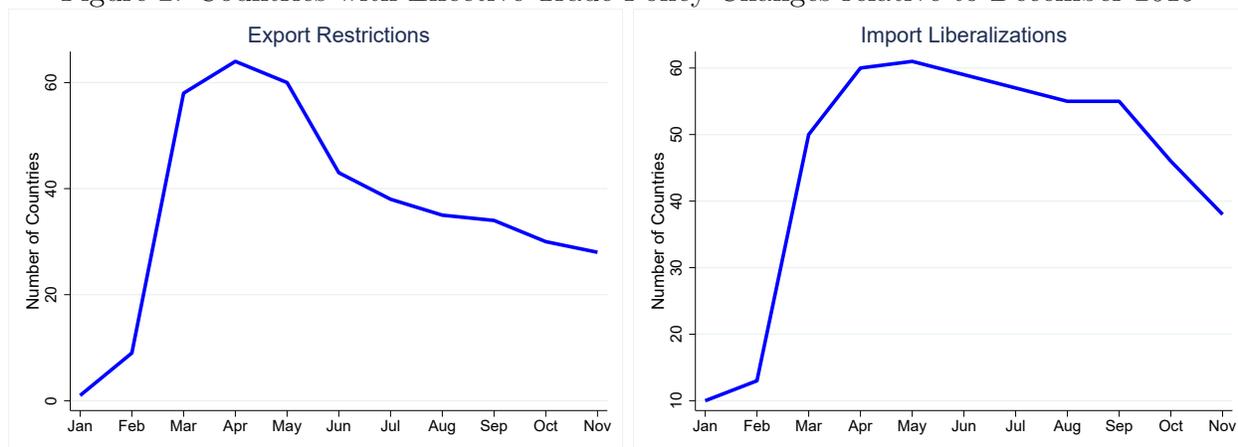
Figure 3 reports the number of country-product pairs with either export restrictions or import liberalizations on COVID-related goods between January and November 2020. Thus, this figure captures fluctuations in the number of essential medical goods that were subject to trade policy changes during the pandemic. There is a big spike in April 2020 in the

⁶Given that we do not rely on a common data sources to compute the price changes of the four COVID-19 product categories under analysis, we avoid directly comparing N95 prices with the prices of the remaining categories. The corresponding price changes from SHOPP for nitrile gloves, face shields and surgical masks are 200%, 900%, and 1,500%, respectively.

⁷<https://www.globaltradealert.org/>.

⁸https://www.wto.org/english/tratop_e/covid19_e/covid19_e.htm.

Figure 2: Countries with Effective Trade Policy Changes relative to December 2019



Note: x -axis corresponds to months in 2020. We restrict attention to trade policy changes on essential medical goods as classified in the text.

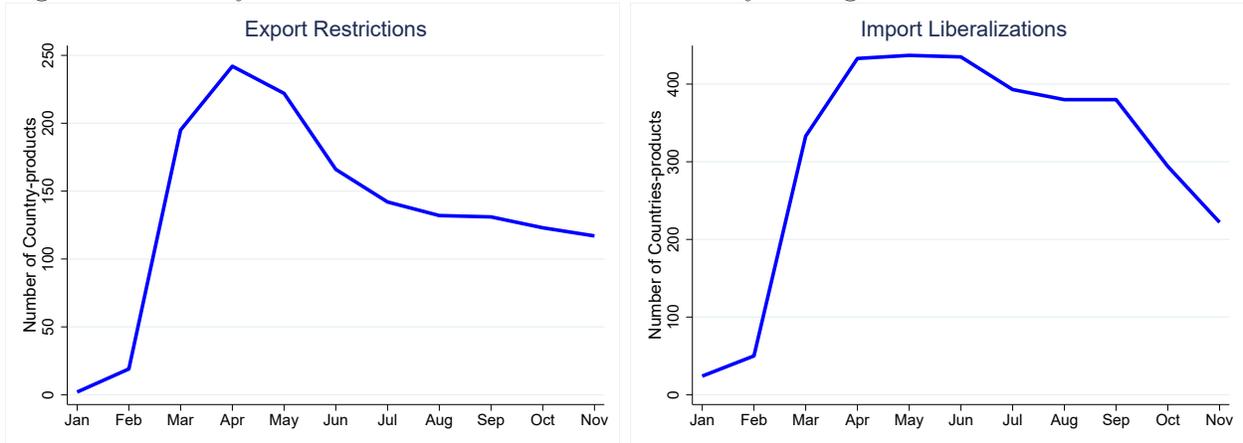
number of country-products subject to trade policy changes. At that point, 242 country-products were subject to export restrictions whereas 433 country-products were subject to import liberalizations. These policies were largely temporary and, by November 2020, there were 117 country-products with export restrictions and 222 country-products with import liberalizations.

These findings show that a large number of countries responded to the COVID-19 pandemic and its associated shortage of essential medical goods by (i) introducing export restriction on these goods, and (ii) removing barriers to import these goods. In the next section we set up a quantitative general equilibrium model to interpret the evidence documented above. In the rest of the paper, we investigate the implications of these policies and the extent to which they constitute an optimal response to a pandemic.

3 Model

We study a small open economy that trades goods and financial assets with the rest of the world. The small open economy and the rest of the world produce varieties in each of two sectors: a sector that produces essential goods and one that produces non-essential goods. Thus, the small open economy has access to four types of varieties: a domestic and foreign variety of essential goods, and a domestic and foreign variety of non-essential goods. All of these goods are traded internationally. We refer to variables corresponding to the essential

Figure 3: Country-Products with Effective Trade Policy Changes relative to December 2019



Note: x -axis corresponds to months in 2020. We restrict attention to trade policy changes on essential medical goods as classified in the text.

and non-essential goods using subscripts e and c , respectively.

There are five types of representative agents: a household, a producer of domestic essential goods, a producer of domestic non-essential goods, a producer of an essential good composite, and a producer of a non-essential good composite.

3.1 Household

The economy is populated by a representative household that is infinitely lived and discounts the future at rate $\beta < 1$. The household is endowed with one unit of labor that is supplied inelastically at wage rate w_t , and the household also owns domestic producers of essential and non-essential goods. Thus, every period the household earns labor income w_t as well as the profits or losses $\pi_{e,t}$ and $\pi_{c,t}$ incurred by the respective domestic producers.

Households have access to international financial markets where they can trade a one-period risk-free bond vis-a-vis the rest of the world. The bond is denominated in units of the numeraire and trades at an exogenous interest rate r that is time-invariant. Following Schmitt-Grohé and Uribe (2003), we assume households' bond-holding choices b_{t+1} are subject to a quadratic bond-holding cost $\frac{\Omega_b}{2} (b_{t+1} - \bar{b})^2$ denominated in units of non-essential goods, where Ω_b is a constant that controls the cost of adjusting bonds, and \bar{b} denotes the steady-state level of bond-holdings.

The household's budget constraint in a given period t is then given by:

$$p_{c,t}c_t + p_{e,t}e_t + b_t + p_{c,t}\frac{\Omega_b}{2}(b_{t+1} - \bar{b})^2 = w_t + \pi_{c,t} + \pi_{e,t} + \frac{b_{t+1}}{1+r},$$

where $p_{c,t}$ and $p_{e,t}$ denote the price of non-essential and essential goods, respectively, and c_t and e_t denote the consumption of non-essential and essential goods, respectively. Note this formulation implies bond-holdings $b_{t+1} > 0$ denote debt with the rest of the world, while $b_{t+1} < 0$ denotes savings lent to the rest of the world.

We assume that the household's period utility function is given by:

$$u(x_t) = \frac{x_t^{1-\xi}}{1-\xi},$$

where $1/\xi$ is the intertemporal elasticity of substitution and x_t is a constant elasticity of substitution bundle of essential and non-essential goods:

$$x_t = \left[(1-\gamma)c_t^{\frac{\rho-1}{\rho}} + \gamma \left(\frac{e_t}{\bar{e}_t} \right)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}},$$

where the parameter γ controls the relative importance of the two goods for the household's utility, ρ denotes the elasticity of substitution between essential and non-essential goods, and we refer to \bar{e}_t as the "reference level" of essential goods relative to which household consumption of these goods is evaluated. We model this reference level as exogenous and time-varying.

The goal of this non-standard utility specification is to capture key dimensions along which essential goods might be different from non-essential goods. The utility derived from the consumption of essential goods is a function of the ratio between the consumption level e_t and a reference level \bar{e}_t . Thus, a given level of essential goods provides high utility based on whether e_t is sufficiently higher than \bar{e}_t rather than on the absolute level of consumption. This captures the idea that households evaluate the consumption of essential goods such as food or health services relative to some reference level of needs for these goods. While akin to the subsistence level featured by Stone-Geary preferences, our specification allows for $e_t < \bar{e}_t$. Later in the paper we interpret changes of this reference level \bar{e}_t as capturing an increase in the amount of essential goods required during a pandemic.

