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Online Appendix to Shortages of Critical Goods in a Global Economy

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Shortages of Critical Goods in a Global Economy¹

Appendix for Online Publication

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¹The views expressed in this paper are those of the individual authors and do not necessarily reflect official positions of the Federal Reserve Bank of Dallas, the Federal Reserve System, or the Board of Governors.

Appendix A: Data sources

This appendix describes the main data sources used throughout the paper.

COVID-19 products The classification of COVID-19 related products is from Annex 1 of the following document created by the World Trade Organization (WTO): https://www.wto.org/english/news_e/news20_e/rese_03apr20_e.pdf. The list of 6-digit HS codes is: 340220, 401519, 621010, 630790, 650500, 650610, 842139, 900490, 901812, 901819, 901839, 901920, 902000, 902212, 902214, 902519.

Policy interventions Data on trade policy interventions are from Global Trade Alert: <https://www.globaltradealert.org/>. We restrict our attention to policy interventions that involve export restrictions (imposing export bans, licensing requirements, taxes, quotas, and non-tariff measures), import liberalizations (reducing import tariffs, licensing requirements, quotas, bans and non-tariff measures), and industrial policy (financial grants, state aid, state loans, loan guarantees, production subsidies, capital injections). We use data from February 2020 and January 2021.

Specifically, we group the policy interventions reported in the original dataset into the three groups that we study as follows. Export restrictions consist of the tightening or introduction of any of the following policies: export tax, local supply requirement for exports, export licensing requirement, export ban. Import liberalizations consist of the relaxation of any of the following policies: import tariff quota, import tariff, import licensing requirement, internal taxation of imports, import quota, import-related non-tariff measure. Industrial policies consist of the introduction or expansion of any of the following policies: financial grant, state aid, state loan, interest payment subsidy, tax or social insurance relief, loan guarantee, production subsidy, localization incentive, price stabilization, in-kind grant, capital injection and equity.

Financial policy interventions Data on financial policy interventions, used in Section 7.3 of the paper and in Appendix B, are from the Global Trade Alert New Industrial Policy Observatory (GTA-NIPO).

Sectoral output Gross output and value added by industry are from the Bureau of Economic Analysis (BEA), GDP by industry: <https://www.bea.gov/data/gdp/gdp-industry>. We use data for the year 2019. Medical goods correspond to the categories “Medical equipment and supplies manufacturing” and “Pharmaceutical and medicine manufacturing.”

International trade flows Monthly data on imports and exports of medical goods (values and unit prices) are from the US Census, USA Trade Online: <https://usatrade.census.gov/>.

Production and demand for COVID-19 goods Data on demand and production (domestic and imports) are from estimates computed by the White House Task Force. The projections were created by the White House Supply Chain Task Force, released by Democratic Sen. Maggie Hassan’s office: <https://www.hassan.senate.gov/imo/media/doc/SCTF%20Demand%20PPE%20Chart.pdf>

Financial conditions Bank lending standards are from the Federal Reserve’s Senior Loan Officer Opinion Survey on Bank Lending Practices, measured as the net percentage of domestic banks tightening standards for commercial and industrial loans to large and middle-market firms and to small firms (FRED series DRTSCILM and DRTSCIS). Corporate bond spreads are Moody’s seasoned Aaa and Baa corporate bond yields relative to the yield on 10-year Treasury constant maturity securities (FRED series AAA10Y and BAA10Y).

Appendix B: Additional evidence on financial-policy interventions

This appendix presents additional descriptive evidence on financial-policy interventions during shortages of essential goods. We document the prevalence of government policies designed to support firms’ access to finance during the COVID-19 pandemic. We interpret this evidence as showing that financial interventions were an important component of the policy response, rather than as identifying the presence or quantitative importance of the financial friction in our model.

1 Cross-country evidence

To investigate the prevalence of financial-oriented industrial policy interventions during the COVID-19 pandemic, we analyze data from the New Industrial Policy Observatory 2.0 (NIPO 2.0), which tracks industrial policies related to medical products across 76 jurisdictions worldwide. These data allow us to document the extent to which governments implemented financial support policies for producers of essential goods during the pandemic.

We categorize industrial policy measures into three distinct groups:

1. *Financial policies*, which provide firms with financial support through instruments such as capital injections, equity stakes, interest payment subsidies, loan guarantees, state loans, and other forms of financial assistance.
2. *Procurement policies*, which focus on reducing demand risk through purchase guarantees and grants.
3. *Other policies*, which support production through alternative channels.

Table 1 presents the distribution of these policies across OECD countries during 2020–2022. Financial support measures accounted for 46.8% of the industrial policy interventions recorded in OECD countries, compared with 32.0% for demand-oriented policies. The share of financial support measures was particularly high in certain countries, such as Canada (75.7%) and Germany (66.7%). These patterns show that financial support was an important component of the recorded policy response across a range of advanced economies.

OECD			USA		CAN	
Policy	Number	%	Number	%	Number	%
Financial	336	46.8	45	27.11	56	75.68
Demand	230	32.03	42	25.3	3	4.05
Other	152	21.17	79	47.59	15	20.27
EU			GER		UK	
Policy	Number	%	Number	%	Number	%
Financial	25	60.98	22	66.67	8	34.78
Demand	7	17.07	9	27.27	13	56.52
Other	9	21.95	2	6.06	2	8.70

Table 1: Number of policies, regulations, and firm-specific interventions

Governments in these economies made extensive use of financial channels to support producers of essential medical goods during the pandemic. These measures accounted for a substantial share of the industrial policy interventions recorded in the dataset.

Table 2 further illustrates the widespread nature of financial industrial policy interventions: 76.7% of OECD countries adopted at least one industrial policy—such as direct loans, loan guarantees, or bond purchases—that provided financial support to producers of medical products during the pandemic. The broad adoption of these measures across diverse

institutional and financial environments further motivates studying financial interventions alongside trade and industrial policies.

Category	Number	Share of OECD Countries (%)
Financial	23	76.67
Demand	23	76.67
Other	18	60.00

Table 2: Number of countries with at least one policy or firm-specific intervention

1.1 U.S. evidence

We next examine detailed evidence from the United States. Specifically, we document financial measures implemented by multiple U.S. government agencies to support producers of essential medical goods during the COVID-19 pandemic.

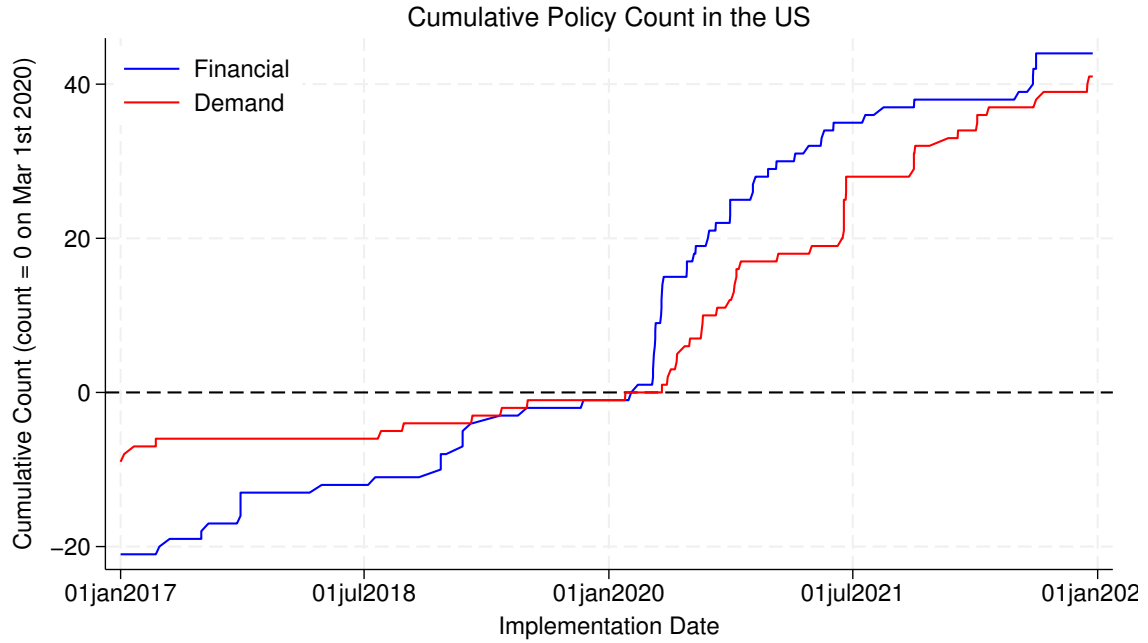


Figure 1: Cumulative Policy Count in the U.S.

