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Can the Covid Bailouts Save the Economy?

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Abstract

The covid-19 crisis has led to a sharp deterioration in firm and bank balance sheets. The government has responded with a massive intervention in corporate credit markets. We study equilibrium dynamics of macroeconomic quantities and prices, and how they are affected by this policy response. The interventions prevent a much deeper crisis by reducing corporate bankruptcies by about half and short-circuiting the doom loop between corporate and financial sector fragility. The additional fiscal cost is zero since program spending replaces what would otherwise have been spent on financial sector bailouts. An alternative intervention that targets aid to firms at risk of bankruptcy prevents more bankruptcies at much lower lower fiscal cost, but only enjoys marginally higher welfare. Finally, we study longer-run consequences for firm leverage and intermediary health when pandemics become the new normal.

JEL: G12, G15, F31.
Keywords: covid-19, bailout, credit crisis, financial intermediation

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1 Introduction

The global covid-19 pandemic has resulted in unprecedented contraction in aggregate consumption, investment, and output in nearly every developed economy. For example, U.S. GDP fell 5% in 2020.Q1 and 33% in 2020.Q2 annualized. Mandatory closures of non-essential businesses and voluntary reductions in spending cut off revenue streams and brought many firms to the brink of insolvency. Firms pulled credit lines (Li, Strahan, and Zhang, 2020), raided cash reserves, and laid off or furloughed workers.

In an effort to stabilize the economy and prevent an economic collapse, the U.S. Congress authorized four rounds of bailouts worth \$3.8 trillion. The Federal Reserve Board launched a slew of programs, worth \$2.3 trillion, several of which are aimed at keeping credit to businesses flowing. In this paper, we ask how effective the government's corporate loan programs are likely to be, once fully deployed.

Because the deepest recessions are typically associated with financial sector weakness (Reinhart and Rogoff, 2009; Jorda, Schularick, and Taylor, 2017), a key question is whether the interventions are able to short-circuit a doom loop in which corporate defaults bring down the financial intermediary sector which, in turn, leads to a corporate credit crunch. Using a rich model of corporate and financial sector interactions, we compare a situation with and without the corporate sector bailout programs. The additional bank stress tests that the Federal Reserve conducted in May 2020 show that the pandemic has the potential to do much harm to the banking sector, despite the strong balance sheets going into the crisis.[1] Second, we ask what fiscal ramifications these programs have in the short and in the long run. Third, we propose an alternative corporate loan policy design that increases welfare and has lower fiscal cost. Finally, we study the long-run impact on non-financial and financial sector health from the realization that pandemics may be recurring events in the future.

We set up and solve a general equilibrium model, extending Elenev, Landvoigt, and Van Nieuwerburgh (2020) to allow for government interventions in the credit market. The model features a goods-producing corporate sector financed with debt and equity and an intermediary sector financed by deposits and equity. The household sector consists of shareholders and

[1] https://www.federalreserve.gov/publications/files/2020-sensitivity-analysis-20200625.pdf

savers. Savers invest in safe assets, both bank deposits and government debt, and in risky corporate debt. Financial intermediaries make long-term risky loans to non-financial firms funded by short-term safe liabilities obtained from savers. Shareholders own the equity of non-financial and financial firms. The model produces occasional but severe financial crises whereby corporate defaults generate a wave of bank insolvencies, which feed back on the real economy. The calibrated model matches many features of macro-economic and financial quantity and price data.

We conceptualize the covid-19 shock as the joint effect of three changes. First, there is a large decline in average firm revenue in the non-financial corporate sector, engineered through a decline in average firm productivity that also stands in for the economic repercussions of lock-down measures and declines in labor supply. Second, the dispersion in firm-level productivity increases (Barrero, Bloom, and Davis, 2020), capturing the stark heterogeneity in how firms and sectors are affected by the pandemic. The increase in cross-sectional dispersion is likely to remain in place for a second year. Finally, the onset of covid-19 triggers the realization that pandemics will be a rare but recurring phenomenon in the future. The first two changes affect the short-run economic response, while the fourth one matters for the long-run. The covid shock triggers severe firm revenue shortfalls, making it impossible for many firms to pay their employees, their rent, and their existing debt service in the absence of government intervention.

Absent policy to support struggling firms, the covid shock triggers a wave of corporate defaults. The corporate defaults inflict losses on their lenders, principally the financial intermediaries (e.g. banks and insurance companies) but also the households who directly hold corporate debt (including bond mutual funds). The financial sector distress manifests itself in higher credit spreads. The higher cost of debt for firms and the uncertain economic outlook generate a large decline in corporate investment. A substantial share of intermediaries fail and are bailed out by the government. The cost of these rescue operations adds to the already higher government spending and lower tax revenues that accompany any severe recession (e.g., higher spending on unemployment insurance and food stamps). The mutually reinforcing spirals of firm distress, financial sector distress, and government bailouts create a macro-economic disaster. The non-linearity of the model solution is crucial to generate this behavior.

We then evaluate three government policies aimed at short-circuiting this doom loop. The first one is a policy that buys risky corporate debt on the primary or secondary debt market, funded by issuing safe government debt. It is calibrated to the size of the primary and secondary market corporate credit facilities and the term asset lending facility. We call this intervention the corporate credit facility (CCF). The CCF are allowed to buy $850 billion in corporate debt, which represents 8.9% of the outstanding stock of debt or 3.9% of GDP. The second one is a program in which banks make short-term bridge loans to non-financial firms at a low interest rate. The loan principal is forgiven when loans are used to pay employees. The government provides a full credit guarantee to the banks. This policy captures the institutional reality of the Paycheck Protection Program (PPP). The PPP program has a size of $671 billion or 3.1% of GDP. The third program also provides bank-originated bridge loans to non-financial firms. However, these loans are not forgivable, and they carry a modest interest rate. Moreover, banks must retain a fraction of the risk so that the government guarantee is partial. This program reflects the details of the Main Street Lending Program (MSLP), which has a size of $600 billion or 2.8% of GDP. We consider the combination of all three programs to be the counterpart to the real world intervention.

Our main result is that the bridge loan programs (PPP and MSLP) are successful at preventing corporate bankruptcies and a financial crisis. Intermediaries are able to continue making loans, suffering merely a decline in net worth rather than a major meltdown. Credit spreads still rise but not as much as they would absent policy. Facing a modestly higher cost of debt, firms borrow and invest less. However, investment shrinks by much less than it would absent policy. Preventing intermediary defaults avoids the fiscal outlay associated with intermediary bailouts. This cost reduction is offset by the direct costs of the programs. The PPP provides debt forgiveness and therefore has a much higher direct cost than the MSLP, which contains no forgiveness. In contrast to the PPP and MSLP, the CCF is much less effective. It lowers credit spreads, as intended, but increases risk-free interest rates. The latter effect reflects the higher stock of government debt resulting from the purchases of corporate debt. The loan rate falls by much less than the credit spread, muting the investment response. Deploying all three programs (the PPP, MSLF, and CCF) increases societal welfare by 1.6% in consumption equivalent units compared to a scenario without any government-sponsored corporate loan programs (the "No covid-policy" scenario). The primary deficit balloons relative to the no-pandemic situation, but not more than it would have absent the covid loan programs. The government issues 14% of GDP in additional debt in 2020. Savers who must absorb the extra debt in equilibrium require a higher interest rate, relative to no-policy. Government debt takes twenty years to come back down to pre-pandemic levels.

Since the loans are given to all firms, the PPP in particular wastes resources on firms that do not need the aid. We contrast the actual government programs with a hypothetical policy that conditions on need. Both which firms receive credit and how much credit they obtain now depend on firm-level productivity. We find that a much smaller-sized program is needed to prevent a lot more bankruptcies. This conditional bridge loan (CBL) program increases welfare by 1.9% compared to the No covid-policy scenario. This also suggests that the real-life policy combination (with a 1.6% gain) is not far off that of a perfectly targeted program, at least in terms of aggregate welfare. The distributional consequences, however, differ across the programs. Of course, the informational requirements on the government to implement this CBL program are more stringent.

Finally, we turn to the longer-term implications. The pandemic not only creates a massive unanticipated shock, but also creates an "awakening" to the possibility that pandemics may be recurring—albeit low-probability—events forever after. This is in the spirit of Kozlowski, Veldkamp, and Venkateswaran (2020), who emphasize the effects of "beliefs scarring." While this "awakening" has only minor implications in the short-run response of the economy, it leads to an economy that is different in the long-run. The post-pandemic economy features less corporate debt, lower output, and a smaller but more robust financial sector.

As a methodological contribution, we extend the numerical solution procedure developed in Elenev, Landvoigt, and Van Nieuwerburgh (2020) to compute the economy's response to unanticipated ("MIT") shocks. Global solution methods, such as transition function iteration from Elenev, Landvoigt, and Van Nieuwerburgh (2020), approximate the economy's rational expectations equilibrium; the policy functions obtained through this solution method generally do not capture the economy's response to an unexpected shock. In this paper, we calculate transition paths that return the economy to the rational expectations law of motion after unexpected shocks.

Related Literature Our paper contributes to three strands of the literature. The first one is a new literature that has sprung up in response to the covid-19 pandemic. The focus of this literature has been on understanding the interaction of the spread of the disease and the macro-economy.[2] This literature has not yet studied the role of government intervention in an equilibrium model of non-financial firms and financial intermediaries. Faria-e-Castro (2020) provides a DSGE model to analyze fiscal policies that help stabilize household income. It finds that unemployment insurance is the most effective stabilization tool for borrowing households, while saving households favour unconditional transfers. Liquidity assistance programs are effective if the policy objective is to stabilize employment in the affected sector. Fahlenbrach, Rageth, and Stulz (2020) show that firms that had better liquidity buffers before the pandemic showed smaller stock market declines. A few papers have begun to analyze the empirical effects of the PPP program. Granja, Makridis, Yannelis, and Zwick (2020) find that PPP loans were unevenly distributed in space, not always going to the areas that were hit hardest, in part due to unequal distribution by banks. Humphries and Ulyssea (2020) finds that information frictions and the "first-come, first-served" design of the PPP program skewed its resources towards larger firms. Cororaton and Rosen (2020) studies the public firm borrowers of the PPP and emphasizes the need for better targeting towards firms with liquidity needs, consistent with our findings.

A second branch of the literature studies government interventions in the wake of the Great Financial Crisis. In contrast with the current crisis, most of these interventions were aimed at stabilizing the financial sector. TARP provided equity injections, the GSEs were bailed out, FDIC guarantees on bank debt, and a myriad of Federal Reserve commitments worth $6.7 trillion (TALF, TSL, CPFF, etc.) provided liquidity to the banking and mortgage sectors. Blinder and Zandi (2015) provide a retrospective. The only direct interventions in the non-financial sector were the auto sector bailouts. Of the $84 billion of TARP money committed, the cost of the auto bailouts was ultimately $17 billion. A large literature studies the micro- and macro-

[2]Some of the early contributions to this fast-growing literature include Atkeson (2020), Eichenbaum, Rebelo, and Trabandt (2020), von Thadden (2020), Krueger, Uhlig, and Xie (2020a,b), Kaplan, Moll, and Violante (2020), Hagedorn and Mitman (2020), Rampini (2020), Brotherhood, Kircher, Santos, and Tertilt (2020), Bethune and Korinek (2020), Guerrieri, Lorenzoni, Straub, and Werning (2020), Ludvigson, Ng, and Ma (2020), Alvarez, Argente, and Lippi (2020), Jones, Philippon, and Venkateswaran (2020), Glover, Heathcote, Krueger, and Rios-Rull (2020), Greenstone and Nigam (2020), Kozlowski, Veldkamp, and Venkateswaran (2020), Farboodi, Jarosch, and Shimer (2020), and Xiao (2020).

prudential policy response to the financial crisis. Elenev, Landvoigt, and Van Nieuwerburgh (2020) provides references and studies the effect of tighter bank capital requirements. The calibration in this paper starts from the higher capital levels in place at the end of 2019.

While some are sanguine about the government's ability to spend trillions more (Blanchard, 2019), Jiang, Lustig, Van Nieuwerburgh, and Xiaolan (2020b) warn of higher yields on government debt. Our model predicts that the covid-19 bailouts will lead to higher interest rates in the short run and require higher future tax rates to bring the debt back down. To keep government debt finite, tax rates must increase in the level of government debt at medium-run frequencies. At business-cycle frequencies, tax revenues are pro-cyclical. The model also captures the increase in transfer spending, such as unemployment insurance and food stamps, that accompanies a deep recession. While the awakening to future pandemics creates persistent changes, the model has no permanent shocks. This is an important assumption to keep government debt risk-free (Jiang, Lustig, Van Nieuwerburgh, and Xiaolan, 2020a).

The rest of the paper is organized as follows. Section 2 discusses the evolution of credit spreads and the institutional detail of the corporate lending programs introduced during the covid pandemic. Section 3 provides a discussion of the model. Section 4 contains the main results on the short-run policy effects. Section 5 studies the long-run implications, comparing an economy where pandemics become the New Normal to an economy where they don't. Section 6 concludes.

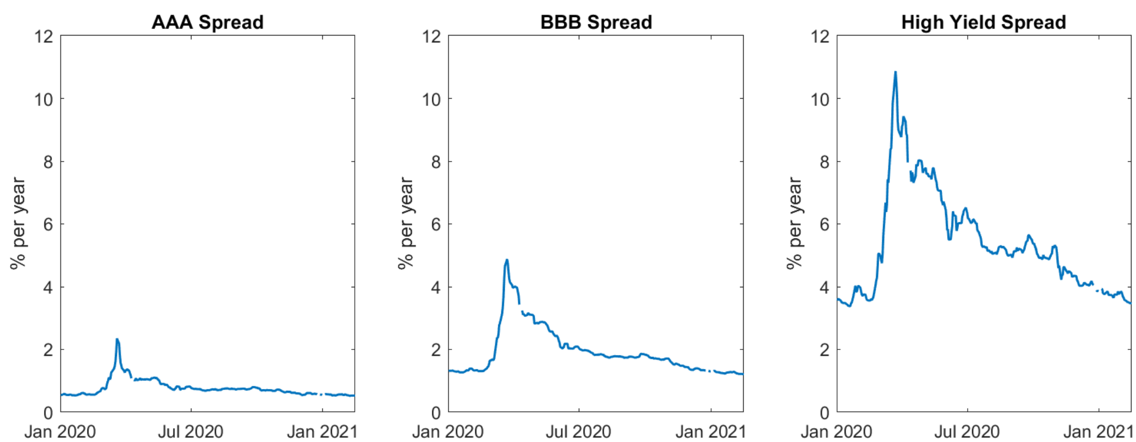
2 Institutional Background

2.1 Credit Market Disruption

Credit Spreads A first sign of trouble in the corporate sector showed up in the prices of corporate bonds. Figure 1 shows the AAA-rated, BBB-rated, and High Yield credit spreads between January 1, 2020 and April 27, 2020. The time series measures the spread for corporate debt over a duration-adjusted safe yield (swap rate). Naturally, credit spreads are lower for the safest firms (AAA), intermediate for the lowest-rated investment-grade firms (BBB), and highest for the firms rated below investment grade (High Yield). The AAA spread went from

0.56% on February 18, before the covid crisis began in the U.S., to a peak value of 2.35% on Friday March 20 and remained very high on Monday March 23 at 2.18%. The BBB spread increased from 1.31% on February 18 to 4.88% on March 23. The High Yield spread went from 3.61% on February 18 to 10.87% on March 23. For comparison, the only other two peaks of comparable magnitude in the High Yield index were October 2011 (European debt crisis, 8.98%) and February 2016 (Chinese equity market crash, 8.87%). On both occasions, the BBB spread remained below 3.25% and the AAA spread below 1%. To find a widespread spike like the one in the covid pandemic, we have to go back to the Great Financial Crisis. On December 15, 2008, the High Yield index peaked at 21.8%, the BBB index was at 8.02%, and the AAA spread was 3.85%.

Figure 1: High Yield Bond Spread



The left panel plots the ICE BofA AAA U.S. corporate index option-adjusted spread. The middle panel plots the ICE BofA BBB U.S. corporate index option-adjusted spread. The right panel plots the ICE BofA High Yield U.S. corporate index option-adjusted spread. The data are daily for January 1, 2020 until February 15, 2021. Source: FRED.

The policy interventions of March 23 and April 9, 2020, discussed in detail below, were successful in closing the credit spreads. The high yield spread tapered back off to 7.35% by April 14. The BBB spread was at 3.11%, and the AAA spread at 1.00%. Since then, spreads have continued to drift down eventually reaching their pre-pandemic levels by year end.

Treasury Yields and Sovereign CDS Spreads Figure 2 shows U.S. Treasury yields of maturities 1, 5, and 10-years in the left panel and U.S. sovereign credit default swap (CDS) spreads of maturities 1-, 5-, and 10-years in the middle panel. Ten-year Treasury yields decline from 1.55% on February 18 to 0.54% on March 9. This corresponds to a 10.5% increase in bond prices in 14 business days. We interpret this sharp decline in interest rates as a combination of (i) lower growth expectations (Gormsen and Koijen, 2020), and (ii) precautionary savings/flight-to-safety as the market woke up to the possibility of a severe crisis.

In the following seven trading days, there is a sharp reversal and 10-year interest rates doubles from 0.54% to 1.18% on March 18, a 6.1% drop in the bond price. We believe this sharp decline in interest rates is due to a combination of (i) expectations of large bailouts which need to be absorbed by savers, (ii) increased credit risk of the U.S. government, and (iii) distressed selling of safe assets to meet margin calls in other parts of investors' portfolios and regulatory constraints preventing others from stepping in (He, Nagel, and Song, 2020). We see a 5-7bps jump in CDS spreads between March 9 and 18.[3] Just prior to the peak in interest rates, in an emergency meeting on Sunday March 15, the Fed lowered the policy rate from 1.25% to 0.25% and announced a $700bn Treasury and Agency purchase program. This followed an earlier rate cut by 50 bps on March 3. On March 23, the Fed announced that the Quantitative Easing program would be unlimited in size. The intervention was successful in propping up government bond prices and 10-year yields fell back down to around 65 bps by April 27, a 5.2% increase in bond prices from March 18. The 10-year Treasury ended the year 2020 at 93 basis points, down 100 basis points from the start of the year. U.S. sovereign CDS spreads also normalized to pre-crisis levels.