The household's problem can be written as:

$$\max_{\{x_t, c_t, e_t, b_{t+1}\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{x_t^{1-\xi}}{1-\xi}$$

subject to

$$x_t = \left[(1-\gamma)c_t^{\frac{\rho-1}{\rho}} + \gamma \left(\frac{e_t}{\bar{e}_t} \right)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}} \quad \forall t = 0, \dots, \infty$$

$$p_{c,t}c_t + p_{e,t}e_t + b_t + p_{c,t} \frac{\Omega_b}{2} (b_{t+1} - \bar{b})^2 = w_t + \pi_{c,t} + \pi_{e,t} + \frac{b_{t+1}}{1+r} \quad \forall t = 0, \dots, \infty,$$

where the expectation operator is conditional on the information set at time period $t = 0$.

3.2 Rest of the world

The rest of the world is the trade and financial partner of the domestic economy. On the one hand, it produces a differentiated foreign variety in each sector $j \in \{c, e\}$, which is sold at a perfectly elastic price $q_{j,t}^m$ and subject to a sector-specific iceberg trade cost τ_j .⁹ These goods make up the domestic economy's imports. On the other hand, the rest of the world has a perfectly elastic demand for the domestic economy's varieties in each sector $j \in \{c, e\}$ at price $q_{j,t}^x$. These are the domestic economy's exports. Finally, the rest of the world is the financial counterpart of the domestic economy, demanding or supplying bonds at a perfectly elastic interest rate r .

3.3 Producers of domestic variety in sector $j \in \{c, e\}$

In each sector $j \in \{c, e\}$, a representative firm produces a domestic variety of either non-essential ($j = c$) or essential ($j = e$) goods using capital $k_{j,t}$ and labor $n_{j,t}$ at a time-invariant level of productivity A_j . The amount produced in each sector j is given by $y_{j,t} = A_j (n_{j,t}^\alpha k_{j,t}^{1-\alpha})^\eta$, where α controls the labor share, $1 - \alpha$ controls the capital share, and $\eta \in (0, 1)$ denotes the degree of decreasing returns to scale.¹⁰

Every period t , firms choose the amount of labor to use in production in t and the amount

⁹We abuse notation by indexing the non-essential and essential good sectors by c and e . Wherever necessary we distinguish these indexes from the variables used to denote the household's consumption of non-essential and essential goods, c_t and e_t .

¹⁰We assume the production technology features decreasing returns to scale to ensure the existence of a steady-state with non-zero production in both sectors across an arbitrary set of parameters.

of investment for production in $t+1$. We assume that investment and the capital stock consist of non-essential goods so that increasing the amount of capital by one unit in the following period requires investing $i_{j,t}$ units of non-essential goods today. Capital depreciates at rate δ , which implies that next period's capital stock $k_{j,t+1}$ is given by $(1 - \delta)k_{j,t} + i_{j,t}$.

Given our focus on investigating the economy's adjustment to an increased demand for essential goods, we introduce sectoral capital and labor adjustment costs in each sector to help us discipline the degree to which sectoral production can be changed over time. We assume that capital and labor adjustment costs are quadratic, consist of non-essential goods, and are given by:

$$\begin{aligned}\phi_{k,j}(k_{j,t+1}, k_{j,t}) &= \frac{\Omega_{k,j}}{2} \left(\frac{k_{j,t+1}}{k_{j,t}} - 1 \right)^2 \\ \phi_{n,j}(n_{j,t}, n_{j,t-1}) &= \frac{\Omega_{n,j}}{2} \left(\frac{n_{j,t}}{n_{j,t-1}} - 1 \right)^2,\end{aligned}$$

where $\Omega_{k,j}$ and $\Omega_{n,j}$ are positive sector-specific constants that control the degree to which adjusting production inputs is costly.

The representative firm produces a differentiated variety that is sold domestically and abroad. The firm chooses domestic sales subject to a downward-sloping demand function from domestic producers of composite goods. Exports are chosen subject to the perfectly elastic demand from the rest of the world at price $q_{j,t}^x$.

Then, the firm's problem consists of choosing the amount of labor, investment, and market-specific prices and quantities in each period to maximize lifetime discounted profits, where future returns are discounted at rate m_{t+1} . The firm's problem can be expressed as:

$$\begin{aligned}
& \max_{\{n_{j,t}, i_{j,t}, k_{j,t+1}, y_{j,t}^d, q_{j,t}^d, y_{j,t}^x\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} m_t \left[q_{j,t}^d y_{j,t}^d + q_{j,t}^x y_{j,t}^x - w_t n_{j,t} - p_{c,t} i_{j,t} \right. \\
& \quad \left. - p_{c,t} \phi_{k,j}(k_{j,t+1}, k_{j,t}) - p_{c,t} \phi_{n,j}(n_{j,t}, n_{j,t-1}) \right] \\
& \text{subject to} \\
& k'_{j,t} = (1 - \delta)k_{j,t} + i_{j,t} \quad \forall t = 0, \dots, \infty \\
& y_{j,t}^d + y_{j,t}^x = A_j \left(n_{j,t}^\alpha k_{j,t}^{1-\alpha} \right)^\eta \quad \forall t = 0, \dots, \infty \\
& y_{j,t}^d = \omega_j \left(\frac{q_{j,t}^d}{p_{j,t}} \right)^{-\sigma} y_{j,t} \quad \forall t = 0, \dots, \infty \\
& y_{j,t}^x \geq 0 \quad \forall t = 0, \dots, \infty,
\end{aligned}$$

where $q_{j,t}^d$ and $q_{j,t}^x$ denote the domestic and export price of the domestic variety in sector j , while $y_{j,t}^d$ and $y_{j,t}^x$ denote their respective quantities. The third constraint consists of the demand function faced domestically, which results from the problem of producers of composite good j described below.¹¹ Given the perfectly elastic demand faced from the rest of the world, the fourth constraint ensures that exports are weakly positive.

Finally, we assume that producers are myopic and do not internalize the impact of their production decisions on the household's utility. Thus, we assume that the rate at which firms discount the future is given by $m_t = \beta^t$ rather than by the household's stochastic discount factor. This assumption allows us to consider economies in which producers of essential goods do not internalize the importance of their production for social welfare beyond their focus on profit maximization. This assumption is consistent with recent studies on the importance of short-termism and hyperbolic discounting for the decisions of firms and individuals (Graham, Harvey, and Rajgopal 2005; Terry 2017; Azzimonti 2011; Krusell and Smith 2003; Cao and Werning 2018). In the quantitative analysis, we investigate the importance of this externality relative to an economy in which firms internalize the impact of production and investment decisions on welfare.

¹¹We remove the markup distortions that arise due to monopolistic competition by subsidizing every unit of domestic sales by $\frac{1}{\sigma-1}$; we omit this subsidy from the formulation above to simplify the exposition.

3.4 Producers of composite good $j \in \{c, e\}$

A representative firm produces a composite good $y_{j,t}$ by combining varieties of the good produced domestically ($z_{j,t}^d$) and abroad ($z_{j,t}^m$). To do so, the firm operates a constant elasticity of substitution technology given by:

$$y_{j,t} = \left[\omega_j z_{j,t}^d \frac{\sigma-1}{\sigma} + (1 - \omega_j) z_{j,t}^m \frac{\sigma-1}{\sigma} \right]^{\frac{\sigma}{\sigma-1}},$$

where $\omega_j \in (0, 1)$ denotes the relative weight of domestic vs. imported goods in the production of the composite good, and $\sigma > 0$ denotes the elasticity of substitution between domestic and imported varieties of good j .

The problem of the firm consists of choosing the amounts of inputs $z_{j,t}^d$ and $z_{j,t}^m$ to maximize profits. While the price of the domestic variety is given by $q_{j,t}^d$, the price of the imported variety is given by $\tau_j q_{j,t}^m$, the product of the foreign price and the trade costs. We assume that these trade costs are ad valorem and such that $\tau_j \geq 1$.