Figure 1 shows the cumulative implementation of different types of policies in the United States during the COVID-19 pandemic. Financial support policies increased substantially over this period, illustrating that financial interventions formed an important component of the U.S. policy response.

The following specific cases illustrate the range of financial support provided to firms during the pandemic:

1. **Ology Bioservices Inc.** received a \$25 million loan through the Federal Reserve's Main Street Lending Program, with the Fed purchasing 95% of the loan to mitigate risk for the originating bank. The loan included favorable terms, including deferred principal and interest payments, and provided financing to a producer of essential medical goods.
2. **Pfizer Inc.** benefited from \$32 million in Federal Reserve bond purchases via the Secondary Market Corporate Credit Facility. This intervention provided market liquidity to a pharmaceutical company involved in vaccine development.
3. **Ginkgo Bioworks, Inc.** secured a \$1.1 billion loan from the U.S. International Development Finance Corporation to facilitate mass production of key vaccine raw materials and expand COVID-19 testing capacity.

4. **Dendreon Pharmaceuticals LLC** obtained a \$10 million Paycheck Protection Program loan, later forgiven, providing financial support to maintain operations.

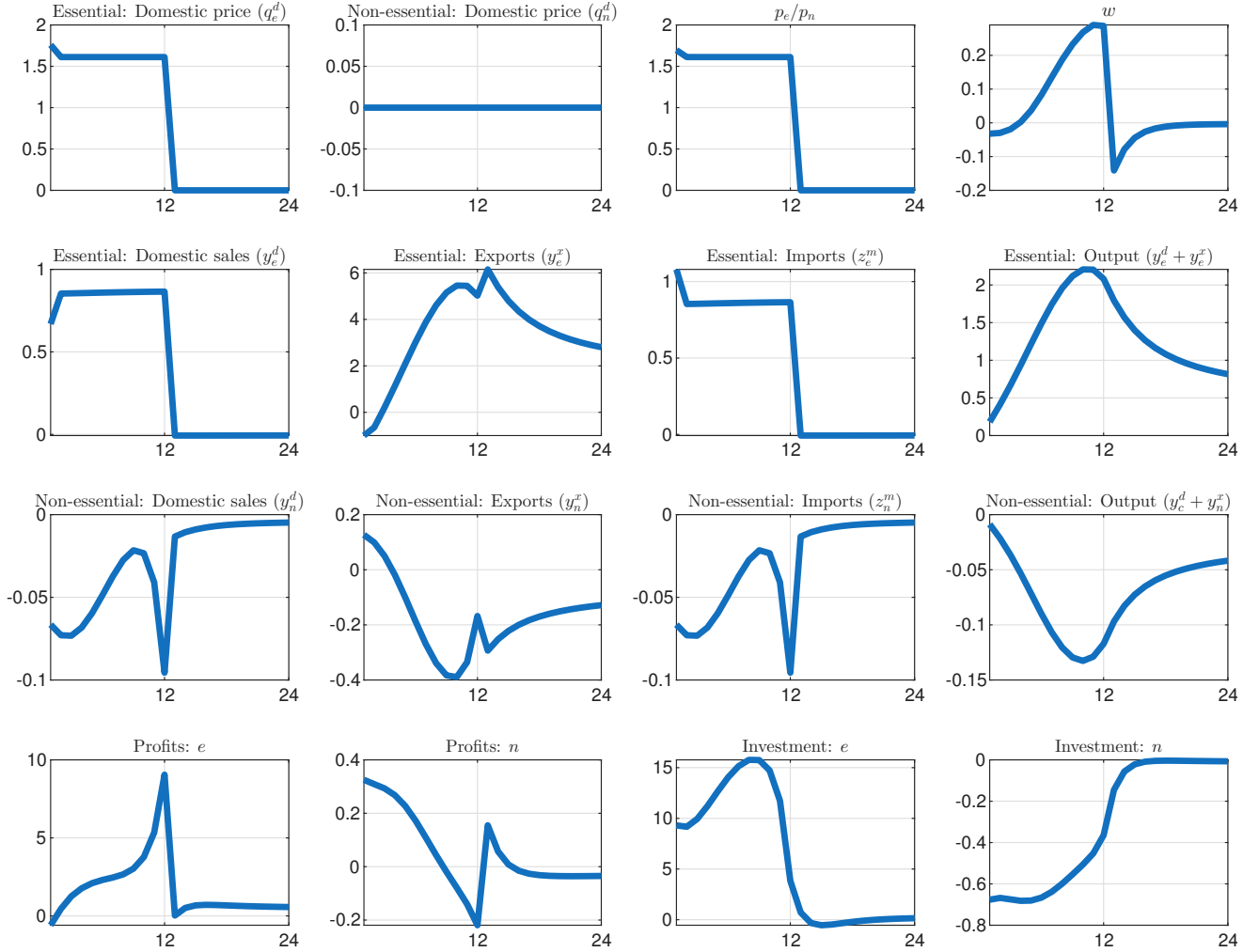
These examples illustrate the diversity of financial interventions used during the pandemic, including direct lending, credit-risk sharing, bond purchases, and forgivable loans. Together with the cross-country evidence, they document the widespread use of financial support as part of the policy response to shortages of essential goods. This evidence motivates the analysis in Section 7, where we compare alternative financial-policy instruments and examine how their welfare effects depend on how they are designed and funded. The evidence does not identify the specific leverage-dependent borrowing friction in our model or establish its quantitative importance in accounting for the observed policy response.

Appendix C: Additional quantitative findings

This appendix presents additional findings that complement those presented in the paper.

2 Impulse response functions

Figure 2 displays impulse response functions for additional variables that complement those presented in the paper. The shocks considered here are identical to those described in the main analysis; we focus specifically on the dynamics under the scenario without policy interventions.



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.

Figure 2: Impulse response functions, additional variables

3 Key channels

In this section, we investigate the key features of the model that account for the welfare-maximizing trade and industrial policies in response to the shocks that we study. Tables 3 and 4 report the optimal trade and industrial policies, respectively, under alternative versions of the model. Unless otherwise specified, we compute the results reported in each row of these tables, recalibrating the model to match the steady-state targets but keeping the parameters that discipline the dynamics as

Table 3: Key channels underlying welfare-maximizing trade policy

	Export tax	Import tariff	Welfare gain
Baseline	14.45%	− 9.54%	0.267%
No shocks (steady state)	0.00%	0.00%	0.000%
No household heterogeneity (representative household)	− 2.30%	1.65%	0.017%
Weaker inter-temporal complementarity ($\xi = 0.50$ vs. $\xi = 2$)	− 0.53%	0.52%	0.001%
Weaker intra-temporal complementarity ($\rho = 0.80$ vs. $\rho = 0.29$)	1.79%	− 0.80%	0.002%
Lower adjustment costs ($\Omega_{k,e} = \Omega_{\ell,e} = 0$)	6.81%	− 4.07%	0.045%
Higher adjustment costs ($\Omega_{k,e} = \Omega_{\ell,e} = 100$)	21.12%	−29.37%	0.923%
Lower leverage premium ($\psi = 0.05$ vs. $\psi = 0.17$)	11.84%	− 8.06%	0.184%
Higher leverage premium ($\psi = 0.50$ vs. $\psi = 0.17$)	15.58%	− 9.85%	0.293%
No essential-sector borrowing	16.02%	−10.02%	0.307%

in the baseline. Each table also reports the associated *welfare gain*: the consumption-equivalent welfare improvement that the welfare-maximizing policy delivers relative to the no-policy economy, expressed as the uniform percentage increase in consumption over the twelve pandemic periods that equates the two.

