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IMF Working Paper

Reducing Risk While Sharing It: A Fiscal Recipe for the EU at the Time of COVID-19

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Prepared by Nicoletta Batini,[1] Francesco Lamperti,[2] and Andrea Roventini[3]

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September 2020

Abstract

The COVID-19 lockdowns have brought about the need of large fiscal responses in all European countries. However, countries across Europe are differently equipped to respond to the shock due to differences in economic conditions and fiscal space. In this paper, we build on the model by Berger et al. (2019) to compare gains from alternative mechanisms of EU fiscal integration in the presence of moral hazard. We show that any EU response strategy to the COVID-19 crisis excluding mutual financial support to member countries lacks credibility. Some form of fiscal risk sharing is indeed better than none, and the associated moral hazard can be hedged by introducing fiscal centralization to Brussels. While the desirable level of centralization increases monotonically with the stock of a country's debt issued to finance COVID-related spending, the degree of risk sharing responds non-linearly. When the costs of delegating fiscal authority are relatively low, the optimal policy envisages increasingly higher delegation of fiscal authority and lower fiscal risk sharing. On the contrary, when the costs of transferring fiscal powers are relatively high the optimal mix favors more risk sharing. Proposed arrangements at the EU level in response to the COVID-19 shock seem reflecting these basic insights by rotating around a combination of fiscal risk sharing and delegation in the form of fiscal conditionality.

JEL Classification Numbers: H10; H70; H81; H84.
Keywords: COVID-19; European fiscal union; fiscal integration; risk sharing; fiscal delegation.

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Reducing risk while sharing it: a fiscal recipe for the EU at the time of COVID-19*

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Abstract

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*Contacts: N. Batini: nbatini@imf.org.; F. Lamperti: f.lamperti@santannapisa.it; A. Roventini: a.roventini@santannapisa.it. The Matlab codes to replicate the analysis and the figures are available from the authors upon request.

1 Introduction

The Global Coronavirus Crisis (GCC) is a joint health and economic crisis of unprecedented proportions in recent history. Reflecting the spread of the contagion, which continues to ravage countries around the world in a series of waves and had affected over 54 million people causing over 1.3 million deaths by end-November 2020, most governments have ordered "lock-downs", namely universal physical confinement to avoid contagion and closure of "non-essential" economic activities. As a result, global GDP has plummeted and a global recession of the magnitude of the Great Depression is in the making (IMF 2020). The crisis has been accompanied by historically unprecedented capital flight from emerging and developing countries and by a bout of financial market volatility unseen since the 1930s (Reinhart et al. 2020).

More so than in any previous crises, the GCC and the design of effective policies to respond to it are afflicted by extraordinary uncertainty, given the lack of clarity surrounding aspects about the disease, its path of contagion within and across countries, and the possibility of finding a cure or a vaccine in the very short term. It is thus no surprise that what constitutes the best economic policy response to the GCC is hotly debated. Many have been asking for a much larger fiscal stimulus than that for the Global Financial Crises to defibrillate the global economy before it is too late (Draghi 2020, IMF 2020, Kapoor & Buiter 2020, Stiglitz 2020). Others believe that a more paced response, focused on health, food and essential services expenditure may be more appropriate during the initial phase of the pandemic to avoid front-loading fiscal insolvencies given the uncertain duration of the shock (Romer & Garber 2020, Krugman 2020, Griffith-Jones et al. 2020). In this case the bulk of the fiscal stimulus could be postponed to after the pandemic is over. Calls are also being made to make the post-coronavirus stimulus "green" as a way to ensure that climate change agendas do not get sidetracked (Bozuwa et al. 2020, Plant 2020), and efforts are being made both in the EU and in other countries to ensure that plans for the post-COVID recovery embed at least some clear green goals.

The GCC is likely to put undue fiscal stress onto the European Union, given that the common COVID-19 shock will hit member countries asymmetrically, and not only from an epidemic perspective. Indeed, the ability to respond counter-cyclically is affected by stark differences in available policy space, the economic structure (prevalence of certain sectors) and growth outlooks (Bruegel 2020, IMF 2020, Chen et al. 2020). In the last few months EU countries have discussed fiercely over the desirable policy package to deploy against the crisis, knowing that the agreed solution will not only affect the pace of the recovery, but could jeopardize the same European project if not carefully planned to minimize differentials in its economic impact across the region. Reflecting these premises, a coordinated fiscal response has emerged so far, involving: (i) pandemic-crisis credit lines provided of the European Stability Mechanism; (ii) government guarantees to the European Investment Bank to extend loans to companies; (iii) SURE, a temporary loan-based instrument to mitigate the surging unemployment supported by guarantees from EU countries.[1] In addition, there is the proposal of creating a Recovery Fund - labelled as "Next Generation EU" (NGEU) - which will be made up of 500 billion euros in grants and 250 billion euros to jumpstart European economies after the COVID-19 emergency is passed. Resources raised by the EU on capital markets and directed to the NGEU are going to be spent on health, green and digital policies.

