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Shortages of Critical Goods in a Global Economy: Optimal Trade and Industrial Policy

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Abstract

This paper studies optimal trade and industrial policy in response to shortages of critical goods following global shocks. We develop a dynamic open-economy model with essential and non-essential goods, heterogeneous households, and incomplete financial markets. When global demand for essential goods rises, households fail to internalize how their borrowing choices affect aggregate interest rates, leading to excessive discounting of future returns and underinvestment. Trade amplifies shortages as producers reallocate supply toward exports. Calibrated to the U.S. during COVID-19, the model shows that export taxes, import subsidies, and production subsidies mitigate shortages, increase welfare, and align with observed cross-country policy responses.

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1 Introduction

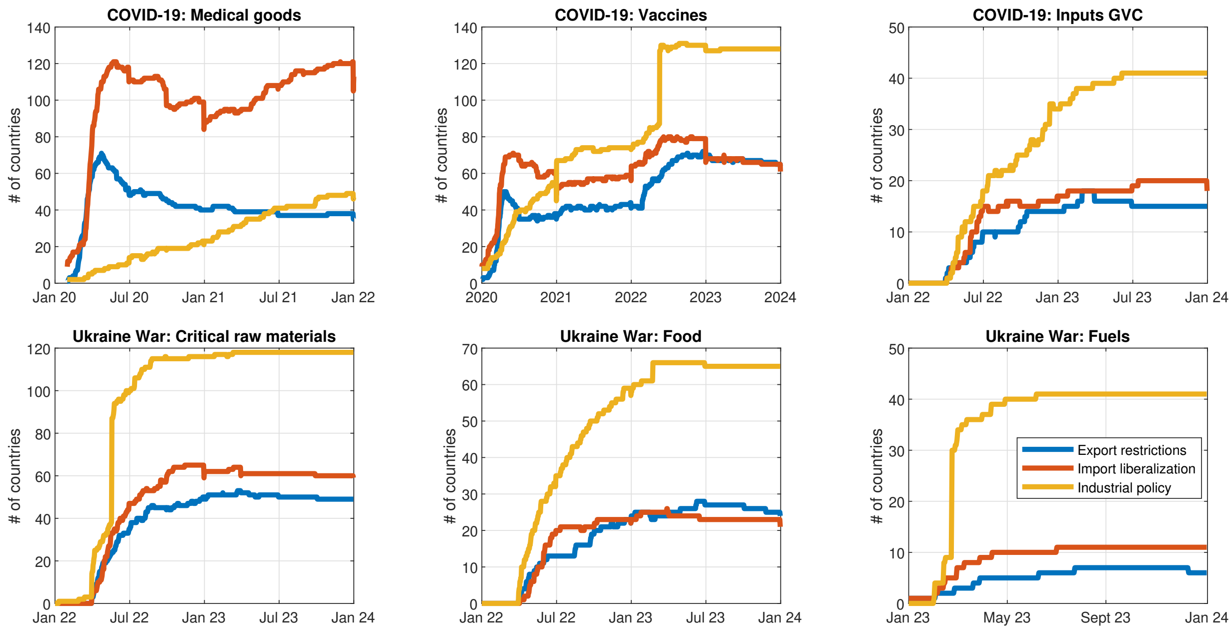
After decades of trade liberalization, the global economy is witnessing a renewed turn toward protectionism. Recent crises—including the COVID-19 pandemic, the Russian invasion of Ukraine, and rising geopolitical tensions—have exposed the vulnerabilities of open economies heavily reliant on imports of critical goods such as semiconductors, energy and raw materials, and medical equipment. These episodes triggered severe shortages that prompted governments around the world to enact a wave of trade and industrial policy interventions, including export controls, import liberalizations, and production subsidies.

Indeed, in the aftermath of Russia's invasion of Ukraine and the COVID-19 pandemic, there was a sharp increase in the number of countries that introduced trade and industrial policies to mitigate shortages of goods affected by these episodes: raw materials, food, and fuels during the Ukraine war; medical goods, vaccines, and global value chain inputs—e.g., semiconductors—during COVID-19. Figure 1, based on data from Global Trade Alert, suggests countries attempted to address shortages of these goods by restricting exports, liberalizing imports, and promoting domestic production.

Motivated by these patterns, in this paper we study the role of trade and industrial policy in mitigating shortages of critical goods. Our focus is on ex-post interventions—that is, how policy can be used to mitigate the impact of shortages after they occur, rather than prevent them in advance. We develop a dynamic model of a small open economy in which firms produce essential and non-essential goods, accumulate capital, and trade with the rest of the world. Despite international specialization, domestic firms often have the capacity to expand production in response to shortages. However, this adjustment may be inefficient when the private cost of investment exceeds its social return—particularly when scaling up production requires large upfront investments financed through internal funds or costly borrowing.

Our model focuses on two key frictions that distort firms' investment behavior. First, households face incomplete financial markets and borrow at an endogenous interest rate. While each household internalizes the effect of its own borrowing on the interest rate, they do not account for how their borrowing affects the borrowing costs faced by others. This partial internalization gives rise to a borrowing externality, distorting the discounting of future returns. As a result, firms undervalue future profits, weakening their incentives to invest. Second, firm ownership is imperfectly diversified across households. In an environment with these features, producers under-invest relative to the first-best, introducing a role for policy.

Figure 1: Trade and Industrial Policies Following Global Shocks



Notes: Data from Global Trade Alert's "The Essential Goods Initiative+: Tracking policies in essential goods including Food, Fuel, Critical Raw Materials and Medical Products." The figure illustrates the cumulative number of policy interventions by type following global shocks, specifically the COVID-19 pandemic and the Russian invasion of Ukraine.

The first channel is well documented in the literature on financial frictions and incomplete markets in both emerging and advanced economies (Buera, Kaboski, and Shin 2011; Midrigan and Xu 2014; Dinlersoz et al. 2018; Leibovici and Wiczer 2023). Empirical evidence suggests that financial constraints impaired firms' ability to scale up production during COVID-19, a concern widely recognized by policymakers. Firm-level data from the New Industrial Policy Observatory (NIPO) show that nearly half of all industrial policy interventions targeting medical goods in OECD countries focused on easing financial constraints—through direct loans, loan guarantees, and bond purchases. We also document that even prominent U.S. public firms received targeted financial support to expand production capacity.

The second channel is motivated by empirical evidence on the concentration of firm ownership, summarized in Table 2. In both the U.S. and Europe, ownership of private firms is highly concentrated—often by a single household—while public firms also exhibit substantial concentration, with the top 20 shareholders holding over 56% of firm value on average. Broader evidence on stock market participation and entrepreneurial risk further suggests that firm ownership is far from perfectly diversified across the population (Cooper et al. 2016; Asker, Farre-Mensa, and Ljungqvist 2015; Smith et al. 2019; Poterba et al. 1995).

To study the role of trade and industrial policies to mitigate shortages of critical goods, we construct a model in which essential and non-essential goods are combined using a constant elasticity of substitution (CES) technology to produce final goods. Essential goods can be complementary to non-essential goods, implying that even small disruptions can have large aggregate effects. Furthermore, the effective contribution of essential goods is evaluated relative to a time-varying reference level, capturing the evolving need or demand conditions for these goods over time—for example, the surge in demand for PPE during COVID-19.

Firms hire labor and accumulate capital subject to sector-specific adjustment costs. Households supply labor inelastically, differ in their firm ownership shares, and face borrowing constraints due to incomplete financial markets. These frictions imply that households have heterogeneous stochastic discount factors—they value future income differently depending on their relative financial positions. Firms make investment decisions based on the discount rates of their owners, leading to underinvestment relative to the socially efficient level, especially following global demand shocks. This inefficiency is exacerbated by concentrated firm ownership, which increases dispersion in marginal valuations and dampens aggregate investment. As a result, policy interventions can raise welfare.

We model shortages of essential goods as arising from a global increase in their demand—though analogous results would apply to negative supply shocks. Domestically, this is captured by a rise in the reference level of essential goods, reflecting heightened need (e.g., for PPE during a pandemic). Internationally, higher global demand raises the prices of both imports and exports, encouraging producers to expand supply. This expansion, however, requires financing. With incomplete financial markets, households do not internalize the general equilibrium effects of their borrowing on interest rates. In response to the shock, households that do not own essential goods producers borrow heavily to smooth consumption, raising interest rates for everyone. As a result, households that do own essential goods producers—those with an incentive to invest—face higher borrowing costs and discount future returns more steeply. This leads to underinvestment and a muted production response relative to an economy with complete markets and perfect risk-sharing.

We begin by qualitatively characterizing equilibrium outcomes relative to the social optimum. In the competitive equilibrium, incomplete financial markets and the endogeneity of interest rates imply that households internalize the impact of their own borrowing on the interest rate, but not the aggregate consequences of their borrowing for others. This partial internalization leads to heterogeneous stochastic discount factors across households.

In contrast, a social planner fully internalizes the general equilibrium effect of borrowing and equalizes discount factors across agents. As a result, the competitive equilibrium is inefficient: firms discount future profits using the SDFs of their owners, which are too low relative to the planner's valuation, leading to underinvestment. The resulting inefficiency can be represented as a time-varying wedge in the firm's first-order conditions for capital and labor. In the presence of a global demand shock, these wedges dampen firms' incentives to scale up production, underscoring the potential for policy interventions to raise welfare.

We use our model to quantify the macroeconomic implications of shortages of critical goods and to study the optimal use of trade and industrial policies in response. We focus on a concrete application: the shortages of essential medical goods that arose during the first year of the COVID-19 pandemic, prior to the widespread deployment of vaccines. To capture this episode, we model a transitory, unexpected global increase in the demand for essential goods. Domestically, the shock is represented by a rise in the reference level of essential goods; internationally, it is captured by increases in export and import prices, reflecting higher global need.[1] Agents are assumed to operate under perfect foresight.

We calibrate the model to match key features of the U.S. economy before and during the pandemic. We estimate that essential and non-essential goods are complementary (with an elasticity of substitution of 0.29), and that both labor and capital are subject to significant adjustment costs. These features imply that households are unable to easily substitute away from essential goods, and that firms are unable to quickly scale up production. As a result, although domestic producers increase output in response to higher prices, much of the additional supply is exported, limiting the domestic availability of essential goods.

We then investigate the role for trade and industrial policy interventions to mitigate the impact of shortages of essential goods. We endow the government with three policy instruments on the trade and production of essential goods: an import subsidy, an export tax, and a production subsidy. The government's problem consists of unilaterally choosing one-time changes to these instruments for the duration of the shocks to maximize a population-weighted utilitarian social welfare function subject to a balanced budget. As in Itskhoki and Moll (2019), we focus on realistic policy instruments that have been widely implemented during recent crises—particularly in response to COVID-19—such as export

[1] We focus on the policy implications of large, sudden demand shocks for critical goods, rather than modeling the pandemic itself. In particular, we abstract from features like disease transmission or epidemiological dynamics (e.g., Çakmaklı et al. 2023).

restrictions, import liberalizations, and production subsidies, rather than exploring the full space of theoretical first-best interventions. We additionally do not allow for direct transfers of resources across households, and we remove markup distortions to ensure there is no role for policy interventions in the steady-state.[2]

When we only allow for trade policy, the government finds it optimal to introduce a 13.61% export tax and a 9.33% import subsidy. These policies reallocate sales from foreign to domestic consumers and increase the availability of essential goods domestically. However, the export tax reduces firms' incentives to invest, leading to a decline in total output. In contrast, when only industrial policy is allowed, the government implements a 16.86% production subsidy. This raises output, but much of the additional supply is exported due to high global prices, with limited improvement in domestic consumption.

The largest welfare gains arise when trade and industrial policies are implemented jointly. In this case, the optimal policy mix consists of a 24.94% export tax, an 18.96% import subsidy, and a 32.11% production subsidy. This combination simultaneously boosts production and reallocates supply toward domestic use, leading to a substantial increase in the consumption of essential goods and the largest welfare improvement among the three alternatives that we consider. The complementarity between trade and industrial policy is consistent with real-world policy responses: many countries introduced simultaneous export restrictions and domestic production incentives during the pandemic. In the U.S., for example, the Defense Production Act was used to scale up production of PPE and vaccines while limiting exports abroad (Bown 2022).

Throughout, we use analytical expressions from the model to show how each policy addresses a distinct margin. Export taxes reduce domestic prices, mitigating the intertemporal inefficiencies that arise when households discount future returns too steeply. However, lower domestic prices also weaken firms' investment incentives. Production subsidies restore investment incentives by raising expected returns for firms, yet without trade intervention, much of the additional output is exported. Import subsidies complement the mix by correcting the resulting inefficiency in consumption composition due to the reduced domestic prices. Together, these instruments target separate wedges in the economy, and we show that they are strongly complementary—jointly delivering larger welfare gains than when implemented

[2]By studying a small open economy without markup distortions, we abstract from terms-of-trade effects and ensure that the economy is efficient in the pre-shock steady state. This allows us to isolate the role of financial frictions in shaping the optimal policy response to shocks.

in isolation.