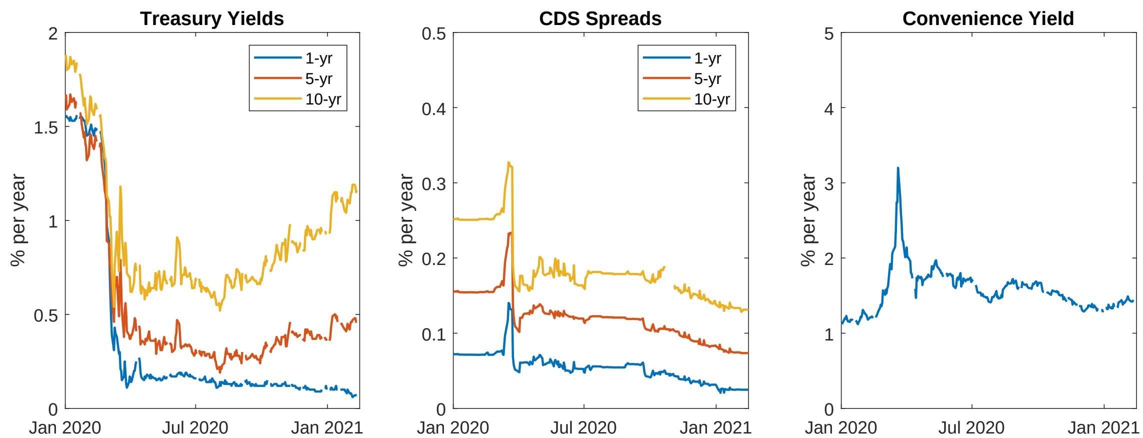
Investors –so far– seem quite sanguine about the massive expansion in government debt in 2020 ($4.21 trillion or 20.1% of 2020 GDP), fueled by a 18.5% of GDP primary deficit. This debt expansion pushed the U.S. federal debt held by the public above 100% in 2020, the highest level since World War II.

The U.S. benefits from its status as global safe asset. The true safe rate, without convenience, is higher than the Treasury bond yield. A standard measure of the convenience yield advocated by Krishnamurthy and Vissing-Jorgensen (2012)), the spread between the AAA-rated corporate bond yield and the 10-year Treasury, increased substantially in March, peaking on March 20, before settling back down to a level 50 bps above its pre-crisis level. Of course, the AAA-

[3]CDS spreads peak across developed countries (Augustin, Sokolovski, Subrahmanyam, and Tomio, 2020).

corporate spread reflects all interventions by the Fed in both the Treasury and corporate bond markets, and extracting the true convenience yield from this measure is a difficult task. With this caveat in mind, the evidence suggests that the risk-free rate did not fall as much as the Treasury yield during the first two months of the covid crisis.

Figure 2: High Yield Bond Spread



The left panel plots the U.S. Treasury Bond constant-maturity yields on bonds of maturities 1, 5, and 10 years. The middle panel plots the U.S. sovereign CDS spread of maturities 1, 5, and 10 years. The right panel plots the Moody's AAA-rated corporate bond yield minus the 10-year constant maturity Treasury yield. The data are daily for January 1, 2020 until February 15, 2021. Source: FRED and Markit.

Corporate Default The delinquency rate on commercial and industrial loans at all commercial banks has increased modestly from 1.13% in 2019.Q4 to 1.30% in 2020.Q3. Data from Fitch Ratings shows that the trailing twelve-month default rate for leveraged loans was 4% in July 2020, the highest level since 2010.

Moody's reports that 211 rated corporate issuers defaulted in 2020, double the number in 2019. Of the $234 billion in debt that went in default, $132 billion was in the form of corporate bonds and $102 billion in corporate loans. Two-thirds of these defaults were in the U.S.; 72% by volume. The issuer-weighted annual default rate was 3.1% in 2020, twice the 1.5% rate in 2019, and the highest annual rate since 2009. Among high-yield issuers, the twelve-month trailing default rate increased from 3.2% at the end of 2019 to 6.7% at the end of 2020. Moody's predicts that the high-yield default rate will peak at 7.3% in March 2021 before slowing down to 4.7% at the end of 2021. Moody's also finds higher than average losses-given-default.

Evidence of rising defaults also come from the commercial mortgage market. Trepp reports a sharp rise in the CMBS delinquency rate (60+ days late) from 2.04% in February 2020 to 7.15% in May and 10.32% in June, equalling the previous peak distress levels from 2010. Since then, the CMBS delinquency rate has gradually improved to 7.58% in January 2021, but remain high by historical standards. Taken together, this section shows that the covid-19 pandemic was associated with substantial corporate distress, despite massive government intervention.

2.2 Policy Response

Central Banks and Treasury departments around the world mounted massive responses to the crisis. We focus on the United States. Most relevant for our purposes are several new government programs that provide bridge loans to the corporate sector as part of the $2.2 trillion CARES Act passed on March 27, 2020. The Federal Reserve Bank uses its balance sheet to lever up the equity commitments made by the Treasury. The Fed first announced the establishment of these programs on March 23. On April 9, the Fed clarified how much leverage it would provide to each of the facilities to scale up the aid to corporations. The Fed announcement amounted to a $2.3 trillion relief package. On April 23, Congress approved a new $484 billion rescue package, which included $321 billion in additional money for the paycheck protection program defined below. On April 30, the modalities of the MSLP were announced. Appendix A provides the details of these policies. Here we focus on the mapping of this intricate set of interventions into our model. We consider three programs: bond purchases, forgivable bridge loans, regular bridge loans.

CCF = Corporate Bond Purchases The government mounted a large purchase program of corporate bonds, comprised of the primary and secondary corporate credit facilities (PMCCF, SMCCF), and the term asset lending facility (TALF). The combined program size is $850 billion, which constitutes $850/$21,729=3.9% of 2019 GDP.[4] Corporate bonds are purchased

[4] According to S&P Global, the size of the U.S. corporate bond market is $9,300 billion as of January 2019. Of this, $7,144 billion is bonds issued by non-financial corporations, of which $4,717.6 is rated investment grade. The size of the corporate loan market, the C&I loans held by all U.S. commercial banks, is $2,360 billion at the end of 2019. Since the model has only one type of debt, we divide the $850 billion purchases by the size of the overall non-financial corporate debt market of $9504 ($7144+$2360). This generates a purchase share of 8.9% of the overall corporate debt market. The model matches both the share of purchases out of GDP and the share of purchases out of the stock of debt since it matches the ratio of the corporate debt market to GDP.

at market prices.

PPP = Forgivable Bridge Loans The second program is the Small Business Administration's Paycheck Protection Program. Banks make loans to non-financial firms that are 100% guaranteed by the government and 100% forgiven. There is no risk retention requirement for the banks.[5] PPP loans feature debt forgiveness to the extent that firms use them to keep employees on the payroll. For example, the part of the loan that is used to pay rent is not forgiven. We suspect that the vast majority of firms who obtained PPP loans will enjoy full debt forgiveness since money is fungible and firms can always "use the proceeds to make payroll." Moreover, the fraction of loan proceeds that must be used for payroll expenses to preserve debt forgiveness was lowered from 75% to 60% on July 20. The forgiveness is modeled as a -100% interest rate earned by the government. Banks earn a 1% interest rate on the loans, just like in the data. The size of the PPP program is $671 billion, which is 3.1% of 2019 GDP. For simplicity, these are one-period loans. In the model, firms can refinance these loans after a year in the regular long-term corporate debt market.

MSLP = Regular Bridge Loans The third policy is modeled after the Main Street Lending Programs. Firms receive bridge loans from banks. Banks have a 5% risk retention requirement; the government bears 95% of the default risk. Banks earn an interest rate of 3% on the bridge loans. For simplicity, these are one-period loans, which can be refinanced in the regular debt market. The size of this program is $600 billion or 2.8% of 2019 GDP.

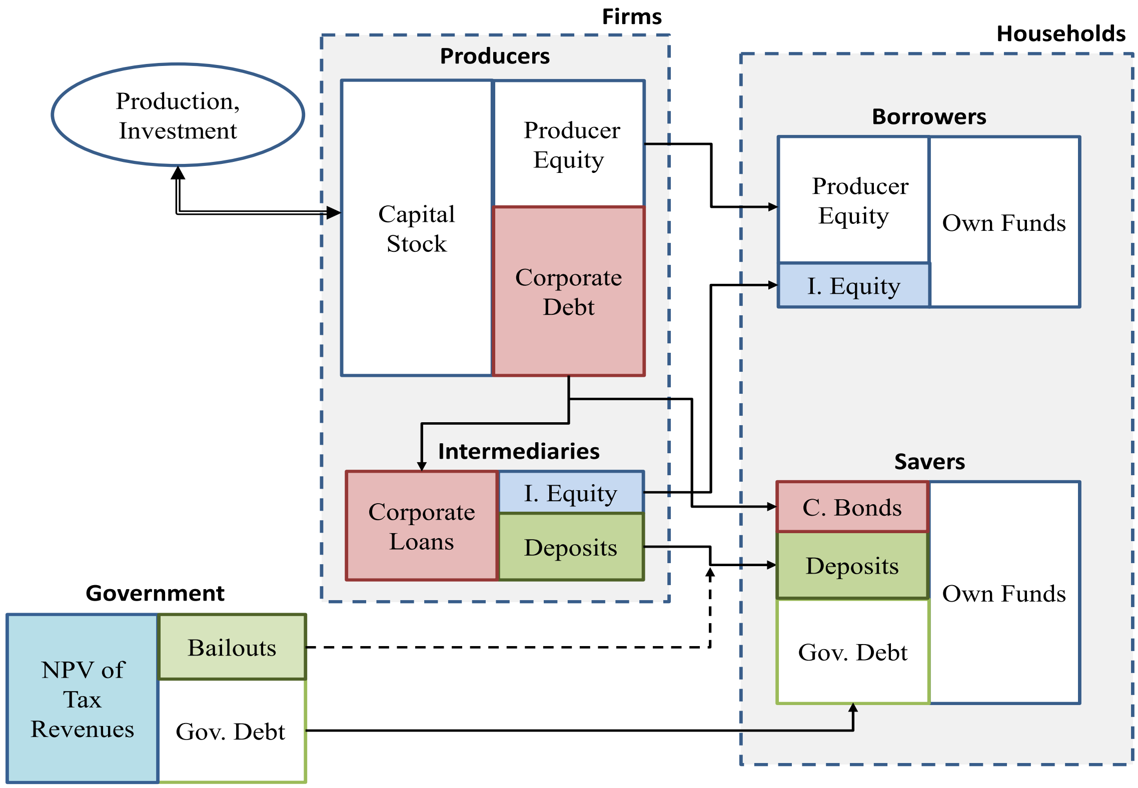
Combo We also study the combination of these three programs. Combined, they represent an outlay of 9.8% of GDP. This is the model counter-part to the real world intervention.

3 The Model

The model setup is taken from Elenev, Landvoigt, and Van Nieuwerburgh (2020). Figure 3 illustrates the balance sheets of the model's agents and their interactions.

[5] We abstract from the fact that the PPP loans target small firms. In reality, several larger firms ended up receiving these loans as well (Humphries and Ulyssea, 2020; Cororaton and Rosen, 2020).

Figure 3: Overview of Balance Sheets of Model Agents



3.1 Setup

Preferences The model features two groups of households: borrowers and savers. Both have Epstein-Zin preferences over utility streams $\{u_t^j\}_{t=0}^{\infty}$ with intertemporal elasticity of substitution ν_j and risk aversion σ^j

$$U_t^j = \left\{ (1-\beta_j) \left(u_t^j\right)^{1-1/\nu_j} + \beta_j \left(\mathrm{E}_t \left[(U_{t+1}^j)^{1-\sigma_j} \right] \right)^{\frac{1-1/\nu_j}{1-\sigma_j}} \right\}^{\frac{1}{1-1/\nu_j}}, \tag{1}$$

for $j = B, S$. Savers are more patient than borrowers: $\beta_B < \beta_S$.

Borrowers Borrowers are the shareholders of both goods-producing firms, called producers, and financial intermediaries, called banks, earning dividend income D_t^P and D_t^I. They inelastically supply labor L^B to producers. Borrowers also operate a technology that turns consumption into capital goods subject to investment adjustment costs $\Psi(\cdot)$, which depend on the investment-capital ratio X_t/K_t. They choose consumption C_t^B and investment X_t to maximize life-time utility U_t^B in (1), subject to the budget constraint:

$$C_t^B + X_t + \Psi(X_t/K_t)K_t \leq \; (1-\tau_t^B)w_t^B L^B + p_t X_t + D_t^P + D_t^I + G_t^{T,B} + O_t^B. \tag{2}$$

where w_t^B is the wage rate, τ_t^B the labor income tax rate, p_t is the relative price of investment goods, $G_t^{T,B}$ government transfer income, and O_t^B other income defined below.

Savers Savers do not directly hold corporate equity to capture the reality of limited participation in equity markets. However, they invest in both risk-free assets (bank and government debt) and risky corporate debt issued by firms. Entering with wealth W_t^S, the saver's problem is to choose consumption C_t^S, short-term bonds B_{t+1}^S, and corporate debt A_{t+1}^S to maximize life-time utility U_t^S in (1), subject to the budget constraint:

$$C_t^S + (q_t^f + \tau^D r_t^f)B_{t+1}^S + q_t^m A_{t+1}^S + \Psi^S(A_{t+1}^S) \leq W_t^S + (1-\tau_t^S)w_t^S L^S + G_t^{T,S} + O_t^S, \tag{3}$$

where q_t^f is the price of short-term bonds, q_t^m the price of corporate debt. Labor is supplied inelastically and taxed at rate τ^S. While savers can invest in the corporate debt of producers directly, they are at a comparative disadvantage relative to banks, as modeled through the holding cost function:

$$\Psi^S(A_{t+1}^S) = \frac{\varphi_1}{2}\left(\frac{A_{t+1}^S}{\varphi_0} - 1\right)^2 \varphi_0. \tag{4}$$

It is this holding cost which provides a role for intermediaries to transform short-term safe deposits into long-term risky loans.

Producers A continuum of producers combine capital k_t and labor l_t using a Cobb-Douglas production technology to produce output.

$$y_t = \omega_t Z_t k_t^{1-\alpha} l_t^{\alpha},$$

Labor input l_t is the composite of borrower and saver labor $l_t = (l_t^B)^{\gamma_B}(l_t^S)^{\gamma_S}$, with $\gamma_B + \gamma_S = 1$. Shocks to total factor productivity (TFP) Z are the first source of aggregate risk in the model. Individual producers are subject to idiosyncratic productivity shocks ω_t with mean one. The

ω_t-shocks are uncorrelated across firms and time. However, the cross-sectional dispersion of the ω-shocks varies over time; specifically, $\sigma_{\omega,t}$ follows a first-order Markov process. Productivity dispersion is the second exogenous source of aggregate risk in the model. We refer to changes in $\sigma_{\omega,t}$ as uncertainty shocks; it can alternatively be interpreted as a capital misallocation shock.

Producers buy and sell capital at price p_t in a competitive market. They borrow in the corporate debt market by issuing corporate debt to banks and savers at price q_t^m. They issue equity to borrowers. Corporate debt is long-term, modeled as a perpetuity with declining payments $\{1, \delta, \delta^2, \ldots\}$, where δ captures the duration of the bond. We define a "face value" $F = \frac{\theta}{1-\delta}$ as a fixed fraction θ of all repayments for each bond issued. Per definition, interest payments are the remainder $\frac{1-\theta}{1-\delta}$. Interest expenses are tax deductible. Producers have limited liability and may default for liquidity reasons.

The decision problem of producers within each period has the following timing:

1. The aggregate productivity shock Z_t is realized. Given capital k_t and outstanding debt a_t^P, producers choose labor inputs l_t^j, $j \in \{B, S\}$. Further, producers pay a fixed cost of production to operate (rents, insurance, etc.) ς is the fixed cost that is proportional in capital k_t.

2. Idiosyncratic productivity shocks ω_t are realized. Production occurs. Producers that cannot service their debt from current profits default and shut down.

3. Failed producers are replaced by new producers such that the total mass of producers remains unchanged. All producers pay a dividend, issue new debt, and buy capital for next period.

The pre-tax profit at stage 2 is:

$$\pi_t = y_t - \sum_j w_t^j l_t^j - a_t^P - \varsigma k_t, \tag{5}$$

Producers with $\pi_t < 0$ are in default, and are seized and resolved by their creditors. This implies a default threshold:

$$\omega_t^* = \frac{a_t^P + \varsigma k_t + \sum_j w_t^j l_t^j}{Z_t k_t^{1-\alpha} l_t^\alpha}, \tag{6}$$

such that producers with low idiosyncratic shocks $\omega_t < \omega_t^*$ default. Firms that do not have enough revenue to service their debt and pay their employees default. The crucial friction that generates defaults is a timing assumption that corporations must service their debt before they can raise new equity or debt.

Each period, producers are expected to pay a fraction ϕ_0^P of their net worth to their shareholders, the borrowers, as dividend. Producers can also raise new equity e_t^P.

We can state the producer's problem recursively using producer net worth n_t^P and aggregate state $\mathcal{S}_t$:

$$V^P(n_t^P, \mathcal{S}_t) = \max_{e_t^P, k_{t+1}, a_{t+1}^P} \phi_0^P n_t^p - e_t^P + \mathrm{E}_t \left[\mathcal{M}_{t,t+1}^B V^+(k_{t+1}, a_{t+1}^P, \mathcal{S}_{t+1}) \right], \tag{7}$$

subject to the budget constraint:

$$(1 - \phi_0^P) n_t^P + e_t^P \geq p_t k_{t+1} - q_t^m a_{t+1}^P, \tag{8}$$

and the leverage constraint:

$$\Phi p_t k_{t+1} \geq F a_{t+1}^P. \tag{9}$$

Constraint (9), familiar from Kiyotaki and Moore (1997), limits the face value of firm debt to a fraction Φ of its capital valued at market prices.