No shocks The second row of each table reports the optimal policies in the absence of shocks — that is, in the steady state of the model. We observe that there is essentially no role for either trade or industrial policy in the steady state: the computed policy rates and welfare gains are zero. Thus, the welfare-maximizing policy interventions are driven by the impact of the shocks and do not arise due to long-run forces that are also active in the steady state of the model. Particularly critical in accounting for this property of the model is abstracting from terms of trade effects by removing markup distortions due to monopolistic competition (Gali and Monacelli 2005).

No household heterogeneity The third row of each table reports the optimal policies in an economy without household heterogeneity. In particular, we consider an economy with one representative household that owns all domestic producers. We find that both trade and industrial policy interventions are substantially attenuated relative to the baseline.

Inter-temporal complementarity The fourth row of each table reports the optimal policies in an economy with weaker inter-temporal complementarities ($\xi = 0.50$ instead of $\xi = 2$). We find that the optimal trade and industrial policies are significantly smaller, suggesting a much lower role for policy interventions. A lower value of ξ implies a higher inter-temporal elasticity of substitution, so households find it easier to reduce consumption during the shocks in exchange for higher consumption afterwards. Thus, the government finds it optimal to avoid the costs involved with adjusting production decisions to increase consumption of essential goods.

Intra-temporal complementarity The fifth row of each table reports the optimal policies in an economy with weaker intra-temporal complementarities ($\rho = 0.80$ instead of $\rho = 0.29$). We find that the welfare-maximizing trade policy is significantly mitigated under weaker intra-temporal complementarities. These allow households to more easily substitute essential with non-essential goods, sidestepping the increased need for essential goods and higher prices.

In contrast, we find that the welfare-maximizing industrial policy is not significantly affected by the degree of intra-temporal complementarities. That is, even if households can more easily substitute essential with non-essential goods, household heterogeneity and incomplete markets imply that firms' investment decisions are not socially optimal. Thus, industrial policy is effective in this case since it primarily affects firms' inter-temporal decisions, without much impact on intra-temporal ones.

Table 4: Key channels underlying welfare-maximizing industrial policy

	Total sales subsidy	Welfare gain
Baseline	11.71%	0.088%
No shocks (steady state)	0.00%	0.000%
No household heterogeneity (representative household)	2.50%	0.023%
Weaker inter-temporal complementarity ($\xi = 0.50$ vs. $\xi = 2$)	2.37%	0.010%
Weaker intra-temporal complementarity ($\rho = 0.80$ vs. $\rho = 0.29$)	11.14%	0.086%
Lower adjustment costs ($\Omega_{k,e} = \Omega_{\ell,e} = 0$)	16.25%	0.332%
Higher adjustment costs ($\Omega_{k,e} = \Omega_{\ell,e} = 100$)	36.48%	0.073%
Lower leverage premium ($\psi = 0.05$ vs. $\psi = 0.17$)	11.58%	0.133%
Higher leverage premium ($\psi = 0.50$ vs. $\psi = 0.17$)	11.95%	0.078%
No essential-sector borrowing	12.07%	0.073%

Sectoral adjustment costs The sixth and seventh rows of each table report the optimal policies under alternative sectoral adjustment costs. Trade policy interventions are larger when adjustment costs are higher. The production subsidy is larger than in the baseline under both alternative calibrations, and is especially large when adjustment costs are high. Thus, the relation between adjustment costs and the production subsidy is not monotone across all three calibrations. Higher adjustment costs nevertheless raise the payoff from interventions that reallocate production across markets instead of relying exclusively on changes in production scale.

Leverage premium The eighth and ninth rows of Tables 3 and 4 report the welfare-maximizing policies under alternative values of the slope of the leverage premium, ψ . The trade policy response and its welfare gains increase with the slope of the premium: the export tax rises from 11.84% when $\psi = 0.05$ to 15.58% when $\psi = 0.50$, as producers' investment and production decisions become more responsive to financial conditions. In contrast, the production subsidy is largely unaffected by the slope of the premium, ranging from 11.58% to 11.95%.

No essential-sector borrowing Finally, the tenth row of each table restricts borrowing by the essential-sector household while retaining borrowing by the non-essential-sector household. We find the welfare-maximizing policy response is larger with more limited access to financial markets for essential producers.

4 Welfare-maximizing policy

4.1 One instrument at a time

Table 5 reports the welfare-maximizing policy interventions under alternative policy mixes to those considered in the paper. The first row reports the welfare-maximizing policy intervention when only an export tax is available to the government. The second row reports the welfare-maximizing policy interventions when only an import tariff is available to the government.

We find only a quantitatively negligible role for import policy in the absence of export taxes. This suggests that, while export taxes improve welfare by reallocating sales from exports toward domestic sales, import subsidies are primarily introduced to mitigate other distortions generated by this reallocation. In particular, export taxes reallocate sales from exports toward domestic sales by reducing the price of domestic essential goods, which increases demand for domestic essential goods relative to imported ones. As described in the paper, it is then optimal to introduce an import subsidy to mitigate this reallocation of demand.

	Export tax	Import tariff
Only export tax	11.15%	–
Only import tariff	–	-0.48%

Table 5: Welfare-maximizing policy, one instrument at a time

4.2 One shock at a time

Table 6 reports the welfare-maximizing policy interventions when introduced in response to a counterfactual scenario in which the economy faces each of the shocks in isolation rather than jointly. We restrict attention here to the case in which the government has access to both trade and industrial policy instruments. The first row reports the optimal policies when the economy only faces an increase in the reference level of essential goods. The second row reports the optimal policies when the economy only faces an increase in the price of imports of essential goods. The third row reports the optimal policies when the economy only faces an increase in the price of exports of essential goods.

We find that the welfare-maximizing policy response to each of the shocks in isolation is similar to the response when the shocks are faced jointly, combining an export tax, an import subsidy, and a production subsidy. The only exception is the response to a shock to import prices, under which it is optimal to introduce a small export subsidy rather than an export tax.

	Export tax	Import tariff	Total sales subsidy
Only shock to reference level	13.01%	-4.38%	7.08%
Only shock to price of imports	-0.99%	-7.80%	12.20%
Only shock to price of exports	16.51%	-7.08%	27.09%

Table 6: Welfare-maximizing policy, one shock at a time

4.3 Sensitivity analysis

This appendix studies the sensitivity of the findings reported in the paper. Table 7 reports the optimal policies under alternative specifications. We restrict attention here to the case in which the government has access to both trade and industrial policy instruments. The first row of the table reproduces the optimal policies from the baseline analysis reported in the paper.

Rows 2–5 of the table examine the sensitivity of the findings to alternative shocks. Row 2 reports the optimal policies when the economy also experiences a decline of labor supply throughout the pandemic, in addition to the other shocks considered in the baseline. We consider an exogenous 7.8% decline of the aggregate labor endowment throughout the 12 months of the pandemic.² Row 3 reports the optimal policies in an economy that experiences a longer pandemic, modeled by considering shocks and policies that last 24 months rather than 12 as in the baseline. Row 4 reports the optimal policies in an economy that experiences a milder pandemic, modeled by considering smaller shocks (1/4 of the baseline). Row 5 reports the optimal policies in an economy that experiences a higher increase in import prices (50% higher than the baseline). We find the welfare-maximizing policy responses are consistent with those reported in the baseline.