We conclude the paper with a series of quantitative and empirical exercises presented in the Appendix. These include robustness checks, sensitivity analyses, and a decomposition of the welfare gains from optimal policy. Following Benabou (2002) and Boar and Midrigan (2022), we show that approximately two-thirds of the welfare gains are driven by efficiency improvements, with the remainder reflecting redistributive effects. We also explore how the strength of intra- and intertemporal complementarities, as well as sectoral adjustment costs, shape the magnitude of optimal interventions. Finally, we compare our model's implications with cross-country policy responses during COVID-19 across countries that differ in their trade dependence to access essential goods — we document empirical patterns consistent with those implied by our theoretical framework.

Related Literature Our paper contributes to large literatures that study optimal trade policy in open economies with heterogeneous firms (Costinot, Rodríguez-Clare, and Werning 2020; Demidova and Rodríguez-Clare 2009), and optimal industrial policy as means to achieve long-term development (Juhász, Lane, and Rodrik 2023; Caliendo and Parro 2022; Costinot et al. 2019; Lashkaripour and Lugovskyy 2023). In contrast to much of the literature, our paper studies the role for optimal trade and industrial policy interventions arising purely from distortions in the dynamic response to shocks, rather than from long-run distortions in the allocation of production and trade across countries.

The role for policy interventions in our economy arises from the combination of incomplete markets and the concentration of firm ownership across a subset of the population. This channel is most closely related to Itskhoki and Moll (2019) and Caballero and Lorenzoni (2014), who study optimal policy design in dynamic environments where firms' decisions are distorted by frictions in financial markets.

Our paper is also related to recent studies on the aggregate importance of small but systemic sectors. Baqaee and Farhi (2019) and Baqaee and Farhi (2024) show 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. We study the policy implications of related forces using a dynamic environment with goods essential for either consumption or production, with production decisions subject to distortions.

Finally, our paper is most closely related to recent studies of shortages of critical goods during crises and the potential for policy interventions. For instance, Traiberman and Rotemberg (2023), Grossman, Helpman, and Lhuillier (2023), and Adamopoulos and Leibovici (2024) study the role for policy interventions ex-ante rather than ex-post, as we do in our work. Shortages of critical goods during COVID-19 have also led to a surge of papers proposing international coordination mechanisms (Stellinger, Berglund, and Isakson 2020; Acharya et al. 2020; Evenett 2020; Baldwin and Evenett 2020) as well as domestic industrial policies (Athey et al. 2022; Bown 2022; Bown, Snyder, and Staiger 2022) to avoid future shortages. A broader set of papers has also recently studied the role of international trade as a transmission channel for shocks across countries (Cakmakli et al. 2021; Bonadio et al. 2021; LaBelle, Leibovici, and Santacreu 2021; Antràs, Redding, and Rossi-Hansberg 2023; Eppinger et al. 2021).

2 Empirical Evidence

This section provides empirical motivation for the policy focus and frictions at the core of our model. We begin by documenting how governments responded to recent global shocks—especially COVID-19—by implementing trade and industrial policies targeting critical goods. We then present evidence that financial constraints were a central concern during this period, shaping both firm behavior and government policy. Finally, we document the prevalence of concentrated firm ownership, which may amplify financial constraints and limit firms' ability to scale up during crises.

2.1 Trade and Industrial Policy Responses to Global Shocks

We begin by systematically documenting the trade and industrial policy interventions implemented in response to two recent major global shocks: the COVID-19 pandemic and the Russian invasion of Ukraine.

To do so, we use data from Global Trade Alert (GTA), a comprehensive database tracking trade and industrial policy measures worldwide. GTA provides detailed descriptions of each policy intervention, including implementation dates, affected goods or sectors, and the countries implementing them. We use this data to analyze the timing, scope, and sectoral focus of policy responses to recent global shocks. Figure 1, first presented in the introduction, shows the cumulative number of interventions over time, disaggregated by policy type and shock episode.

We find that governments increasingly relied on trade and industrial policies to address shortages of critical goods. Specifically, during the Russian invasion of Ukraine, numerous countries implemented policies targeting raw materials, food, and fuels. Similarly, the

Table 1: Medical Goods Policy Interventions, 2020–2022

Policy Type	Share of Total Policies (%)	Countries with ≥1 Policy (%)
Financial	46.8	76.7
Demand	32.0	76.7
Other	21.2	60.0

Note: Data from GTA NIPO 2.0. The table categorizes policy interventions by type and shows their prevalence among OECD countries during the COVID-19 pandemic.

COVID-19 pandemic led to extensive policy interventions aimed at securing medical goods, vaccines, and critical global value chain inputs, notably semiconductors. Common responses included export restrictions, import liberalizations, and production subsidies. Many of these policies remain active.[3]

2.2 Financial Policies and Shortages of Medical Goods During COVID-19

The widespread use of industrial policy during the COVID-19 pandemic raises important questions about the specific frictions these interventions aimed to address. We use detailed policy data to uncover the underlying rationales, focusing in particular on the role of financial constraints. Our analysis shows that governments widely viewed limited access to financing as a key obstacle to expanding the supply of essential medical goods. This highlights the relevance of financing frictions as a central policy concern and motivates the channels we study in our model. In particular, these interventions functioned as industrial policies—not to stabilize financial markets broadly, but to enable rapid production expansion in critical sectors by easing firms' access to liquidity and credit.

Our analysis draws on data from the New Industrial Policy Observatory 2.0 (NIPO 2.0), which tracks firm-level industrial policy interventions across 76 jurisdictions. We categorize these industrial policy interventions into three groups: (*i*) industrial policy designed to address liquidity and credit constraints (such as direct loans, loan guarantees, and bond purchases); (*ii*) industrial policy via procurement, aimed at reducing demand uncertainty; and (*iii*) other production support measures. As shown in Table 1, financial-oriented industrial policies accounted for 46.8% of all industrial policy interventions targeting medical goods in OECD countries—more than any other category. Moreover, 76.7% of OECD countries implemented at least one industrial policy designed to address liquidity and credit constraints

[3] Data from Global Trade Alert (GTA): `https://www.globaltradealert.org/`.

Table 2: Firm Ownership Concentration in the U.S. and Europe

Firm type	Statistic	Value	Source
United States			
Private	Share of firms with $<$ 4 owners	97.4%	SBO
Private	Out of these: Avg. ownership share of top owner	86.2%	SBO
Public	Avg. ownership share of top 3 owners	23%	OECD
Public	Avg. ownership share of top 20 owners	56%	OECD
Europe			
Private	Share of firms owned by single household	74%	Peter (2021)
Private	Share of firms with single household owns $>$ 50%	90%	Peter (2021)
Public	Avg. ownership share of top 3 owners	49%	OECD
Public	Avg. ownership share of top 20 owners	66%	OECD

Note: The data on private firms in the U.S. is based on authors' calculations from the U.S. Census Bureau's 2007 Survey of Business Owners (SBO). The data on private firms in Europe is from Peter (2021). The data on public firms is from De La Cruz, Medina, and Tang (2019) — an OECD report with ownership information on public firms across countries. The values corresponding to this report are approximated based on the report's figures.

(such as direct loans, loan guarantees, and bond purchases), despite having relatively advanced financial markets. These findings point to the significance of financial constraints in determining firms' ability to scale up production quickly, even in countries with highly developed financial markets.[4]

The U.S. experience provides illustrative examples of industrial policy responses addressing financial frictions. For instance, Ology Bioservices received a $25 million loan via the Federal Reserve's Main Street Lending Program; Pfizer benefited from $32 million in Federal Reserve bond purchases; Ginkgo Bioworks secured a $1.1 billion loan for capacity expansion; and Dendreon Pharmaceuticals obtained a $10 million loan through the Payment Protection Program. Additionally, through the Defense Production Act (DPA), the U.S. government provided targeted financial support—including direct loans, loan guarantees, and purchase commitments—to firms producing critical medical goods, further alleviating financial constraints on rapid production expansion.

Taken together, these policy actions suggest that alleviating financial constraints was a central objective of industrial policy during the pandemic, and they motivate the role of

[4] Additional data is provided in the Appendix.

financial frictions in our model.

2.3 Firm Ownership Concentration Across Countries

Building on the evidence that financial constraints shaped industrial policy responses during COVID-19, we now present data on a structural characteristic that may intensify such frictions: the prevalence of concentrated firm ownership. Table 2 summarizes patterns of ownership concentration across private and public firms in the United States and Europe. In the United States, private firms typically have very few owners; 97.4% have fewer than four owners, and within this group, the largest shareholder holds an average equity stake of over 86%. While public firms exhibit relatively more dispersed ownership, their ownership structure remains significantly concentrated, with the top three shareholders holding an average of 23% and the top 20 shareholders accounting for 56% of firm equity on average.

European data reveal similarly high levels of ownership concentration. Private firms are predominantly controlled by single households: 74% of these firms are entirely owned by one household, and 90% have majority ownership by a single household. Public firms in Europe also display substantial concentration among major shareholders; the top three owners control on average nearly half (49%) of firm equity, and the largest twenty shareholders control about two-thirds (66%).

These empirical patterns motivate a key feature of our model: imperfect diversification in firm ownership. This allows us to examine the extent to which ownership concentration can amplify the effects of financial frictions and shape the effectiveness of policy interventions during crises.

3 Model

We study a small open economy that trades goods and financial assets with the rest of the world. The economy is populated by five types of agents: households, producers of sectoral varieties, producers of sectoral composite goods, producers of final goods, and a government. Sectoral varieties are produced domestically and abroad in two sectors: essential and non-essential. We denote variables corresponding to these sectors using subscripts e and n, respectively. All varieties can be traded internationally — thus, the economy has access to four types of varieties: a domestic and imported variety of essential goods, and a domestic and imported variety of non-essential goods. We let domestic non-essential varieties be the numeraire. Varieties in each sector are produced using labor and capital, which are mobile across sectors. Sectoral composite goods aggregate domestic and imported varieties in each sector, and final goods aggregate sectoral composite goods across sectors. In the rest of this section, we describe each of these agents in detail.

3.1 Households

The economy is populated by a unit measure of infinitely-lived households who discount the future at rate $\beta < 1$. There are two types of households who differ in their source of income: Households of type $i \in \{n, e\}$ are endowed with λ_i units of labor and own producers of the domestic variety of good i.[5] Labor is supplied inelastically to an economy-wide labor market at wage rate w_t.[6] Thus, every period households earn labor income $\lambda_i w_t$ as well as the profits or losses π_{it} of the respective domestic producer. In addition, every period households receive lump-sum transfers $\mathcal{T}_{it}$ from the redistribution of revenue collected by the government through import tariffs, export taxes, or sales taxes implemented by the government.[7]

As in Bewley-Huggett-Aiyagari models (Bewley, 1977; Huggett, 1993; Aiyagari, 1994), we assume that households have access to incomplete financial markets. They can trade a one-period risk-free bond vis-a-vis each other as well as with the rest of the world at an interest rate that is increasing in the aggregate level of debt. The bond is denominated in units of the numeraire. Following Schmitt-Grohé and Uribe (2003), households' bond-holding choices b_{it+1} are subject to interest rate $1 + r_t$, where $r_t = r^* + \Omega_r \left[e^{\left(b_{nt+1} + b_{et+1} - \bar{b}\right)} - 1 \right]$. The parameter Ω_r is a constant that controls the elasticity of the interest rate to deviations of aggregate debt from $\bar{b}$, and r^* denotes the interest rate in the rest of the world. The interest rate is determined in equilibrium and depends on aggregate debt, which households take into account when making their borrowing decisions.

The budget constraint of household $i \in \{n, e\}$ in period t is given by:

$$p_t c_{it} + b_{it} = \lambda_i w_t + \pi_{it} + \frac{b_{it+1}}{1 + r_t} + \mathcal{T}_{it},$$

where c_{it} is consumption of final goods, p_t is the price of final goods, p_{nt} is the price of the non-essential good composite, and $b_{it+1} > 0$ ($b_{it+1} < 0$) denotes debt (savings).

Household i's period utility function is given by $u(c_{it}) = \frac{(c_{it}/\lambda_i)^{1-\xi}}{1-\xi}$, expressed as a function of per capita consumption, with $1/\xi$ denoting the intertemporal elasticity of substitution.

[5] We normalize the economy's aggregate labor supply to unity — thus, $\lambda_n + \lambda_e = 1$.

[6] Labor supply is freely mobile across sectors, so the wage is equalized.

[7] $\mathcal{T}_{it} < 0$ denotes a lump-sum tax.