ELVN shows that the producer problem aggregates. That means that we can solve the problem of a representative borrower making aggregate capital, labor, debt, and equity choices, while still having only a fraction of all producers to default on their corporate debt in a given period.

Intermediaries Intermediaries ("banks") are financial firms that buy long-term risky corporate debt issued by producers and use this debt as collateral to issue short-term debt to savers. They maximize the present discounted value of net dividend payments to their shareholders, the borrowers.

Similar to producing firms, banks are required to pay a fraction ϕ_0^I of equity as dividend each period, but they can deviate from this target by issuing equity e_t^I at a convex cost $\Psi^I(e_t^I) =$

$\frac{\phi_1^I}{2}(e_t^I)^2$. Like firms, banks are subject to idiosyncratic profit shocks ϵ_t^I, realized at the time of dividend payouts. The shocks are i.i.d. across banks and time with $\mathrm{E}(\epsilon_t^I) = 0$ and c.d.f. F_ϵ, and capture unmodeled heterogeneity in bank portfolios.

Banks hold a diversified portfolio of corporate debt. At the beginning of each period, banks own a_t^I bonds and have to repay b_t^I deposits. The repayment on performing loans in the current period is thus $(1 - F_{\omega,t}(\omega_t^*))a_t^I$. For firms that default, banks repossess the firms, sell current period's output, pay current period's wages, and sell off the assets, yielding a recovery payoff per bond of:

$$M_t = \frac{F_{\omega,t}(\omega_t^*)}{A_t^P}\left[(1-\zeta^P)\left(\mathrm{E}_{\omega,t}\left[\omega \mid \omega < \omega_t^*\right] Y_t + \left((1-\delta_K)p_t - \varsigma\right) K_t\right) - \sum_j w_t^j \bar{L}^j\right], \tag{10}$$

where A_t^P, Y_t, and K_t denote aggregate producer debt, output and capital, respectively, and ζ^P is the fraction of firm assets and output lost to lenders in bankruptcy. A fraction η^P of this bankruptcy cost is a deadweight loss to society, while the remainder is a transfer payment to households, the variable denoted by O in the households' budget constraints.

By inflicting losses on their lenders, corporate defaults cause financial intermediary fragility. Banks' net worth goes down because of the losses they suffer, and because of the lower equilibrium value of corporate loans. Lower corporate bond prices (higher yields) reflect both higher default risk and a higher default risk premium.

For some banks, the losses will be so severe that they choose to default. Each intermediary optimally decides on bankruptcy, conditional on net worth n_t^I and the idiosyncratic profit shock realization ϵ_t^I. Bankrupt intermediaries are liquidated by the government, which redeems deposits at par value. The government incurs bankruptcy costs; a fraction ζ^F of bank assets are lost in the liquidation process. A fraction η^F of bankruptcy costs are deadweight losses to society, the remainder is rebated to households (included in the O terms). Immediately after bank liquidations, shareholders replace all bankrupt intermediaries with new banks that receive initial equity equal to the average equity of non-defaulting banks. Banks must pay a deposit insurance fee κ to the government that is proportional to the amount of short-term bonds (deposits) they issue. Like firms, intermediaries are subject to corporate profit taxes at rate τ^{Π}. We can now state the recursive problem of an individual bank as:

$$V^I(n_t^I, \epsilon_t^I, \mathcal{S}_t) = \max_{a_{t+1}^I, b_{t+1}^I, e_t^I} \phi_0^I n_t^I - e_t^I + \epsilon_t^I + \mathrm{E}_t \left[\mathcal{M}_{t,t+1}^B \max\{V^I(n_{t+1}^I, \epsilon_{t+1}^I, \mathcal{S}_{t+1}), 0\} \right] \qquad (11)$$

subject to the budget constraint:

$$(1 - \phi_0^I) n_t^I + e_t^I - \Psi^I(e_t^I) \geq q_t^m a_{t+1}^I - (q_t^f + \tau^{\Pi} r_t^f - \kappa) b_{t+1}^I, \qquad (12)$$

and the regulatory constraint:

$$q_t^f b_{t+1}^I \leq \xi q_t^m a_{t+1}^I. \qquad (13)$$

Intermediaries discount future payoffs by $\mathcal{M}_{t,t+1}^B$, which is the stochastic discount factor of their shareholders, the borrowers. The continuation value takes into account the possibility of optimal bank default, in which case shareholders get zero.

Banks are subject to a standard regulatory capital constraint (13) to limit moral hazard associated with deposit insurance (capturing regulation under Basel 2/3 or Solvency 2/3). The parameter ξ determines how much deposits can be issued against each dollar of assets (corporate loans). Banks' leverage choice is affected by the same tax benefit and cost of distress trade-off faced by firms. Banks enjoy deposit insurance and have a unique ability to provide safe assets to patient households. These two additional forces increase banks' desire for leverage and will help the model match much higher financial than non-financial sector leverage.

ELVN shows that the bank problem aggregates. That means that we can solve the problem of a representative bank, while still having only a fraction of all banks default in a given period.

Government The government issues one-period risk-free debt. Debt repayments and government expenditures are financed by new debt issuance and tax revenues, resulting in the budget constraint:

$$B_t^G + G_t \leq q_t^f B_{t+1}^G + T_t \qquad (14)$$

We impose a transversality condition on government debt. Government tax revenues, T_t, are comprised of labor income tax, non-financial and financial profit tax, deposit income tax, and deposit insurance fee receipts. Government expenditures, G_t, are the sum of exogenous government spending, G_t^o, transfer spending G_t^T, and financial sector bailouts. Government policy parameters are $\Theta_t = \left(\tau_t^i, \tau^\Pi, \tau^D, G_t^o, G_t^{T,i}, \xi, \kappa\right)$. Tax rates and spending will be allowed to depend on aggregate productivity to capture automatic stabilizers.[6] The capital requirement ξ in equation (13) and the deposit insurance fee κ are macro-prudential policy tools.

Since there is no nominal side to the model, the paper is silent on conventional monetary policy. Our preferred interpretation of the government is as the combination of Treasury and Central Bank. Government debt is the sum of Treasury debt and bank reserves. Fed purchases of Treasury debt in exchange for bank reserves (unconventional monetary policy) is impotent when there only is one-period government debt.

3.2 Equilibrium

Given a sequence of aggregate productivity shocks $\{Z_t, \sigma_{\omega,t}\}$, idiosyncratic productivity shocks $\{\omega_{t,i}\}_{i\in B}$, and idiosyncratic intermediary profit shocks $\{\epsilon_{t,i}\}_{i\in I}$, and given a government policy Θ_t, a competitive equilibrium is an allocation $\{C_t^B, X_t\}$ for borrower-entrepreneurs, $\{e_t^P, K_{t+1}, A_{t+1}^P, L_t^j\}$ for producers, $\{C_t^S, A_{t+1}^S, B_{t+1}^S\}$ for savers, $\{e_t^I, A_{t+1}^I, B_{t+1}^I\}$ for intermediaries, and a price vector $\{p_t, q_t^m, q_t^f, w_t^B, w_t^S\}$, such that given the prices, borrower-entrepreneurs and savers maximize life-time utility, intermediaries maximize shareholder value, the government satisfies its budget constraint, and markets clear. The market clearing conditions are:

$$\text{Risk-free bonds: } B_{t+1}^G + B_{t+1}^I = B_{t+1}^S \tag{15}$$

$$\text{Loans: } A_{t+1}^P = A_{t+1}^I + A_{t+1}^S \tag{16}$$

$$\text{Capital: } K_{t+1} = (1-\delta_K)K_t + X_t \tag{17}$$

$$\text{Labor: } L_t^j = \bar{L}^j \text{ for } j = B, S \tag{18}$$

$$\text{Goods: } Y_t = C_t^B + C_t^S + G_t^o + X_t + K_t\Psi(X_t, K_t) + \Psi^I(e_t^I) + \Psi^S(A_{t+1}^S) + DWL_t \tag{19}$$

[6] The labor income tax rate also depends on the level of government debt. This is necessary to keep government debt stationary and risk-free. Since this a model with transitory shocks, like most macro models, the stochastic discount factor does not contain a large permanent component (Alvarez and Jermann, 2005). A model with a permanent component in both output and the SDF would require much larger adjustments to tax rates to keep government debt risk-free (Jiang, Lustig, Van Nieuwerburgh, and Xiaolan, 2020b,a).

The last equation is the economy's resource constraint. It states that total output (GDP) equals the sum of aggregate consumption, discretionary government spending, investment including capital adjustment costs, bank equity adjustment costs, saver monitoring costs, and aggregate resource losses (DWL_t) from corporate and intermediary bankruptcies.

3.3 Welfare

In order to compare economies that differ in their policy parameter vector Θ, we must take a stance on how to weigh borrower and saver households. We compute an ex-ante measure of welfare based on compensating variation similar to Alvarez and Jermann (2005). Consider the equilibrium of two different economies $k = 0, 1$, characterized by policy vectors Θ^0 and Θ^1, and denote expected lifetime utility at time 0 for agent j in economy k by $\bar{V}^{j,k} = \mathrm{E}_0[V_1^j(\cdot;\, \Theta^k)]$. Denote the time-0 price of the consumption stream of agent j in economy k by:

$$\bar{P}^{j,k} = \mathrm{E}_0\left[\sum_{t=0}^{\infty} \mathcal{M}_{t,t+1}^{j,k} C_{t+1}^{j,k}\right],$$

where $\mathcal{M}_{t,t+1}^{j,k}$ is the SDF of agent j in economy k. The percentage welfare gain for agent j from living in economy Θ^1 relative to economy Θ^0, in expectation, is:

$$\Delta \bar{V}^j = \frac{\bar{V}^{j,1}}{\bar{V}^{j,0}} - 1.$$

Since the value functions are expressed in consumption units, we can multiply these welfare gains with the time-0 prices of consumption streams in the Θ^0 economy and add up:

$$\mathcal{W}^{cev} = \Delta \bar{V}^B \bar{P}^{B,0} + \Delta \bar{V}^S \bar{P}^{S,0}.$$

This measure is the minimum one-time wealth transfer (expressed in units of the numeraire) in the Θ^0 economy (the benchmark) required to make agents at least as well off as in the Θ^1 economy (the alternative). If this number is positive, a transfer scheme can be implemented to make the alternative economy a Pareto improvement. If this number is negative, such a scheme cannot be implemented because it would require a bigger transfer to one agent than the other is willing to give up.

3.4 Solution

The aggregate state variables of the economy are productivity Z_t, uncertainty state $\sigma_{\omega,t}$, the aggregate capital stock K_t, and the distribution of financial wealth among borrowers, firms, intermediaries, savers and the government. Optimizing agents have rational expectations and know the stochastic transition law mapping today's state $\mathcal{S}_t = [Z_t, \sigma_{\omega_t}, K_t, N_t^P, N_t^I, W_t^S, B_t^G]$ into the distribution of tomorrow's state $\mathcal{S}_{t+1}$. Put simply, each agent must forecast how the state variable evolves, including the bankruptcy decisions of borrowers and intermediaries. We solve the model using global projection-based numerical methods.

A technical contribution of this paper is to incorporate unexpected shocks, such as the covid shocks discussed below. The solution algorithm established in ELVN relies on Markov dynamics in the model's state variables. In particular, ELVN define "transition functions" that map today's aggregate state variable realizations into tomorrow's endogenous aggregate state, for each possible realization of the exogenous stochastic process driving the economy. These transition functions encode the rational expectation equilibrium's law of motion for the state variables, and jointly with the policy functions for prices and agent choices characterize the economy.

Transition and policy functions computed based on the algorithm in ELVN assume that all exogenous shocks affecting the economy are completely described by the Markov transition laws for the exogenous state variables, aggregate TFP and uncertainty shocks. When an unanticipated (MIT) shock hits the economy in period t, the transition functions no longer provide the correct law of motion for the state variables from t to $t+1$. Rather, the transition $t \rightarrow t+1$ is a one-time event that depends on the exact nature of the unexpected shock in t. Assuming that no further unanticipated shocks occur in $t+1$, the economy follows the "usual" law of motion encoded by the transition functions from $t+1$ onward. Our methodological innovation in this paper is to extend the algorithm in ELVN to allow for such one-time transitions back to the saddle path of the rational expectations equilibrium. This requires us to compute the one-time transitions $t \rightarrow t+1$ for all endogenous state variables jointly with policy functions in t. Appendix C contains details.

3.5 Calibration

The model is calibrated at annual frequency and matches a large number of moments related to the macro economy, credit markets, non-financial and financial sector leverage ratios, corporate default and loss rates, bank bankruptcies, as well as a number of fiscal policy targets. Appendix D presents the details of the calibration. Here, we discusses how we conceptualize the pandemic shock and covid-related government policy response.

3.5.1 Covid Shock

The cross-sectional variance σ_ω^2 follows a two-state Markov chain fluctuating between a low and a high-uncertainty regime. Aggregate TFP shocks follow an independent 5-state Markov chain.

The covid shock is modeled as the combination of four ingredients. The first aspect of the covid shock is a transition from the low- ($\sigma_{\omega,L}^2$) to the high-uncertainty regime ($\sigma_{\omega,H}^2$). Because of persistence in σ_ω^2, the economy may remain in the high uncertainty state for additional periods, with probabilities dictated by the Markov chain.

Second, we assume that the productivity dispersion is unexpectedly high: $\sigma_{\omega,covid}^2 > \sigma_{\omega,H}^2 > \sigma_{\omega,L}^2$. This is modeled as a one-period unexpected (MIT) shock. The rise of VIX to an all-time high serves as motivation for this assumption. More broadly, the notion of increased firm productivity dispersion captures capital misallocation. During covid, some firms (like cruise companies and airlines) saw much greater reductions in revenues than others, while some even saw significant increases in revenue (Amazon, Netflix, Zoom). Barrero, Bloom, and Davis (2020) provide evidence for rising firm dispersion during the covid-19 pandemic.

The third aspect of the covid shock is a decline in average firm productivity μ_ω, leading to a decline in average firm revenue. We model this as an additional unexpected change (MIT shock). A decline in average firm productivity has the same effect as a decline in aggregate TFP, except that TFP is persistent and TFP fluctuations are anticipated. The unexpected and pervasive nature of revenue drops in the cross-section of firms is well captured by the unanticipated one-year drop in μ_ω. Since this is a supply-side shock, it can also stand in for government-mandated closures of non-essential businesses. We target the observed decline of 3.5% in real per capital GDP in 2020.

Fourth, the pandemic causes the realization that an economic shock like the pandemic could reoccur in the future, an "awakening" to a "new normal." Formally, we include the pandemic state (low μ_ω, high $\sigma_{\omega,covid}$) as an extra state of the world that occurs with low but not zero probability, $p_{covid} = 1\%$. Furthermore, once the pandemic hits, it is likely to persist for an additional year with 50% probability. Thus, pandemics last an average of 2 years.[7] The pandemic shock is thus not only an MIT shock in the first period, but also a change in beliefs from $p_{covid} = 0\%$ to $p_{covid} = 1\%$ going forward.

This last assumption has two important consequences, as we shall see. In the short-run it affects the response of short-term interest rates. Because the pandemic is expected to last two rather than one year, expected growth is low rather than high conditional on being in the first period of the pandemic. This makes interest rates low rather than high when the pandemic hits. Second, the recurrent nature of pandemics has important implications for the long-run behavior of the economy which we explore in the last part of the paper.

3.5.2 Policy Response

The aim of government policies is to stave off or at least weaken corporate defaults. This weakens the vicious cycle between corporate and banking fragility which chokes off investment and economic activity. We consider four policies, motivated by the discussion in section 2.2. To determine the magnitudes of these policies intervention, we calculate the dollar-amounts for program sizes listed in section 2.2 as fractions of 2019 GDP, assuming that the programs are fully utilized.[8] Regarding the policies' fiscal impact, our approach is to consolidate the balance sheet of the Treasury and the Federal Reserve.[9] Appendix B contains the details on how we implement the bridge loan programs in the model.

CCF = Corporate Bond Purchases The corporate bond purchase policy has the government buying long-term risky corporate debt from both banks and savers in proportion to their

[7]The covid pandemic has now entered its second year with vaccine distribution expected to last well into 2021. The 1918-20 Spanish flu also ran over more than two full years.

[8]To the extent that they are not in the data, we would need to scale down the size of the programs.

[9]This implies that the "leverage" the Fed provides beyond the amounts allocated by the Treasury is just another form of (short-term) government borrowing. To the extent that the Fed finances loan purchases by issuing interest-bearing reserves, this is consistent with our model that only has short-term (one-period) government debt.

holdings and at market prices. The government issues short-term government debt to finance these purchases. Treasury debt is held by the savers in equilibrium. The size of the program is the same as in the data, 3.9% of pre-pandemic GDP.

PPP= Forgivable Bridge Loans We consider a bridge loan program that closely reflects the PPP and is of the same size as in the data (3.1% of 2019 GDP).

Each firm receives an equal-size bridge loan from private lenders. The size of the loan is dictated by the total size of the program. The firm receives the loan in stage 2 of its problem, after production but before defaults and trading in financial markets. The loan must be repaid at the end of the period, in stage 3 of the firm's intra-period problem. At that point, firms can refinance the debt on the regular long-term corporate debt market. Since the firm receives the bridge loan before defaulting and the size of the loan is a multiple $\bar{A}^{brU}$ of the firm's wage bill, the default threshold becomes:

$$\omega_t^{*,brU} = \frac{\varsigma k_t + (1 - \bar{A}^{brU}) \sum_j w_t^j l_t^j + a_t^P}{Z_t k_t^{1-\alpha} l_t^\alpha}. \tag{20}$$

Producers with low idiosyncratic productivity $\omega_t < \omega_t^{*,brU}$ default. This is a smaller fraction since the policy lowers the default threshold compared to the no-policy case ($\omega_t^{*,brU} < \omega_t^*$). Thus the bridge loans help a mass of firms prevent default and the concomitant losses. It also avoids the deadweight losses to society associated with these defaults. Some firms with low productivity still default, notwithstanding the bridge loan program. The remaining losses are born by banks and the government depending on the extent of government guarantees. A policy parameter I_{br} measures the share of the losses born by the government, ranging from 0 (no guarantees for bridge loans) to 1 (full guarantees). In the PPP, $I_{br} = 1$.