The firm's problem in period t is then given by:

$$\max_{y_{j,t}, z_{j,t}^d, z_{j,t}^m} p_{j,t} y_{j,t} - q_{j,t}^d z_{j,t}^d - \tau_j q_{j,t}^m z_{j,t}^m$$

subject to

$$y_{j,t} = \left[\omega_j z_{j,t}^d \frac{\sigma-1}{\sigma} + (1 - \omega_j) z_{j,t}^m \frac{\sigma-1}{\sigma} \right]^{\frac{\sigma}{\sigma-1}}.$$

3.5 Market clearing conditions

We let the price of the domestic variety of non-essential goods in the home country $q_{c,t}$ be our numeraire. Then, a *competitive equilibrium* consists of:

- prices $\left\{ w_t, p_{c,t}, p_{e,t}, q_{e,t}^d, q_{c,t}^d \right\}_{t=0}^{\infty}$,
- allocations:

$$\left\{ c_t, e_t, \pi_{c,t}, \pi_{e,t}, n_{c,t}, n_{e,t}, k_{c,t}, k_{e,t}, i_{c,t}, i_{e,t}, y_{c,t}, y_{c,t}^d, y_{c,t}^x, z_{c,t}^d, z_{c,t}^m, y_{e,t}, y_{e,t}^d, y_{e,t}^x, z_{e,t}^d, z_{e,t}^m \right\}_{t=0}^{\infty},$$

such that the following conditions hold:

1. Given prices, allocations solve the household's problem

2. Given prices, allocations solve problem of domestic producers
3. Given prices, allocations solve problem of composite good producers
4. Labor market clears: $n_{c,t} + n_{e,t} = 1 \forall t$
5. Home essential goods market clearing: $y_{e,t}^d = z_{e,t}^d \forall t$
6. Home non-essential goods market clearing: $y_{c,t}^d = z_{c,t}^d \forall t$
7. Essential composite good market clearing: $e_t = y_{e,t} \forall t$
8. Non-essential composite good market clearing:

$$c_t + \sum_{j \in \{c,e\}} \left[i_{j,t} + \frac{\Omega_{k,j}}{2} \left(\frac{k_{j,t+1}}{k_{j,t}} - 1 \right)^2 + \frac{\Omega_{n,j}}{2} \left(\frac{n_{j,t}}{n_{j,t-1}} - 1 \right)^2 \right] = y_{c,t} \forall t$$

4 Quantitative impact of a pandemic

We now investigate the impact of a pandemic in the model presented in the previous section. We begin by estimating the model to match salient features of the U.S. economy. We then examine the dynamics of the economy following a pandemic, and the role of international trade policy to mitigate some of these effects. In the next section we investigate the key channels that account for our findings.

4.1 Parameterization: Predetermined and pre-pandemic

To parametrize the model, we consider a period in the model to be a month in the data. We partition the parameter space into three groups: a set of predetermined parameters, a set of parameters that we estimate to match moments of the U.S. economy prior to the onset of COVID-19, and a set of parameters estimated to match the dynamics of the U.S. economy following COVID-19. We describe our approach to estimating this last set of parameters after describing how we model a global pandemic.

Predetermined parameters The set of predetermined parameters consists of the discount factor β , the intertemporal elasticity of substitution $1/\xi$, the elasticity of substitution

between domestic and foreign varieties of essential and non-essential goods (Armington elasticity) σ , the labor share α , the degree of returns to scale η , and the capital depreciation rate δ . We normalize weights ω_e and ω_c to $1/2$, and the productivity of essential good producers to 1. Table 2 reports the parameter values used throughout.

We set the values of β , σ , α , η , and δ to standard values from the literature. We set β to 0.99, and the elasticity of substitution to 4 following Simonovska and Waugh (2014), implying that domestic and foreign varieties of essential and non-essential goods are relatively substitutable. We set the labor share α to 0.66 and the degree of returns to scale η to 0.85 following Midrigan and Xu (2014) and Atkeson and Kehoe (2007). We set the monthly depreciation rate δ to 1% which implies an annual depreciation rate $\approx 11\%$.

Two key elasticities remain to be specified to parameterize the model: the intertemporal elasticity of substitution $1/\xi$ of the aggregate consumption bundle, and the intratemporal elasticity of substitution ρ between essential and non-essential goods. In our baseline, we consider $1/\xi = 0.10$ and, in the following subsections, estimate ρ to be below unity to match the dynamics of non-essential goods during the pandemic. Then, we consider a model in which essential goods are critical to household utility given that (i) essential and non-essential goods are complements, and that (ii) it is hard for households to substitute consumption of the aggregate bundle over time. We evaluate the role played by these complementarities after presenting our main results.

Thus, our model captures the potentially significant impact that limited access to essential goods can have on utility despite constituting a small fraction of the aggregate consumption bundle. If essential and non-essential goods are complementary within a period, scarce essential goods can make a significant dent on period utility regardless of the amount of non-essential goods that households might be able to consume. Similarly, if the aggregate consumption bundle is hard to substitute across periods, then lower utility in a given period due to limited essential goods will be hard to compensate with higher utility in some future period. Therefore, when a pandemic hits, essential goods need to be consumed right then, and there is little room to substitute its consumption within the period by consuming other goods, or over time by having greater consumption in the future.

Parameters estimated to match targets prior to COVID-19 The set of estimated parameters consists of the productivity of non-essential good producers A_c , the weight γ of

Table 2: Predetermined parameters

Parameter	Value	Description
β	0.99	Discount factor
$1/\xi$	0.10	Intertemporal elasticity of substitution
σ	4	Armington elasticity
α	0.66	Labor share
η	0.85	Returns to scale
δ	0.01	Capital depreciation rate ($\approx 11\%$ annual depreciation)
$\omega_e = \omega_c$	0.50	Weight on home goods
A_e	1	Productivity of essential good sector

essential goods in the household’s period utility function, the international trade costs τ_e and τ_c in essential and non-essential goods, the steady-state level of debt \bar{b} , and the reference level of essential goods \bar{e} in the steady-state.

We choose these six parameters to ensure that the steady-state of our model captures the following features of the U.S. economy prior to the onset of COVID-19: (i) the net exports-to-GDP ratio in essential goods, (ii) the share of essential goods in aggregate GDP, (iii) the share of essential good absorption that is imported, (iv) the share of non-essential good absorption that is imported, and (v) the aggregate net exports-to-GDP ratio. In addition, we focus on an economy such that (vi) $e = \bar{e}$ in the steady-state.

To compute empirical counterparts for these moments, we begin by classifying goods into essential and non-essential. Limited data availability prior to COVID-19 prevents us from restricting attention solely to those medical goods that have been key during COVID-19.¹² Thus, we define essential goods as consisting of a broader range of medical goods: (i) medical equipment and supplies manufacturing, and (ii) pharmaceutical and medicine manufacturing. Non-essential goods are defined to consist of the rest of U.S. manufactures. We compute all moments using data collected by the Bureau of Economic Analysis (BEA) and the U.S. Census for 2019.¹³

¹²The main constraint that we face is that the product-level gross output data is not sufficiently disaggregated to distinguish between personal protective equipment and other medical goods.

¹³International trade data from U.S. Census consists of product-level data at the HS-6-digit level of disaggregation. There are a total of 5,402 product categories, out of which 92 belong to the medical sector.

Table 3: Estimated parameters, pre-pandemic steady-state

Parameter	Value	Description
A_c	1.379	Sectoral productivity
γ	0.032	Utility weight on essential goods
τ_e	1.177	Trade costs on essential goods
τ_c	1.359	Trade costs on non-essential goods
\bar{b}	-2.683	Steady-state level of debt
\bar{e}	0.368	Reference level of essential goods

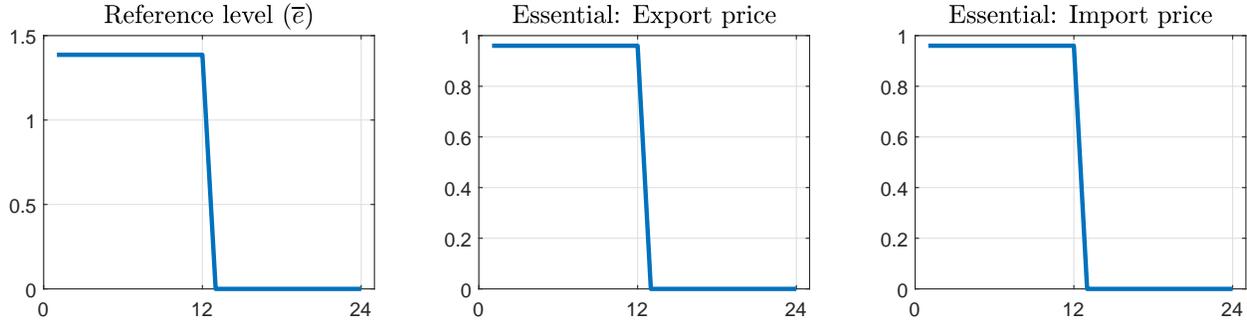
Moment	Target value	Model
NX_e/GDP_e	-0.174	-0.174
GDP_e/GDP	0.106	0.106
$M_e/p_e e$	0.380	0.380
$M_c/p_c c$	0.285	0.285
NX/GDP	-0.028	-0.028
e/\bar{e}	1.000	1.000

The estimated parameters as well as the empirical targets and their model counterparts are reported in Table 3. We find that the six parameters can be chosen to match the six targets exactly. To be a net importer of essential goods, the model requires producers of non-essential goods to be more productive than producers of essential goods. The model requires a very low utility weight on essential goods in order to match the low share of essential goods in aggregate GDP. Trade costs determine the extent to which absorption of essential and non-essential goods is imported. And, finally, the aggregate net exports-to-GDP ratio is determined by the steady-state level of debt \bar{b} .

4.2 A global pandemic

Motivated by the empirical evidence documented in Section 2, we model a global pandemic as the combination of unexpected domestic and foreign shocks that hit the steady-state of our economy.

On the domestic front, the economy experiences a shock to the reference level of essential



Note: x -axes denote time periods. y -axes are expressed as log deviations from steady-state.