Rows 6–7 examine sensitivity to alternative estimation targets. Row 6 considers an economy recalibrated to match a pre-pandemic steady-state with a lower output share of essential goods (1/2 of the baseline). Row 7 considers an economy with a lower import share of essential goods (30% of absorption). The optimal policies in both cases are nearly identical to the baseline.

²We focus on employment (all employees, non-farm), which we obtain from FRED: <https://fred.stlouisfed.org/graph/?g=V1Ss>. We compute the change of employment by comparing average employment between March 2020 and Feb 2021 relative to employment in Feb 2020.

	Export tax	Import tariff	Total sales subsidy
Baseline	25.18%	-18.66%	28.66%
Decline in labor supply (-7.8%)	25.57%	-18.30%	27.83%
Longer pandemic (24 months)	22.49%	-15.96%	39.17%
Milder pandemic (1/4 shock)	7.07%	-6.08%	7.13%
Higher import price increase (1.5x)	30.45%	-16.48%	30.06%
Lower output share of essential goods	27.86%	-19.70%	27.39%
Lower import share of essential goods	26.19%	-18.50%	28.60%
Policy implemented for 6 months	23.83%	-17.45%	28.87%
Policy implemented for 24 months	25.20%	-18.86%	27.48%
Model with workers and capitalists	15.42%	-13.81%	-1.64%
Markup distortions	14.88%	-20.81%	—

Table 7: Welfare-maximizing policy, sensitivity analysis

Rows 8–9 examine sensitivity to the duration of policies. We keep the duration of the shocks as in the baseline (12 months) and vary the duration of policy implementation. Row 8 reports optimal policies when implemented for 6 months; Row 9 reports those implemented for 24 months. In both cases, the optimal policies are nearly identical to the baseline.

Row 10 examines sensitivity to an alternative partitioning of agents. In the baseline, there are two types of agents and two sectors, each agent supplying labor and owning and operating the firm in one sector. Here, we consider an alternative that separates these roles. Workers, with mass 0.99, supply all labor, receive wage income, and do not own firms or borrow. Capitalists, with mass 0.01, supply no labor, own and operate the firms in both sectors, and choose a single debt position, subject to a leverage-dependent premium with leverage measured against the combined value of capital in the two sectors:

$$L_t^K = \frac{b_{t+1}^K}{p_{nt}(k_{nt} + k_{et})},$$

where b_{t+1}^K denotes the capitalists’ debt. Both sectoral capital stocks therefore relax the same borrowing friction, and investment in both sectors is valued using the capitalists’ stochastic discount factor. We recalibrate the model under this ownership structure, re-estimating the parameters that govern the post-shock dynamics, and find that the welfare-maximizing trade policy remains similar, combining an export tax with an import subsidy, while the production subsidy becomes a small sales tax.

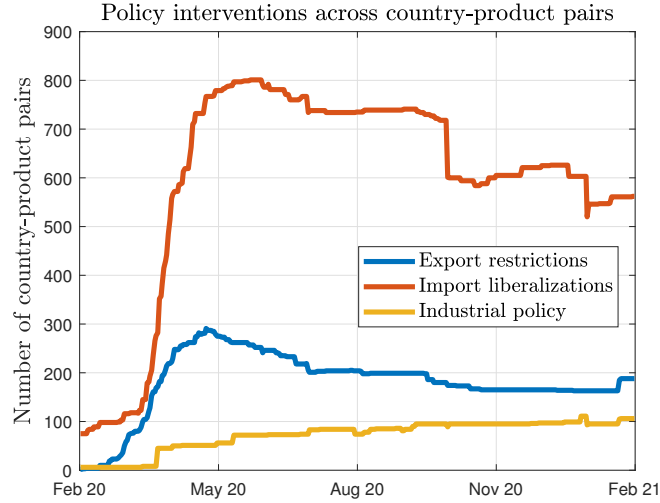
Finally, we examine the sensitivity of our findings to domestic markup distortions by removing the sales subsidy that offsets these distortions in the baseline. In this environment, trade policy affects welfare partly through its effects on domestic prices. Because trade policy is then relevant even in the absence of shocks, we report the incremental change in the welfare-maximizing trade policy induced by the shock. This exercise considers trade policy only, so it should be compared with the baseline trade policy reported in the paper, an export tax of 14.45% and an import subsidy of 9.54%.

4.4 Trade and industrial policies by trade dependence: Model vs. data

The findings reported in the paper show that trade and industrial policies can be an effective way to address shortages of critical goods in an open economy. In this section, we investigate whether the likelihood of these responses depends on the extent that countries depend on trade to access the respective goods. To do so, we focus on the case of essential medical goods following COVID-19.

We use data from Global Trade Alert on trade and industrial policy interventions by country and product categories.

Figure 3: Policy interventions following shortages of PPE during COVID-19



Note: The x-axis corresponds to months. We restrict attention to trade and industrial policy changes on essential medical goods as classified in the text. We focus on country-product pairs with positive exports.

We restrict attention to PPE that was critical at the onset of the COVID-19 pandemic. In particular, we restrict our analysis to 16 PPE-related products demanded during COVID-19, as classified by the World Trade Organization (WTO).³ We use these data to document the evolution of the number of country-product pairs that experienced changes in export restrictions, import liberalizations, and industrial policy interventions between February 2020 and January 2021. To examine the prevalence of policies designed to increase production or curb exports, we restrict attention to country-product pairs with positive exports during 2019.⁴

Figure 3 plots the number of country-product pairs with policies to restrict exports, liberalize imports, and encourage production. The figure shows a sharp increase in the number of trade and industrial policy interventions from February 2020 through January 2021. By the end of April 2020, 279 country-product pairs were subject to newly introduced export restrictions, 779 had experienced a liberalization of import barriers, and 51 were subject to industrial policies. While trade policy interventions were mostly temporary, many were still in place a year into the pandemic. By the end of January 2021, there were still 188 and 562 export restrictions and import liberalizations in place, respectively. In contrast, production subsidies were introduced gradually, going from 51 in April 2020 to 106 in January 2021.

Trade policy To examine how trade policy varies with trade dependence, we measure the latter based on product-level trade imbalances. We classify country-product pairs into two groups based on their trade imbalance in 2019 using data from CEPII: country-product pairs with a trade deficit and those with a surplus.⁵ For each group, Figure 4 plots the share of country-product pairs with export restrictions and import liberalizations.

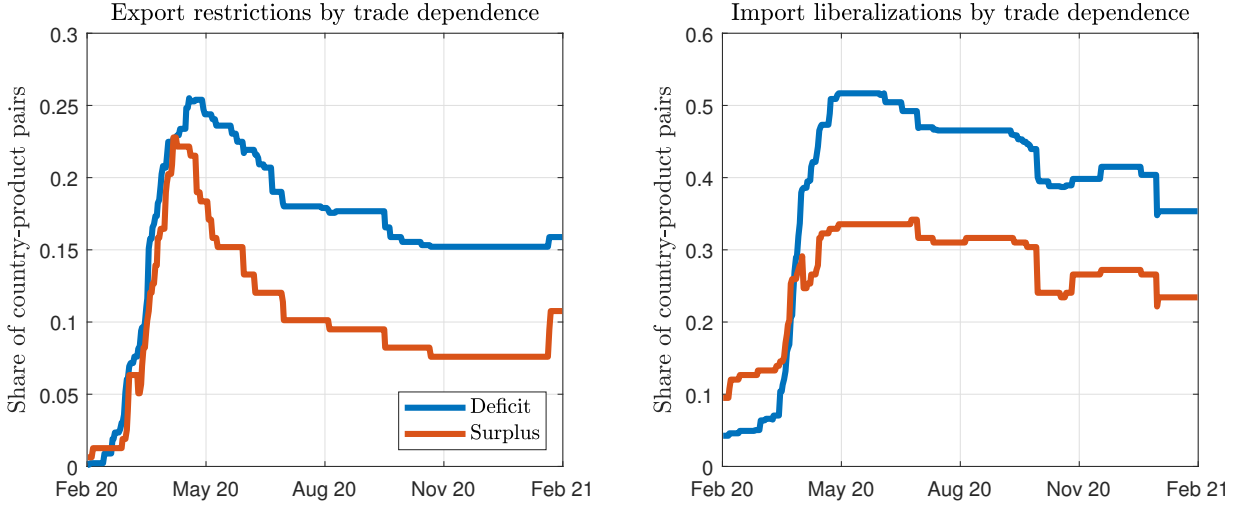
We find that country-product pairs with trade deficits prior to the pandemic were more likely subject to trade policy interventions. On the one hand, country-product pairs with a deficit were more likely to liberalize import barriers. In contrast, the likelihood of introducing export restrictions during the first months of the pandemic was largely independent

³See https://www.wto.org/english/tratop_e/covid19_e/covid19_e.htm for details on the products that we focus on. The list of 6-digit HS codes is: 340220, 401519, 621010, 630790, 650500, 650610, 842139, 900490, 901812, 901819, 901839, 901920, 902000, 902212, 902214, 902519.