Firms pay an interest rate $r^{br} = 1\%$ to banks on the bridge loans. After this interest payment, the loans are forgiven by the government. To capture the debt forgiveness aspect of the PPP, the bridge loans carry a $r^{gov} = -100\%$ interest rate to the government (i.e., the effective interest rate faced by firms is $r^{br} + r^{gov} = -99\%$).

MSLP= Regular Bridge Loans The third policy, modeled after the MSLP, is similar to the PPP except for three features. First, there is partial risk retention by banks: $I_{br} = 0.95$.

Second, the principal is not forgiven ($r^{gov} = 0$). Third, the interest rate paid to banks is higher: $r^{br} = 3\%$. The size is the same as in the data at 2.8% of pre-pandemic GDP.

CBL=Conditional Bridge Loans As a fourth, hypothetical, policy we consider a conditional bridge loan program. The government can target firms that are most likely to default if they do not receive a bridge loan. Specifically, a firm of productivity ω_t receives a bank loan of size $\bar{A}^{brC}(1-\omega_t)\sum_j w_t^j l_t^j$ in stage 2 of the firm problem. The conditionality operates both on the extensive and intensive margins. First, only firms with $\omega_t < \omega_t^*$ receive bridge loans. Second, the loan size is larger the lower the firm's productivity.

This bridge loan program changes the default threshold from ω_t^* to $\omega_t^{*,brC}$:

$$\omega_t^{*,brC} = \frac{\varsigma k_t + (1-\bar{A}^{brC})\sum_j w_t^j l_t^j + a_t^P}{Z_t k_t^{1-\alpha} l_t^{\alpha} - \bar{A}^{brC}\sum_j w_t^j l_t^j}. \tag{21}$$

All other aspects of the program are the same as for the regular bridge loan program. In particular, we consider a program configuration that is the average of PPP and MSLP: a debt forgiveness of 50% of the principal ($r^{gov} = -50\%$), and interest payments to banks of $r^{br} = 2\%$ of the principal. The conditional bridge loan will generally be more effective, on a per-dollar-basis, in preventing firms from defaulting than the PPP. Hence, we do not fix the size of the CBL program, but rather compute what fraction of GDP the government must spend to eliminate all defaults.

The CBL policy imposes strong information requirements on the government: It must observe each firm's productivity. In reality, there is an issue of asymmetric information —firms know more about their drop in revenue than the government— as well as moral hazard —firms have an incentive to overstate their need. Imperfect verification on the part of the government, especially in an episode of scarce time and resources, makes these frictions potentially important. We view the cost difference between the PPP and the CBL programs as an estimate of the extra costs of imperfect information or enforcement.[10]

[10]One can envision bridge loan programs that condition on industry. Such programs would have much weaker informational requirements while still providing better targeting than unconditional bridge loans. Since covid-19 clearly affected some sectors more than others, this may be an attractive policy alternative. The model could be extended to have a productivity shock ω that contains an industry-specific component and a component that is firm-specific and orthogonal to the industry. Policies could then be made contingent on the industry-specific

4 Results

4.1 Decomposing the Effects of the Shock

We start by analyzing how each aspect of the covid-19 shock contributes to the decline in macro aggregates in Figure 4. We do so in the economy without covid policy. Note that this economy still has counter-cyclical fiscal policy and a bank bailout (deposit insurance) policy. The first bar in each panel denotes the effect of an anticipated economic uncertainty shock (transition to $\sigma_{\omega,H}$). The next bar adds the unanticipated additional increase in uncertainty. The third bar adds the decline in average firm productivity. The last bar adds the New Normal shock, which increases the probability of future pandemics to 1% and increases the duration of a pandemic once the economy is in one (average duration of 2 years). The last bar shows the total effect of the covid-shock.

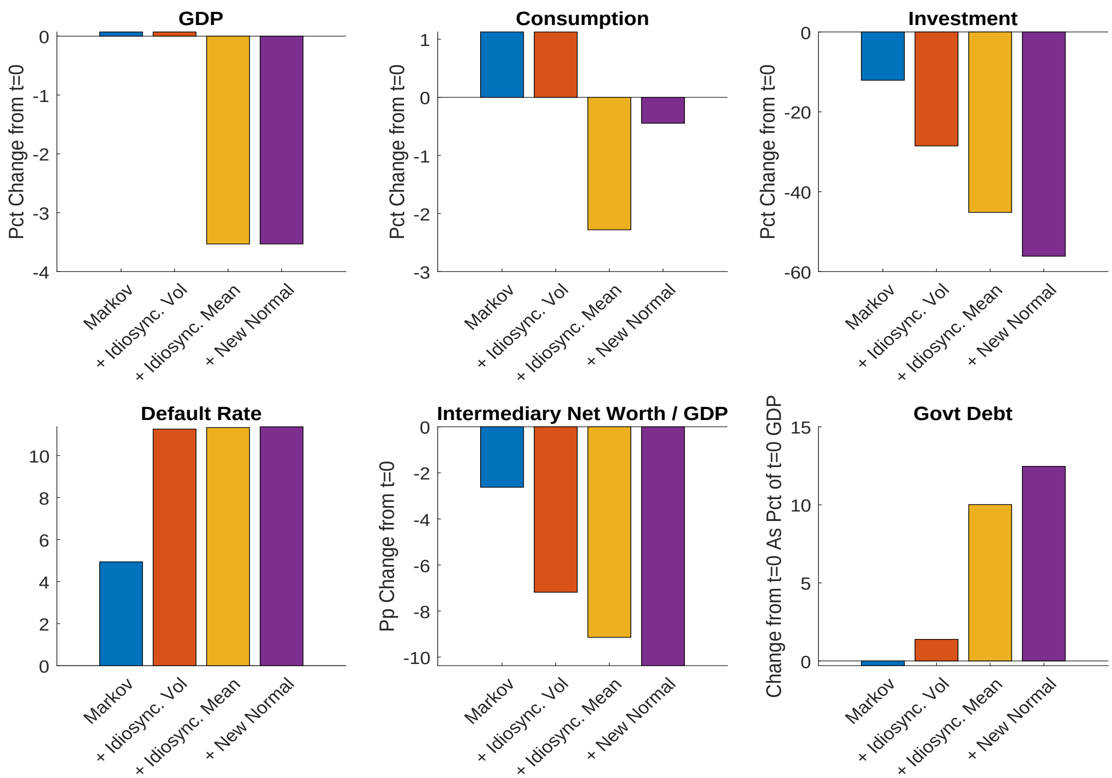
The plot clarifies that the decline in mean firm productivity is the largest driver of the decline in GDP. Corporate defaults are driven by both the anticipated and unanticipated uncertainty shocks. Each of the shocks contributes to the decline in aggregate investment and to the decline in intermediary net worth. We discuss the model's response to the covid shock absent covid policy in more detail in the next section.

4.2 First-Period Policy Response

Figures 5, 6, 7, and 8 summarize our main short-run results. Each graph plots the impact of the covid shock in the year in which it hits the economy, i.e., in 2020. The first (dark blue) bar shows the effect on the economy without covid policy response. The other bars respond to the four actual government policies: forgivable bridge loans (PPP, orange), regular bridge loans (MSLP, yellow), corporate bond purchases (CCF, purple), and the combination of all three (Combo, green). The last bar is for the hypothetical conditional bridge loan program (CBL, light blue).

component. Greenwald, Landvoigt, and Van Nieuwerburgh (2021) implement a related idea of conditioning mortgage payments on the local component of house prices that is orthogonal to both the aggregate component and the house-specific component. The tools developed in that paper could be used for such an extension.

Figure 4: Shock Components



Note: this figure plots the cumulative contributions of each component of the covid shock.

4.2.1 No Covid Policy

We first consider a (counter-factual) scenario in which the government does not respond to the covid crisis, except through its usual counter-cyclical spending and pro-cyclical tax policies and its bank bailout policies. Corporate defaults and loan losses skyrocket in response to the covid shock. The default rate in the non-financial sector goes from its normal level of 1.9% per year to 11.4%, a sixfold increase. The loss rate also increases by a factor of six to 5.8%.

These loan losses trigger credit disintermediation: the fraction of corporate debt held by savers rises sharply from 15% before the crisis to 63%, which means the intermediary share drops sharply. The loan losses not only cause a smaller but also a weaker banking sector. Financial fragility manifests itself in an increase in the bank failure rate— 23% of the banks become insolvent—and a decline in aggregate intermediary net worth, as shown in Figure 6. Higher credit spreads are a manifestation of the increased scarcity of banks' resources; they

Figure 5: Policy Responses to Covid Crisis: Non-financial Firms

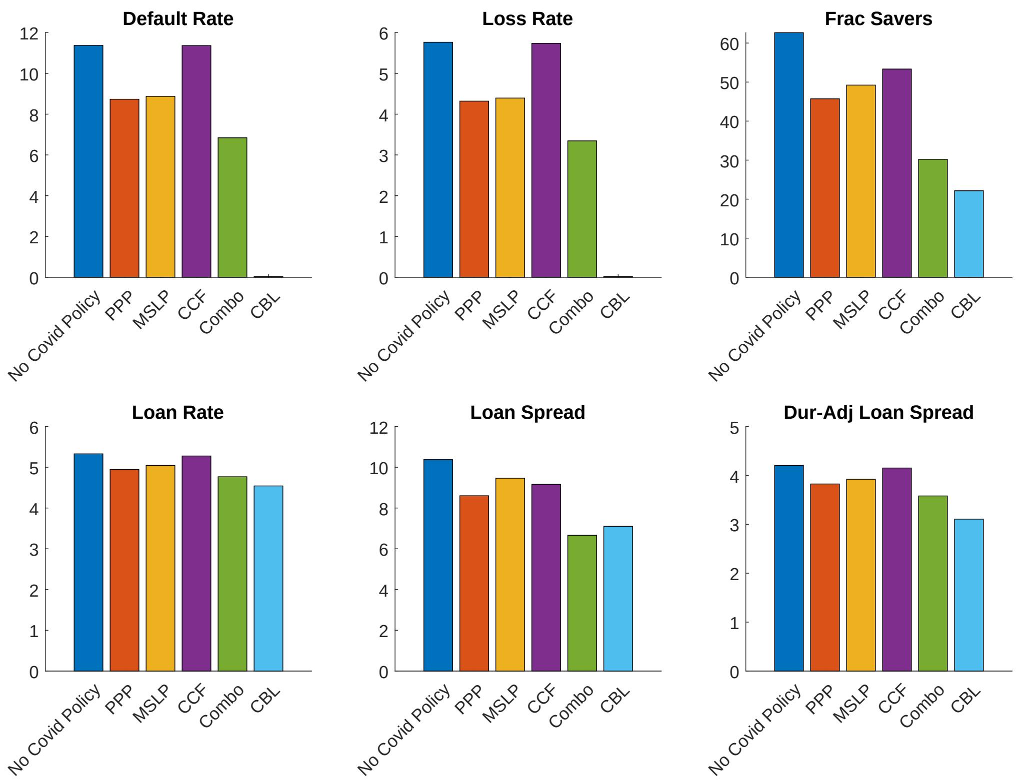
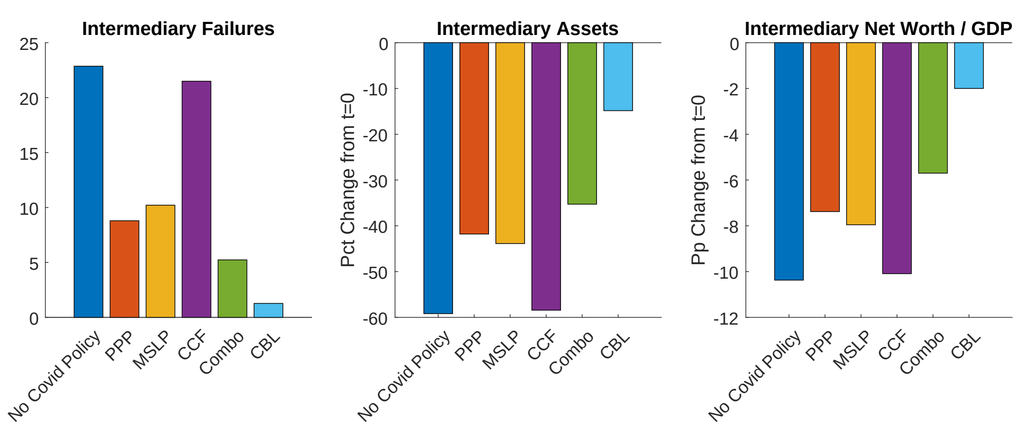


Figure 6: Policy Responses to Covid Crisis: Financial Intermediaries



reflect not only a higher amount of credit risk but also a higher price of credit risk. The increase in the credit spread can be seen most clearly in the last panel of Figure 5 which plots a duration-adjusted loan spreads, as Figure 1 did for the data.

Faced with higher costs of debt, firms reduce investment. As shown in Figure 7, investment falls by 56%. Both firm and bank defaults create a surge in deadweight losses, which reduces resources available for investment or consumption. Aggregate consumption falls by 0.45%.

The economic downturn and the concomitant bank bailouts trigger a massive increase in the primary deficit which swells to 10% of $t = 0$ pre-covid GDP (GDP0 for short) in the period of the shock. Government consumption (discretionary and transfer spending) is 3.2% points of GDP0 higher due to automatic stabilization programs (e.g., unemployment insurance, food stamps, etc.) and tax revenue falls by 4.1% points as a share of GDP0. However, the main spending increase comes from bailing out the banking sector to the tune of 6.6% of GDP0. Adding the interest service on the debt leads to a total of 12.5% of GDP0 in new debt that must be raised. The real one-year Treasury rate falls to -5.0% from a level of 2.2% before the crisis.

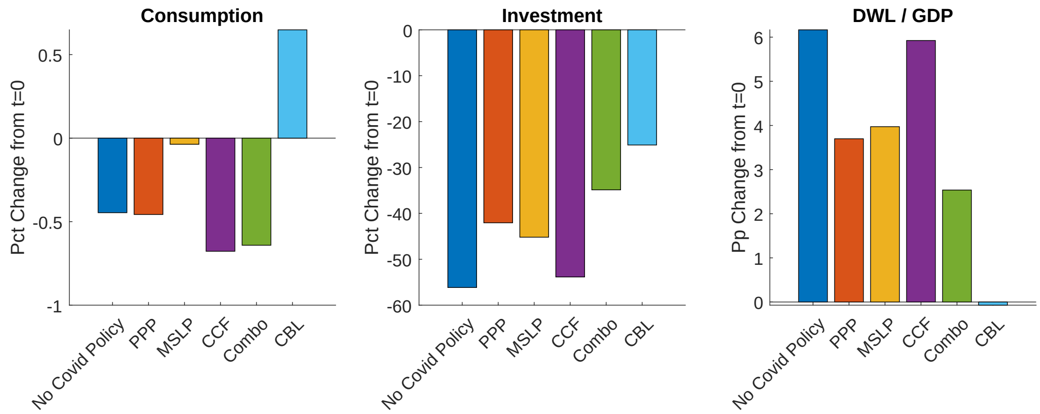
In sum, absent policy, the economy suffers a large decline in macro-economic activity, a rise in corporate defaults, a rise in bank defaults and loss in intermediary capacity, and a spike in credit spreads which feeds back on the real economy and discourages investment. Government debt balloons. The decline in economic activity depresses real interest rates. Can covid policy improve on this disastrous outcome?

4.2.2 PPP

The PPP policy (orange bars) provides forgivable bridge loans to all firms. The loans make a substantial dent in non-financial corporate defaults which fall by 2.6% points, a 23.2% reduction. This is enough to eliminate 2/3 of all *bank* bankruptcies. The fall in intermediary assets and net worth is also substantially smaller. The reduced financial distress mitigates the increase in the corporate loan rate. The intervention helps "close credit spreads" without directly targeting spreads. The forgivable loans put cash in firms' pockets which, combined with the lower loan rates, substantially reduce the fall in investment. Instead of falling by 56%, investment falls by 42%. Deadweight losses are reduced by nearly half compared to the no covid policy scenario.