Figure 4: A global pandemic

goods \bar{e} . This captures the increased need for medical goods to keep individuals safe and healthy during COVID-19, e.g., protective medical equipment such as sterile gloves, medical protective clothing, protective goggles, and masks. Therefore, our analysis abstracts from other multifaceted effects of the pandemic (e.g., social distancing policies, infection and death rates, increased unemployment), solely restricting attention to the increased demand for essential goods.

On the foreign front, the economy experiences two shocks. One shock is to the price of imported essential goods, and the other is a shock to the price of exports of essential goods. As documented in Section 2 and widely reported during the pandemic, the pandemic featured an increased demand for essential goods by all countries, which led to higher prices and rationing of essential goods. We model these effects as arising from shocks to q_e^x and q_e^m . To simplify the analysis, we assume that import and export prices increase by the same amount.

We consider a pandemic that lasts for 12 months, and let period 0 denote the initial steady-state. The full path of shocks is observed in period 1: in that period agents observe that the pandemic raises \bar{e} , q_e^x , and q_e^m for 12 periods, with their values reverted back to their steady-state in period 13. To simplify the analysis, we assume that the shocked parameters increase once-and-for-all during the pandemic.

Given data limitations, we parameterize the shocks by restricting attention to the four critical COVID-19 goods identified by the White House COVID-19 Supply Chain Task Force (WHTF) and described in detail in Section 2: N95 masks, surgical masks, face shields, and nitrile gloves. We set the shock to the reference level \bar{e} to match information on the increased demand for these goods as estimated by the WHTF and documented in Figure 2.1. For each

Table 4: Estimated parameters, pandemic dynamics

Parameter	Value	Description
ρ	0.373	Elasticity essential and non-essential
$\Omega_{k,c} = \Omega_{n,c}$	5.021	Adjustment costs: Non-essential
$\Omega_{k,e} = \Omega_{n,e}$	607.907	Adjustment costs: Essential
Ω_b	0.007	Bond-holding cost

Moment	Target value	Model
$e_t : \log(\text{Avg. Jun-Aug '20} / \text{Pre-pandemic})$	0.580	0.601
$y_{c,t} : \log(\text{Min. Mar-Dec '20} / \text{Pre-pandemic})$	-0.107	-0.105
$c_t : \log(\text{Min. Mar-Dec '20} / \text{Pre-pandemic})$	-0.199	-0.199
$NX_{e,t} : \log(\text{Avg. Mar-Aug '20} / \text{Pre-pandemic})$	0.680	0.680

good, we first identify the highest increase in demand relative to pre-pandemic demand, and then compute the median across goods. We find the demand for the median good to increase by 1.39 log-points at the peak relative pre-pandemic demand. We thus consider an increase of \bar{e} such that $\Delta \ln \bar{e} = 1.39$ during the 12 months of the pandemic. Figure 4 plots the dynamics of the shocks that characterize a pandemic in our model.

We set the shock to import and export prices to match information on changes in unit values of critical COVID-19 goods from the United States International Trade Commission (USITC) and the World Customs Organization (WCO). First, we identify the set of product codes corresponding to goods identified as critical by the WHTF, as described above.¹⁴ Then, for each good we identify the highest price change relative to pre-pandemic prices, and finally compute the median across goods. We find the price of the median good increased by 0.96 log-points at the peak relative to pre-pandemic prices. We thus consider an increase of import and export prices such that $\Delta \ln q_e^x = \Delta \ln q_e^m = 0.96$ during the 12 months of the pandemic.

Parameters estimated to match dynamics following COVID-19 Given our approach to modeling the pandemic, we estimate the remaining parameters to match salient

¹⁴We restrict attention to product codes with valid information throughout the first 12 months of the pandemic.

features of the dynamics of the U.S. economy following the onset of COVID-19: the elasticity of substitution ρ between essential and non-essential goods, the capital and labor adjustment costs $\{\Omega_{k,e}, \Omega_{n,e}\}$ faced by producers of essential goods, the capital and labor adjustment costs $\{\Omega_{k,c}, \Omega_{n,c}\}$ faced by producers of non-essential goods, and the bond-holding costs Ω_b . Given data limitations, we simplify the estimation by assuming that $\Omega_{k,e} = \Omega_{n,e}$ and $\Omega_{k,c} = \Omega_{n,c}$.

We choose these four parameters to match the following features of the U.S. economy after the onset of COVID-19: *(i)* the growth of essential good consumption during the second quarter of the pandemic relative to pre-pandemic levels, *(ii)* the trough of non-essential good output during the pandemic relative to pre-pandemic levels, *(iii)* the trough of non-essential good consumption during the pandemic relative to pre-pandemic levels, *(iv)* the growth of net exports of essential goods over the first six months of the pandemic relative to pre-pandemic levels.

We compute empirical counterparts for these moments as follows. We measure consumption of essential goods to compute moment *(i)* based on estimates of domestic production and imports by the White House COVID-19 Supply Chain Task Force for four critical goods, as described in Section 2. We first compute the median growth across goods for each month, and then average across months. We measure consumption and output of non-essential goods to compute moments *(ii)* and *(iii)* based on aggregate data from the Bureau of Economic Analysis. And, finally, we measure net exports of essential goods to compute moment *(iv)* using data for a broad range of medical goods.

We estimate the parameters through a simulated method of moments (SMM) algorithm, designed to minimize the sum of absolute deviations between the empirical moments and their model counterparts, assigning equal weight to each of the moments. Table 4 reports the estimated parameters as well as the empirical targets and their model counterparts. All moments are matched almost exactly except for the growth of essential good consumption. We find that essential and non-essential goods are estimated to be complementary, with an elasticity of substitution equal to 0.373. We estimate positive sectoral adjustment costs in both sectors, with larger costs faced by producers of non-essential goods. And, finally, we estimate mild bond-holding costs equal to 0.007.

4.3 Dynamics following a global pandemic

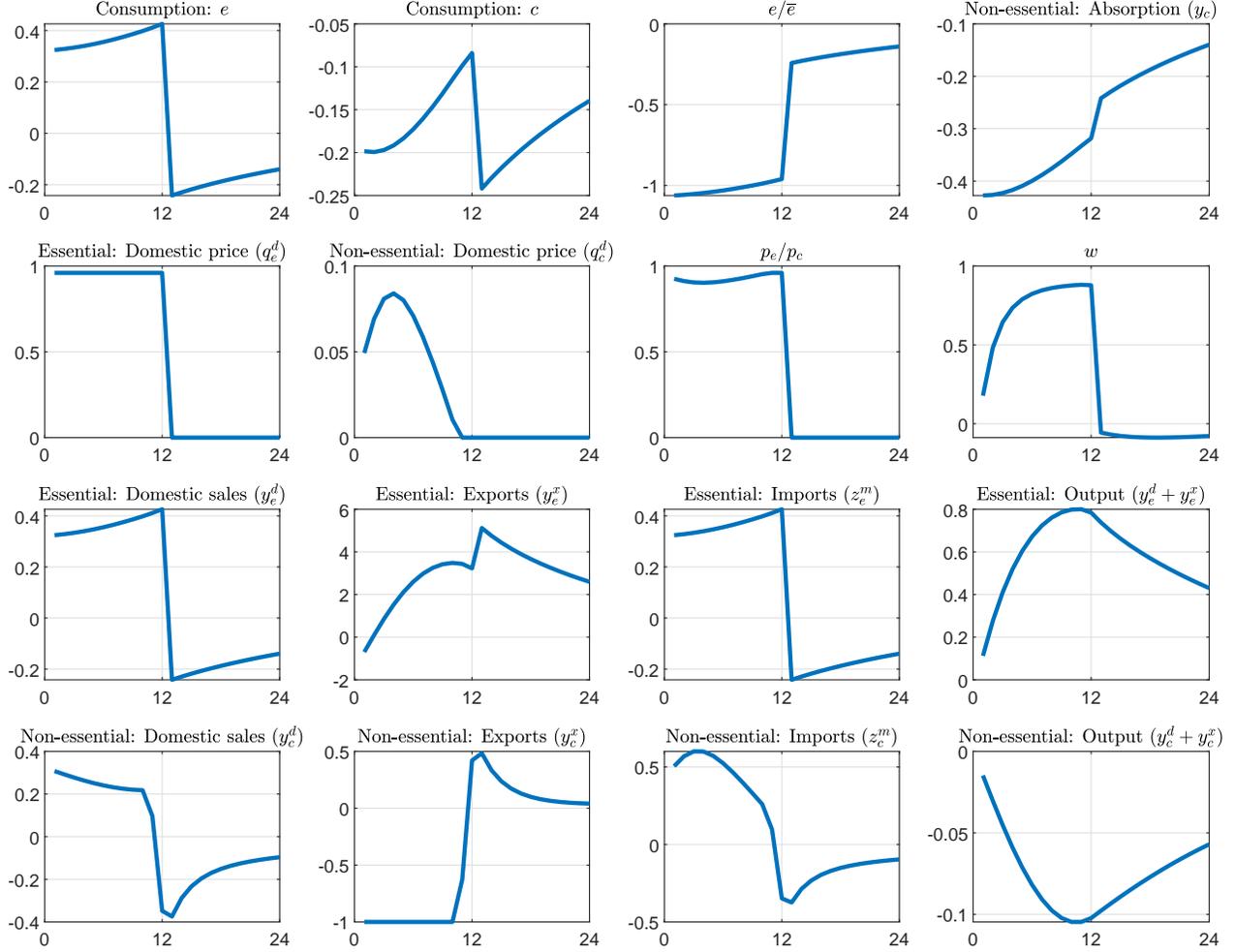
We begin by examining the impact of a global pandemic on key economic outcomes. To do so, Figure 5 plots impulse response functions following the shocks presented in Figure 4. Each panel presents the dynamics of key variables expressed in log-deviations from their steady-state values.¹⁵ We restrict attention to the dynamics over the first two years (24 periods), after which most variables are close to their steady-state values.