Then, household i's problem is:

$$\max_{\{c_{it},b_{it+1}\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{(c_{it}/\lambda_i)^{1-\xi}}{1-\xi}$$

subject to

$$p_t c_{it} + b_{it} = \lambda_i w_t + \pi_{it} + \frac{b_{it+1}}{1+r_t} + \mathcal{T}_{it} \quad \forall t = 0, ..., \infty,$$

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

3.2 Producers of final goods

The final goods purchased by households and firms are produced by a representative firm combining essential e_t and non-essential n_t composite goods. To do so, the firm operates a constant elasticity of substitution technology given by:

$$y_t = \left[(1-\gamma)n_t^{\frac{\rho-1}{\rho}} + \gamma \left(\frac{e_t}{\overline{e}_t}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}},$$

where the parameter γ controls the relative importance of the two goods for the aggregate absorption bundle, ρ denotes the elasticity of substitution between essential and non-essential goods, and $\overline{e}_t$ refers to the "reference level" of essential goods relative to which absorption of these goods is evaluated. We model this reference level as exogenous and time-varying. Moreover, we capture the critical nature of essential goods by assuming they are complementary with non-essential goods ($\rho < 1$) — in Section 5 we estimate this to be the case.

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

$$\max_{y_t,n_t,e_t} p_t y_t - p_{nt} n_t - p_{et} e_t$$

subject to

$$y_t = \left[(1-\gamma)n_t^{\frac{\rho-1}{\rho}} + \gamma \left(\frac{e_t}{\overline{e}_t}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}.$$

The goal of this specification is to capture key dimensions along which essential goods may differ from non-essential goods. First, essential and non-essential goods are complementary with each other. Thus, even if essential goods constitute a small fraction of aggregate absorption, shocks to the demand or supply of these goods may have significant aggregate implications if complementarities are sufficiently strong. Second, the contribution of essential goods to the production of final goods is a function of the ratio between e_t and a reference level $\overline{e}_t$. This captures that demand for some goods is often evaluated relative to the perceived need for them. Finally, this specification allows us to capture the importance of essential goods for either consumption or production. In particular, final goods may be interpreted as consisting of a bundle of consumption goods or, alternatively, as capturing an aggregate production technology with essential and non-essential inputs.

3.3 Producers of composite goods $j \in \{n, e\}$

The sectoral composite goods used to produce final goods are themselves produced by combining sectoral varieties produced domestically (q^d_{jt}) and abroad (q^m_{jt}). To do so, the firm operates a constant elasticity of substitution technology given by:

$$y_{jt} = \left[\omega_j {q^d_{jt}}^{\frac{\sigma-1}{\sigma}} + (1-\omega_j) {q^m_{jt}}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}},$$

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 amount of inputs q^d_{jt} and q^m_{jt} to maximize profits. The prices of the domestic and imported varieties are given by p^d_{jt} and p^m_{jt}, respectively. Imports are subject to iceberg trade costs τ_j and import tariffs τ^m_{jt} that are ad-valorem and such that $\tau_j \geq 1$.[8]

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

$$\max_{y_{jt}, q^d_{jt}, q^m_{jt}} p_{jt} y_{jt} - p^d_{jt} q^d_{jt} - (1+\tau^m_{jt}) \tau_j p^m_{jt} q^m_{jt}$$

subject to

$$y_{jt} = \left[\omega_j {q^d_{jt}}^{\frac{\sigma-1}{\sigma}} + (1-\omega_j) {q^m_{jt}}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}.$$

3.4 Producers of domestic variety in sector $j \in \{n, e\}$

Domestic varieties in sector $j \in \{n, e\}$ are produced by a representative firm using capital k_{jt} and labor ℓ_{jt}, with a time-invariant productivity A_j. The amount produced in each sector j is given by $A_j \left(\ell^{\alpha}_{jt} k^{1-\alpha}_{jt}\right)^{\eta}$, where α controls the labor share, $1-\alpha$ controls the capital share,

[8] Negative import tariffs denote import subsidies.

and $\eta \in (0, 1)$ denotes the degree of decreasing returns to scale.[9]

In every period t, firms choose the amount of labor to use in that period and the amount of capital investment for production in period $t+1$. Each sector's investment and capital stock are made up of non-essential goods. Thus, to increase the amount of capital by one unit in the following period requires investing I_{jt} units of non-essential goods today. Given that capital depreciates at rate δ, next period's capital stock k_{jt+1} is $(1-\delta)k_{jt} + I_{jt}$.

We introduce sectoral capital and labor adjustment costs to help us discipline the degree to which sectoral production can change over time. We assume that capital and labor adjustment costs are quadratic and denominated in units of non-essential goods:

$$\phi_{kj}(k_{jt+1}, k_{jt}) = \frac{\Omega_{kj}}{2}\left(\frac{k_{jt+1}}{k_{jt}} - 1\right)^2$$
$$\phi_{\ell j}(\ell_{jt}, \ell_{jt-1}) = \frac{\Omega_{\ell j}}{2}\left(\frac{\ell_{jt}}{\ell_{jt-1}} - 1\right)^2,$$

where Ω_{kj} and $\Omega_{\ell j}$ are non-negative sector-specific constants.

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 p^x_{jt}. Export revenues are subject to an ad-valorem tax rate τ^x_{jt}, and total sales are subject to an ad-valorem subsidy τ^y_{jt}.[10]

The firm's problem consists of choosing labor, investment, and market-specific prices and quantities in each period to maximize lifetime discounted profits given initial capital stock k_{j0}. Given that the representative firm that produces domestic variety j is owned by households of type j, the firm values returns across time periods and states of the world

[9] We assume the production technology features decreasing returns to scale to ensure the existence of a steady state with positive exports across a nondegenerate set of parameters.

[10] Negative export taxes denote export subsidies, and negative sales subsidies denote taxes.

according to its owners' stochastic discount factor m_{jt}.[11] The firm's problem is given by:

$$\max_{\{\ell_{jt}, i_{jt}, k_{jt+1}, p^d_{jt}, y^d_{jt}, y^x_{jt}\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} m_{jt} \Big\{ (1+\tau^y_{jt}) p^d_{jt} y^d_{jt} + (1+\tau^y_{jt} - \tau^x_{jt}) p^x_{jt} y^x_{jt} - w_t \ell_{jt} - p_{nt} I_{jt}$$
$$- p_{nt}\phi_{kj}(k_{jt+1}, k_{jt}) - p_{nt}\phi_{\ell j}(\ell_{jt}, \ell_{jt-1}) \Big\}$$
$$\text{subject to} \quad k_{jt+1} = (1-\delta) k_{jt} + I_{jt} \quad \forall t = 0, ..., \infty$$
$$y^d_{jt} + y^x_{jt} = A_j \left(\ell^{\alpha}_{jt} k^{1-\alpha}_{jt} \right)^{\eta} \quad \forall t = 0, ..., \infty$$
$$y^d_{jt} = \omega_j \left(\frac{p^d_{jt}}{p_{jt}} \right)^{-\sigma} y_{jt} \quad \forall t = 0, ..., \infty$$
$$y^x_{jt} \geq 0 \quad \forall t = 0, ..., \infty,$$

where p^d_{jt} and p^x_{jt} denote the domestic and export price of the domestic variety in sector j, while y^d_{jt} and y^x_{jt} 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 above.[12] Given the perfectly elastic demand faced from the rest of the world, the fourth constraint ensures exports are weakly positive.

3.5 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 imported variety in each sector $j \in \{n, e\}$, which is sold at a perfectly elastic price p^m_{jt} and subject to a sector-specific iceberg trade cost τ_j. These are 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 $j \in \{n, e\}$ at price p^x_{jt}. These are the domestic economy's exports. Finally, the rest of the world is the financial counterpart of the domestic economy, with an elastic demand or supply of bonds at interest rate r_t that depends on the economy's aggregate level of debt.

3.6 Government

Finally, the economy is populated by a government that collects revenue from the taxation of imports $\{\tau^m_{jt}\}_{j\in\{n,e\}}$ and exports $\{\tau^x_{jt}\}_{j\in\{n,e\}}$, and which uses these revenues to subsidize domestic production $\{\tau^y_{jt}\}_{j\in\{n,e\}}$ and to provide lump-sum transfers to households $\{\mathcal{T}_{it}\}_{i\in\{n,e\}}$.

[11] The stochastic discount factor of households of type i, m_{it+1}, is defined in Section 4.

[12] We abstract from the impact on optimal policy of markup distortions induced by monopolistic competition. To do so, we let the government subsidize domestic sales with a proportional subsidy equal to $\frac{1}{\sigma-1}$, financed via lump-sum taxes levied on the owners of the respective producer; we omit this subsidy from the formulation above to simplify the exposition.

The government does not have access to financial markets, so its budget constraint has to be balanced every period. The government's budget constraint is given by:

$$\mathcal{T}_{nt} + \mathcal{T}_{et} = \sum_{j \in \{n,e\}} \left\{ \tau_{jt}^m \tau_j p_{jt}^m q_{jt}^m + \tau_{jt}^x p_{jt}^x y_{jt}^x - \tau_{jt}^y \left[p_{jt}^d y_{jt}^d + p_{jt}^x y_{jt}^x \right] \right\}.$$

Given a set of taxes and subsidies, there are multiple configurations of lump-sum transfers that can ensure the budget is balanced. To characterize the multiple arrangements available, we let $\psi_{ijt}^k \in (0,1)$ denote the share of revenue from policy $k \in \{m, x, y\}$ on good $j \in \{n, e\}$ in period t that is redistributed lump-sum to households of type $i \in \{n, e\}$ — where $k = m$ denotes import tariffs, $k = x$ denotes export taxes, and $k = y$ denotes sales subsidies. Then, transfers $\{\mathcal{T}_{it}\}_{i \in \{n,e\}}$ need to satisfy:

$$\mathcal{T}_{it} + \sum_{j \in \{n,e\}} \psi_{ijt}^y \tau_{jt}^y \left(p_{jt}^d y_{jt}^d + p_{jt}^x y_{jt}^x \right) = \sum_{j \in \{n,e\}} \psi_{ijt}^x \tau_{jt}^x p_{jt}^x y_{jt}^x + \sum_{j \in \{n,e\}} \psi_{ijt}^m \tau_{jt}^m \tau_j p_{jt}^m q_{jt}^m,$$

where budget balance is ensured by $\psi_{njt}^k + \psi_{ejt}^k = 1$. We discuss our approach to specifying parameters $\{\psi_{ijt}^k\}$ when investigating optimal policy design in Section 6.

3.7 Equilibrium

Consider a sequence of shocks $\left\{ \bar{e}_t, p_{jt}^x, p_{jt}^m \right\}_{t=0, j \in \{n,e\}}^{\infty}$, a sequence of trade policy instruments $\left\{ \tau_{jt}^x, \tau_{jt}^m \right\}_{t=0, j \in \{n,e\}}^{\infty}$, a sequence of industrial policy instruments $\left\{ \tau_{jt}^y \right\}_{t=0, j \in \{n,e\}}^{\infty}$, and initial values $\{b_{j0}, k_{j0}\}_{j \in \{n,e\}}$. We let the price of the domestic variety of non-essential goods in the home country p_{nt}^d be the numeraire. Then, a *competitive equilibrium* consists of:

- wages $\{w_t\}_{t=0}^{\infty}$, prices p_t and $\left\{ p_{jt}, p_{jt}^d \right\}_{t=0, j \in \{n,e\}}^{\infty}$, interest rates $\{r_t\}_{t=0}^{\infty}$,
- allocations:

$$\left\{ c_{jt}, b_{jt+1}, \mathcal{T}_{jt}, \pi_{jt}, \ell_{jt}, k_{jt+1}, i_{jt}, y_{jt}, y_{jt}^d, y_{jt}^x, q_{jt}^d, q_{jt}^m, y_t, n_t, e_t \right\}_{t=0, j \in \{n,e\}}^{\infty},$$

such that the following conditions hold:

1. Given prices, allocations solve problem of each household type
2. Given prices, allocations solve problem of final good producers
3. Given prices, allocations solve problem of composite goods producers of each type

4. Given prices, allocations solve problem of producers of domestic varieties of each type

5. Government's budget is balanced

6. Labor market clears: $\ell_{nt} + \ell_{et} = \lambda_n + \lambda_e \ \forall t$

7. Domestic essential goods market clearing: $y^d_{et} = q^d_{et} \ \forall t$

8. Domestic non-essential goods market clearing: $y^d_{nt} = q^d_{nt} \ \forall t$

9. Essential composite goods market clearing: $e_t = y_{et} \ \forall t$

10. Non-essential composite goods market clearing:

$$n_t + \sum_{j\in\{n,e\}} \left[i_{jt} + \frac{\Omega_{kj}}{2}\left(\frac{k_{jt+1}}{k_{jt}} - 1\right)^2 + \frac{\Omega_{\ell j}}{2}\left(\frac{\ell_{jt}}{\ell_{jt-1}} - 1\right)^2 \right] = y_{nt} \ \forall t$$

11. Final goods market clearing: $\sum_{i\in\{n,e\}} c_{it} = y_t \ \forall t$.

12. Interest rates consistent with aggregate debt: $r_t = r^* + \Omega_r \left[e^{\left(b_{nt+1}+b_{et+1}-\bar{b}\right)} - 1 \right]$

4 Mechanism

In this section, we characterize the sources of inefficiency in our model and examine how they shape equilibrium outcomes. We begin by describing the social planner's problem and contrasting it with the competitive equilibrium. We then identify key sources of inefficiency and analyze how these distortions affect equilibrium allocations. Finally, we examine the implications of these inefficiencies in the context of pandemic-like shocks, modeled as unexpected increases in the demand for essential goods. Throughout this analysis, we abstract from adjustment costs, as these represent real frictions that affect the planner's problem and competitive equilibrium symmetrically, and therefore do not constitute an independent source of inefficiency.