Because PPP loans are forgivable, the direct effect of the policy is to add 9.2% of GDP0 to the deficit. The policy also results in a 171 bps higher safe rate of interest which will cause higher debt service costs in the future. However, the policy saves 4.0% of GDP0 in bank bailouts that do not occur. All told, the primary deficit is 9.2% of GDP0. The increase in debt is 11.2% of GDP0 which is 1.3% points lower than in the do nothing scenario. The government is saving

Figure 7: Policy Responses to Covid Crisis: Macroeconomy



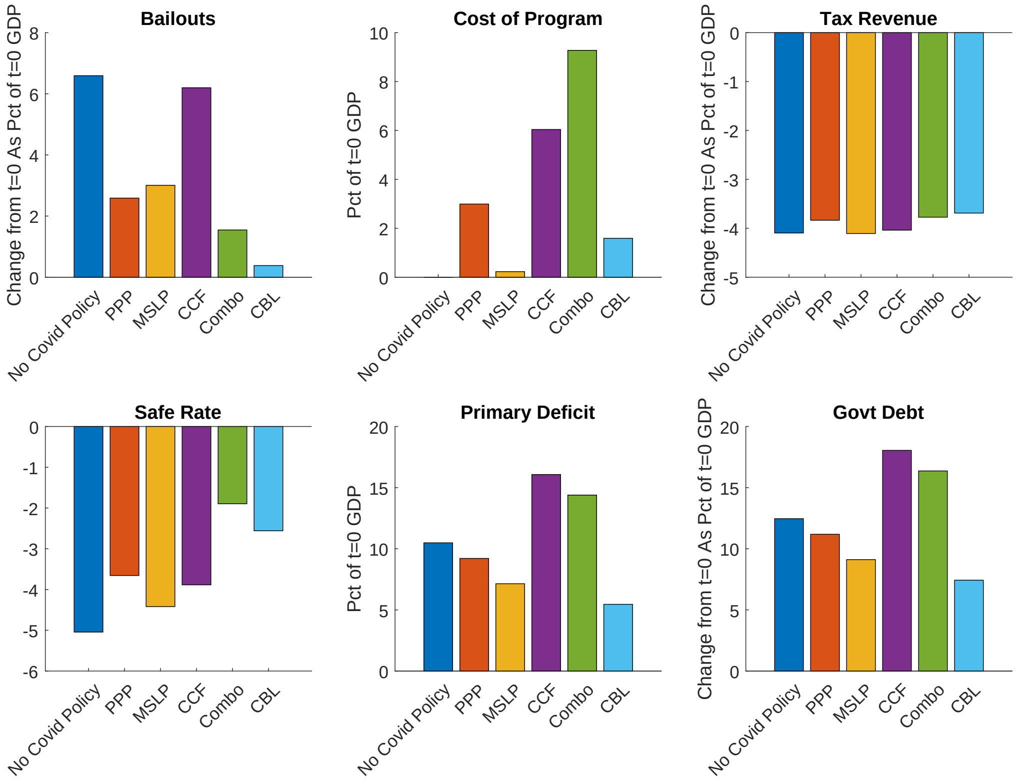
money by spending money. The higher safe rate relative to the do-nothing case encourages saving over consumption. This helps explain why the fall in consumption is still 0.46% despite the sharp reduction in lost resources due to bankruptcies.

4.2.3 MSLP

Next we consider the MSLP (yellow bars), which gives regular bridge loans to firms with a 3% interest rate and 5% bank risk retention (95% government guarantee). The program has approximately the same size (2.8% of GDP vs. 3.1%) as the PPP. Even though the loans are not forgivable, the program is still successful at reducing firm defaults (-22% compared to no covid policy). Bank defaults are also lower than in the no covid-policy case (10.2%), but not quite as low as in the PPP (8.8%) because banks now share in some of the losses through the risk retention feature of the MSLP bridge loans. Because there is more residual financial fragility, credit spreads and interest rates on corporate loans remain somewhat more elevated than in the PPP. Corporate investment falls by 45%, a bit more than in the PPP.

The MSLP program is not expensive to the government since there is no debt forgiveness feature, and since most firms end up being able to pay back the loan. Yet, the program still eliminates the majority of bank bankruptcies, and saves much of the cost of bank bailouts. The primary deficit is about 7% of GDP0. The government must issue less new debt, 9.1% of GDP0. Lower new debt issuance helps keep the interest rate low, which in turn reduces the debt service going forward and the additional debt that needs to be issued. The safe rate of -4.4% is close to the do-nothing case, substantially lower than the 2.2% pre-pandemic level. The lower

Figure 8: Policy Responses to Covid Crisis: Fiscal Policy



safe interest rate discourages saving and results in a smaller drop in aggregate consumption of 0.04%.

4.2.4 CCF

A large bond purchasing program of 6.0% of the stock of corporate debt (purple bars) is not very effective at mitigating the crisis. Loan losses are not reduced. More surprisingly, loan rates are not lowered much, only 5 basis points, compared to the no covid-policy scenario. While the loan spread goes down 121 basis points, the effect is largely offset by an increase in the safe rate. Therefore, it is no surprise that the fall in investment is not very different compared to the baseline scenario. Similarly, the policy does not help much in terms of countering financial fragility. Bank bailouts are reduced, but by much less than under the other policies.

In order to finance the corporate debt purchases, the government must issue 6.0% of GDP worth of additional Treasuries. The primary deficit including the bond purchases is 16.1% of

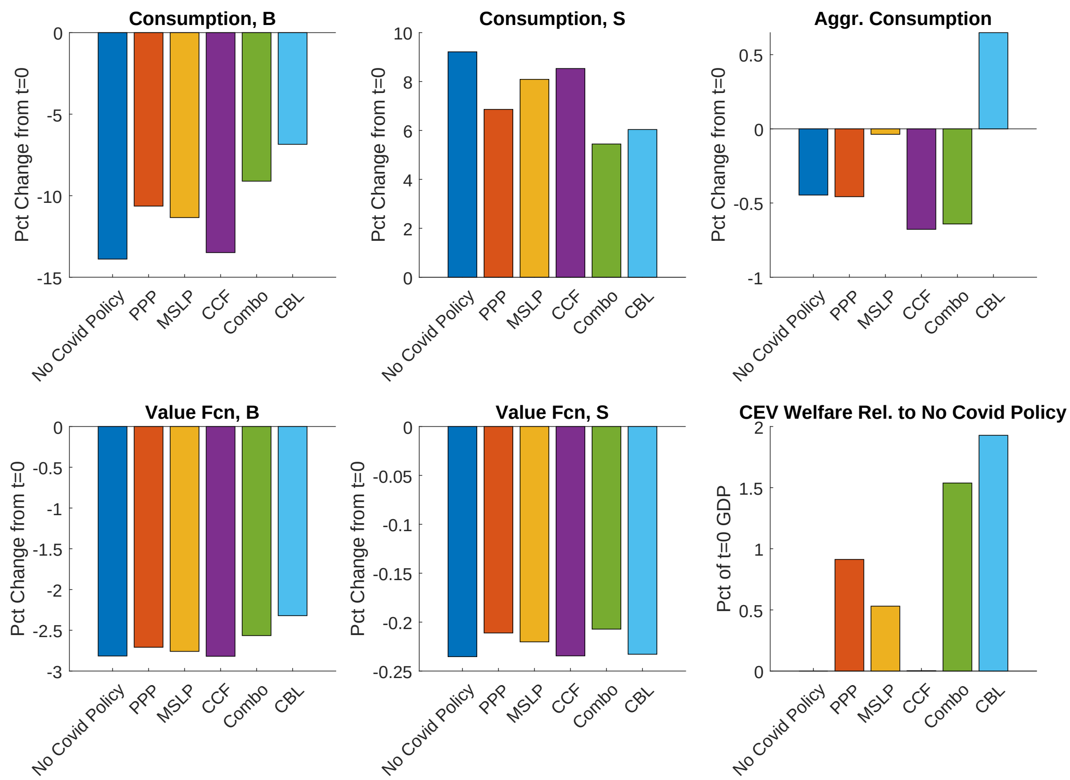
GDP0. The corporate bond purchases substantially increase safe interest rates relative to the do nothing scenario. The price effects on the debt imply that the government debt increases by 18.0% of GDP0, 5.6% points more than under no policy. The higher safe interest rates discourage consumption, which falls by 0.68%. Higher safe rates also increase the cost of funding for banks. This hampers their recapitalization and amplifies their financial fragility.

4.2.5 Combination Policy

The government is combining the three previous policies in reality. The results from the combo policy are plotted in the green bars. They are the model's closest prediction for what happens by the end of 2020 after (and if) all policies have been fully deployed. The three policies are a potent cocktail to fight the economic fallout from the pandemic. The policy combo lowers corporate defaults and losses by 40% compared to no policy. Bank bankruptcies are reduced by 77%, and bank net worth losses are only half as large as under no policy. Credit spreads are greatly reduced (by 194 bps). Safe rates fall by much less than other scenarios, which offsets some but not all of the effect of lower spreads on the corporate loan rate. Facing a lower cost of debt, investment falls by 35% compared to 56% under no policy. The primary deficit of 14.4% of GDP0 is lower than under no covid-policy. The government spends less on policy measures than what it would have spent on higher bank bailouts instead. Aggregate consumption falls by 0.64%, which is larger than under no covid-policy because of the higher safe interest rates which induces households to consume less.

Figure 9 summarizes the welfare effects of the various policies. The bottom row shows the change in value functions of borrowers and savers, relative to pre-pandemic period. The value function summarizes the expected, risk-adjusted discounted value of the current and all future consumption impacts. The bottom right panel shows a measure of how much permanent consumption the economy would be willing to give up to adopt each of the policies relative to a no-policy alternative. The CEV welfare measure aggregates the value functions of the two groups of households by their respective values of a dollar of consumption in the covid state; recall the welfare discussion in Section 3.3. The two bridge loan legs of the policy combo are both valuable, with the PPP being more valuable than the MSLP. The CCF barely increases welfare. Combined, they increase aggregate welfare by 1.5% of permanent consumption.

Figure 9: Policy Responses to Covid Crisis: Welfare



Note: Aggregate welfare is unchanged under the CCF policy relative to the Do nothing scenario.

The top row of Figure 9 shows the *first-period* consumption response to the covid shock for each of the two agents. Borrowers, who are the shareholders of non-financial and financial firms, face a large drop in consumption and are substantially worse off. Savers consume more in the first period but, as we know from their value functions, are still worse off due to future consumption declines and the risk in consumption. Both agents benefit similarly from the policies.

4.2.6 Contingent Bridge Loans

The last policy we analyze assumes that banks make productivity-contingent loans (light blue bars). The loans are forgivable and 100% guaranteed by the government, just like the PPP loans. It is an alternative to the policies enacted, albeit a somewhat idealistic one given the informational requirements it imposes on the (banks who implement it on behalf of the) government. Nevertheless, the experiment is instructive. This policy eliminates nearly all corporate default. It also eliminates all bank default and most of the credit disintermediation. Bank net worth only falls by 2.0% of GDP rather than 10.4% under no policy. Since firms face a lower cost of debt under this policy than under the combo policy, investment falls by only 25%, the least among all experiments.

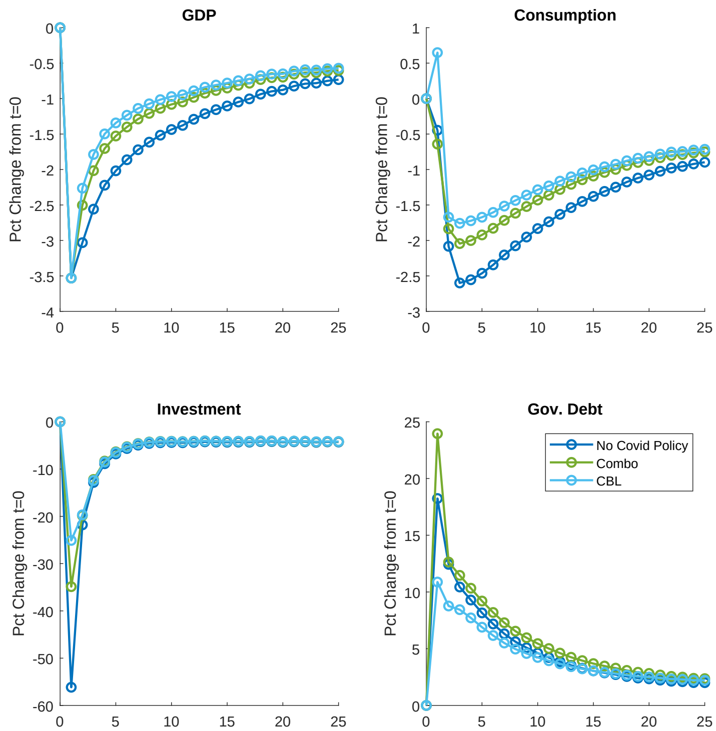
The size of this program is endogenous, and calibrated to eliminate all defaults. The cost ends up being 1.6% of GDP0. The lower direct fiscal outlay helps stem the rise in the primary deficit and the additional debt that needs to be raised. The primary deficit in the year of the covid shock is 5.5% of GDP0. Only 7.4% of GDP0's worth of new Treasury debt must be issued, 8.9% points less than under the combo policy. Interest rates are 66 bps lower than in the combo policy. Hence, this program is not only more effective at eliminating corporate defaults and improving the health of the banking sector, it also is cheaper for the government and reverses the declines in aggregate consumption we found for all other policies (0.65%).

Welfare is 1.9% higher in the CBL scenario, an increase that is 0.4% greater than in the combo policy. We conclude that the real-life combo is not that far off from a policy that seems much better targeted but (therefore) also much harder to implement.

4.3 Cumulative Effects

So far, we have analyzed only the first period of the covid shock. Figure 10 shows the long-run response of the macro-economic aggregates over 25 years. The model generates a very large cumulative loss in GDP, consumption, and investment as the economy transitions to a "new normal" in which pandemics remain a (rare) fact of life. The sharp fall in investment is mostly a one-year phenomenon but it persistently depresses the stock of capital and hence the output-producing capacity of the economy. Persistence also comes from the two-year expected duration of the pandemic. Finally, intermediary recapitalization takes time and lends persistence to the crisis. The model produces a gradual recovery with a long tail of modestly depressed economy activity. While the economy converges to the same long-run level regardless of the pandemic policy, government intervention does substantially alter the transition path. The CBL program boosts cumulative consumption over the transition path by 9.8% of pre-crisis GDP relative to the no covid-policy scenario, with the combo program not far behind at 7.3%.

Figure 10: Policy Responses to Covid Crisis: Long-run



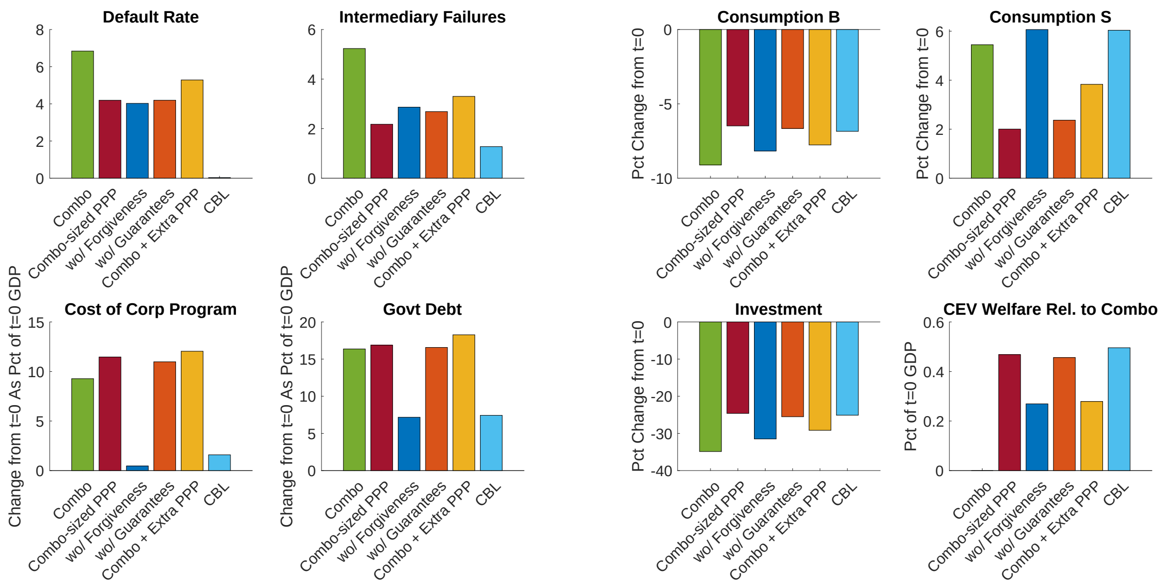
Note: this figure plots the increase in government debt as a percentage of its $t = 0$ level. Figure 8 plots the increase in government debt as a percentage of GDP0.

The last panel of Figure 10 shows the evolution of government debt, and suggests it will take a very long time to stabilize its level. Interestingly, even though the combo policy leads to a larger expansion of debt, the debt is paid back faster than under no covid-policy. This is due to the better health of the financial system along the transition path under the combo policy.

4.4 Some Policy Variations

The model can be used to evaluate the various levers inherent in the government policies. We consider four, summarized in Figure 11. In a first exercise, we envision that the government runs only a PPP but uses the combined resources of all three programs (9.3% of GDP). This "combo-sized PPP" is very effective at reducing bankruptcies, more so than the real-world combo policy. It promotes better financial stability and results in a smaller drop in investment. The program costs more, but saves more on bank bailouts, so that the increase in government debt is the same. It generates slightly higher welfare. The gains mainly accrue to borrowers who consume more in the crisis period at the expense of the savers.

Figure 11: Policy Levers: Some Variations



Next, we explore the effect of debt forgiveness. We keep the combo-sized PPP fixed but force firms to pay back the loans. The program becomes much cheaper to the government but is equally effective in terms of reducing corporate bankruptcies.[11] When firms need to repay the loans, their net worth is lower, which leads to lower corporate bond prices in equilibrium. This lowers intermediary net worth and increases intermediary bankruptcies. Eliminating the forgiveness feature reduces welfare slightly.

Next, we turn back on loan forgiveness but switch off government guarantees. Banks bear all losses from corporate default, if any. Since the program is so effective at reducing defaults, eliminating government guarantees slightly increases intermediary failures but otherwise has only minor effects.

Finally, we consider an additional round of PPP loans, equal in size to the original PPP component of the Combo policy. This is the costliest policy, raising government debt the most. The additional PPP loans help bring down defaults and boost investment, but the policy is less effective than the other alternatives as it still includes the comparatively less effective MSLP

[11]There is a slight reduction in corporate bankruptcies through an equilibrium effect on wages which increases firm survival.

and CCF legs.

In sum, a larger PPP effort with forgiveness and with government guarantees generates the highest welfare, closing almost the entire gap between Combo and CBL policies.

5 Long-Run Consequences

Eventually, the economy converges to a "new normal." Productivity returns to its steady-state values. Yet agents are still aware that once in a hundred years, a pandemic may strike again. How does the steady state of this economy compare to that of the economy without pandemics? What are the long-term consequences of adding pandemics to the agents' information set?

Table 1 performs this comparison. Firm leverage in the "New Normal" adjusts downward endogenously due to the higher inherent risk. This makes the economy safer, but also shrinks the size of the intermediary sector by about 5% of GDP. With less credit extended to the non-financial sector, the economy shrinks permanently. Further, investment and consumption growth are much more volatile. Both borrowers and savers are worse off. While borrower consumption volatility increases by over 10.0%, mean borrower consumption only falls by 0.1%. For borrowers, the reduction in GDP is partly offset by the expansion in equity financing of firms, which results in borrowers capturing a larger share of aggregate income. Saver consumption declines by 0.5%, more than GDP. All told, households would be willing to pay 2.8% of baseline GDP to avoid the transition to the economy with (infrequently) recurring pandemics.