The complementarity between essential and non-essential goods implies that the increase in the reference level of essential goods raises the demand for these goods. If these goods were to be substitutes, then increases in the reference level could be offset by increasing consumption of non-essential goods. Yet, despite the increased demand for essential goods, consumption of these goods increases gradually due to a combination of domestic and international factors. On the domestic front, producers of essential goods increase their output gradually due to the costs involved in adjusting production, thereby preventing firms from producing enough additional goods to satisfy the increased demand. On the international front, the price of imports increases substantially, making it very costly to alleviate the increased needs via imports.

There is an additional channel that combines both domestic and international factors: the increased price of exports of essential goods due to the global nature of the pandemic. The higher price of exports leads domestic producers of essential goods to raise the domestic price of these goods and to reallocate sales from the domestic to the foreign market. Thus, exports of essential goods increase substantially after the first two months of the pandemic; in particular, they increase more rapidly than domestic sales of these goods.

The global pandemic also affects the consumption and production of non-essential goods. Recall that these goods are used for household consumption, to accumulate capital, and as sectoral adjustment costs. Household consumption of non-essential goods declines during the pandemic since it is complementary with e/\bar{e} . However, the overall demand for non-essential goods increases due to the reallocation of production towards essential goods, raising investment and expenditures on adjustment costs. This increased demand for non-essential goods is supplied through both higher imports and domestic sales. However, the higher factor costs reduce total production of non-essential goods, leading to a significant decline of exports.

¹⁵Except for exports which are expressed as percent deviation from steady-state.



Note: x -axes denote time periods (months). y -axes are expressed as log deviations from steady-state, except for exports which is expressed as $(y_{e,t}^x - y_{e,0}^x)/y_{e,0}^x$, where period 0 denotes the pre-pandemic steady-state.

Figure 5: Dynamics following a global pandemic

Our key finding is, thus, that consumption of essential goods increases gradually throughout the pandemic, and remains substantially below its reference level by the end of the pandemic. Adjusting production is costly and takes time, and that is one factor that slows down the consumption of essential goods. But, strikingly, we find that exports increase faster than domestic sales, as higher export prices lead firms to reallocate sales towards exports, pricing out domestic consumers. In the next subsection we investigate the extent to which these dynamics are welfare-maximizing or whether they might be improved upon via trade policies that facilitate domestic access to essential goods.

4.4 Optimal trade policy during a pandemic

As we show in the previous subsection, our model features a gradual increase of consumption of essential goods during a pandemic, remaining substantially below the increased needs. In particular, we find that exports of these goods increase relatively more than domestic sales. Thus, we now investigate the extent to which these dynamics are indeed welfare-maximizing, or whether there is a role for government policy to increase consumption of essential goods. Motivated by the drastic changes to trade policy on essential goods observed during COVID-19, as documented in Section 2, we now ask: To what extent would it be optimal for the government to adjust international trade policy on essential goods during a pandemic?

We answer this question by investigating the optimal design of trade policy *during* a pandemic; thus, we restrict attention to optimal policy *ex-post*. We endow the government of our small open economy with two trade policy instruments that apply only to essential goods: (i) import tariffs/subsidies, and (ii) exports taxes/subsidies. To simplify the analysis, we restrict attention to one-time changes to (i) and (ii) that remain active throughout the duration of the pandemic, reverting back to zero (i.e., their steady-state values) after the pandemic ends in period 13. Revenue collected through these instruments is reimbursed as a lump-sum transfer to the households; similarly, subsidies distributed through these instruments are taxed lump-sum to households. Note that this is a unilateral trade policy and we do not allow for retaliation.

The government's problem consists of choosing the value of each of these instruments throughout the pandemic to maximize the household's lifetime expected utility starting from the period in which the pandemic hits (period 1). Formally, the problem is given by:

$$\max_{\nu_m, \nu_x} \mathbb{E}_1 \sum_{t=1}^{\infty} \beta^{t-1} \frac{x_t^{CE}(\nu_m, \nu_x)^{1-\xi}}{1-\xi}$$

where ν_m and ν_x denote import tariffs and export taxes, respectively, while $x_t^{CE}(\nu_m, \nu_x)$ denotes the period- t consumption bundle in a competitive equilibrium following the realization of the shocks described in previous sections and subject to import tariffs ν_m and export tariffs ν_x throughout the duration of the pandemic. The expectations operator is conditional on the information set in period 1; that is, the period in which the shocks are realized.

Table 5 reports the optimal import tariffs and export taxes that solve the government's

Table 5: Optimal trade policy following a pandemic

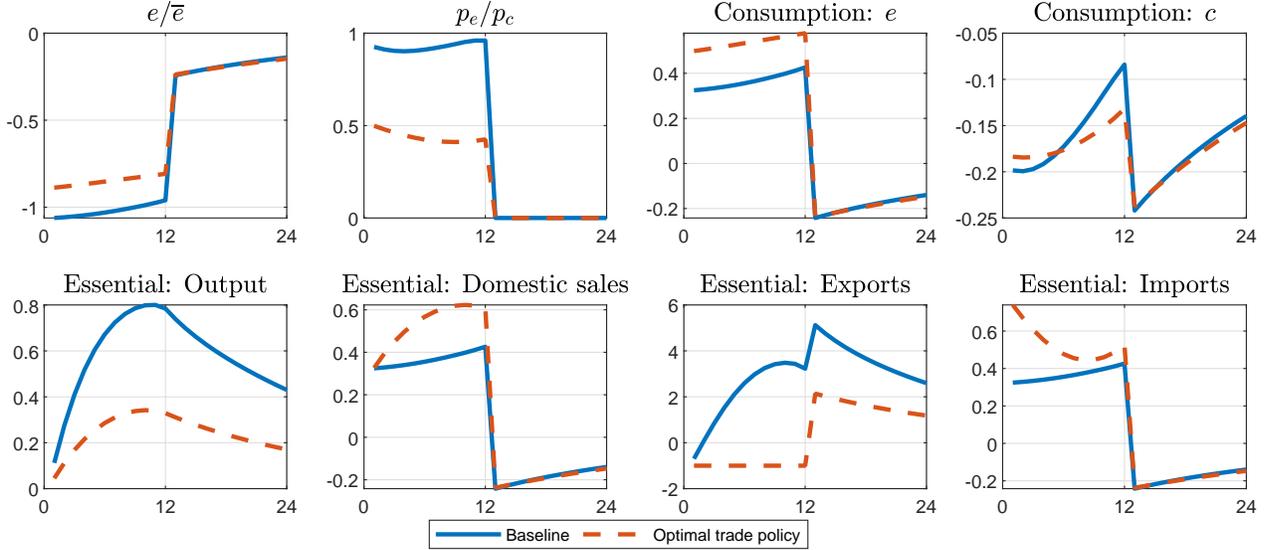
	Export tax	Import tariff	Welfare gain
Baseline	43.83%	−40.64%	4.07%
No pandemic (steady-state)	0.00%	0.00%	—
Rational firms (non-myopic)	0.00%	0.00%	0.00%
Weak intra-temporal complementarity ($\rho = 1.50$)	14.30%	− 5.62%	0.08%
Weak inter-temporal complementarity ($\xi = 0.50$)	5.23%	− 4.44%	0.04%
Net exporter of essential goods ($NX_e/GDP_e = 0.80$)	13.55%	−11.95%	0.04%

problem.¹⁶ The first row of this table shows that the government finds it optimal to introduce a 43.83% tax on exports of essential goods during the pandemic, along with a 40.64% subsidy on imports of essential goods. This trade policy response is consistent with the drastic trade policy changes observed across countries during COVID-19, as documented in Section 2. In particular, we interpret export taxes and import subsidies as consistent with a broad range of barriers to export and incentives to import introduced during COVID-19 (e.g., the introduction of export bans or quotas, the decline in import tariffs, etc.).

We contrast these findings with the optimal trade policy instruments in an economy that is not subject to a pandemic but which remains at the initial steady-state throughout. The second row of the table reports that the optimal trade policy instruments in this case are to keep import tariffs and export taxes at zero, their steady-state values. This finding shows that the optimal trade policy response during the pandemic is indeed a response to the pandemic and not arising from other motives for trade policy that could be featured by our model.