4.1 Planner's Problem

We begin by characterizing the social planner's problem, which provides a useful benchmark for evaluating the efficiency of market outcomes. The planner maximizes the population-weighted sum of household utilities subject to the economy's technological and resource constraints. Formally, the planner solves:

$$\max_{\{c_{it},\ell_{it},k_{it},y_{it}^{d},y_{it}^{x},y_{it}^{m}\}} \mathcal{V}_t = \lambda_n V_{nt} + \lambda_e V_{et}$$

where $V_{it} = \sum_{t=0}^{\infty} \beta^t \frac{(c_{it}/\lambda_i)^{1-\xi}}{1-\xi}$ represents the lifetime utility of household $i \in \{n, e\}$, with per-capita consumption defined as (c_{it}/λ_i), and λ_i denotes the mass of households of type i. The planner faces the following constraints:

- Production technology: $y_{it}^d + y_{it}^x = A_i(\ell_{it}^{\alpha} k_{it}^{1-\alpha})^{\eta}$ for $i \in \{n, e\}$
- Capital accumulation: $k_{it+1} = (1-\delta)k_{it} + I_{it}$ for $i \in \{n, e\}$
- Sectoral goods aggregation:

$$n_t = \left[\omega_n (y_{nt}^d)^{\frac{\sigma-1}{\sigma}} + (1-\omega_n)(y_{nt}^m)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$
$$e_t = \left[\omega_e (y_{et}^d)^{\frac{\sigma-1}{\sigma}} + (1-\omega_e)(y_{et}^m)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

- Final goods aggregation: $c_{et} + c_{nt} = \left[(1-\gamma) n_t^{\frac{\rho-1}{\rho}} + \gamma (e_t/\bar{e}_t)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}$
- External constraint: $\sum_i p_{it}^m y_{it}^m + B_t = \frac{B_{t+1}}{1+r^* + \Omega_r[e^{(B_{t+1}-\bar{b})}-1]} + \sum_i p_{it}^x y_{it}^x$

where we denote imported quantities as y_{it}^m, corresponding to q_{jt}^m in the decentralized model. Although the planner has full control over domestic allocations, the economy remains subject to an external constraint involving both goods prices (p_{it}^m and p_{it}^x) and financial markets (r^* and the borrowing premium governed by Ω_r). These international prices and financial conditions enter the planner's problem explicitly because we consider a small open economy: both trade in goods and borrowing in financial markets occur at terms determined externally. Thus, even the planner must take these external terms as given, reflecting the same constraints faced by households in the decentralized equilibrium. The complete derivation, including the full set of first-order conditions and their economic interpretation, is provided in the Appendix.

In our analysis, the planner represents a country-level social planner operating in a small open economy. The planner takes international prices and borrowing terms as given but fully internalizes the domestic general equilibrium effects of aggregate borrowing—specifically, how it affects the interest rate through the endogenous premium. While technological constraints and the external environment are the same as in the decentralized equilibrium, the planner corrects the borrowing externality that arises from households failing to internalize how their individual borrowing contributes to the aggregate interest rate. Importantly, since domestic borrowing and lending can occur within the country and net out in aggregate, the planner faces no household-level borrowing constraints. The resulting allocation is thus the first-best, conditional on the external environment, and serves as a benchmark for evaluating the inefficiencies that arise in the competitive equilibrium due to incomplete markets.

4.2 Sources of Inefficiency

In this section, we evaluate the efficiency of the competitive equilibrium allocations by comparing them with those of the social planner. Specifically, we contrast the first-order conditions of the planner's problem with those of the competitive equilibrium to identify wedges between private and social incentives. As we show below, these wedges arise due to the interaction between financial frictions and household heterogeneity, primarily creating distortions in consumption-savings decisions. While households in the decentralized economy optimize based on their individual constraints and prices, they fail to internalize how their borrowing decisions influence aggregate borrowing costs and the allocation of resources across sectors. We focus our discussion here on the main sources of inefficiency, relegating a complete characterization of the planner's and competitive equilibrium problems—including all equilibrium conditions—to the Appendix.

4.2.1 Characterizing Equilibrium Distortions

The sources of inefficiency in the competitive equilibrium are incomplete financial markets and household heterogeneity. These features distort households' consumption-savings decisions by affecting how agents discount future payoffs. To illustrate this clearly, we now contrast households' Euler equations in the competitive equilibrium with the Euler equation implied by the planner's solution. In the competitive equilibrium, these decisions are characterized by:

$$\underbrace{\beta\left(\frac{c_{it+1}}{c_{it}}\right)^{-\xi}\left(\frac{\overline{e}_{t+1}}{\overline{e}_t}\right)^{\frac{\rho-1}{\rho}}\frac{\left[c_{et}+c_{nt}\right]^{\frac{1}{\rho}}}{\left[c_{et+1}+c_{nt+1}\right]^{\frac{1}{\rho}}}\frac{e_t^{\frac{1}{\sigma}-\frac{1}{\rho}}}{e_{t+1}^{\frac{1}{\sigma}-\frac{1}{\rho}}}\frac{q_{et}^{m\frac{-1}{\sigma}}}{q_{et+1}^{m\frac{-1}{\sigma}}}}_{\text{SDF (competitive equilibrium), } m_{it+1}}=\frac{p_{et}^m}{p_{et+1}^m}\times\underbrace{\frac{R_t-b_{it+1}\Omega_r e^{(b_{nt+1}+b_{et+1}-\bar{b})}}{R_t^2}}_{\text{Marginal borrowing cost (household-specific)}}$$

In contrast, the Euler equations in the planner's problem are given by:

$$\underbrace{\beta\left(\frac{c_{it+1}}{c_{it}}\right)^{-\xi}\left(\frac{\overline{e}_{t+1}}{\overline{e}_t}\right)^{\frac{\rho-1}{\rho}}\frac{[c_{et}+c_{nt}]^{\frac{1}{\rho}}}{[c_{et+1}+c_{nt+1}]^{\frac{1}{\rho}}}\frac{e_t^{\frac{1}{\sigma}-\frac{1}{\rho}}}{e_{t+1}^{\frac{1}{\sigma}-\frac{1}{\rho}}}\frac{y_{et}^{m\frac{-1}{\sigma}}}{y_{et+1}^{m\frac{-1}{\sigma}}}}_{\text{SDF (planner), } \widetilde{m}_{t+1}}=\frac{p^m_{et}}{p^m_{et+1}}\times\underbrace{\frac{R_t-B_{t+1}\Omega_r e^{(B_{t+1}-\bar{b})}}{R_t^2}}_{\text{Marginal borrowing cost (aggregate)}}$$

The key difference arises because individual households internalize how their borrowing affects the interest rate they face, but do not internalize the broader general equilibrium consequences of their actions.

The key difference arises because individual households internalize how their borrowing affects the interest rate they face, but do not internalize the broader general equilibrium consequences of their actions. In particular, they fail to account for how the increase in the interest rate caused by their borrowing affects the consumption and investment decisions of other households. In contrast, the planner fully internalizes this aggregate effect through its influence on the borrowing premium. As a result, in the presence of financial frictions ($\Omega_r > 0$), the stochastic discount factors in the competitive equilibrium (m_{it+1}) are household-specific, while the planner uses a single, common discount factor ($\widetilde{m}_{t+1}$). When $\Omega_r = 0$, this wedge disappears and the competitive equilibrium coincides with the planner's allocation.

These distortions affect other margins in our economy, which we characterize next.

Investment. The distortions in households' stochastic discount factors also affect firms' investment decisions. Specifically, in the planner's solution, investment satisfies:

$$\widetilde{m}_{t+1}\left[p^x_{it+1}\left((1-\alpha)\eta A_i(\ell^{\alpha}_{it+1}k^{1-\alpha}_{it+1})^{\eta}/k_{it+1}\right)+\Omega^m_{nt+1}(1-\delta)\right]=\Omega^m_{nt},$$

whereas firms in the competitive equilibrium solve:

$$m_{it+1}\left[p^x_{it+1}\left((1-\alpha)\eta A_i(\ell^{\alpha}_{it+1}k^{1-\alpha}_{it+1})^{\eta}/k_{it+1}\right)+\Omega^m_{nt+1}(1-\delta)\right]=\Omega^m_{nt}.$$

In both expressions, we use Ω^m_{jt} to denote the shadow value of capital in sector j at time t.

Because households fail to internalize how their individual borrowing affects the equilibrium interest rate, their stochastic discount factors reflect a higher marginal cost of future consumption relative to the social planner's valuation. As a result, firms in the competitive equilibrium assign a lower value to future returns than would be socially optimal, leading to underinvestment in physical capital. This distortion depresses the investment in physical capital below the socially optimal level. That is, the borrowing externality distorts the intertemporal allocation of resources, leading to inefficiently low capital accumulation and muted production responses.

Labor. Labor choices follow identical first-order conditions in both the planner's solution and the competitive equilibrium:

$$p_{it}^x \left[\alpha \eta A_i (\ell_{it}^{\alpha} k_{it}^{1-\alpha})^{\eta} / \ell_{it} \right] = w_t.$$

However, the inefficiencies in capital accumulation imply that the competitive equilibrium features an inefficiently low capital stock relative to the planner's solution. This lower capital stock reduces the marginal product of labor, thereby distorting relative wages and employment across sectors. As a result, even though households and firms respond optimally, the equilibrium labor allocation differs from the socially efficient outcome. Thus, the distortion originating in borrowing and investment decisions indirectly distorts the allocation of labor, amplifying the overall inefficiency of the decentralized equilibrium.

Production and Trade. Finally, the optimality conditions determining the composition of production between domestic sales and exports, as well as the choice between domestically produced goods and imports, remain identical in both environments.[13] However, the previously described distortions in capital accumulation imply a lower equilibrium capital stock in the competitive equilibrium relative to the planner's solution. Consequently, output and trade volumes are systematically lower in the decentralized equilibrium, reflecting the inefficiencies from distorted borrowing and investment decisions into production and international trade patterns.

4.3 Impact of Pandemic Shocks

We now analyze how the inefficiencies characterized above affect the economy's response to pandemic-like shocks. We model a pandemic as a shock that increases the demand for essential goods ($\bar{e}_t$), accompanied by corresponding increases in global prices (p_{et}^m and p_{et}^x), consistent with our small open economy setting. To illustrate the economic implications, we examine the direct effects on consumption and borrowing decisions, and then discuss how these effects affect investment, labor, and trade.

[13] See the Appendix for detailed derivations of these optimality conditions.

On the demand side, two main forces shape the response of essential goods consumption. First, the higher reference level ($\overline{e}_t$) directly increases essential goods consumption. Second, the complementarity between essential and non-essential goods ($\rho < 1$) restricts households' ability to substitute away from essential goods, even as their relative prices rise:

$$\frac{e_t}{n_t} = \left(\frac{p_{et}}{p_{nt}}\right)^{-\rho} \left(\frac{\gamma}{1-\gamma}\right)^{\rho} \overline{e}_t^{1-\rho}.$$

Moreover, households' limited intertemporal substitution ($1/\xi < \infty$) reinforces the persistence of overall final goods demand, as households prefer smooth consumption profiles over time.

On the supply side, the borrowing frictions we characterized earlier also distort production responses during a pandemic. Both types of households increase their borrowing: essential-goods-producing households borrow to finance expanded production, while both household types borrow to smooth consumption. However, neither internalizes how their increased borrowing raises the economy-wide interest rate. As a result, aggregate borrowing costs increase, distorting discount rates. In contrast, the social planner accounts for these effects and chooses borrowing to mitigate the negative effect on investment.

These inefficiencies have three main consequences during pandemic shocks. First, underinvestment in the essential sector limits the economy's ability to scale up production in response to increased demand. Second, distorted borrowing conditions lead to uneven welfare impacts, as some households face tighter credit while others benefit from rising prices. Third, elevated interest rate premiums reduce overall allocative efficiency, making it harder for resources to move where they are most needed during the adjustment process. These dynamics underscore the scope for welfare-improving policy interventions, which we explore in the next section.

5 Quantitative analysis

While our model can be used to study shortages of critical goods in different episodes, we focus on a particular application: shortages of essential medical goods during the outbreak of COVID-19. We use this episode to explore the quantitative importance of the channels outlined in the previous section and evaluate the role for policy interventions. Specifically, the pandemic led to a massive increase in the demand for essential medical equipment and supplies (e.g., gowns, masks, gloves, intensive-care equipment, etc.) that have been critical to combat it and prevent the spread of the disease. While supply increased gradually in an attempt to satisfy the high demand for these goods, countries have faced supply shortages, forcing them to ration these goods and face exorbitant prices.