⁴We group the policy interventions reported in the original dataset into the three groups that we study as follows. Export restrictions consist of the tightening or introduction of any of the following policies: export tax, local supply requirement for exports, export licensing requirement, export ban. Import liberalizations consist of the relaxation of any of the following policies: import tariff quota, import tariff, import licensing requirement, internal taxation of imports, import quota, import-related non-tariff measure. Industrial policies consist of the introduction or expansion of any of the following policies: financial grant, state aid, state loan, interest payment subsidy, tax or social insurance relief, loan guarantee, production subsidy, localisation incentive, price stabilization, in-kind grant, capital injection and equity.

⁵http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele.asp.

Figure 4: Trade policy interventions during COVID-19 by trade dependence



Note: The x-axis corresponds to months. We restrict attention to trade policy changes on essential medical goods as classified in the text. We focus on country-product pairs with positive exports.

Table 8: Welfare-maximizing trade policy and sectoral imbalances

	Export tax	Import tariff
Trade deficit of essential goods ($NX_e/GDP_e = -0.30$)	15.46%	− 9.89%
Trade surplus of essential goods ($NX_e/GDP_e = 0.30$)	9.57%	− 6.19%

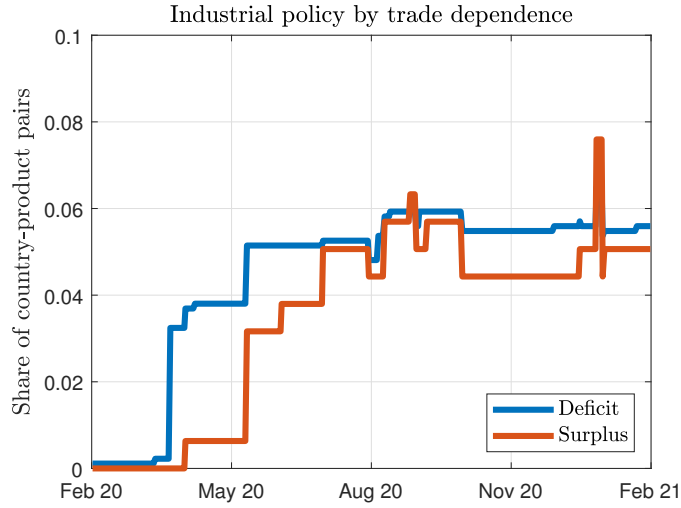
of trade dependence. Export restrictions, however, were removed faster among country-product pairs with a trade surplus, suggesting that countries with a comparative advantage in these products were better equipped to scale up production in the face of global shortages.

To contrast these empirical findings with the implications of the model, we examine whether the welfare-maximizing trade policy interventions also depend on the degree of international trade dependence. To do so, we investigate two counterfactual economies with alternative degrees of international trade dependence on essential goods. In particular, we keep the predetermined parameters and the parameters estimated to match the post-shock dynamics as in the baseline, and we recalibrate the parameters estimated to match the pre-shock steady state, targeting a net exports-to-GDP ratio in essential goods equal to ± 0.30 .

We report our findings in Table 8. As in the data, both sets of countries find it optimal to introduce policies that restrict exports and liberalize imports. Moreover, countries with a trade deficit of essential goods introduce larger trade policy interventions: Export taxes and import subsidies are both higher in these countries than among those with a surplus. Countries with a trade deficit of essential goods are more dependent on the rest of the world to access these goods and, thus, are more negatively affected by their price increase. Thus, these countries have a greater incentive to reallocate exports and increase imports. We interpret these differences as consistent with the evidence documented above: Economies with larger deficits of essential goods respond more strongly to shortages of these goods.

Industrial policy We conclude by examining the extent to which welfare-maximizing industrial policy interventions vary with trade dependence. Figure 5 plots the share of country-product pairs subject to industrial policy interventions across countries with a deficit or surplus of essential goods prior to the pandemic. We find there is minimal variation in the likelihood of introducing industrial policy measures across these two sets of country-product pairs. Consistent with this evidence, Table 9 shows that the extent of the industrial policy interventions implied by the model are also largely independent of the extent

Figure 5: Industrial policy interventions during COVID-19 by trade dependence



Note: The x-axis corresponds to months. We restrict attention to industrial policy interventions on essential medical goods as classified in the text. We focus on country-product pairs with positive exports.

Table 9: Welfare-maximizing industrial policy and sectoral imbalances

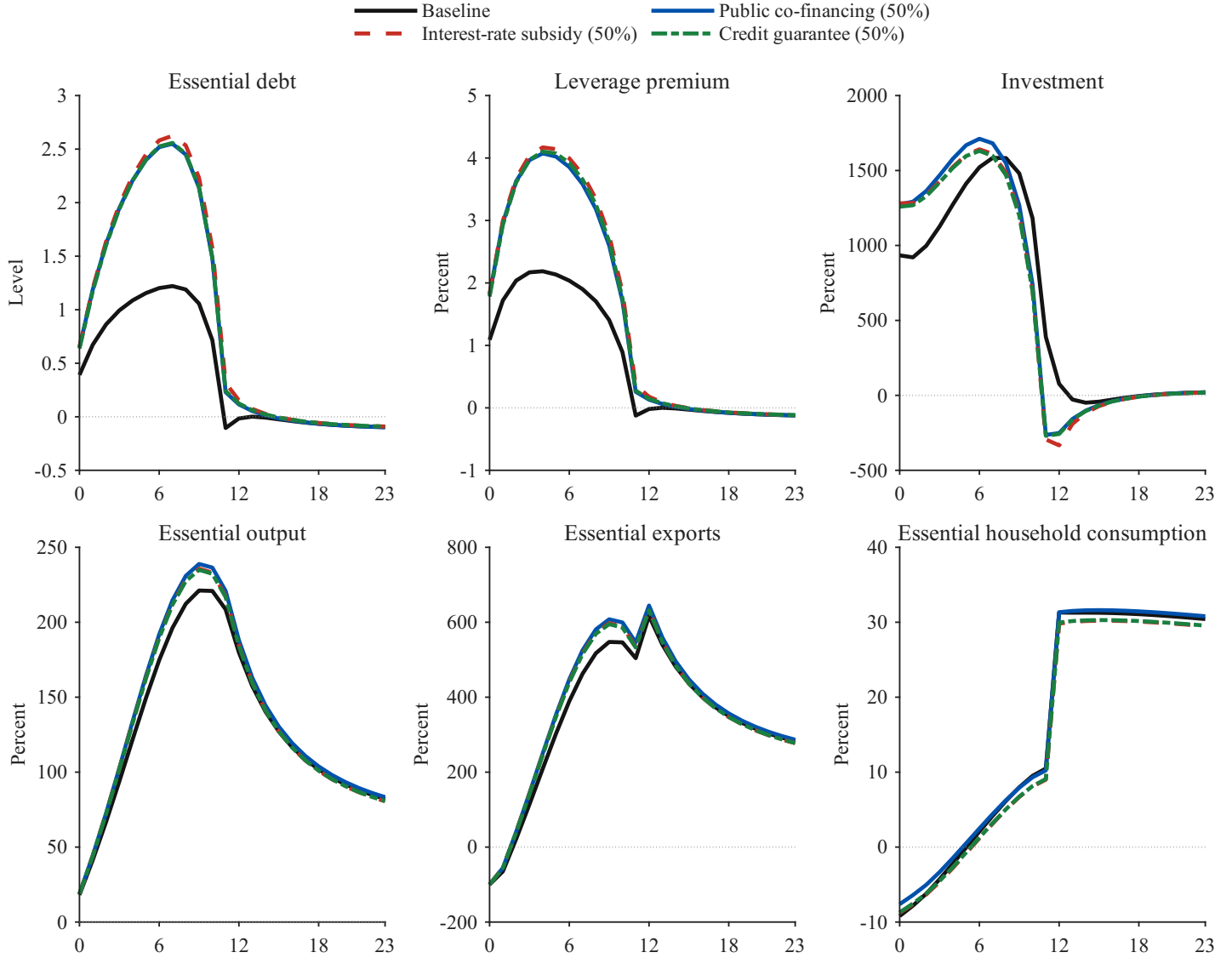
	Total sales subsidy
Trade deficit of essential goods ($NX_e/GDP_e = -0.30$)	11.92%
Trade surplus of essential goods ($NX_e/GDP_e = 0.30$)	11.18%