In Appendix E, we present the short-run impacts for a version of the model where the pandemic does not cause the realization that an economic shock like the pandemic could reoccur in the future. In other words, a pandemic shock lasts for one period. While "normal" i.e. non-pandemic levels of low TFP and high idiosyncratic productivity may persist, eventually the economy returns to its pre-pandemic state. A pandemic shock with no long-term consequences produces only a slightly milder crisis. The equilibrium impact of policies and their welfare ranking is unchanged.

Table 1: Long-Run Effects of a Pandemic State

	One-time Pandemic	Recurrent Pandemics
	Firms	
1. Mkt value capital/ Y	214.5	213.1
2. Book val corp debt/ Y	75.8	71.6
3. Book corp leverage	35.4	33.6
4. % producer constr binds	0.2	0.0
5. Default rate	1.93	2.05
6. Loss-given-default rate	49.0	46.7
7. Loss Rate	0.93	0.94
	Intermediaries	
8. Mkt val assets / Y	65.6	60.9
9. Mkt fin leverage	87.8	87.8
10. % intermed constr binds	73.5	76.3
11. Bankruptcies	0.01	0.13
12. Wealth I / Y	8.3	7.7
13. Franchise Value	7.3	9.3
	Savers	
14. Deposits/GDP	58.8	54.6
15. Government debt/GDP	71.3	72.4
16. Corp Debt Share S	15.4	16.4
	Prices	
17. Risk-free rate	2.22	2.21
18. Corporate bond rate	4.21	4.25
19. Credit spread	1.99	2.04
20. Excess return on corp. bonds	1.08	1.12
		% change
	Welfare	
21. Value function, B	0.263	-0.10
22. Value function, S	0.372	-0.12
23. DWL/GDP	0.619	7.17
	Size of the Economy	
24. GDP	0.986	-0.40
25. Capital stock	2.113	-1.03
26. Aggr. Consumption	0.633	-0.33
27. Consumption, B	0.261	-0.10
28. Consumption, S	0.371	-0.48
	Volatility	
29. Investment gr	9.12%	19.47
30. Consumption gr	1.73%	-0.61
31. Consumption gr, B	2.61%	9.96
32. Consumption gr, S	2.47%	-3.17
33. Aggr. welfare* $\mathcal{W}^{cev}$		-2.80

Rows 1-20 report variables in levels, multiplied by 100 for readability. Rows 21-32 report variables in levels in the left column and percentage differences with the first column in the right column. Row 33 reports the change in aggregate welfare from the One-Time to Recurrent Pandemics, expressed in percentage of baseline GDP.

6 Conclusion

The covid pandemic poses severe challenges for the economy of most developed countries. We focus on the health of the corporate sector and its ramifications for the health of the financial sector and the macro-economy. Absent policy intervention, a negative feedback loop between corporate default and financial intermediary weakness creates a macro-economic disaster. Government-funded corporate lending programs such as the Payroll Protection Program are effective at breaking the vicious cycle. They avoid a substantial share of corporate bankruptcies and most of their financial-sector and macro-economic fallout. In contrast, credit facilities that buy corporate bonds in secondary markets are much less effective. Combined, the programs provide a potent cocktail that prevents 7.3% in cumulative consumption losses and creates large welfare benefits compared to a scenario without covid loan programs. The interventions have long-run fiscal implications which we quantify. The realization that pandemics may re-occur affects the long-run size of the non-financial and financial sectors.

Much work remains to be done. One could augment the model with a monetary sector and study how conventional and non-conventional monetary interventions interact with the corporate lending policies analyzed here. While we consider expansion of government transfer policies, the demand side of the model could be enriched as well. One could augment the model with an epidemiological block that captures the spread of the disease, introduce firms that produce different types of goods (social and private consumption) which are differentially affected, and endogenize labor supply. As the government programs are fully rolled out, it will be important to study their effectiveness using firm- and bank-level data. Our model can serve as a useful framework for hypothesis testing.

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A Policy Response: Program Details

1. Credit facilities for large firms

   – The Primary Market Corporate Credit Facility (PMCCF) is for new bonds and loans with maturities up to four years, issued by non-financial companies that are investment-grade (or were as of March 22). Interest rates are issuer-specific and informed by market conditions, plus a 100 bps facility fee. Loans may be syndicated, in which case the PMCCF participates under the same terms as the other syndicate partners.

   – The Secondary Market Corporate Credit Facility (SMCCF) provides liquidity for outstanding corporate bonds with (mostly) investment grade ratings. The Facility also may purchase U.S.-listed exchange-traded funds (ETFs) whose investment objective is to provide broad exposure to the market for U.S. corporate bonds. Bonds are bought at fair market value. The ETF purchases allow for High Yield bond purchases, for example, through a High Yield credit index.

   – The Term Asset-Backed Securities Loan Facility (TALF) enables the issuance of asset-backed securities backed by student loans, auto loans, credit card loans, loans guaranteed by the Small Business Administration (SBA), existing commercial mortgage-backed securities (CMBS) and collateralized loan obligations (CLO). TALF only purchases AAA-rated tranches.

   – These three programs support up to $850 billion in credit backed by $85 billion in credit protection provided by the Treasury. The PMCCF, SMCCF, and TALF receive $50bn, $25bn, and $10bn in equity from the Treasury, respectively. Loans from the Fed to these facilities provide leverage of 10-to-1 to the Treasury funds. In the case of the SMCCF, the leverage from Treasury depends on the instrument: 10x for Investment Grade corp bonds, 7x for Investment Grade ETFs, and 3x for High Yield ETF.

2. The Main Street Lending Program targets small and mid-sized businesses (below 15,000 employees or with 2019 revenues of $5 billion or less). Banks originate these loans, retain a portion and sell the remainder to the facility. Principal and interest on these four-year loans are deferred for 1 year. The facility's size is $600 billion in loans, backed by $75 billion in equity from the Treasury. As announced on April 30, there are three facilities that differ in the details of the loan features and banks' risk retention requirements. Firms may only participate in one of the three programs and only if they have not also participated in the PMCCF and have not received other direct support under the CARES Act. All loans carry an interest rate of LIBOR + 300bps.

   – The Main Street New Loan Facility (MSNLF): loan made on or after 4/24/2020; banks retain 5% share; minimum loan size $0.5 mi; maximum loan size $25 mi as long as the total debt after the loan remains below 4 times 2019 EBITDA; amortizes 1/3 in years 2, 3, and 4; is not junior to any existing firm debt.

   – The Main Street Priority Loan Facility (MSPLF): loan made after 4/24/2020; banks retain 15% share; minimum loan size $0.5 mi; maximum loan size $25 mi as long as the total debt after the loan remains below 6 times 2019 EBITDA; amortizes 15% in years 2 and 3, and 70% in year 4; is senior to all other corporate debt except mortgage debt.

  - The Main Street Expanded Loan Facility (MSELF): upsized tranche upsized after 4/24/2020 on a loan made before 4/24/2020 with at least 18 months remaining maturity; banks retain 5% share; minimum loan size $10 mi; maximum loan size $200 mi as long as the total debt after the loan remains below 6 times 2019 EBITDA and the loan amount is less than 35% of existing corporate debt that is pari passu with the loan; amortizes 15% in years 2 and 3, and 70% in year 4; is senior or pari passu to all other corporate debt except mortgage debt.

3. The Small Business Administration's Paycheck Protection Program (PPP) targets small companies with fewer than 500 employees. Initially, up to $350 billion in loans made by banks are guaranteed by the Small Business Administration. The money ran out within days. The April 23 top-up increased the size of the program to $671 billion. The loan principal is up to 2.5 months of payroll, with a maximum of $10 million. The loan maturity is two years and the interest rate is 1%. The CARES Act provides for forgiveness of up to the full principal amount of qualifying PPP loans. The amount of loan forgiveness depends on the total amount of payroll costs, payments of interest on mortgage obligations, rent payments on leases, and utility payments over the eight-week period following the date of the loan. However, not more than 25 percent of the loan forgiveness amount may be attributable to non-payroll costs. The Fed provides term financing to banks, collateralized by PPP loans up to their face value.

B Implementation Details for Bridge Loans in the Model

B.1 Targeted and Untargeted Bridge Loans

B.1.1 Firms

At the liquidity stage before defaults, firms receive a bridge loan $\bar{A}^{brP} \sum_j w_t^j l_t^j$ from banks, where $P \in \{T, U\}$ denotes the type of program, such that their profit is

$$\pi_t = \omega_t Z_t k_t^{1-\alpha} l_t^{\alpha} - (1 - \bar{A}^{brP}) \sum_j w_t^j l_t^j - a_t^P - \varsigma k_t. \tag{22}$$

This equation reflects that firms use the bridge loans for payroll expenses. Producers with $\pi_t < 0$ are in default and shut down. This implies a default threshold in the presence of bridge loans $\omega_t^{*,brP}$, given in equation (20) in the main text.

Non-defaulting firms immediately repay the bridge loan after the liquidity stage of the problem. Their net worth is only reduced by the interest payments associated with bridge loans, relative to the baseline model without such loans. The interest expense on the bridge loans, taking into account tax deductibility of interest, is:

$$(r^{br} + r^{gov})(1 - \tau^{\Pi})\bar{A}^{brP} \sum_j w_t^j l_t^j.$$

Individual producer net worth at the beginning of next period becomes:

$$\begin{aligned}\Pi(\omega', \tilde{k}_t, \tilde{a}_t^P, \mathcal{S}_t) = (1 - \tau^{\Pi})\omega' Z_t^A \tilde{k}_t^{1-\alpha} \tilde{l}(\tilde{k}_t, \tilde{a}_t^P, \mathcal{S}_t)^{\alpha} - (1 - \tau^{\Pi}) \sum_j w_t^j \tilde{l}^j(\tilde{k}_t, \tilde{a}_t^P, \mathcal{S}_t) \\ + \left((1 - (1 - \tau^{\Pi})\delta_K)p_t - (1 - \tau^{\Pi})\varsigma\right) \tilde{k}_t - \left(1 - \tau^{\Pi} + \delta q_t^m\right) \tilde{a}_t^P \\ - (r^{br} + r^{gov})(1 - \tau^{\Pi})\bar{A}^{brP} \sum_j w_t^j \tilde{l}(\tilde{k}_t, \tilde{a}_t^P, \mathcal{S}_t).\end{aligned} \tag{23}$$

This implies that bridge loans without interest and debt forgiveness, $r^{br} = r^{gov} = 0$, leave the net worth of surviving firms and their dividends unchanged. Aggregate firm net worth needs to be reduced by the collective interest expense on the bridge loans by integrating across producers. We denote the ω of the highest-productivity firm that receives a bridge loan as $\bar{\omega}_t^P$. For untargeted loans we have $\bar{\omega}_t^U = \infty$, implying that all firms receive loans, and for the targeted program $\bar{\omega}_t^T = \omega_t^*$, implying that only firms that would default without a bridge loan receive a loan. Thus aggregate interest is

$$r^{br}(1 - \tau^{\Pi})\bar{A}^{brP} W_t \int_{\omega_t^{*,brP}}^{\bar{\omega}_t^P} dF_t(\omega) = \left(F_t(\bar{\omega}_t^P) - F_t(\omega_t^{*,br})\right)(r^{br} + r^{gov})(1 - \tau^{\Pi})\bar{A}^{brP} W_t,$$

where we denote the aggregate wagebill of all firms as $W_t = \sum_j w_t^j \bar{L}^j$.

B.1.2 Banks

Bridge loans are junior to regular loans/bonds. Thus, defaulting firms do not pay back bridge loans. Lenders (banks and savers) apply bridge loan cash of defaulting firms towards the recovery value of regular loans/bonds. They can recover a fraction $1 - \zeta_t^{br}$ of each dollar of bridge loan. The total recovery per outstanding face value is:

$$M_t = \frac{F_{\omega,t}(\omega_t^{*,br})}{A_t^P} \left[(1 - \zeta^P)\left(\omega_t^{-,brP} Y_t + ((1 - \delta_K)p_t - \varsigma) K_t\right) - (1 - (1 - \zeta^{br})\bar{A}^{brP}) W_t\right], \tag{24}$$

where we have defined

$$\omega_t^{-,brP} = \mathrm{E}_{\omega,t}\left[\omega \,|\, \omega < \omega_t^{*,brP}\right].$$

How bank wealth is affected by bridge loans depends on whether the government takes on losses incurred on these loans, i.e. whether it guarantees those loans. Aggregate bridge loan losses are:

$$\int_0^{\omega_t^{*,brP}} dF_t(\omega)\, \bar{A}^{brP} W_t = F_{\omega,t}(\omega_t^{*,brP})\bar{A}^{brP} W_t.$$

The variable I_{br} measures the fraction of losses that the government absorbs; it is between 0 (no guarantees) and 1 (full guarantee). We assume that banks receive the interest income from bridge loans, regardless of the government guarantees that are in place, as long as the interest rate on these loans is positive. Then bank net worth is:

$$N_t^{I,brP} = N_t^I + \bar{A}^{brP} W_t \left[(F_{\omega,t}(\bar{\omega}_t^P) - F_{\omega,t}(\omega_t^{*,brP})) r^{br} - (1 - I_{br}) F_{\omega,t}(\omega_t^{*,brP}) \right],$$

where N_t^I is bank net worth in the baseline model without bridge loans.

B.1.3 Government

Government expenditure is

$$G_t^{br} = G_t + \bar{A}^{brP} W_t \left[I_{br} F_{\omega,t}(\omega_t^{*,br}) - (F_{\omega,t}(\bar{\omega}_t^P) - F_{\omega,t}(\omega_t^{*,brP})) r^{gov} \right],$$

where G_t is government expenditure in the baseline model without bridge loans. For the baseline case of full government guarantees $I_{br} = 1$ and debt forgiveness $r^{gov} = -1$, government spending goes up by $F_{\omega,t}(\bar{\omega}_t^P)\bar{A}^{brP} W_t$, i.e. the wage bill multiple $\bar{A}^{brP}$ for all firms that participate.

Taxes are

$$T_t^{br} = T_t - \tau^{\Pi}(F_{\omega,t}(\bar{\omega}_t^P) - F_{\omega,t}(\omega_t^{*,brP}))(r^{br} + r^{gov})\bar{A}^{brP} W_t.$$

Tax revenue is lower by the tax benefit to firms on bridge loan interest.

B.1.4 Deadweight Losses

DWL from bridge loans are

$$\zeta^{br} \eta^P F_{\omega,t}(\omega_t^{*,brP}) \bar{A}^{brP} W_t.$$

These need to be added to aggregate deadweight losses from the baseline model. Similarly,

$$\zeta^{br}(1 - \eta^P) F_{\omega,t}(\omega_t^{*,brP}) \bar{A}^{brP} W_t$$

needs to refunded to households as a transfer.

B.2 Conditional Bridge Loans

B.2.1 Firms

At the liquidity stage before defaults, firms with productivity below $\bar{\omega}_t^C$ receive a bridge loan $\bar{A}^{brC}(1 - \omega_t) a_t^P$ from banks such that their profit is

$$\pi_t = \omega_t Z_t k_t^{1-\alpha} l_t^{\alpha} - \sum_j w_t^j l_t^j - (1 - \bar{A}^{brC} + \bar{A}^{brC} \omega_t) a_t^P - \varsigma k_t. \tag{25}$$

Firms now need to repay $\omega_t a_t^P$ in total, where a_t^P are the principal and interest payments due this period. Producers with $\pi_t < 0$ are in default and shut down. This implies a default threshold in the presence of bridge loans $\omega_t^{*,brC}$ given in equation (21) in the main text.

Non-defaulting firms immediately repay the bridge loan after the liquidity stage of the problem. Their net worth is only reduced by the interest payments associated with bridge loans, relative to the baseline model without such loans. The interest expense on the bridge loans, taking into account tax deductibility of interest, is:

$$(r^{br} + r^{gov})(1 - \tau^{\Pi})\bar{A}^{brC}(1 - \omega_t)a_t^P.$$

Individual producer net worth at the beginning of next period becomes:

$$\begin{aligned}\Pi(\omega', \tilde{k}_t, \tilde{a}_t^P, \mathcal{S}_t) = &(1 - \tau^{\Pi})\omega' Z_t^A \tilde{k}_t^{1-\alpha}\tilde{l}(\tilde{k}_t, \tilde{a}_t^P, \mathcal{S}_t)^{\alpha} - (1 - \tau^{\Pi})\sum_j w_t^j \tilde{l}^j(\tilde{k}_t, \tilde{a}_t^P, \mathcal{S}_t) \\ &+ \left((1 - (1 - \tau^{\Pi})\delta_K)p_t - (1 - \tau^{\Pi})\varsigma\right)\tilde{k}_t - \left(1 - \tau^{\Pi} + \delta q_t^m\right)\tilde{a}_t^P \\ &- (r^{br} + r^{gov})(1 - \tau^{\Pi})\bar{A}^{brC}(1 - \omega')a_t^P.\end{aligned} \tag{26}$$

This implies that bridge loans without interest, $r^{br} = r^{gov} = 0$, leave the net worth of surviving firms and their dividends unchanged. Aggregate firm net worth needs to be reduced by the collective interest expense on the bridge loans by integrating across producers. To do this, we denote the aggregate bridge loan amount going to no-defaulting producers as

$$A_t^{brC} = \left((1 - F_t(\omega_t^{*,br}))(1 - \omega^{+,brC}) - (1 - F_t(\bar{\omega}_t^C))(1 - \omega^{+,C})\right)\bar{A}^{brC}A_t^P, \tag{27}$$

where we have defined

$$\omega_t^{+,brC} = \mathrm{E}_{\omega,t}\left[\omega \,|\, \omega \geq \omega_t^{*,br}\right]$$

and

$$\omega_t^{+,C} = \mathrm{E}_{\omega,t}\left[\omega \,|\, \omega \geq \bar{\omega}_t^C\right].$$

Total interest expenses for producers are

$$(1 - \tau^{\Pi})(r^{br} + r^{gov})A_t^{brC}.$$

B.2.2 Banks

Bridge loans are junior to regular loans/bonds. Thus, defaulting firms do not pay back bridge loans. Lenders (banks and savers) apply bridge loan cash of defaulting firms towards the recovery value of regular loans/bonds. They can recover a fraction $1 - \zeta_t^{br}$ of each dollar of bridge loan. The total recovery per outstanding face value is:

$$M_t = \frac{F_{\omega,t}(\omega_t^{*,brC})}{A_t^P}\left[(1 - \zeta^P)\left(\omega_t^{-,br}Y_t + ((1 - \delta_K)p_t - \varsigma)K_t\right) - \sum_j w_t^j \bar{L}^j + \bar{A}^{brC}(1 - \zeta^{br})(1 - \omega_t^{-,brC})\right], \tag{28}$$

where we have defined

$$\omega_t^{-,brC} = \mathrm{E}_{\omega,t}\left[\omega \,|\, \omega < \omega_t^{*,brC}\right].$$

How bank wealth is affected by bridge loans depends on whether the government takes on losses incurred on these loans, i.e. whether it guarantees those loans. Aggregate bridge loan losses are:

$$O_t^{brC} = \int_0^{\omega_t^{*,br}} (1-\omega)\, dF_t(\omega)\, \bar{A}^{brC} A_t^P = F_{\omega,t}(\omega_t^{*,br})(1-\omega_t^{-,br})\bar{A}^{brC} A_t^P.$$

The variable I_{br} measures the fraction of losses that the government absorbs; it is between 0 (no guarantees) and 1 (full guarantee). We assume that banks receive the interest income from bridge loans, regardless of the government guarantees that are in place. Then bank net worth is:

$$N_t^{I,br} = N_t^I + r^{br} A_t^{brC} - (1-I_{br}) O_t^{brC},$$

where N_t^I is bank net worth in the baseline model without bridge loans.