We begin by documenting salient features of the dynamics of demand, supply, and prices of essential medical goods during the COVID-19 pandemic. We then describe our approach to modeling this episode in our framework. We describe our estimation strategy to match salient features of the U.S. economy both prior to and during the COVID-19 pandemic. We conclude this section by studying the dynamics of the economy throughout this episode.

5.1 Essential medical goods during COVID-19 in the U.S.

To examine the dynamics of demand and supply of personal protective equipment (PPE) during COVID-19 in the U.S., we use data from the White House COVID-19 Supply Chain Task Force.[14] Consistent with this dataset, we focus on the following types of PPE: N95 respirators, surgical masks, gloves, and face shields. We interpret the evidence documented for these goods as representative of the broader category of PPE essential for preventing the spread of COVID-19.

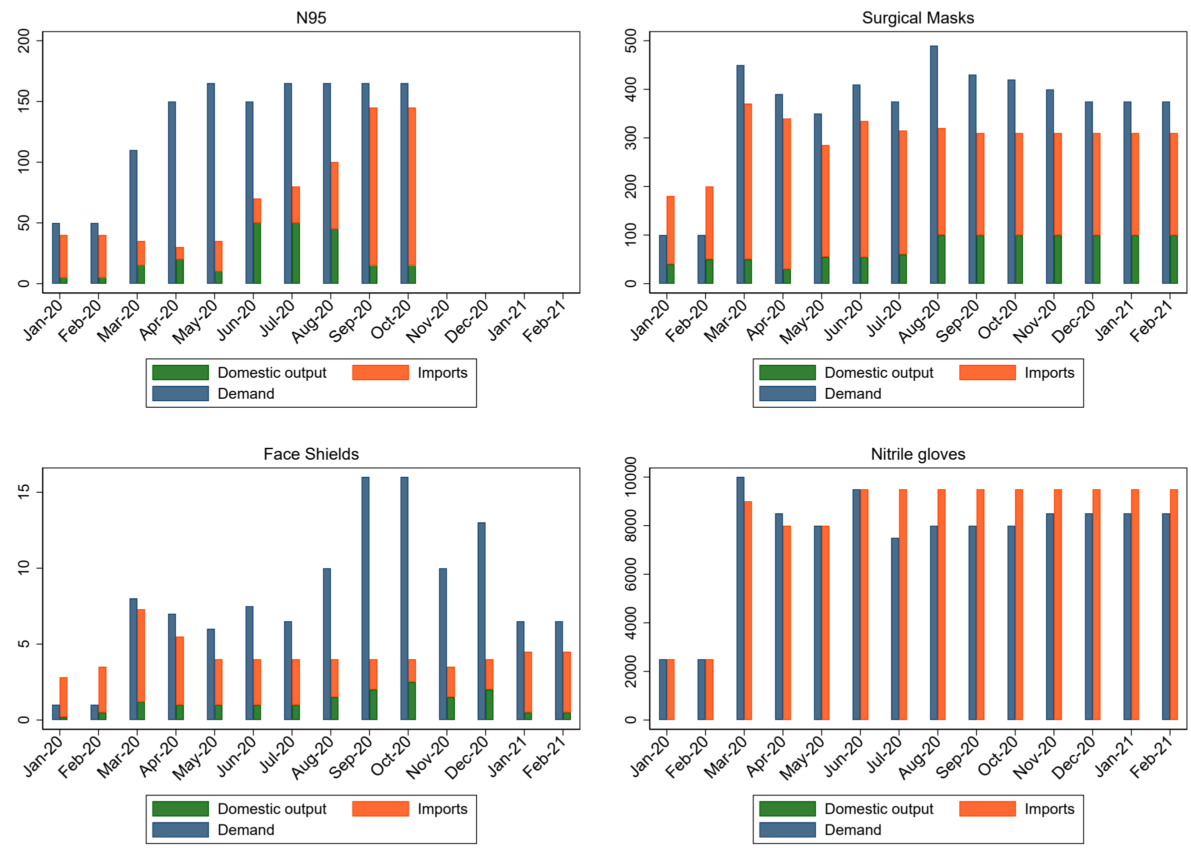
Demand vs. supply of personal protective equipment We begin by documenting the evolution of demand and supply of PPE. Our analysis is based on estimates of the demand and supply of these goods reported by the task force for Jan 2020 - Feb 2021, right before the introduction of COVID-19 vaccines. Figure 2 reports our findings, with blue bars representing PPE demand as estimated by the Task Force, while the sum of the green (absorption of domestic goods) and red (absorption of imported goods) bars represent PPE supply available for consumption. Therefore, observations with blue bars (demand) higher than the red-green bars (supply) reflect shortages of the given product in the given period. We highlight three key facts.

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 and imported consumption of all such goods increased during

[14] See `https://crsreports.congress.gov/product/pdf/R/R46628`.

Figure 2: PPE Demand and Supply in the U.S., Jan 2020 – Feb 2021



Note: The y-axes are expressed in millions of units. Data from the White House Supply Chain Task Force.

the pandemic, this increase was not sufficiently large to meet the spike of demand, leading to shortages.

Finally, we observe that international trade is a critical source of PPE in the U.S. In particular, across all four types of 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, the contribution of U.S. producers is minimal across all categories.

Price changes of personal protective equipment We now investigate the implications of shortages of essential goods for prices. To do so, we document the price changes across the four PPE categories identified by the White House COVID-19 Supply Chain Task Force. We obtain information on price changes by combining 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

Table 3: PPE Prices

Peak price change relative to 2019 average	
N95 respirators	1,513%
Surgical masks	104.8%
Face shields	21.01%
Nitrile gloves	95.35%

Note: For nitrile gloves, face shields, and surgical masks, the peak price change is computed using data from March to December 2020. For N95 masks, the peak price change is based on data for April 2020.

monthly unit values of U.S. imports reported across disaggregate 10-digit HS product categories. First, we identify the set of 10-digit HS product codes corresponding to nitrile gloves, face shields, and surgical masks. For each 10-digit HS product, we compute the peak price change in 2020 relative to its average price in 2019. Then, for each broad 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.[15] Thus, we obtain prices of N95 masks from a study conducted by The Society for Healthcare Organization Procurement Professionals (SHOPP) in April 2020.[16] The prices reported in 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.

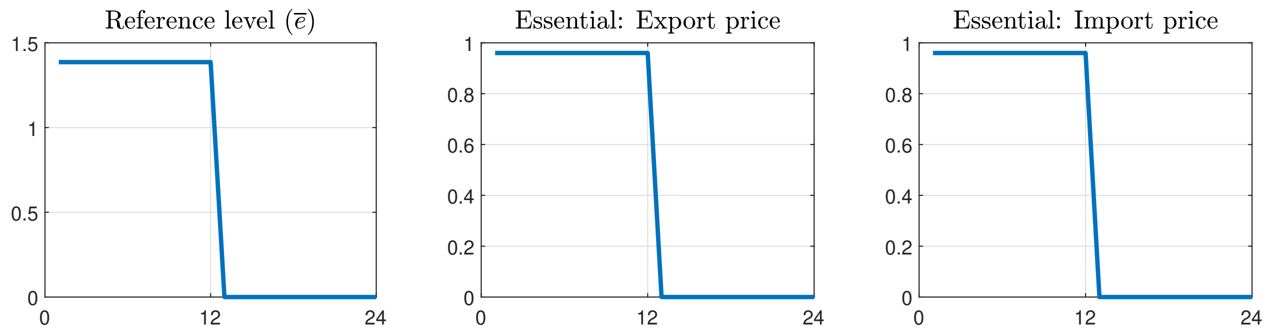
We report our findings in Table 3. We find that the price of PPE increased substantially during the pandemic, likely reflecting the severe supply shortages documented above. Relative to the average prices throughout 2019, the peak increase in the price of N95 respirators was 1,513%, while the respective values for surgical masks and nitrile gloves was 104% and 95%, respectively. Face shields experienced the lowest price increase, equal to 21% at the peak relative to the 2019 average. These price changes are consistent with Bown (2021).[17]

[15] The July 1st, 2020 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.

[16] See https://shopp.org/.

[17] See Cabral and Xu (2021) for a detailed analysis of the role of price gouging on observed price changes.

Figure 3: Global demand shock



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

5.2 Global demand shock in the model

Motivated by this evidence, we model a pandemic in our model as consisting of a global increase in the demand for essential goods. Given the small open economy nature of the model, we implement it as the combination of domestic and foreign shocks. Domestically, the economy experiences a shock that increases the reference level of essential goods $\bar{e}$. This captures the increased need for PPE throughout COVID-19. On the foreign front, the economy experiences shocks to the price of imports and exports of essential goods. As documented above and reported throughout, the pandemic increased global demand for essential goods, which led to higher prices and rationing of essential goods. We model these effects as captured by shocks to p_e^x and p_e^m.[18]

Given the high-frequency dynamics of the pandemic, we interpret a period in the model as a month in the data. And given our focus on shortages of essential medical goods prior to the development of vaccines, we study shocks that last for 12 months. We study the perfect foresight solution of the model in response to these shocks. We let period 0 denote the initial steady state. The full path of shocks is observed in period 1. Agents observe an increase of $\bar{e}$, p_e^x, and p_e^m for 12 periods, with their values reverting back to their initial steady-state levels in period 13. To simplify the analysis, we assume that each shocked parameter increases once before reverting back to steady state.

We parameterize the shocks by restricting attention to the four essential medical goods identified by the White House COVID-19 Supply Chain Task Force and described in detail in Section 5.1. We set the shock to the reference level $\bar{e}$ to match the increased demand for

[18] To simplify the analysis, we assume that import and export prices increase by the same amount.

these goods documented in Figure 2. In our model, $\overline{e}$ captures the time-varying reference level of essential goods in the final goods aggregator, and a higher value of $\overline{e}$ reflects a greater perceived need or demand for essential goods—such as that observed during a public health emergency. For each good, we first identify the peak demand over this period relative to pre-pandemic demand and then compute the median across goods. The demand for the median good increases by 1.39 log-points at the peak. Thus, we consider an increase of $\overline{e}$ such that $\Delta \ln \overline{e} = 1.39$ throughout the 12 months of the pandemic. Figure 3 plots the dynamics of the shocks that characterize a pandemic in our model.

We set the shocks to import and export prices to match changes in the unit values of essential COVID-19 goods from the USITC and the World Customs Organization. First, we identify the set of product codes corresponding to goods identified as essential, as described above.[19] For each good we identify the highest price change relative to pre-pandemic prices, and then compute the median across goods. While we rely on the same data used for Table 3, here we pool all underlying product codes and abstract from the broad product categories. We find the price of the median good increased by 0.96 log-points at the peak. Thus, we consider an increase of import and export prices such that $\Delta \ln p_e^x = \Delta \ln p_e^m = 0.96$ during the 12 months of the pandemic.

5.3 Parameterization

To parameterize the model, we partition the parameter space into three sets of parameters: predetermined parameters, parameters estimated to match moments of the U.S. economy prior to the onset of COVID-19, and parameters estimated to match the dynamics of the U.S. economy following COVID-19.

Predetermined parameters Predetermined parameters are set to standard values from the literature and consist of the discount factor β, the intertemporal elasticity of substitution $1/\xi$, the elasticity of substitution between domestic and imported varieties of essential and non-essential goods 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 goods producers to 1. We focus an economy with balanced trade in the steady state — thus, we have that the steady-state levels of debt b_n and b_e held by households of each type are equal to zero.

[19] We restrict attention to products with non-missing data throughout the first 12 months of the pandemic. Thus, we exclude N95 masks since they were not separately reported prior to July 2020.

Table 4: Predetermined parameters

Parameter	Value	Description
β	$0.96^{\frac{1}{12}}$	Discount factor
$1/\xi$	0.50	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

Table 4 reports the parameter values used throughout. We set β to $0.96^{\frac{1}{12}}$, which implies an annual interest rate of 4% given we set $r^* = 1/\beta$. We set the intertemporal elasticity of substitution $1/\xi$ to 0.50 ($\xi = 2$), consistent with empirical estimates using aggregate data (Hall 1988; Campbell and Mankiw 1989). The elasticity of substitution σ is set to 4 following Simonovska and Waugh (2014), implying domestic and imported varieties are relatively substitutable. We set the labor share α to 2/3 and returns to scale η to 0.85 from Midrigan and Xu (2014) and Atkeson and Kehoe (2007). We set the monthly depreciation rate δ to 1%, implying an annual depreciation rate $\approx$ 11%, consistent with equipment depreciation estimates in U.S. manufactures (Albonico, Kalyvitis, and Pappa 2014).

Parameters estimated to match targets prior to shocks The set of parameters estimated to match moments of the U.S. economy prior to COVID-19 consists of the productivity of non-essential goods producers A_n, the iceberg trade costs τ_e and τ_n, the reference level of essential goods $\overline{e}$ in the steady state, the weight γ of essential goods in the technology of final goods producers, and the measures λ_n and λ_e of households of each type. We normalize the mass of households in the economy to unity. Thus, given a value of $\lambda_n \in (0,1)$, we have $\lambda_e = 1 - \lambda_n$.