These striking findings raise numerous questions on the impact of these policies and the sources that account for the optimal trade policy response during a pandemic. We address these questions in two ways. First, in the next subsection we investigate the impact of optimal trade policy on the dynamics following a pandemic. Second, in the next section we investigate the role played by various features of the model in accounting for our findings.

¹⁶The trade policy instruments that solve the government’s problem are optimal subject to the trade policy instruments that we endow the government with. While they are welfare-improving, they need not achieve the first-best allocations or solve the government’s problem under a broader set of instruments.



Note: x -axes denote time periods (months). y -axes are expressed as log deviations from steady-state, except for exports which is expressed as $(y_{e,t}^x - y_{e,0}^x)/y_{e,0}^x$, where period 0 denotes the pre-pandemic steady-state.

Figure 6: Pandemic dynamics under optimal trade policy

Impact of optimal trade policy We now investigate the impact of the optimal trade policy response during a pandemic. How different are the dynamics of the economy during a pandemic under optimal trade policy, and along which dimensions? To address these questions, Figure 6 contrasts impulse response functions for key variables of the model under the optimal trade policy response vs. the dynamics without trade policy changes.

We find that optimal trade policy allows households to increase their consumption of essential goods relatively more than in the baseline model without trade policy changes. This mitigates the decline of essential good consumption relative to their reference level, e/\bar{e} . Notice, however, that consumption of these goods remains substantially below the reference level even under optimal trade policy.

On the one hand, the tax on exports leads firms to reduce the domestic price of essential goods. While this discourages production of essential goods, slowing down the increase of output, it leads to a reallocation of sales from exports to domestic consumers. Thus, domestic sales increase relatively more than under the baseline, while exports decline to zero throughout the duration of the pandemic.

Thus, optimal export taxes result from balancing two conflicting forces: they reduce the incentives to produce essential goods, which are much needed during the pandemic, but they reduce the domestic price of essential goods, increasing domestic access to such

domestically-produced goods.

On the other hand, the import subsidy allows households to purchase imports of essential goods at a lower price, increasing imports of these goods. Thus, we find that both export taxes and import subsidies increase domestic consumption of essential goods, mitigating the negative impact of the pandemic due to the increase in the reference level \bar{e} .

5 Key determinants of optimal trade policy

We now investigate the features of our model that account for the optimal response of international trade policy during a pandemic. We focus on four channels that, combined, create a role for changes in international trade policy to improve welfare.

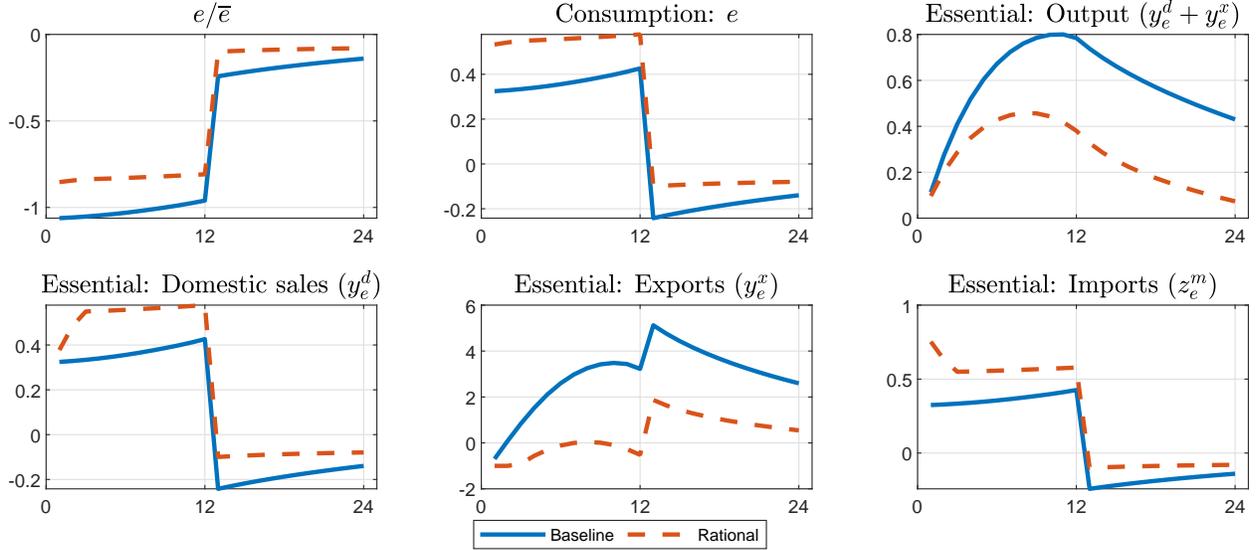
5.1 Myopic firms

We begin by investigating the role played by our assumption that firms are myopic and discount future profits at rate $1/(1+r)^{17}$. We do so by studying an alternative version of the model in which the goals of households and firms are aligned, and firms discount profit flows with the household’s stochastic discount factor; we refer to this alternative economy as one with “rational” firms. We keep all parameter values unchanged at the values reported in the previous section.

Figure 7 contrasts the impulse response functions for key variables of the model between our baseline economy and the economy with rational firms. We find that the economy with rational firms features dynamics of production and consumption of essential goods that are close to those attained under the optimal trade policy (Figure 6). Consumption of essential goods increases more than in the baseline model through an increase of both domestic sales and imports. But production of essential goods increases less than in the baseline, and there is a much milder response of exports.

In the economy with myopic firms, the higher price of essential goods during the pandemic leads firms to rapidly scale up production, incurring significant costs of adjustment early in the pandemic to increase sales and profits later on. This intertemporal tradeoff is costly to households, as they are required to finance short-term losses at the onset of a pandemic, to be compensated with higher income later on. Their low intertemporal elasticity of substitution

¹⁷Or at rate β , given $\beta(1+r) = 1$.



Note: x -axes denote time periods (months). y -axes are expressed as log deviations from steady-state, except for exports which is expressed as $(y_{e,t}^x - y_{e,0}^x)/y_{e,0}^x$, where period 0 denotes the pre-pandemic steady-state.

Figure 7: Pandemic dynamics, role of firm-level myopia

exacerbates the cost of this tradeoff. In contrast, in the economy with rational firms, firms internalize the cost of rapidly scaling up production and, instead, increase production at a more gradual scale. This provides households with higher disposable income to increase their demand for domestic and imported essential goods, increasing their overall consumption of essential goods.

We conclude this discussion by examining the implications of firm myopia for optimal policy. To do so, we recompute the optimal import tariffs and export taxes under the assumption that firms are rational, following the approach described in the previous section. The third row of Table 5 shows that the optimal policy response in this alternative environment is to keep import tariffs and export taxes unchanged at their zero steady-state values. Thus, we conclude that firm myopia plays a fundamental role in creating a role for trade policy interventions in our economy. In particular, the goal of these policies is to realign the goals of the firms with those of households.

5.2 Intra- and inter-temporal complementarities

We now investigate the role played by the intra- and inter-temporal complementarities featured by our model. On the one hand, we estimate the intra-temporal elasticity of substitu-

tion between essential and non-essential goods to be below unity, capturing the difficulty to substitute goods needed during a pandemic with consumption of other less essential goods. On the other hand, we consider a parametrization with a low intertemporal elasticity of substitution, to capture the difficulty to tradeoff consumption bundles over time, particularly during a pandemic.

Intra-temporal complementarities We study the role of intra-temporal complementarity by considering an alternative version of the model in which essential and non-essential goods are more easily substitutable within a given time period. In particular, we set $\rho = 1.50$ and re-estimate the parameters in Table 3 to ensure we capture salient cross-sectional features of the U.S. economy prior to COVID-19; all other parameters are kept unchanged at their baseline values. Figure 8 contrasts the impulse response functions for key variables of the model between our baseline economy and the economy with weaker intra-temporal complementarity.

We find substantial differences across these economies. With a higher substitutability between essential and non-essential goods, households reduce their consumption of essential goods rather than increase it in response to the higher reference level realized during the pandemic. The foregone consumption of essential goods is, thus, replaced by consumption of non-essential goods. Exports of essential goods increase, but production increases less as there is a large drop in domestic demand of these goods.

These findings imply that households experience a much sharper and persistent decline of e/\bar{e} during the pandemic. However, in contrast to the baseline economy, the contribution of this decline to overall welfare is more easily substituted by increased consumption of non-essential goods. Therefore, we find that the economy with weak intra-temporal complementarities features a much milder motive for optimal trade policy interventions, as reported in the fourth row of Table 5: the optimal export tax is 14.30% and the optimal import subsidy is 5.62%.

Inter-temporal complementarities We study the role of inter-temporal complementarities by considering an alternative version of the model in which the household's consumption bundle is more easily substitutable across time periods than in our baseline. In particular, we set $\xi = 0.50$ and re-estimate the parameters in Table 3 to capture salient cross-sectional

features of the U.S. economy prior to COVID-19; all other parameters are kept unchanged at their baseline values. Figure 8 contrasts the impulse response functions of key variables of the model between our baseline economy and the economy with weaker inter-temporal complementarity.