B.2.3 Government

Government expenditure is

$$G_t^{br} = G_t + I_{br} O_t^{brC} - r^{gov} A_t^{brC},$$

where G_t is government expenditure in the baseline model without bridge loans. As for the unconditional loans, the baseline case of full government guarantees with $I_{br} = 1$ and $r^{gov} = -1$ implies that government spending rises by the full amount of the loan program

$$F_t(\bar{\omega}_t^C))(1-\omega^{-,C})\bar{A}^{brC} A_t^P,$$

with $\omega^{-,C} = \mathrm{E}_{\omega,t}\left[\omega \,|\, \omega < \bar{\omega}_t^C\right]$.

Taxes are

$$T_t^{br} = T_t - \tau^{\Pi}(r^{br} + r^{gov}) A_t^{brC}.$$

Tax revenue is lower by the tax benefit to firms on bridge loan interest.

B.2.4 Deadweight Losses

DWL from bridge loans are

$$\zeta^{br} \eta^P O_t^{brC}.$$

These need to be added to aggregate deadweight losses from the baseline model. Similarly,

$$\zeta^{br}(1-\eta^P) O_t^{brC}$$

needs to refunded to households as a transfer.

C Computing Transitions With Unanticipated Shocks

This section uses the notation of Elenev, Landvoigt, and Van Nieuwerburgh (2020), Appendix B. In particular, we denote the sets of policy, transition and forecasting functions defined in ELVN by $\mathcal{C}_P$, $\mathcal{C}_T$ and $\mathcal{C}_F$, respectively. The timing of the unanticipated shocks is as follows:

- At the beginning of period t, the aggregate state of the economy is known and given by realizations of the state variables $[Z_t^A, \sigma_{\omega,t}, K_t, A_t^P, N_t^I, B_t^G]$.

- An unexpected shock to the parameter vector of the model hits at the beginning of t, before production or trade in any markets occur. Denote the vector of parameters in t by Θ_t.

- Agents observe the unexpected shock and adjust their decisions and expectations accordingly, believing that from $t+1$ onward the only stochastic events are characterized by the exogenous state variables $[Z_t^A, \sigma_{\omega,t}]$, and all parameters revert to the vector $\bar{\Theta}$, at which values they will remain forever after.

This timing implies that the dynamics of the economy from $t+1$ onward is fully characterized by the functions $\mathcal{C}^{(t+1)} = \{\mathcal{C}_P(\bar{\Theta}), \mathcal{C}_T(\bar{\Theta}), \mathcal{C}_F(\bar{\Theta})\}$. We first compute these functions by running the algorithm in ELVN to convergence for the baseline calibration of the economy $\bar{\Theta}$.

To solve for the dynamics following the unexpected shock, we need to solve for policy and transition functions $\mathcal{C}^t = \{\mathcal{C}_P(\Theta_t), \mathcal{C}_T(\Theta_t)\}$. Forecasting functions do not need to be separately computed for time-t parameters since we explicitly compute the transition from t to $t+1$, and apply forecasting functions $\mathcal{C}_F(\bar{\Theta})$ to the correct $t+1$ values of the aggregate state variables.

Intuitively, agent choices and market prices at t depend on parameters Θ_t *and* expectations of $t+1$ state variables for each possible realization of the exogenous shocks. The values of $t+1$ state variables in turn depend on time-t choices and prices. The algorithm in ELVN solves this fixed point problem iteratively for a constant parameter vector $\bar{\Theta}$. For any given iteration, the algorithm does not enforce that agents' expectations of next period's aggregate state are consistent with today's choices and prices. However, as the algorithm converges, current period decisions and expectations about next period's state become mutually consistent. This approach is tractable even for large models with many state variables, since it keeps the system of equations that must be solved at each point in the state space as small as possible. However, it no longer works with a one-time unexpected shock Θ_t.

Hence, in case of an MIT shock, we need to solve for policy and transition functions from t to $t+1$ jointly. In practice, this means that in period t, we need to solve the system of equations (E1) – (E15) from Step 2.C of ELVN's algorithm jointly with transition functions (T1) – (T4) from Step 2.D. The system of equations that needs to be solved thus consists of the 15 equilibrium conditions in (E1) – (E15), and $4N^x$ additional equations that apply (T1) – (T4) for each possible realization of the exogenous aggregate state in $t+1$ (there are N^x possible realizations). Expectations for $t+1$ are computed under the assumption that from then on, the economy will follow the law of motion given by $\mathcal{C}^{(t+1)}$.

Solving for policy and transition functions jointly guarantees that these function are mutually consistent and agents are optimally responding to the shock Θ_t. Our approach to computing transition paths after unexpected shocks is therefore similar to what the algorithm developed in Cao and Nie (2017) refers to as "consistency equations". Unlike the transition function approach of ELVN, Cao and Nie (2017) apply consistency equations at each iteration of the algorithm, unrelated to transitions after unexpected shocks.

In case of multiple consecutive periods with unexpected shocks, the procedure outlined in this appendix can be applied sequentially.

D Calibration Details

This appendix describes the calibration in detail. Most of the description follows Elenev, Landvoigt, and Van Nieuwerburgh (2020).

The model is calibrated at annual frequency. A subset of model parameters, listed in Table D.1, have direct counterparts in the data. The remaining parameters are calibrated to match target moments from the data within the model. While these parameters are chosen simultaneously to match all targeted moments, Table D.2 lists for each parameter the specific moment that is most affected by this parameter.

Table D.1: Pre-Set Parameters

Par	Description	Value	Source
	Exogenous Shocks		
$\{p^{\omega}_{LL}, p^{\omega}_{HH}\}$	transition prob	0.91, 0.8	Bloom et al. (2012)
	Population and Labor Income Shares		
ℓ^i	pop. shares $\in \{S, B\}$	76.6,23.4%	Population shares SCF 95-13
γ^i	inc. shares $\in \{S, B\}$	62.2,37.8%	Labor inc. shares SCF 95-13
	Corporate Loans and Intermediation		
δ	average life loan pool	0.937	Corp bond duration fcn (see ELVN)
θ	principal fraction	0.582	Corp bond duration fcn (see ELVN)
η^P	% bankr. loss is DWL (producers)	0.2	Bris, Welch, and Zhu (2006)
η^I	% bankr. loss is DWL (banks)	36.2	Bennett and Unal (2015)
$\bar{\zeta}^I$	% Resolution cost failed banks	33.2	Bennett and Unal (2015)
ϕ_0^I	target bank dividend	0.068	Avg bank div
ϕ_0^P	target firm dividend	0.078	Avg nonfin firm div
ρ	bank default cost	0^*	Baseline
	Preferences		
$\sigma^B = \sigma^S$	risk aversion B S	1	Log Utility
$\nu^B = \nu^S$	IES B S	1	Log Utility
	Government		
τ^D	interest rate income tax rate	13.2%	tax code; see text
κ	deposit insurance fee	0.00084	Deposit insurance revenues/bank assets

$*\rho$ is increased to 0.04 when the unanticipated pandemic shock is realized.

Aggregate Productivity Following the macro-economics literature, the TFP process Z_t follows an AR(1) in logs with persistence parameter ρ_Z and innovation volatility σ_Z. Because TFP is persistent, it becomes a state variable. We discretize Z_t into a 5-state Markov chain using the Rouwenhorst (1995) method. The procedure chooses the productivity grid points and the transition probabilities between them to match the volatility and persistence of HP-detrended GDP. GDP is endogenously determined but heavily influenced by TFP. Consistent with the model, our measurement of GDP excludes net exports and government investment. We define the GDP deflator correspondingly. Observed real per capita HP-detrended GDP has a volatility of 2.56% and its persistence is 0.55, both of which the model matches.

Idiosyncratic Productivity We calibrate firm-level productivity risk directly to the micro evidence. We normalize the mean of idiosyncratic productivity at $\mu_\omega = 1$. We let the cross-sectional standard deviation of idiosyncratic productivity shocks $\sigma_{t,\omega}$ follow a 2-state Markov chain, with four parameters. Fluctuations in $\sigma_{t,\omega}$ govern aggregate corporate credit risk since high levels of $\sigma_{t,\omega}$ cause a larger left tail of low-productivity firms to default in equilibrium. We refer to periods in the high $\sigma_{t,\omega}$ state as *high uncertainty* periods. We set $(\sigma_{L,\omega}, \sigma_{H,\omega}) =$ (0.1,0.18). The value for $\sigma_{L,\omega}$ targets the unconditional mean corporate default rate. The model-implied average default rate of 2.2% is similar to the data.[12] The high value, $\sigma_{H,\omega}$, is chosen to match the time-series standard deviation of the cross-sectional interquartile range of firm productivity, which is 4.9% according to Bloom, Floetotto, Jaimovich, Saporta-Eksten, and Terry (2018) (their Table 6). The transition probabilities from the low to the high uncertainty state of 9% and from the high to the low state of 20% are taken directly from Bloom, Floetotto, Jaimovich, Saporta-Eksten, and Terry (2018).[13] The model spends 31% of periods in the high uncertainty regime. Like in Bloom et al., our uncertainty process is independent of the (first-moment) aggregate TFP shock. About 10% of periods feature both high uncertainty and low TFP realizations. We will refer to those periods as financial recessions or financial crises, since those periods will feature (endogenous) financial fragility in the equilibrium of the model. Using a long time series for the U.S., Reinhart and Rogoff (2009) find the same 10% frequency of financial crises.

Production Investment adjustment costs are quadratic. We set the marginal adjustment cost parameter $\psi = 2$ in order to match the observed volatility of (detrended) log investment of 8.13%. The model generates a value of 9.47%. We set the parameter α in the Cobb-Douglas production function equal to 0.71, which yields an overall labor income share of 66.20%, the standard value in the business cycle literature. We choose an annual depreciation of capital δ_K of 8.25% to match the investment-to-output ratio of 17.73% observed in the data. The fixed cost of production is set to $\varsigma = 0.004$ targeting a capital-GDP ratio of 224% in the data.

Population and Labor Income Shares To pin down the population shares of savers and borrowers (shareholders), we turn to the Survey of Consumer Finances (SCF). For each household, we define the risky share as the ratio of risky assets to financial assets plus net business wealth. Risky assets consist of stocks, mutual funds, and net business wealth. We then calculate the fraction of households whose risky share is less than ten percent. This amounts to 76.6% of SCF households. These are the savers in our model who hold no equity claims (ℓ^S). The remaining $\ell^B = 23.4\%$ of households have a nontrivial risky share. The labor income share of savers in the SCF is 62.2%. The income share of the borrower-stockholders is the remaining 37.8%. The income shares determine the Cobb-Douglas parameters γ_B and γ_S.

[12] We look at two sources of data: corporate loans and corporate bonds. From the Federal Reserve Board of Governors, we obtain delinquency and charge-off rates on Commercial and Industrial loans and Commercial Real Estate loans by U.S. Commercial Banks for the period 1991-2015. The average delinquency rate is 3.1%. The second source of data is Standard & Poors' default rates on publicly-rated corporate bonds for 1981-2014. The average default rate is 1.5%; 0.1% on investment-grade bonds and 4.1% on high-yield bonds. The model is in between these two values.

[13] They estimate a two-state Markov chain for the cross-sectional standard deviation of establishment-level productivity using annual data for 1972-2010 from the Census of Manufactures and Annual Survey of Manufactures. We annualize their quarterly transition probability matrix.

Table D.2: Calibrated Parameters

Par	Description	Value	Target	Model	Data
Exogenous Shocks					
ρ_Z	persistence TFP	0.4	AC(1) HP-detr GDP 53-14	0.55	0.55
σ_Z	innov. vol. TFP	2.3%	Vol HP-detr GDP 53-14	2.56%	2.56%
$\sigma_{\omega,L}$	low uncertainty	0.1	Avg. corporate default rate	2.09%	2%
$\sigma_{\omega,H}$	high uncertainty	0.18	Avg. IQR firm-level prod (Bloom et al. (2012))	5.00%	4.9%
Production					
ψ	marginal adjustment cost	2	Vol. log investment 53-14	9.47%	8.13%
α	labor share in prod. fct.	0.71	Labor share of output	66.20%	2/3
δ_K	capital depreciation rate	8.25	Investment-to-output ratio, 53-14	17.73%	17.90%
ς	capital fixed cost	0.004	Capital-to-GDP ratio 53-14	215%	224%
Corporate Loans and Intermediation					
ζ^P	Losses on defaulting loans	0.6	Corporate loan and bond severities 81-15	51.90%	51.4%
Φ	maximum LTV ratio	0.4	FoF non-fin sector leverage 85-14	37.42%	37%
σ_ϵ	cross-sect. dispersion ϵ_t^I	1.9%*	FDIC failure rate of deposit. inst., mean	0.63%	0.50%
ϕ_1^I	bank equity issuance cost	7	Bank net payout rate	5.99%	5.75%
φ_0	Saver holdings target	0.0115	Avg corp debt holdings outside lev fin sector	13.94%	13.70%
φ_1	Saver holdings adj cost	0.14	Vol of corp debt holdings outside lev fin sector	3.40%	3.3%
ξ	max. intermediary leverage	0.88	Tier 1 Capital / RWA post D-F 10-19	12.3%	13.1%
Preferences					
β^B	time discount factor B	0.94	Corporate net payout rate	6.92%	6.41%
β^S	time discount factor S	0.982	Mean risk-free rate 76-14	2.22%	2.20%
Government Policy					
G^o	discr. spending	17.2%	BEA discr. spending to GDP 53-14	17.50	17.58%
G^T	transfer spending	2.52%	BEA transfer spending to GDP 53-14	3.15%	3.18%
τ	labor income tax rate	29.3%	BEA pers. tax rev. to GDP 53-14	19.16%	17.30%
τ^Π	corporate tax rate	20%	BEA corp. tax rev. to GDP 53-14	3.56%	3.41%
b_o	cyclicality discr. spending	-2	slope log discr. sp./GDP on GDP growth	-0.88	-0.75
b_T	cyclicality transfer spending	-20	slope log transfer sp./GDP on GDP growth	-8.82	-7.26
b_τ	cyclicality lab. inc. tax	4.5	slope labor tax/GDP on GDP growth	0.63	0.70

$*\sigma_\epsilon$ is increased to 5% when the unanticipated pandemic shock is realized.

Corporate Loans and Producer Financial Frictions In the model, a corporate loan is a geometric bond. The issuer of one unit of the bond at time t promises to pay 1 at time $t+1$, δ at time $t+2$, δ^2 at time $t+3$, and so on. Given that the present value of all payments $(1/(1-\delta))$ can be thought of as the sum of a principal (share θ) and an interest component (share $1-\theta$), we define the book value of the debt as $F = \theta/(1-\delta)$. We set $\delta = 0.937$ and $\theta = 0.582$ ($F = 9.238$) to match the observed duration of corporate debt. The model's corporate loans have a duration of 6.8 years on average.

We set the maximum LTV ratio parameter $\Phi = 0.4$. The LTV constraint limits corporate borrowing as a fraction of the market value of capital. For this value of Φ, the model generates a ratio of borrower book debt-to-assets of 37.42% matching the 37% number for the average ratio of loans and debt securities of the nonfinancial corporate and non-financial non-corporate businesses in the Flow of Funds data.

To compute firms' dividend target as fraction of equity, ϕ_0^P, we construct time series for dividends, share repurchases, equity issuances, and book equity aggregating over all publicly traded non-financial firms. Over the period 1974–2018, non-financial firms paid out 7.8% of their book equity per year as dividends and share repurchases, which is the value we set for ϕ_0^P.