We choose the remaining 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 goods absorption that is imported, (*iv*) the share of non-essential goods absorption that is imported, (*v*) the aggregate absorption of essential goods relative to their reference level, and (*vi*) the share of aggregate labor supplied by households

Table 5: Estimated parameters, pre-shock steady state

Parameter	Value	Description
A_n	1.592	Sectoral productivity
τ_e	0.138	Trade costs on essential goods
τ_n	0.342	Trade costs on non-essential goods
$\overline{e}$	0.312	Reference level of essential goods
γ	0.0021	Utility weight on essential goods
λ_n	0.957	Measure of agents of type n
λ_e	$1-\lambda_n$	Measure of agents of type e
Moment	Target value	Model
NX_e/GDP_e	−0.188	−0.188
GDP_e/GDP	0.043	0.043
$M_e/p_e e$	0.404	0.404
$M_n/p_n n$	0.293	0.293
Aggregate $e/\overline{e}$	1.000	1.000
HH n labor share	0.957	0.957

of type n.

To compute empirical counterparts to 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 PPE that was key at the onset of COVID-19.[20] 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 as consisting of all other goods produced in the U.S.[21] We compute all moments using data from the Bureau of Economic Analysis and the U.S. Census.[22] Finally, we set the target values of moments (v) and (vi) as follows: First, we assume aggregate consumption of essential goods is equal to the reference level in the pre-shock steady state—$e=\overline{e}$. Second, we assume that the share of aggregate labor supplied by households of type

[20]The key constraint that we face is that the product-level gross output data are not sufficiently disaggregated to distinguish between personal protective equipment and other medical goods.
[21]Thus, our empirical counterpart to GDP in the model is U.S. goods GDP.
[22]International trade data from U.S. Census consist of product-level data at the HS-6-digit level of disaggregation. There are a total of 5,402 product categories, from which 92 belong to the medical sector.

n is equal to the share of aggregate output accounted for by the firms they own.[23]

The estimated parameters as well as the empirical targets and their model counterparts are reported in Table 5. We find that the six estimated parameters can be chosen to match the six targets exactly. To have lower net exports of essential goods than non-essential goods, the model requires producers of non-essentials to be more productive than producers of essential goods. The model also requires a very low utility weight on essential goods in order to match the low share of essential goods in aggregate GDP. And, finally, trade costs determine the extent to which absorption of essential and non-essential goods is imported.

Parameters estimated to match dynamics following shocks We estimate the remaining parameters to match salient features of the dynamics of the U.S. economy following the onset of the shocks: the elasticity of substitution ρ between essential and non-essential goods, the capital and labor adjustment costs $\{\Omega_{ke}, \Omega_{\ell e}\}$ faced by producers of essential goods, the capital and labor adjustment costs $\{\Omega_{kn}, \Omega_{\ell n}\}$ faced by producers of non-essential goods, and the interest rate slope Ω_r. We simplify the estimation by assuming that $\Omega_{ke} = \Omega_{\ell e}$ and $\Omega_{kn} = \Omega_{\ell n}$.

We choose the four estimated parameters to match the following features of the U.S. economy after the onset of COVID-19 relative to pre-pandemic levels: (*i*) the growth of essential goods consumption, (*ii*) the growth of absorption of non-essential goods, (*iii*) the growth of output of non-essential goods, and (*iv*) the change of the aggregate net exports to GDP ratio. All moments are computed as the average monthly change throughout Q2 and Q3 of 2020 relative to Q4 of 2019.[24]

We compute empirical counterparts for these moments as follows: We compute moment (*i*) using estimates of domestic sales and imports of four critical goods from the White House COVID-19 Supply Chain Task Force, as described in Section 5.1. We first compute median monthly growth across goods, and then average these monthly medians. We use data on U.S. goods GDP from the BEA to measure consumption and output of non-essential goods, as well as the net exports-to-GDP ratio.

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

[23] In the Appendix we examine the sensitivity of our findings to alternative targets for the output share of essential goods.

[24] The only exception is moment (*i*), which is computed relative to January 2020 due to data availability.

Table 6: **Estimated parameters, post-shock dynamics**

Parameter	Value	Description	
ρ	0.291	Elasticity essential and non-essential	
$\Omega_{k,c} = \Omega_{n,c}$	72.819	Adjustment costs: Non-essential	
$\Omega_{k,e} = \Omega_{n,e}$	4.699	Adjustment costs: Essential	
Ω_r	0.009	Interest rate slope	
Moment		Target value	Model
e_t : log(Avg. Q2-Q3 '20 / Pre-pandemic)		0.619	0.619
c_t : log(Avg. Q2-Q3 '20 / Pre-pandemic)		−0.062	−0.062
$y_{c,t}$: log(Avg. Q2-Q3 '20 / Pre-pandemic)		−0.070	−0.063
NX/GDP: Avg. Q2-Q3 '20 − Pre-pandemic		−0.009	−0.009

their model counterparts, assigning equal weight to each of the moments.[25] Table 6 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 non-essential good output. We find that essential and non-essential goods are estimated to be complementary, with an elasticity of substitution equal to 0.291. We estimate positive sectoral adjustment costs in both sectors, with larger costs faced by producers of non-essential goods. Finally, we estimate an interest rate slope equal to 0.009.

5.4 Dynamics following shortages of essential goods

We now study the impact of a global demand shock by computing impulse response functions following the shocks presented in Figure 3. The dynamics of key variables, expressed as percent deviations from their steady-state values, are presented in Figures 4 and 5.[26] We restrict attention to the dynamics over the first two years (24 periods) following the onset of the shocks.

Production and trade of essential goods We begin with the dynamics of production and trade of essential goods, illustrated in Figure 4. Our starting point is that higher export and import prices of essential goods significantly increase the overall price of essential goods. This result is partially driven by the nontrivial fraction of essential goods that are imported.

[25] We study the perfect foresight solution of the model numerically using global methods.

[26] We report the dynamics of a broader set of variables in the Appendix.

But, moreover, this is also accounted for by the rise of export prices, which leads producers of essential goods to increase the domestic price of domestically produced essential goods.

These higher prices of essential goods increase the returns to accumulating capital and hiring labor for producers of essential goods, rising the optimal production scale — as described in Section 4. However, production increases gradually given the costs to adjust capital and labor. This adjustment of production involves short-run losses financed via equity injections from the households that own these producers — the losses are more than offset by increased profits thereafter.

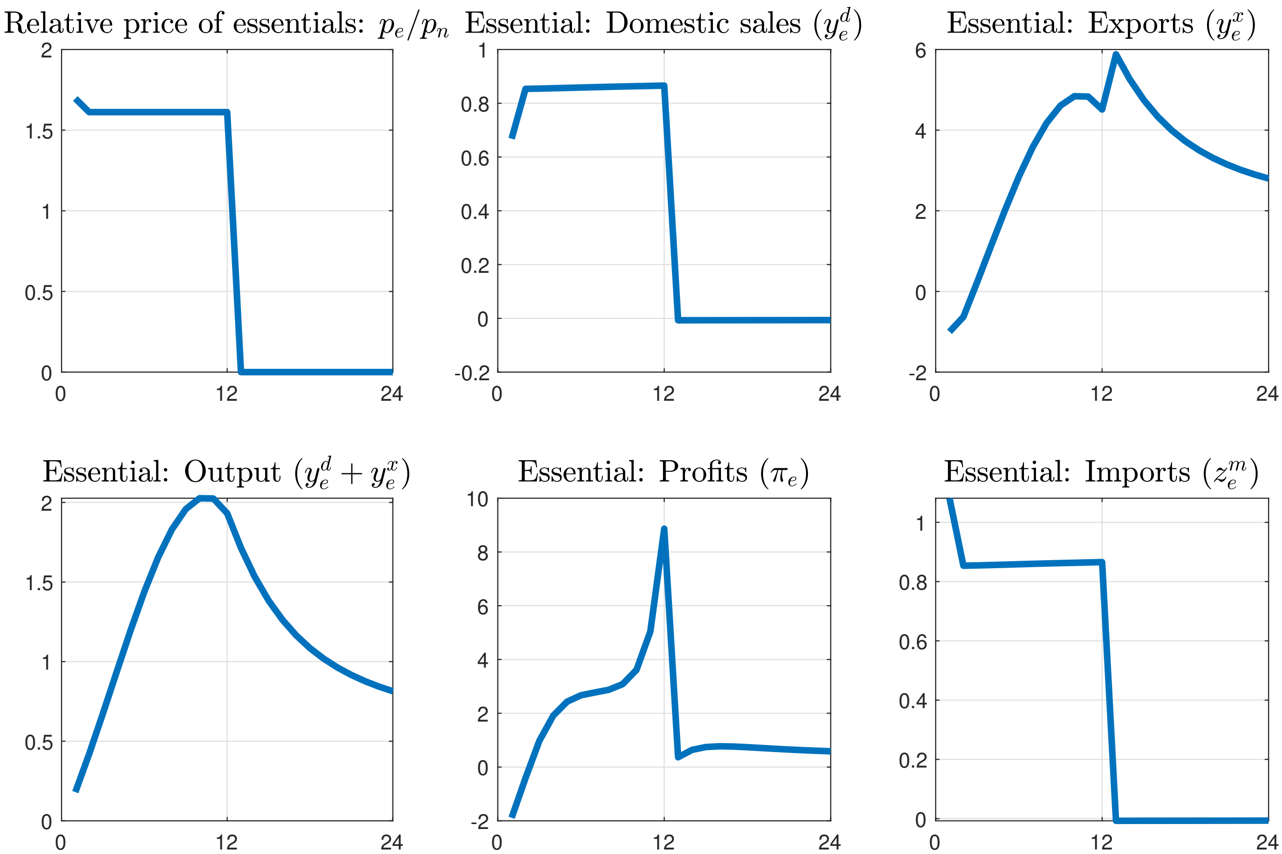
The increased production of essential goods is distributed across all destination markets: Both domestic sales and exports of these goods increase. On the one hand, and despite sizable price increases, domestic demand for essential goods increases given the higher reference level along with the complementarity between essential and non-essential goods — as described in Section 4. Thus, both domestic sales and imports increase significantly throughout the pandemic. On the other hand, exports increase given the attractiveness of the higher export price along with the perfectly elastic demand faced by domestic producers when selling internationally.

Interestingly, we find that exports increase relatively more than domestic sales. Thus, despite the higher domestic need and demand for essential goods, most of the increased production scale is actually exported rather than sold domestically. This implication raises questions about the desirability of the equilibrium outcomes and the potential for policy to increase welfare.

Consumption and discounting Given our setup with heterogeneous households and incomplete markets, the consumption and discounting dynamics implied by the model differ between them, as described in Section 4. Figure 5 plots key variables in the dynamics of consumption and discounting for households of each type.

The consumption dynamics vary markedly across household types. Type e households increase their consumption gradually, whereas type n households show little dynamic adjustment after the initial shock. This divergence arises from the time-varying nature of profits earned by type e households, characterized by substantial initial losses followed by significant returns toward the later stages of the pandemic. Due to financial market imperfections, households are unable to fully borrow against their future income, prompting them to adopt consumption paths that are smooth but steadily increasing.

Figure 4: Dynamics of production and trade of essentials

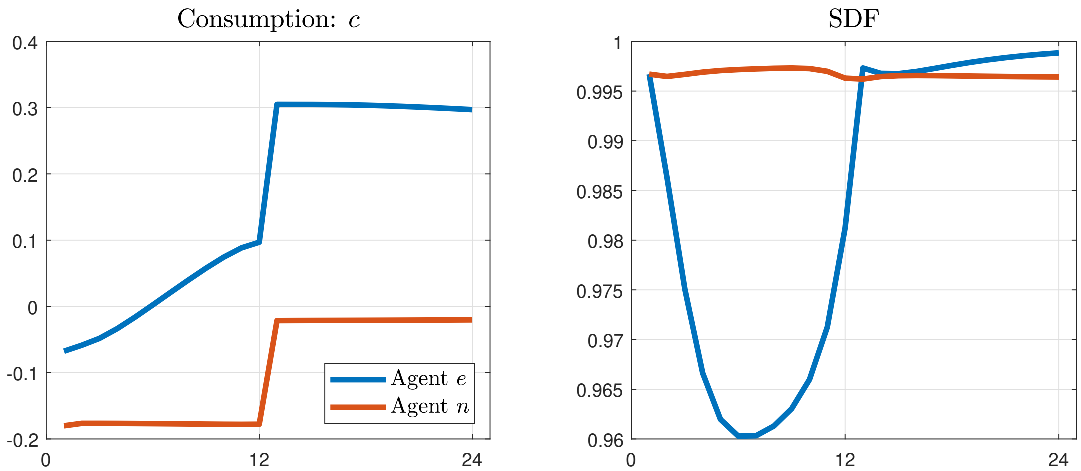


Note: The x-axes denote time periods (months). The y-axes are expressed as percent deviations from steady state. Specifically, percent changes are obtained by multiplying the values in the panel by 100.