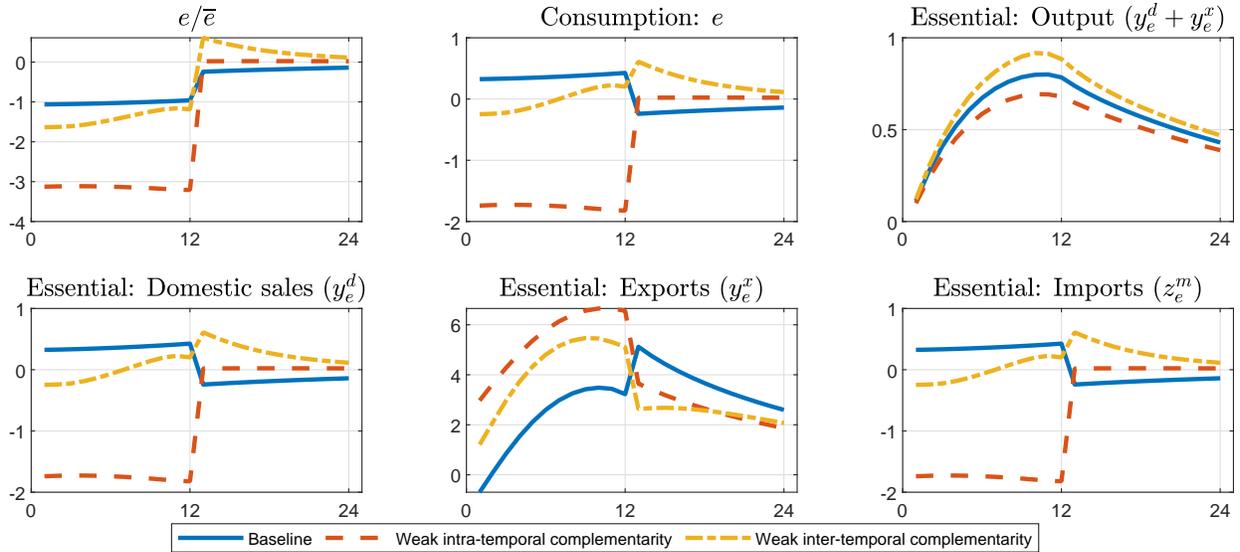
Weak inter-temporal complementarities make it easier for households to substitute consumption over time. This helps them mitigate the impact of the pandemic, allowing them to reduce their consumption of essential goods at its onset, when supply of essential goods is low and the adjustment costs are being incurred, and to substitute such early consumption for increased consumption of essential goods in later time periods. Thus, output and exports of essential goods increase faster than in the baseline, while consumption declines on impact but increases over time. In particular, weak inter-temporal complementarities allow households to easily substitute consumption of essential goods *during* the pandemic with consumption of these goods *after* the pandemic.

As with weak intra-temporal complementarities, these findings imply that increased intertemporal substitution decreases the welfare cost experienced by households during the pandemic: In this alternative environment, households can overcome the increased needs for essential goods during the pandemic with increased consumption of these goods after the pandemic is over, when costs are back at their steady-state levels. Thus, we find that the economy with weak inter-temporal complementarities features a weaker motive for optimal trade policy interventions, as reported in the fifth row of Table 5: the optimal export tax is 5.23% and the optimal import subsidy is 4.44%.

5.3 Dependence on international trade

We conclude the analysis in this section by investigating the role played by the pattern of comparative advantage and dependence on international trade for essential goods. As in the U.S., the baseline economy is highly dependent on international trade for its consumption of essential goods: its import share in these goods is 38%, and their trade deficit equals 17.4% of their total production.

We study the role of this high trade dependence by focusing on the economy's trade balance of essential goods. Our focus on this channel is motivated by the findings of Kohn, Leibovici, and Tretvoll (2021), where the economic impact of sectoral price changes can be significantly determined by the pattern of sectoral trade balances. Thus, we consider an



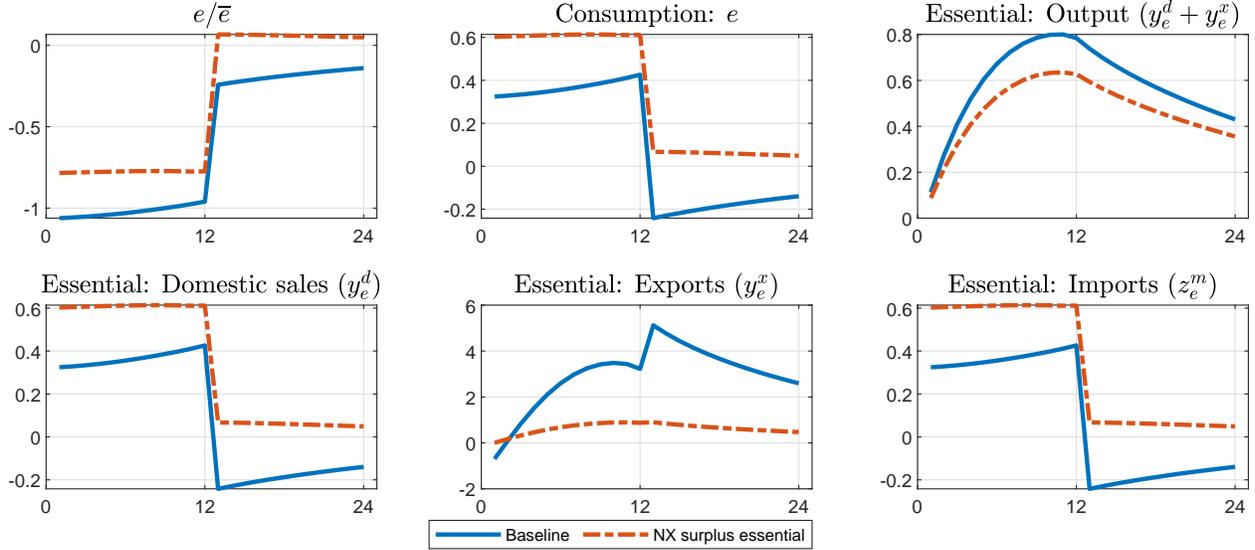
Note: x -axes denote time periods (months). y -axes are expressed as log deviations from steady-state, except for exports which is expressed as $(y_{e,t}^x - y_{e,0}^x)/y_{e,0}^x$, where period 0 denotes the pre-pandemic steady-state.

Figure 8: Pandemic dynamics, role of complementarities

economy recalibrated to match the same cross-sectional features of the U.S. economy prior to COVID-19, but targeting a sectoral trade surplus equal to 80% of total essential good production rather than the sectoral trade deficit observed in the data. We re-estimate the parameters in Table 3 but keep all other parameters at their baseline values.

Figure 9 contrasts key variables of the model between the baseline economy and the alternative economy recalibrated to match a counter-factually high trade surplus in essential goods. We find that consumption of essential goods increases more and faster in the alternative economy than in the baseline, through an increased demand for both domestic and imported varieties. The higher import and export prices of essential goods have two opposing effects. On the one hand, they hurt households as they make domestic and imported varieties more expensive. On the other hand, they increase household income as they increase the profits made by producers of essential goods from both domestic and export sales. The relative importance of these forces is crucially controlled by the economy's trade balance in these goods. As the trade surplus in these goods increases, the relative importance of the latter channel increases, leading to a higher consumption of essential goods and a lower increase of exports.

While the pandemic is costly for the economy with trade surplus in essential goods, these costs are lower than in the baseline, as household consumption of essential goods relative



Note: x -axes denote time periods (months). y -axes are expressed as log deviations from steady-state, except for exports which is expressed as $(y_{e,t}^x - y_{e,0}^x)/y_{e,0}^x$, where period 0 denotes the pre-pandemic steady-state.

Figure 9: Pandemic dynamics, role of international trade dependence

to the reference level declines less. The cost of taxing exports is also higher given the high trade surplus in these goods. Therefore, we find that the optimal trade policy response is substantially milder than in the baseline economy: the optimal export tax is equal to 13.55%, while the optimal import subsidy is 11.95%.

6 Welfare gains from optimal trade policy

We conclude our analysis by investigating the welfare implications of adjusting international trade policy on essential goods optimally during a pandemic. To do so, we compute the welfare gains in consumption-equivalent units between two economies with alternative pandemic dynamics: an economy without changes in international trade policy vs. an economy with optimal changes in international trade policy, as described in previous sections. Specifically, we ask: What percentage increase of the consumption bundle every period would make households in the economy without trade policy changes indifferent to living in an economy with optimal trade policy adjustment during a pandemic?

The last column of Table 5 reports our findings for our baseline model as well as for the alternative economies examined in the previous section. We find that, in the baseline model, households in an economy without trade policy changes would need their consumption bundle

to increase by 4.07% every period forever to remain indifferent to living in the economy under the optimal trade policies reported in the first two columns of the table.

These welfare gains are quantitatively significant, orders of magnitude larger than the welfare cost of business cycles and similar to the welfare gains from trade. Furthermore, note that these are welfare gains that accrue from introducing policies only throughout the duration of the pandemic. Thus, while the policies are introduced only throughout 12 periods, the welfare gains are measured by computing in consumption-equivalence units based on a permanent lifetime proportional increase of consumption.