of trade dependence. In both economies the higher price of exports makes it attractive to increase sales regardless of their net reliance on the rest of the world to access essential goods.

4.5 Financial policies

Figure 6 compares the no-policy economy with the 50% implementation rate of each financial intervention studied in Section 7 of the paper. All three policies encourage borrowing, investment, output, and exports by essential producers. Public co-financing and the credit guarantee give the firm the same financing schedule, so their firm-side dynamics are nearly identical. Their implications for the essential household's consumption differ, however, because of their fiscal incidence: under the credit guarantee, as under the interest-rate subsidy, the government recovers the value of the improved borrowing terms through a lump-sum charge on the firm's owner, which lowers the essential household's consumption relative to public co-financing.

Figure 6: Dynamics under alternative financial policies: common 50 percent rate



Note: The figure compares the no-policy economy with the 50 percent implementation of each financial policy. Policies are active in months 1–12. Essential debt is reported in levels; all other variables are percent deviations from steady state. The x-axes denote months.

Appendix D: Derivations

5 Planner's problem

5.1 External constraint

- We begin by deriving the external constraint from the competitive equilibrium.
- Combine the budget constraints of the worker-entrepreneurs:

$$\sum_i \left[p_t c_{it} + b_{it} + w_t \ell_{it} + p_{nt} I_{it} + p_{nt} \phi_k(k_{it+1}, k_{it}) + p_{nt} \phi_\ell(\ell_{it}, \ell_{it-1}) \right] = \sum_i \left[\lambda_i w_t + (1 + \tau_{it}^y) p_{it}^d y_{it}^d + (1 + \tau_{it}^y - \tau_{it}^x) p_{it}^x y_{it}^x + \frac{b_{it+1}}{(1 + r^*) \Gamma(L_{it})} + \mathcal{T}_{it} \right].$$

- Final-good market clearing implies

$$p_t y_t = p_{nt} n_t + p_{et} e_t, \quad y_t = c_{nt} + c_{et}.$$

- Replace n_t and e_t using the market-clearing conditions for essential and non-essential goods, use the capital accumulation equations, and substitute the government budget constraint. Domestic wage, sales, policy-revenue, and transfer payments cancel.
- The only remaining external payments are imports, exports, and the economy's net foreign position $B_t \equiv b_{nt} + b_{et}$. The leverage premium is an entrepreneur-specific borrowing wedge. The planner allocates resources directly across entrepreneurs and faces the world rate on the economy's net position. Thus, the external constraint is

$$\sum_{i \in \{n, e\}} \tau_i p_{it}^m y_{it}^m + B_t = \frac{B_{t+1}}{1 + r^*} + \sum_{i \in \{n, e\}} p_{it}^x y_{it}^x. \quad (1)$$

5.2 Planner's problem: Setup

- Objective function:

$$\mathcal{V}_0 = \lambda_n V_{n0} + \lambda_e V_{e0}.$$

- Problem:

$$\max \mathcal{V}_0 = \lambda_n V_{n0} + \lambda_e V_{e0}$$

subject to

Worker-entrepreneur welfare

$$V_{n0} = \sum_{t=0}^{\infty} \beta^t \frac{(c_{nt}/\lambda_n)^{1-\xi}}{1-\xi}$$

$$V_{e0} = \sum_{t=0}^{\infty} \beta^t \frac{(c_{et}/\lambda_e)^{1-\xi}}{1-\xi}$$

Domestic variety e

$$k_{et+1} = (1-\delta)k_{et} + I_{et}$$

$$y_{et}^d + y_{et}^x = A_e (\ell_{et}^\alpha k_{et}^{1-\alpha})^\eta$$

Domestic variety n

$$k_{nt+1} = (1-\delta)k_{nt} + I_{nt}$$

$$y_{nt}^d + y_{nt}^x = A_n (\ell_{nt}^\alpha k_{nt}^{1-\alpha})^\eta$$

Composite goods

$$n_t + \sum_{i \in \{n,e\}} [I_{it} + \phi_k(k_{it+1}, k_{it}) + \phi_\ell(\ell_{it}, \ell_{it-1})] = \left[\omega_n^{\frac{1}{\sigma}} (y_{nt}^d)^{\frac{\sigma-1}{\sigma}} + (1-\omega_n)^{\frac{1}{\sigma}} (y_{nt}^m)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

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

Final goods

$$c_{et} + c_{nt} = \left[(1-\gamma) n_t^{\frac{\rho-1}{\rho}} + \gamma \left(\frac{e_t}{\bar{e}_t} \right)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}$$

Labor

$$\lambda_n + \lambda_e = \ell_{nt} + \ell_{et}$$

External constraint

$$\tau_n p_{nt}^m y_{nt}^m + \tau_e p_{et}^m y_{et}^m + B_t = \frac{B_{t+1}}{1+r^*} + p_{nt}^x y_{nt}^x + p_{et}^x y_{et}^x.$$

5.3 Planner's problem: Solution

- Lagrangian:

$$\begin{aligned}
\mathcal{L} = & \lambda_n \sum_{t=0}^{\infty} \beta^t \frac{(c_{nt}/\lambda_n)^{1-\xi}}{1-\xi} + \lambda_e \sum_{t=0}^{\infty} \beta^t \frac{(c_{et}/\lambda_e)^{1-\xi}}{1-\xi} \\
& + \sum_t \mu_{et} [A_e(\ell_{et}^\alpha k_{et}^{1-\alpha})^\eta - y_{et}^d - y_{et}^x] + \sum_t \mu_{nt} [A_n(\ell_{nt}^\alpha k_{nt}^{1-\alpha})^\eta - y_{nt}^d - y_{nt}^x] \\
& + \sum_t \Phi_{nt} \left\{ \left[\omega_n^{\frac{1}{\sigma}} (y_{nt}^d)^{\frac{\sigma-1}{\sigma}} + (1-\omega_n)^{\frac{1}{\sigma}} (y_{nt}^m)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} - n_t \right. \\
& \quad \left. - \sum_{i \in \{n,e\}} [k_{it+1} - (1-\delta)k_{it} + \phi_k(k_{it+1}, k_{it}) + \phi_\ell(\ell_{it}, \ell_{it-1})] \right\} \\
& + \sum_t \Phi_{et} \left\{ \left[\omega_e^{\frac{1}{\sigma}} (y_{et}^d)^{\frac{\sigma-1}{\sigma}} + (1-\omega_e)^{\frac{1}{\sigma}} (y_{et}^m)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} - e_t \right\} \\
& + \sum_t \Phi_{ft} \left\{ \left[(1-\gamma)n_t^{\frac{\rho-1}{\rho}} + \gamma \left(\frac{e_t}{\bar{e}_t} \right)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}} - c_{et} - c_{nt} \right\} \\
& + \sum_t \Phi_{Lt} \{ \ell_{nt} + \ell_{et} - \lambda_n - \lambda_e \} \\
& + \sum_t \theta_t \left\{ p_{nt}^x y_{nt}^x + p_{et}^x y_{et}^x + \frac{B_{t+1}}{1+r^*} - B_t - \tau_n p_{nt}^m y_{nt}^m - \tau_e p_{et}^m y_{et}^m \right\}.
\end{aligned}$$