The heterogeneous path followed by the consumption (and borrowing) dynamics across households is mirrored by the dynamics of each household's SDF. On the one hand, the SDF of households of type n remains relatively unchanged, reflecting their relatively flat pattern of consumption and borrowing throughout the pandemic. On the other hand, the SDF of households of type e declines significantly below its steady-state level throughout the pandemic. These households increase consumption gradually through increased borrowing, which raises the borrowing costs and reduces the SDF.

Differences in discounting across households are also critical to determine investment and hiring decisions of the firms they own. The lower SDF of households of type e imply that producers of essential goods make investment and hiring decisions assigning relatively lower value to future returns, as described in Section 4. This implication raises questions about the desirability of the equilibrium outcomes. We study these and other related questions in

Figure 5: Dynamics of consumption and discounting



Note: The x-axes denote time periods (months). The y-axes are expressed as percent deviations from steady state, except for the SDF which is in levels. Specifically, percent changes are obtained by multiplying the values in the panel by 100.

the next section.

6 Optimal Trade and Industrial Policy

We now study the potential for trade and industrial policies, such as those observed following the onset of COVID-19, to address the inefficiencies identified in our model in Section 4 following pandemic-like shocks. While financial frictions could potentially be addressed more directly through purely financial interventions—such as direct loans or credit guarantees—in practice governments primarily resorted to trade and industrial policies following COVID-19. Thus, our goal is to analyze the desirability of the policies implemented during this episode.

6.1 Government Problem

We endow the government with three policy instruments targeted only on essential goods: (i) ad-valorem import tariffs τ^m_{et}, (ii) ad-valorem export taxes τ^x_{et}, and (iii) ad-valorem sales subsidies τ^y_{et}.[27] We refer to (i) and (ii) as trade policies, and to (iii) as industrial policy. While trade policies alter the incentives to sell and source essential goods domestically or internationally, industrial policies adjust the incentives to produce essential goods. Note that negative values of τ^m_{et} and τ^x_{et} denote subsidies, while negative values of τ^y_{et} denote taxes.

To simplify the analysis, we restrict attention to one-time transitory changes to these

[27]We keep $\tau^m_{nt} = \tau^x_{nt} = \tau^y_{nt} = 0$ throughout.

policy instruments, which become active during the pandemic and revert back to zero (their steady-state values) after the pandemic ends in period 13.

We assume the government's budget constraint is balanced every period. Yet, our setup allows for multiple ways to design the financing of these policy instruments across households. As in Itskhoki and Moll (2019), we do not allow for direct transfers of resources across households. In particular, we assume that (i) revenues from import tariffs on essential goods are rebated back to households in proportion to the share of total imports consumed (that is, $\psi^m_{iet} = q^m_{it} / \sum_k q^m_{kt}$), (ii) revenues from export taxes on essential goods are rebated back to the households that own essential goods producers (that is, $\psi^x_{eet} = 1$ and $\psi^x_{net} = 0$), (iii) subsidies on the production of essential goods are financed by the households that own essential goods producers (that is, $\psi^y_{eet} = 1$ and $\psi^y_{net} = 0$). These constraints prevent the government, for instance, from choosing to tax exports of the firm owned by household e to rebate the tax revenues to household n.

Finally, we focus on a standard utilitarian government objective function whose value in period t consists of the population-weighted average between the value functions V_{nt} and V_{et} of households n and e, respectively, from period t onward. That is, the government's objective is given by:

$$\mathcal{V}_t = \lambda_n V_{nt} + \lambda_e V_{et},$$

where λ_n and λ_e denote the respective population shares of each household type. This objective is the same as the planner's discussed in Section 4, connecting the inefficiencies identified there and the policy interventions analyzed here.

The government's problem consists of choosing policies $(\tau^m_e, \tau^x_e, \tau^y_e)$ throughout the pandemic to maximize its objective function starting from the period in which the shocks are first realized (period 1). Formally, the problem is given by:

$$\max_{\tau^m_e, \tau^x_e, \tau^y_e} \mathcal{V}_1(\tau^m_e, \tau^x_e, \tau^y_e),$$

where $\mathcal{V}_1(\tau^m_e, \tau^x_e, \tau^y_e)$ denotes the government's objective function in period 1 in a competitive equilibrium with policies $(\tau^m_e, \tau^x_e, \tau^y_e)$ implemented throughout the duration of the pandemic.

To isolate the role of the distortions discussed in Section 4 on the optimal policies, we abstract from terms of trade effects by removing markup distortions due to monopolistic competition. We do so by introducing a constant domestic sales subsidy as in Gali and Monacelli (2005). As we show in the Appendix, this implies that the optimal trade and industrial policies in the pre-shock steady state are all zero. Policies are determined and set in period 1, and remain unchanged thereafter until the end of the pandemic—i.e., we assume full commitment.

6.2 Optimal Policies

We solve the government's problem described above under three alternative sets of policy instruments: (*i*) only trade policy, (*ii*) only industrial policy, and (*iii*) both trade and industrial policy.[28] Table 7 reports the optimal policies in each of these cases.

Trade Policy The first row of Table 7 shows that when constrained to trade policy instruments, the government finds it optimal to introduce a 13.61% export tax on essential goods, alongside a 9.33% import subsidy. This policy mix serves two complementary goals: it reallocates essential goods toward domestic households during the pandemic and preserves the efficiency of consumption composition across sources by mitigating the distortions introduced by the export tax.

The export tax directly lowers the domestic price of essential goods relative to the world price. Since firms are price takers in international markets, the export tax reduces the revenue they receive from foreign sales, increasing the attractiveness of selling domestically. As a result, firms reallocate goods toward the domestic market, increasing domestic sales and reducing prices. The resulting domestic price of essential goods is given by:

$$p_{et}^d = \frac{\sigma}{\sigma - 1} \cdot \frac{(1 + \tau_{et}^y - \tau_{et}^x) p_{et}^x}{(1 + \tau_{et}^y)},$$

where τ_{et}^x is the export tax and τ_{et}^y is the production subsidy (which is zero when restricting to trade policy instruments). A higher export tax τ_{et}^x lowers the numerator, thus reducing p_{et}^d. This price reduction increases the consumption of essential goods among households, mitigating the distortion in the household's SDFs by bringing consumption paths closer to what a planner would choose.

However, this intervention creates a secondary distortion: by lowering domestic prices, the export tax shifts consumption toward domestically produced essential goods and away

[28] To solve the government's problem under policies (*i*) and (*ii*), we adjust the problem accordingly. For (*i*), we solve it constraining $\tau_e^y = 0$. For (*ii*), we solve it constraining $\tau_e^m = \tau_e^x = 0$.

from imported varieties, distorting the efficient allocation across sources. To offset this imbalance, the government introduces an import subsidy, which lowers the relative price of foreign varieties and restores the efficient composition of essential goods consumption. The role of the import subsidy is captured by the following optimality condition:

$$\frac{(1+\tau^m_{et})\tau_e}{\frac{\sigma}{\sigma-1}\cdot\frac{(1+\tau^y_{et}-\tau^x_{et})}{(1+\tau^y_{et})}}\cdot\frac{p^m_{et}}{p^x_{et}}=\frac{1-\omega_e}{\omega_e}\cdot\frac{{q^m_{et}}^{-1/\sigma}}{{q^d_{et}}^{-1/\sigma}},$$

which equates the marginal utility-adjusted cost of imported and domestic essential goods. The import subsidy (negative τ^m_{et}) ensures that households do not substitute too strongly toward domestic varieties.

Industrial Policy The second row of Table 7 illustrates the effects of industrial policy. When restricted to this instrument, the government finds it optimal to implement a 16.86% ad-valorem subsidy on the total sales of essential goods. This policy is designed to offset the contraction in investment caused by households' excessive discounting of future returns.

In the model, households face financial frictions that distort their intertemporal choices, reducing the effective value they place on future consumption and returns to investment. As a result, firms underinvest in capital and underhire labor, relative to socially optimal allocations. The production subsidy corrects this by raising the marginal revenue product of inputs and thus restoring investment and production incentives. Formally, the subsidy enters the firm's optimality conditions for capital and labor:

$$m_{et+1}\left[(1+\tau^y_{et}-\tau^x_{et})p^x_{et+1}\left((1-\alpha)\eta A_e(\ell^\alpha_{et+1}k^{1-\alpha}_{et+1})^\eta/k_{et+1}\right)+\Omega^m_{nt+1}(1-\delta)\right]=\Omega^m_{nt}$$
$$(1+\tau^y_{et}-\tau^x_{et})p^x_{et}A_e\alpha\eta(\ell^\alpha_{et}k^{1-\alpha}_{et})^{\eta-1}\ell^{\alpha-1}_{et}k^{1-\alpha}_{et}=w_t.$$

Here, the sales subsidy τ^y_{et} raises the price received by producers, boosting the marginal benefit of labor and capital inputs and encouraging firms to scale up production.

However, the increase in production does not automatically lead to higher domestic consumption. Because essential goods are traded in international markets at perfectly inelastic prices, a share of the additional output is exported. In the absence of complementary trade policy instruments that reallocate sales toward domestic households, the gains from increased production primarily accrue to foreign consumers. As a result, industrial policy has limited capacity to alleviate domestic shortages, even though it effectively addresses the underlying

Table 7: Optimal policies following shocks

	Export tax	Import tariff	Total sales subsidy	Welfare gain
Trade policy	13.61%	−9.33%	—	0.22%
Industrial policy	—	—	16.86%	0.15%
Trade and industrial policy	24.94%	−18.96%	32.11%	0.81%

investment inefficiency.

Trade and Industrial Policies The third row of Table 7 presents optimal trade and industrial policies when implemented jointly. The government finds it optimal to combine a 24.94% export tax, an 18.96% import subsidy, and a 32.11% production subsidy. The magnitude of each policy instrument is larger than when implemented in isolation, reflecting strong complementarities between trade and industrial interventions.

This complementarity arises from the interplay between the different distortions each policy addresses. The export tax reallocates exports toward domestic sales, mitigating the impact of financial frictions on discounting heterogeneity across households. However, in doing so, it also discourages production and alters the composition of consumption away from imports toward domestic goods. The import subsidy offsets the consumption reallocation, ensuring a more balanced sourcing of essential goods. Meanwhile, the production subsidy counteracts the reduced incentives to invest that would otherwise result from the export tax.[29]

Our findings raise numerous questions on the impact of these policies and the channels that account for the optimal policy response to shortages of critical goods. To address these questions, we first examine the welfare gains from these policies. Then, we investigate their impact on equilibrium outcomes. In the Appendix we study the role played by various features of the model in accounting for our findings.[30]

[29] In the Appendix, we report the optimal policy response to each individual shock component and explore robustness across model specifications.

[30] In the Appendix we show that countries more dependent on trade for essential goods—i.e., those running trade deficits prior to the pandemic—were more likely to adopt trade and industrial policies during COVID-19.

6.3 Welfare gains from optimal policies

The welfare gains reported in Table 7 quantify how effectively the policy mechanisms translate into measurable improvements in household well-being. For each alternative set of policy instruments, we compute the welfare gains in consumption-equivalent units between an economy without policy interventions vs. an economy with optimal policy changes. Specifically, we ask: What uniform percentage increase of the consumption bundle of every household over the duration of the shocks would make the government indifferent between an economy with vs. without optimal policy changes?

To answer this question, we solve for the value of α that equates (i) the value of the government's objective function in period 1 without optimal policies but with household consumption evaluated according to period utility $\frac{[(1+\alpha)c]^{1-\xi}}{1-\xi}$ for the duration of the shocks, with (ii) the value of the government's objective function in period 1 under the optimal policies. Thus, the welfare gains are measured based on a proportional increase of consumption throughout the 12 periods that the shocks and policies last for.

We find that the welfare gains from optimal trade policy interventions on essential goods are equal to 0.22% in consumption-equivalent units. That is, households in an economy without policy changes would need their consumption bundle to increase by 0.22% every period for the duration of the shocks to be indifferent to living in the economy that implements the optimal trade policies during the pandemic.