These effects contrast sharply with the welfare gains from optimal trade policy under each of the economies that we analyze in the previous section; see the last column of rows 3 to 6 in Table 5. Consistent with our previous findings, the welfare gains from optimal trade policy are much lower if firms are rational, if there are weak inter- or intra-temporal complementarities, or if the small open economy has a trade surplus in essential goods. The welfare gains are virtually zero in all cases, showing that these channels play a critical role in creating incentives for trade policy interventions that can improve welfare.

7 Concluding remarks

This paper studies international trade policy during a pandemic. We find that international trade plays an important role on the impact of a pandemic, allowing countries to raise their consumption of essential goods through imports, but providing an incentive to domestic producers to reallocate domestic sales to the foreign market to take advantage of the higher export prices for these goods during a pandemic. We find that the unilateral optimal trade policy response is to subsidize imports while taxing exports. These findings are consistent with evidence on changes in trade barriers observed across countries during the COVID-19 pandemic.

Our analysis reveals that firm myopia, intra- and inter-temporal consumption complementarities, and trade dependence on essential goods are all critical ingredients leading to the introduction of export taxes and import subsidies as a way to boost the consumption of essential goods. But our findings also naturally depend on other important features of the analysis. For instance, our focus on a global pandemic rather than a merely domestic epidemic is implicit in our assumption that the price of imports and exports of essential

goods increase along with the higher reference level. Absent these price increases, increasing consumption of essential goods would be much easier and less costly.

Similarly, our analysis restricts attention to the optimal unilateral design of international trade policy. Thus, these findings raise key questions on the potential to identify multilateral trade policy solutions that dominate the incentives to adjust trade policy unilaterally during a pandemic. While a broader multilateral analysis of optimal trade policy is beyond the scope of the paper, this is an important area to be examined in future research.

Finally, we restrict attention to international trade policy instruments and from an ex-post perspective; that is, we focus on the optimal response once the pandemic hits. Non-trade policy instruments such as domestic production or consumption subsidies could complement the trade policy response. But the analysis of policy design ex-ante limits the set of instruments that one could examine, since policies such as ensuring sufficient stock-piles of essential goods could be beneficial if implemented prior to a pandemic but are not likely to be an optimal response once the pandemic is realized. Further analysis of non-trade policies both ex-post and ex-ante are likely to be fruitful areas for future research.

References

- ALVAREZ, F. (2017): “Capital accumulation and international trade,” *Journal of Monetary Economics*, 91, 1–18.
- ANDERSON, J. E., M. LARCH, AND Y. V. YOTOV (2020): “Growth and trade with frictions: A structural estimation framework,” Discussion paper.
- ATKESON, A., AND P. J. KEHOE (2007): “Modeling the transition to a new economy: lessons from two technological revolutions,” *American Economic Review*, 97(1), 64–88.
- AZZIMONTI, M. (2011): “Barriers to investment in polarized societies,” *American Economic Review*, 101(5), 2182–2204.
- BACKUS, D. K., P. J. KEHOE, AND F. E. KYDLAND (1992): “International real business cycles,” *Journal of political Economy*, 100(4), 745–775.
- BALDWIN, R. E., AND S. J. EVENETT (eds.) (2020): *COVID-19 and Trade Policy: Why Turning Inward Won’t Work*. CEPR Press.
- BAQAEE, D., AND E. FARHI (2019a): “Networks, barriers, and trade,” Discussion paper, National Bureau of Economic Research.
- BAQAEE, D. R., AND E. FARHI (2019b): “The macroeconomic impact of microeconomic shocks: beyond Hulten’s Theorem,” *Econometrica*, 87(4), 1155–1203.

- BONADIO, B., Z. HUO, A. A. LEVCHENKO, AND N. PANDALAI-NAYAR (2020): “Global supply chains in the pandemic,” Discussion paper, National Bureau of Economic Research.
- ÇAKMAKLI, C., S. DEMIRALP, E. KALEMLI-OZCAN, S. YEŞİLTAŞ, AND M. A. YILDIRIM (2021): “The economic case for global vaccinations: An epidemiological model with international production networks,” Discussion paper, National Bureau of Economic Research.
- CAO, D., AND I. WERNING (2018): “Saving and dissaving with hyperbolic discounting,” *Econometrica*, 86(3), 805–857.
- COSTINOT, A., A. RODRÍGUEZ-CLARE, AND I. WERNING (2020): “Micro to macro: Optimal trade policy with firm heterogeneity,” *Econometrica*, 88(6), 2739–2776.
- DEMIDOVA, S., AND A. RODRÍGUEZ-CLARE (2009): “Trade policy under firm-level heterogeneity in a small economy,” *Journal of International Economics*, 78(1), 100–112.
- EVENETT, S. (2020): “Tackling COVID-19 together: The trade policy dimension,” *Global Trade Alert*, 23.
- FELBERMAYR, G., B. JUNG, AND M. LARCH (2013): “Optimal tariffs, retaliation, and the welfare loss from tariff wars in the Melitz model,” *Journal of International Economics*, 89(1), 13–25.
- GRAHAM, J. R., C. R. HARVEY, AND S. RAJGOPAL (2005): “The economic implications of corporate financial reporting,” *Journal of accounting and economics*, 40(1-3), 3–73.
- IRWIN, D. A. (2017): *Peddling Protectionism*. Princeton University Press.
- KOHN, D., F. LEIBOVICI, AND H. TRETVOLL (2021): “Trade in commodities and business cycle volatility,” *American Economic Journal: Macroeconomics*, 13(3), 173–208.
- KRUSELL, P., AND A. A. SMITH (2003): “Consumption-savings decisions with quasi-geometric discounting,” *Econometrica*, 71(1), 365–375.
- LABELLE, J., F. LEIBOVICI, AND A. M. SANTACREU (2021): “Global Value Chains and US Economic Activity During COVID-19,” *Federal Reserve Bank of St. Louis Review*.
- MENDOZA, E. G. (1995): “The terms of trade, the real exchange rate, and economic fluctuations,” *International Economic Review*, pp. 101–137.
- MIDRIGAN, V., AND D. Y. XU (2014): “Finance and misallocation: Evidence from plant-level data,” *American economic review*, 104(2), 422–58.
- OLSON, M., AND R. ZECKHAUSER (1966): “An economic theory of alliances,” *The review of economics and statistics*, pp. 266–279.
- OSSA, R. (2011): “A “new trade” theory of GATT/WTO negotiations,” *Journal of Political Economy*, 119(1), 122–152.

- RAVIKUMAR, B., A. M. SANTACREU, AND M. SPOSI (2019): “Capital accumulation and dynamic gains from trade,” *Journal of International Economics*, 119, 93–110.
- SCHMITT-GROHÉ, S., AND M. URIBE (2003): “Closing small open economy models,” *Journal of international Economics*, 61(1), 163–185.
- SCHMITT-GROHÉ, S., AND M. URIBE (2018): “How Important are Terms-Of-Trade Shocks?,” *International Economic Review*, 59(1), 85–111.
- SIMONOVSKA, I., AND M. E. WAUGH (2014): “The Elasticity of Trade: Estimates and Evidence,” *Journal of International Economics*, 92(1), 34–50.
- STELLINGER, A., I. BERGLUND, AND H. ISAKSON (2020): “How trade can fight the pandemic and contribute to global health,” *COVID-19 and Trade Policy: Why Turning Inward Won't Work*.
- TERRY, S. J. (2017): “The Macro Impact of Short-Termism,” .

Appendix

A Data Sources

Here we describe the main data sources used throughout the paper in the empirical section and the quantitative analysis.

1. The classification of COVID-19 related products is from Annex 1 of the following document created by the World Trade Organization (WTO): https://www.wto.org/english/news_e/news20_e/rese_03apr20_e.pdf.
2. Data on trade policy interventions are from Global Trade Alert: <https://www.globaltradealert.org/>. We restrict our attention to policy interventions that involve export restrictions (imposing export bans, licensing requirements, taxes, quotas, and non-tariff measures) and import liberalizations (reducing import tariffs, licensing requirements, quotas, bans and non-tariff measures) We use data from January to December 2020.
3. Domestic gross output and value added data by industry are collected from the Bureau of Economic Analysis (BEA), GDP by industry: <https://www.bea.gov/data/gdp/gdp-industry>. We use data for the year 2019. Medical goods correspond to the categories “Medical equipment and supplies manufacturing” and “Pharmaceutical and medicine manufacturing.”
4. Monthly data on imports and exports of medical goods (values and unit prices) are from the US Census, USA Trade Online: <https://usatrade.census.gov/>.
5. Data on demand and production (domestic and imports) are from estimates computed by the White House Task Force. The projections were created by the White House Supply Chain Task Force, released by Democratic Sen. Maggie Hassan’s office: <https://www.hassan.senate.gov/imo/media/doc/SCTF%20Demand%20PPE%20Chart.pdf>