- FOC B_{t+1} :

$$\frac{\theta_{t+1}}{\theta_t} = \frac{1}{1+r^*} = \beta. \quad (2)$$

- FOC k_{it+1} :

$$\begin{aligned}
& \mu_{it+1}(1-\alpha)\eta A_i \frac{(\ell_{it+1}^\alpha k_{it+1}^{1-\alpha})^\eta}{k_{it+1}} + \Phi_{nt+1}(1-\delta) - \Phi_{nt+1} \frac{\partial \phi_k(k_{it+2}, k_{it+1})}{\partial k_{it+1}} \\
& = \Phi_{nt} \left[1 + \frac{\partial \phi_k(k_{it+1}, k_{it})}{\partial k_{it+1}} \right].
\end{aligned}$$

- FOC ℓ_{it} :

$$\mu_{it}\alpha\eta A_i \frac{(\ell_{it}^\alpha k_{it}^{1-\alpha})^\eta}{\ell_{it}} - \Phi_{nt} \frac{\partial \phi_\ell(\ell_{it}, \ell_{it-1})}{\partial \ell_{it}} - \Phi_{nt+1} \frac{\partial \phi_\ell(\ell_{it+1}, \ell_{it})}{\partial \ell_{it}} + \Phi_{Lt} = 0.$$

- FOC y_{it}^x :

$$-\mu_{it} + \theta_t p_{it}^x = 0.$$

- FOC y_{it}^m :

$$\Phi_{it} = \frac{\theta_t \tau_i p_{it}^m}{\left[\omega_i^{\frac{1}{\sigma}} (y_{it}^d)^{\frac{\sigma-1}{\sigma}} + (1-\omega_i)^{\frac{1}{\sigma}} (y_{it}^m)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}} (1-\omega_i)^{\frac{1}{\sigma}} (y_{it}^m)^{-\frac{1}{\sigma}}}.$$

- FOC y_{it}^d :

$$\Phi_{it} = \frac{\mu_{it}}{\left[\omega_i^{\frac{1}{\sigma}} (y_{it}^d)^{\frac{\sigma-1}{\sigma}} + (1 - \omega_i)^{\frac{1}{\sigma}} (y_{it}^m)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}} \omega_i^{\frac{1}{\sigma}} (y_{it}^d)^{-\frac{1}{\sigma}}}.$$

- FOC c_{it} :

$$\lambda_i \beta^t \lambda_i^{\xi-1} c_{it}^{-\xi} = \Phi_{ft}.$$

6 Competitive equilibrium

6.1 Worker-entrepreneurs

- The leverage and borrowing-premium functions are

$$L_{it} = \frac{b_{it+1}}{p_{nt} k_{it}}, \quad \Gamma(L_{it}) = \exp[\psi(L_{it} - \bar{L})], \quad 1 + r^* = \frac{1}{\beta}. \quad (3)$$

- Lagrangian:

$$\begin{aligned} \mathcal{L}_{i0} = & \sum_{t=0}^{\infty} \beta^t \frac{(c_{it}/\lambda_i)^{1-\xi}}{1-\xi} \\ & + \sum_{t=0}^{\infty} \beta^t \kappa_{it} \left\{ \lambda_i w_t + (1 + \tau_{it}^y) \left(\frac{y_{it}^d}{\omega_i y_{it}} \right)^{-\frac{1}{\sigma}} p_{it} y_{it}^d \right. \\ & \quad + (1 + \tau_{it}^y - \tau_{it}^x) p_{it}^x [A_i (\ell_{it}^\alpha k_{it}^{1-\alpha})^\eta - y_{it}^d] + \frac{b_{it+1}}{(1 + r^*) \Gamma(L_{it})} + \mathcal{T}_{it} \\ & \quad \left. - p_t c_{it} - b_{it} - w_t \ell_{it} - p_{nt} [k_{it+1} - (1 - \delta) k_{it}] - p_{nt} \phi_k(k_{it+1}, k_{it}) - p_{nt} \phi_\ell(\ell_{it}, \ell_{it-1}) \right\} \\ & + \sum_{t=0}^{\infty} \beta^t \Upsilon_{it} [A_i (\ell_{it}^\alpha k_{it}^{1-\alpha})^\eta - y_{it}^d]. \end{aligned}$$

- FOC c_{it} :

$$\lambda_i^{\xi-1} c_{it}^{-\xi} = \kappa_{it} p_t. \quad (4)$$

- FOC b_{it+1} . Since

$$\frac{\partial}{\partial b_{it+1}} \frac{b_{it+1}}{(1 + r^*) \Gamma(L_{it})} = \frac{1 - \psi L_{it}}{(1 + r^*) \Gamma(L_{it})},$$

the debt Euler equation is

$$\beta \frac{\kappa_{it+1}}{\kappa_{it}} = \frac{1 - \psi L_{it}}{(1 + r^*) \Gamma(L_{it})}. \quad (5)$$

In contrast, the planner values the economy's net foreign position at the common world discount factor in equation (2).

6.2 Producers of final goods

- FOC e_t :

$$p_t y_t^{\frac{1}{\rho}} \gamma \left(\frac{1}{\bar{e}_t} \right)^{\frac{\rho-1}{\rho}} e_t^{-\frac{1}{\rho}} = p_{et}.$$

- FOC n_t :

$$p_t y_t^{\frac{1}{\rho}} (1 - \gamma) n_t^{-\frac{1}{\rho}} = p_{nt}.$$

6.3 Producer of composite good $j \in \{n, e\}$

- FOC q_{jt}^d :

$$p_{jt} = \frac{1}{\omega_j^{\frac{1}{\sigma}}} p_{jt}^d y_{jt}^{-\frac{1}{\sigma}} (q_{jt}^d)^{\frac{1}{\sigma}}.$$

- FOC q_{jt}^m :

$$p_{jt} = \frac{1}{(1 - \omega_j)^{\frac{1}{\sigma}}} (1 + \tau_{jt}^m) \tau_j p_{jt}^m y_{jt}^{-\frac{1}{\sigma}} (q_{jt}^m)^{\frac{1}{\sigma}}.$$

6.4 Domestic production within the worker-entrepreneur problem

- FOC ℓ_{it} :

$$0 = \kappa_{it} \left[(1 + \tau_{it}^y - \tau_{it}^x) p_{it}^x \alpha \eta A_i \frac{(\ell_{it}^\alpha k_{it}^{1-\alpha})^\eta}{\ell_{it}} - w_t - p_{nt} \frac{\partial \phi_\ell(\ell_{it}, \ell_{it-1})}{\partial \ell_{it}} \right] \\ - \beta \kappa_{it+1} p_{nt+1} \frac{\partial \phi_\ell(\ell_{it+1}, \ell_{it})}{\partial \ell_{it}} + \Upsilon_{it} \alpha \eta A_i \frac{(\ell_{it}^\alpha k_{it}^{1-\alpha})^\eta}{\ell_{it}}.$$