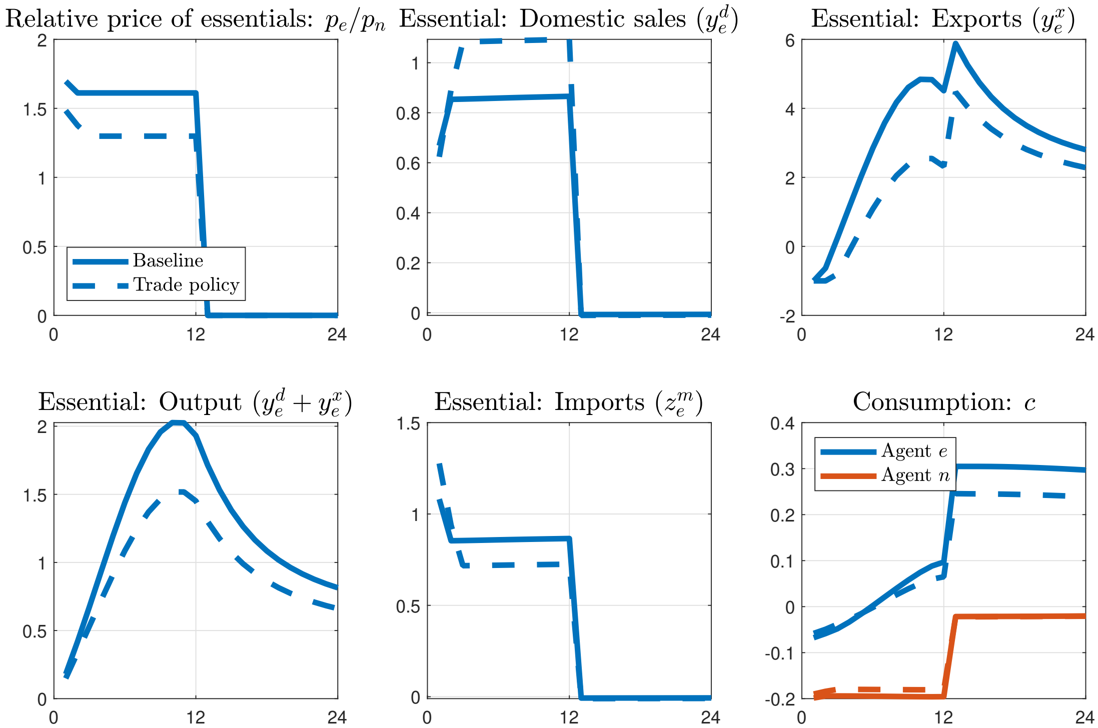
The second row of the table shows that the welfare gains from industrial policies are significantly lower than those from the trade policies: 0.15% vs. 0.22%, respectively. This difference highlights the importance of addressing the fundamental SDF distortion through export taxes, rather than focusing only on production incentives through sales subsidies.

The third row provides evidence of policy complementarity: The welfare gain from combining trade and industrial policies is 0.81%, which is greater than the sum of gains from implementing each policy type separately (0.22% + 0.15% = 0.37%). This strong complementarity confirms our theoretical mechanism—export taxes (24.94%) address the primary SDF distortion, while import subsidies (18.96%) and production subsidies (32.11%) work together to mitigate the secondary distortions that export taxes create.

6.4 Dynamics under optimal policies

Next, we investigate the impact of the optimal policies on the equilibrium dynamics following the shocks. To do so, we contrast the impulse response functions for key variables

Figure 6: Dynamics under optimal trade policy



Note: The x-axes denote time periods (months). The y-axes are expressed as percent deviations from steady state. Specifically, percent changes are obtained by multiplying the values in the panel by 100.

of the model with vs. without the optimal policy interventions.

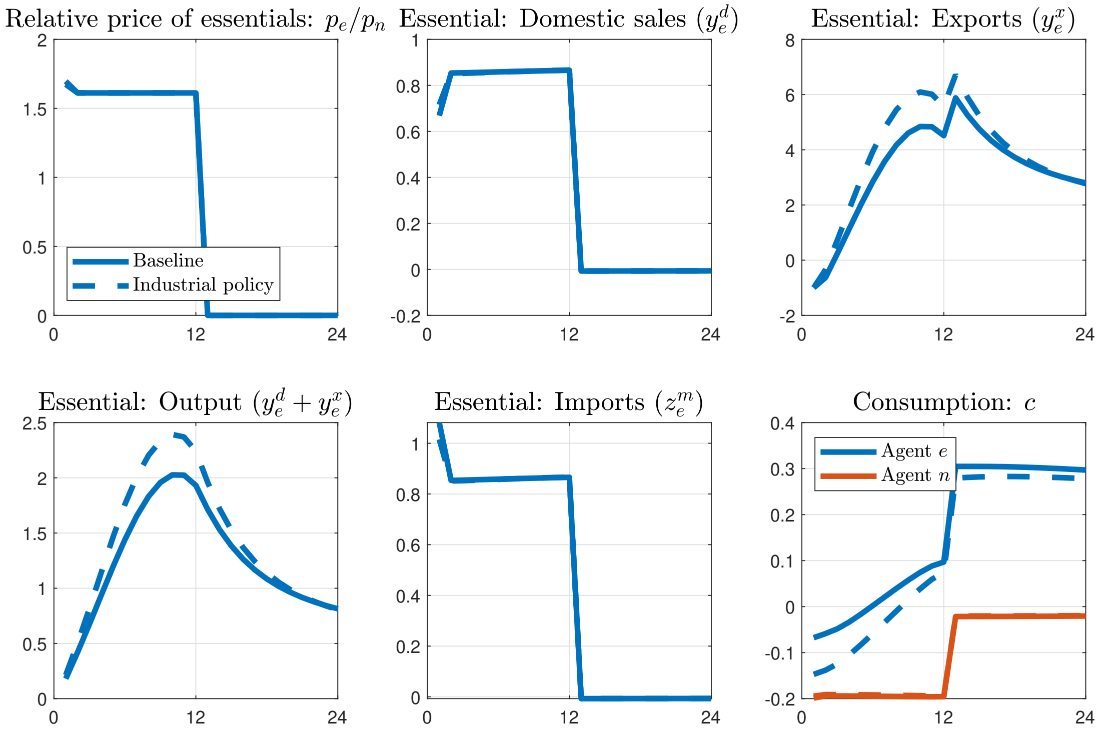
Optimal trade policy We begin with the impact of the optimal trade policy interventions, presented in Figure 6. We find that the optimal trade policy allows households to increase their consumption of essential goods throughout the duration of the shocks relative to the economy without trade policy changes.

The tax on exports leads firms to lower 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 substantially. Thus, optimal export taxes result from balancing two conflicting forces: They reduce the incentives to produce essential goods, but they also increase domestic access to such goods.

The lower price of domestic varieties due to the export tax also reallocates consumption of essential goods from imported to domestic varieties. The government finds it optimal to offset this reallocation of consumption by introducing an import subsidy.[31] This allows

[31] In the Appendix, we show that there is no role for import subsidies when introduced in isolation.

Figure 7: Dynamics under optimal industrial policy



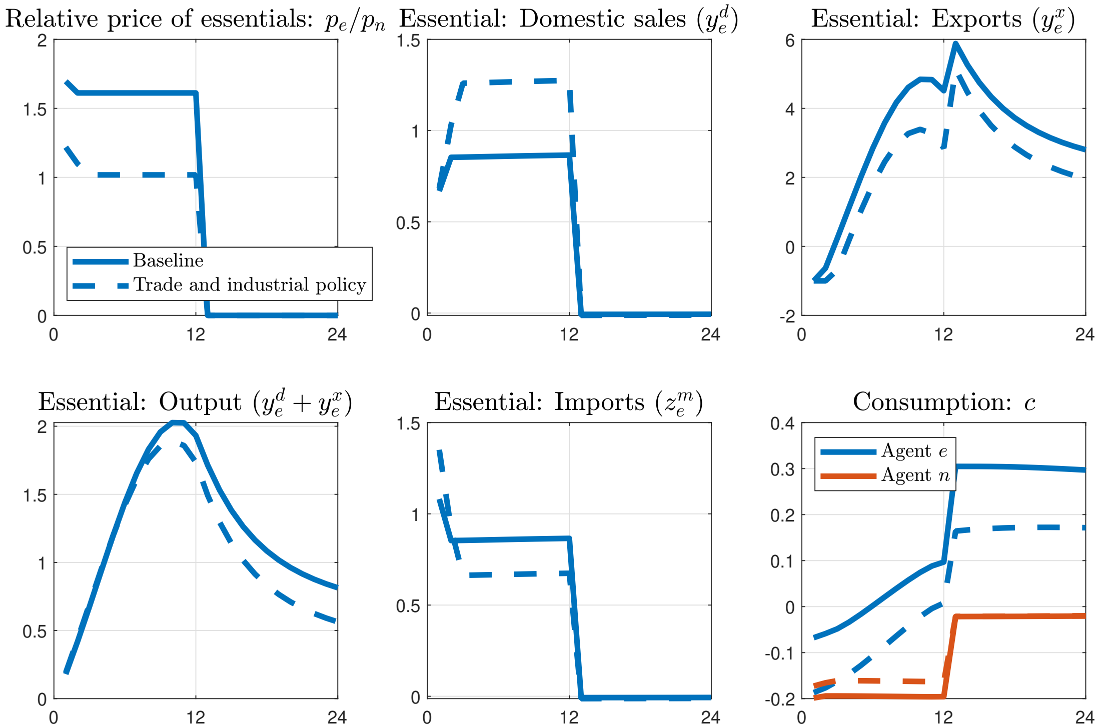
Note: The x-axes denote time periods (months).The y-axes are expressed as percent deviations from steady state. Specifically, percent changes are obtained by multiplying the values in the panel by 100.

households to purchase imports of essential goods at a lower price, increasing imports and total consumption of these goods. Thus, we find that export taxes and import subsidies increase domestic and imported consumption of essential goods, mitigating the negative impact of the increase in the reference level $\bar{e}$.

Optimal industrial policy We now examine the impact of the optimal industrial policy, presented in Figure 7. In contrast to the optimal trade policy, industrial policy leads to an increase in the production of essential goods. This is intuitive, since subsidizing sales of these goods raises the effective return to producing them, leading producers of essential goods to increase their accumulation of physical capital and labor. Yet, we find that industrial policy is not effective at increasing the consumption of essential goods relative to the reference level, despite the increased production.

The missing link between increased production and consumption is accounted for by international trade: Industrial policy is effective at encouraging firms to increase production of essential goods, but the increased output of these goods is primarily exported rather than sold domestically. Given the price of essential goods is determined internationally, it

Figure 8: Dynamics under optimal trade and industrial policy



Note: The x-axes denote time periods (months). The y-axes are expressed as percent deviations from steady state. Specifically, percent changes are obtained by multiplying the values in the panel by 100.

largely pins down the level of domestic demand, leading most additional output to be sold internationally.

Optimal trade and industrial policy The previous findings show that trade and industrial policies have very different impacts on the dynamics following the shocks.[32] The welfare results show that these policies are complementary following the shocks that we study — thus, we now investigate their joint impact, presented in Figure 8. We find that, indeed, trade and industrial policies can jointly increase the consumption of essential goods across most households without discouraging the production of essential goods.

Role of efficiency vs. redistribution To further investigate the channels underlying the role for policy interventions, in the Appendix we decompose the relative importance of efficiency versus redistributive considerations in shaping the optimal trade and industrial policy responses. While our model abstracts from direct redistribution, the policy instruments we

[32]The qualitative effects of the policies on aggregate dynamics are not specific to the relative size of the domestic demand shock versus the international price shock. Specifically, holding shocks fixed, export taxes reduce output by lowering producer returns, while production subsidies increase output by strengthening investment incentives.

analyze indirectly affect agents' welfare by altering both the aggregate availability of essential goods (efficiency) and the relative distribution of consumption across households (redistribution). We quantify the contributions of these two channels by comparing the baseline policy interventions with alternative specifications that isolate pure efficiency considerations (ignoring redistribution). We find that efficiency concerns account for approximately two-thirds of the welfare gains from policy interventions, while redistributive motives explain the remaining third. This suggests that the primary role of optimal trade and industrial policies in our setting is to correct distortions in production and consumption rather than to redistribute resources across households.

Key ingredients Finally, in the Appendix we explore the key economic mechanisms that underpin our policy findings by conducting a series of counterfactual exercises. We find that the rationale for policy interventions hinges on the presence of incomplete financial markets and household heterogeneity—without these, the competitive equilibrium would not feature distortions that motivate policy responses. The strength of intra- and inter-temporal complementarities also plays a crucial role: when households can more easily substitute non-essential for essential goods, or when they can more easily shift consumption intertemporally, the need for policy interventions diminishes. Additionally, sectoral adjustment costs affect the magnitude of the optimal policies, as higher frictions in scaling production amplify the role for government interventions. A detailed discussion of these counterfactual exercises and their implications can be found in the Appendix.

7 Concluding remarks

This paper investigates the optimal role of international trade and industrial policy interventions to address shortages of essential goods in the aftermath of global shocks. We find that a coordinated ex-post policy mix—combining export taxes, import subsidies, and production subsidies—raises welfare by reallocating supply toward domestic use and strengthening firms' incentives to invest. These instruments complement one another by addressing distinct distortions arising from incomplete financial markets and concentrated firm ownership, which jointly lead to underinvestment and inefficient allocations. The policy mix we identify mirrors tools governments used during the COVID-19 pandemic, including the use of export controls and the activation of industrial policies like the Defense Production Act.

Our analysis opens several avenues for future research. One priority is to examine alternative ex-ante interventions, such as credit or macroprudential policies, that more directly target financial frictions. It would also be valuable to extend the framework to large open economies, where trade policy can affect terms of trade, and to richer heterogeneous-agent environments that allow for variation in firm size, wealth, and borrowing constraints. These extensions could provide deeper insight into how policy instruments interact—and how best to design institutional frameworks for mitigating shortages in an increasingly shock-prone global economy.

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