Intermediaries Two parameters jointly control the mean of the bank default rate and its sensitivity to bank value: the default penalty ρ and the cross-sectional dispersion of bank idiosyncratic profit shocks $\sigma_\varepsilon = \mathrm{Var}(\epsilon_t^I)^{0.5}$. A greater value of σ_ε makes bank failures less sensitive to fluctuations in the franchise value of banks, but also leads to more bank failures ceteris paribus. The default penalty ρ can be changed to match the unconditional bank failure rate, given the value for σ_ε. In the calibration of the benchmark model pre-covid, we set $(\rho, \sigma_\varepsilon) = (0, 0.019)$, the values in ELVN. They match the 0.5% average bank failure rate from historical FDIC data. As part of the covid shock, we assume an unexpected change (MIT shock) in these parameters that coincides with the realization of a pandemic to $(\rho, \sigma_\varepsilon) = (0.04, 0.05)$. These parameter values continue to match the average bank failure rate. The higher default penalty during the pandemic can be motivated by government-provided moral suasion that banks who take bailout money need to stay afloat, or by a range of unmodeled government policies such as higher unemployment insurance, checks mailed to households, or quantitative easing that help de-risk the banks' balance sheets. The higher dispersion of bank idiosyncratic shocks can be motivated by the increased dispersion of profitability/losses on the part of banks' balance sheet unrelated to corporate loans, e.g., credit card loans, during covid.

The intermediary borrowing constraint parameter ξ can be interpreted as a minimum regulatory equity capital requirement. We set $\xi = 0.88$ in the baseline calibration, or a 12% equity capital requirement. ELVN choose a 7% minimum bank equity capital since they calibrate to the pre-GFC crisis data. This higher capital requirement reflects the changes made by the Dodd-Frank Act and Basel agreements after the GFC. The average Tier 1 Capital Ratio from 2010 to 2019 is 13.1%. Our model delivers a 12.3% capital ratio. The stronger buffer before the crisis hit helps absorb the impact of the covid shock.

We set the deposit insurance fee as a fraction of bank liabilities, captured by the parameter κ, to the observed 8.4 basis points.

Bennett and Unal (2015) report resolution costs of 33.18% of assets for the average bank taken over by the FDIC between 1986 and 2004. We set $\bar{\zeta}^I = .332$ to match this number.[14] Granja, Matvos, and Seru (2017) report a similar resolution cost of 28% for the period 2007–2013 . Bennett and Unal (2015) also shows that total receivership expenses are 36.2% of the resolution cost. This is a good measure for the fraction of losses from bank failure that are deadweight losses to society. Therefore, we set $\eta^I = 0.362$.

To determine the dividend target ϕ_0^I of banks, we construct time series of dividends, share repurchases, equity issuances, and book equity, aggregating across all publicly-traded banks. Over the period from 1974 to 2018, banks paid out an average 6.8% of their book equity per year as dividends and share repurchases, which is the value we set for ϕ_0^I.

[14] The resolution cost of failed banks is defined as $\zeta_t^I = \bar{\zeta}^I \frac{A_t^P}{A_t^I} \mathrm{E}\left[\frac{A_t^I}{A_t^P}\right]$. This assumption restates bank resolution costs relative to firm credit rather than relative to bank-intermediated firm credit. This is a technical assumption that avoids us having to keep track of A_t^I as an additional state variable.

We calibrate the marginal equity issuance cost for intermediaries, $\phi_1^I = 7$, using the same data. With this parameter, we target the net payout ratio of the financial sector, defined as dividends plus share repurchases minus equity issuances divided by book equity. A higher equity issuance cost makes issuing external equity more expensive, and raises the net payout ratio. Since banks issue equity on average, the net payout rate is 5.75% in the data, lower than the gross payout ratio of 6.8%.

Saver Holding Costs To discipline savers' cost for holding corporate debt, we compute the fraction of corporate liabilities directly held by households in the Flow of Funds. The household share of debt is 13.7% for the sample from 1981-2015 that we use for other financial variables. The holdings of corporate debt by savers in the data include those by mutual funds, pension funds and government retirement systems, as well as by hedge funds. To match this average share in the model, we set the holdings target of savers to $\varphi_0 = 0.0115$. The volatility of saver holdings around the target is governed by the parameter φ_1. We set this parameter to 0.14 to match the volatility of the saver share, which is 3.3% in the data.

Preference Parameters Preference parameters affect many equilibrium quantities and prices simultaneously, and are harder to pin down directly by data. Borrowers and savers have Epstein-Zin utility. We set risk aversion and the inter-temporal elasticity of substitution to one for both: $\sigma_B = \sigma_S = \nu_B = \nu_S = 1$. The model does not require high risk aversion or EIS to generate strong asset price responses to the crisis. The subjective time discount factor of borrowers $\beta_B = 0.94$ targets the net payout ratio of non-financial firms, defined as dividend payouts plus share repurchases minus equity issuances. A higher β_B leads to lower net payout ratio, as more patient borrowers want to accumulate more wealth. In the data, net payouts for non-financial firms were 6.41% of their book equity per year. The time discount factor of savers disproportionately affects the mean of the short-term interest rate. We set $\beta_S = 0.982$ to match the observed average real rate of interest of 2.2%.

Government Parameters To add quantitative realism to the model, we match both the unconditional average and cyclical properties of discretionary spending, transfer spending, labor income tax revenue, and corporate income tax revenue.

Discretionary and transfer spending are modeled as follows: $G_t^i/Y_t = G^i \exp\{b_i z_t\}, i = o, T$, where $z_t = \log(Z_t \mu_\omega)$. The parameters G^o and G^T are set to match average discretionary spending to GDP of 17.58% and transfer spending to GDP of 3.18%, respectively, in the 1953-2014 NIPA data. The model produces 17.50% and 3.15%. The parameters $b_o = -2$ and $b_T = -20$ are set to match the slope in a regression of log discretionary/transfer spending-to-GDP on GDP growth and a constant. The slopes are -0.88 and -8.82 in the model versus -0.71 and -7.14 in the data.

Similarly, the labor income tax rate is $\tau_t = \tau \exp\{b_\tau z_t\}$. We set the tax rate $\tau = 29.3\%$ in order to match observed average income tax revenue to GDP of 17.3%. The model generates an average of 19.16%. We set $b_\tau = 4.5$ to match the regression slope of log income tax revenue-to-GDP on GDP growth and a constant. The slope is 0.63 in the model and 0.70 in the data.

Since the covid shock features both a decline in TFP Z and an unexpected decline in mean firm productivity μ_ω, government spending is unusually high and tax revenue unusually low during the covid recession.

We set the corporate tax rate that both financial and non-financial corporations pay to a constant $\tau^{\Pi} = 20\%$ to match observed corporate tax revenues of 3.41% of GDP. The model generates an average of 3.56%. The tax shields of debt and depreciation substantially reduce the effective tax rate corporations pay, both in the model and in the data.

We set the tax rate on financial income for savers (interest on short-term debt) equal to $\tau^{D} = 13.2\%$, the observed value in the data.

Government debt to GDP averages 73.05% of GDP in a long simulation of the benchmark model. While it fluctuates meaningfully over prolonged periods of time (standard deviation of 12.39%), the government debt to GDP ratio remains stationary.

E Pandemic as a One-Time Shock

We perform the same experiments as in Section 4, but now without assuming that agents' expectations take into account the possibility of future pandemics. In these experiments, the pandemic hits unexpectedly, persists for one period, and then the economy converges back to its original steady state consistent with the laws of motion for the two exogenous state variables: TFP and idiosyncratic productivity dispersion.

Figure E.1: Policy Responses to Covid Crisis: Non-financial Firms

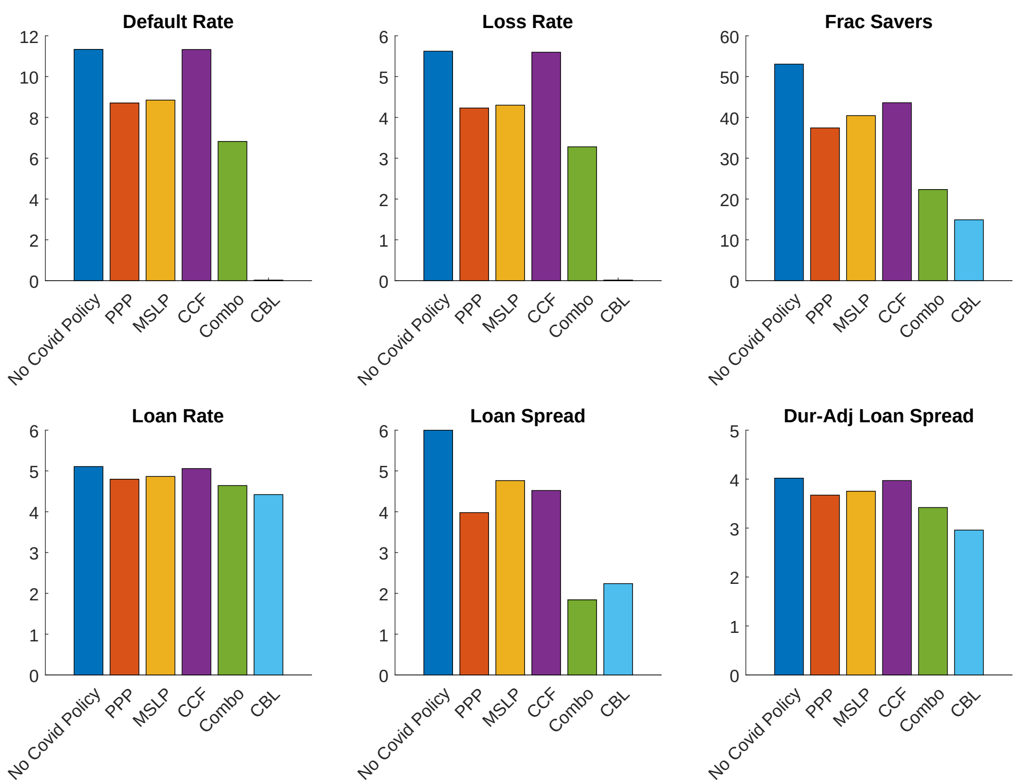


Figure E.2: Policy Responses to Covid Crisis: Financial Intermediaries

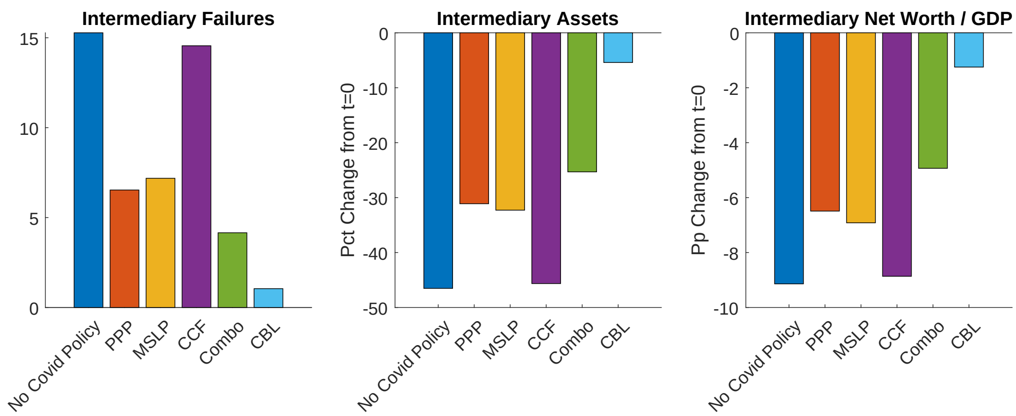


Figure E.3: Policy Responses to Covid Crisis: Macroeconomy

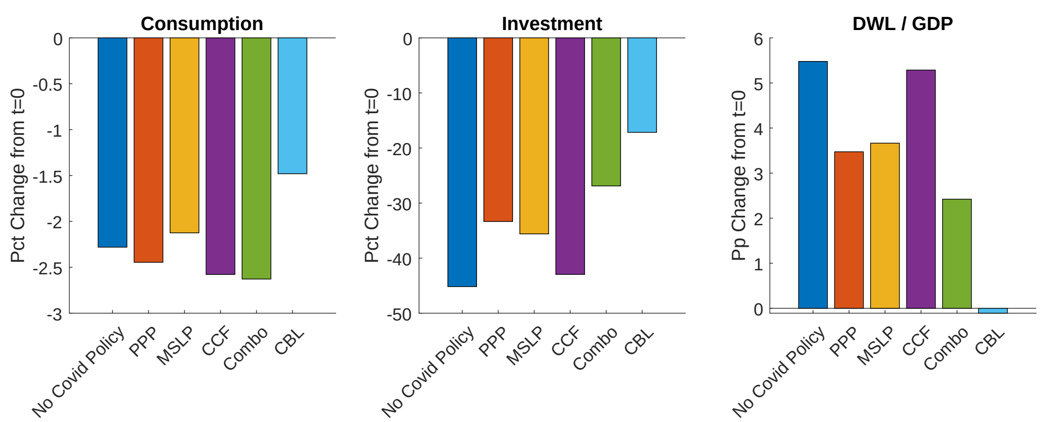


Figure E.4: Policy Responses to Covid Crisis: Fiscal Policy

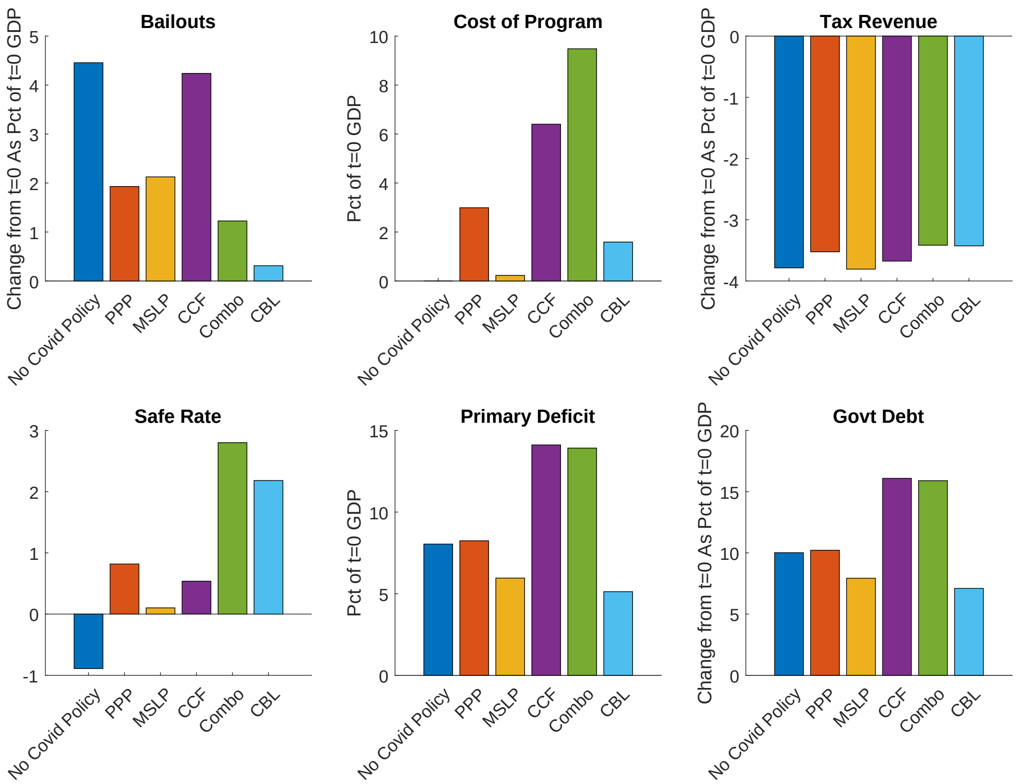
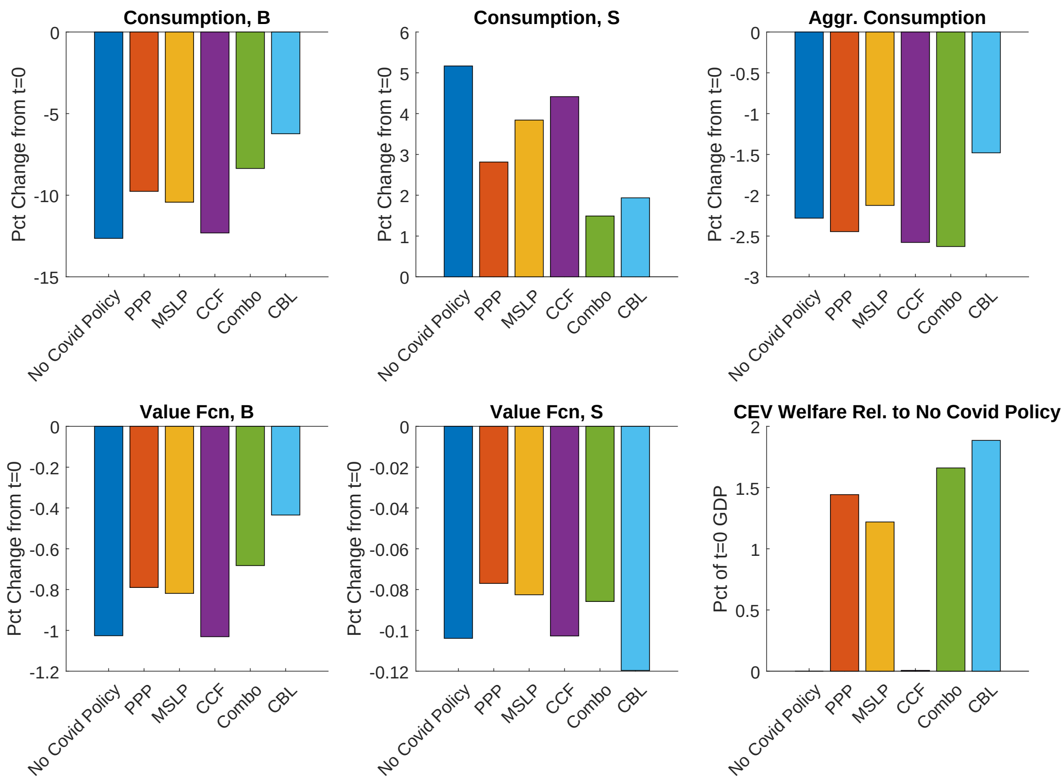


Figure E.5: Policy Responses to Covid Crisis: Welfare



Note: Aggregate welfare is unchanged under the CCF policy relative to the Do nothing scenario.

Figure E.6: Policy Responses to Covid Crisis: Long-run