- FOC k_{it+1} . Since

$$\frac{\partial}{\partial k_{it+1}} \frac{b_{it+2}}{(1 + r^*) \Gamma(L_{it+1})} = \frac{b_{it+2}}{(1 + r^*) \Gamma(L_{it+1})} \frac{\psi L_{it+1}}{k_{it+1}},$$

the capital condition is

$$\kappa_{it} p_{nt} \left[1 + \frac{\partial \phi_k(k_{it+1}, k_{it})}{\partial k_{it+1}} \right] \\ = \beta \kappa_{it+1} \left[(1 + \tau_{it+1}^y - \tau_{it+1}^x) p_{it+1}^x (1 - \alpha) \eta A_i \frac{(\ell_{it+1}^\alpha k_{it+1}^{1-\alpha})^\eta}{k_{it+1}} + p_{nt+1} (1 - \delta) \right. \\ \left. - p_{nt+1} \frac{\partial \phi_k(k_{it+2}, k_{it+1})}{\partial k_{it+1}} + \frac{b_{it+2}}{(1 + r^*) \Gamma(L_{it+1})} \frac{\psi L_{it+1}}{k_{it+1}} \right] \\ + \beta \Upsilon_{it+1} (1 - \alpha) \eta A_i \frac{(\ell_{it+1}^\alpha k_{it+1}^{1-\alpha})^\eta}{k_{it+1}}. \quad (6)$$

The term proportional to $\psi L_{it+1}/k_{it+1}$ is the collateral value of capital: additional capital lowers leverage and the entrepreneur's borrowing premium.

- FOC y_{it}^d :

$$\Upsilon_{it} = \kappa_{it} \left[(1 + \tau_{it}^y)(\omega_i y_{it})^{\frac{1}{\sigma}} p_{it} \frac{\sigma - 1}{\sigma} (y_{it}^d)^{-\frac{1}{\sigma}} - (1 + \tau_{it}^y - \tau_{it}^x) p_{it}^x \right].$$

- Complementary slackness:

$$\Upsilon_{it} [A_i (\ell_{it}^\alpha k_{it}^{1-\alpha})^\eta - y_{it}^d] = 0.$$

6.5 Government budget constraint

- Budget constraint:

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

6.6 Market clearing conditions

- Labor: $\lambda_n + \lambda_e = \ell_{nt} + \ell_{et}$.
- Domestic varieties of good $i \in \{n, e\}$: $q_{it}^d = y_{it}^d$.
- Composite essential goods: $e_t = y_{et}$.
- Composite non-essential goods:

$$n_t + \sum_{j \in \{n, e\}} [I_{jt} + \phi_k(k_{jt+1}, k_{jt}) + \phi_\ell(\ell_{jt}, \ell_{jt-1})] = y_{nt}.$$

- Final goods: $c_{nt} + c_{et} = y_t$.

Appendix E: A costly-enforcement foundation for the leverage premium

This appendix provides a simple costly-enforcement foundation for the leverage-dependent borrowing premium. Larger repayment pledges require more enforcement capacity. Because this capacity is costly, a competitive lender purchases exactly what is required by the loan. We first present an enforcement-cost function that delivers exactly the borrowing premium used in the paper whenever debt is positive. We then show that any smooth enforcement-cost function delivers the same premium to a first-order approximation around zero leverage.

The closest direct precedent is Krassa and Villamil (2000), where enforcement is a costly choice and simple debt can be optimal. The mechanism is also related to costly monitoring and pledgeable income in Holmström and Tirole (1997) and to the balance-sheet-dependent external-finance premium in Bernanke, Gertler, and Gilchrist (1999). These papers motivate the economic mechanism; the exact cost function below is a tractable parameterization of that mechanism.

E.1. Competitive lending with costly enforcement

Fix an entrepreneur i and date t , and suppress subscripts where doing so does not create ambiguity. Define

$$V \equiv p_{nt}k_{it} > 0, \quad b \equiv b_{i,t+1} \geq 0, \quad L \equiv \frac{b}{V}, \quad R^* \equiv 1 + r^*. \quad (7)$$

Here, V is the value of pledgeable capital, b is the face value promised for repayment next period, L is leverage, and $Q(b, V)$ denotes the loan proceeds received by the entrepreneur today.

The lender chooses enforcement intensity $x \geq 0$. Enforcement capacity limits the repayment that can be credibly pledged:

$$b \leq xV. \quad (8)$$

Establishing capacity x costs $Vc(x)$ next period, or $Vc(x)/R^*$ in present value. Competitive lending and free entry therefore imply

$$Q(b, V) + \frac{Vc(x)}{R^*} = \frac{b}{R^*}. \quad (9)$$

Assume $c(0) = 0$ and $c'(x) > 0$ for $x > 0$. A lender never purchases unused enforcement capacity, because reducing x would preserve repayment while lowering costs. Thus, (8) binds:

$$x = \frac{b}{V} = L. \quad (10)$$

Substitution into (9) gives

$$Q(b, V) = \frac{V[L - c(L)]}{R^*} = \frac{b}{R^*\Gamma^E(L)}, \quad \Gamma^E(L) \equiv \frac{L}{L - c(L)}. \quad (11)$$

For positive loan proceeds, $c(L) < L$ at the relevant leverage levels. When $c'(0) = 0$, define $\Gamma^E(0) = 1$ by continuity. Costly enforcement then appears to the entrepreneur as a leverage-dependent gross borrowing premium.

E.2. Exact implementation

Consider the enforcement-cost function

$$c(x) = x[1 - \exp(-\psi x)]. \quad (12)$$

It satisfies $c(0) = c'(0) = 0$, $c'(x) > 0$ for $x > 0$, and $c(x) < x$. Since the enforcement condition binds, $x = L$, and therefore

$$L - c(L) = L \exp(-\psi L).$$

Equation (11) becomes

$$Q(b, V) = \frac{b}{R^* \exp(\psi L)}, \quad \Gamma^E(L) = \exp(\psi L). \quad (13)$$

The current calibration has $\bar{L} = 0$. Hence, on the borrowing branch $b \geq 0$, this is exactly the premium $\Gamma(L) = \exp[\psi(L - \bar{L})]$ used in the paper. For $b < 0$ the entrepreneur is a net saver rather than a borrower, so the costly-enforcement interpretation is not required.

E.3. Marginal conditions

The exact mapping also reproduces the two marginal terms in Appendix D. Using $L = b/V$,

$$\frac{\partial Q(b, V)}{\partial b} = \frac{1 - \psi L}{R^* \exp(\psi L)}, \quad (14)$$

$$\frac{\partial Q(b, V)}{\partial V} = \frac{\psi L^2}{R^* \exp(\psi L)} > 0. \quad (15)$$

The first expression is the marginal-loan-proceeds term in the debt Euler equation (5). The second expression gives the value of additional collateral. Since $V = p_{nt} k_{it}$,

$$\frac{\partial Q}{\partial k_{it}} = \frac{b_{i,t+1}}{R^* \exp(\psi L_{it})} \frac{\psi L_{it}}{k_{it}}, \quad (16)$$

which, after shifting dates, is the collateral-value term in the capital condition (6). The same enforcement problem therefore generates the loan proceeds in the budget constraint, the marginal value of debt in the bond Euler equation, and the collateral value of capital in the capital Euler equation.

E.4. Local result for a general cost function

The exact function in (12) is convenient but not essential. Suppose instead that enforcement costs are smooth near zero and satisfy

$$c(0) = c'(0) = 0, \quad c''(0) = \kappa > 0.$$

Then $c(L) = \frac{\kappa}{2} L^2 + O(L^3)$, and

$$\Gamma^E(L) = \frac{1}{1 - c(L)/L} = 1 + \frac{\kappa}{2} L + O(L^2) = \exp\left(\frac{\kappa}{2} L\right) + O(L^2). \quad (17)$$

Thus, any smooth enforcement technology with zero marginal cost at zero and positive local curvature generates the exponential premium to first order, with

$$\psi = \frac{1}{2} c''(0). \quad (18)$$

The cost function in (12) has $c''(0) = 2\psi$ and therefore implements the mapping exactly rather than only locally.

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