In this paper, we contribute to this debate by modelling the interactions between the European

[1] See Benassy-Quere & Weder di Mauro (2020) and Section 2 for further discussion.

Union and one of its member countries (or group of them). The country needs to decide the size of its fiscal intervention in response to the COVID-19 shock, considering that a weak response may be insufficient to deal effectively with the health and economic shock, while a strong one may put its public debt on an unsustainable path.

Several proposals already exist on how to structure risk sharing in Europe. In particular, numerous scholarly contributions have helped shape the long-lasting debate on how to complete the architecture of the single currency area, a debate that gained momentum as weaknesses in the ability of the euro area to coordinate a response to the global financial crisis (GFC) became apparent in 2011-2012. Among these, many have called explicitly for the creation of a central fiscal capacity (CFC) aimed at dealing with major adverse shocks (Beblavỳ et al. 2015, Abrahám et al. 2017, Arnold et al. 2018, Beetsma et al. 2018, Carnot et al. 2017, Dolls et al. 2018, Berger et al. 2019). Alongside, Bénassy-Quéré et al. (2018) convincingly underscored that an effective solution requires progress on both fronts - risk sharing and risk reduction; and to that end have put forward an ingenuous proposal whereby euro area countries should finance new debt in excess of limits imposed by the EU expenditure fiscal rule with junior debt. The higher yield on junior than on senior debt would encourage fiscal discipline. Bénassy-Quéré et al. (2020) further elaborated a modified plan to deal specifically with the COVID-19 crisis in which they call for a wide-ranging emergency package through which the EU would take responsibility for a substantial share of the overall emergency effort.

Our model builds on the work of Berger et al. (2019) to assess whether some forms of European fiscal risk sharing can lessen this trade off affecting EU countries, allowing a rightly-sized response while minimizing the probability of a sovereign debt crisis that could damage the whole Union.[2] We add to that model a country's decision on COVID-related spending, assuming it is financed through national debt. The additional debt burden affects sovereign risks, default costs and, indirectly, moral hazard - the incentive for individual member countries to overspend or reduce fiscal discipline in presence of fiscal risk sharing. Our model shares some features with the recent work by Gourinchas et al. (2020), in that it trades-off ex-ante support measures versus ex-post bailout, but differs in the spectrum of instruments considered and provides larger emphasis on the joint role of fiscal centralization and risk sharing.[3]

We obtain three key results that reapply and extend the discussion of (Berger et al. 2019) in the times of COVID. First, any EU response strategy to the crisis that excludes mutual financial support of a member country at risk of insolvency as a direct result of the spending caused by the health crisis substantially lacks credibility (under the assumption that the cost to the EU of a member going insolvent are larger than those implied by risk sharing). Second, at least some risk sharing is better than no risk sharing, even when there is a great discrepancy in crisis-related spending across the EU. In addition, it is optimal to accompany risk sharing with some level of centralization of fiscal authority to the European Union to hedge against the possible moral hazard of EU countries. The optimal level of fiscal centralization depends on its costs. When such costs are relatively low, risk sharing and centralization of fiscal authority oppositely respond to changes in sovereign risk. Further, beyond a

[2]In this paper we consider the strategic interaction between the EU and a member country (or group of countries), where the latter should be intended as the relatively "vulnerable" part of the union, which would benefit from risk sharing (via - for example - lower cost of debt). As in Berger et al., the level of risk sharing is interpreted here as the degree by which countries are able to smooth consumption.

[3]In this paper, centralization of fiscal authority should be interpreted as a form of migration of fiscal (and other) policy responsibilities to Brussels in order to facilitate a better coordinated pursuit of jointly accepted goals. It is akin to the concept of delegation in Berger et al. (2019) and the two terms are intended as synonyms, and used interchangeably here, as a result.

certain level of sovereign risk in one or more member countries, full centralization of fiscal authority at Brussels is the optimal policy. In contrast, if the transfer of fiscal authority to the center is costly and/or complicated (e.g. because of political constraints), the two mechanisms are jointly desirable: more risk sharing and more delegation are needed the larger individual countries' debts following the COVID crisis.

The rest of the paper is organized as follows. In Section 2, we review the current EU proposal EU for a coordinated response to the COVID-19 crisis. The models are presented in Section 3. Finally, in Section 4 we discuss the key results from the analysis and ensuing policy implications.

2 The EU response

European countries have been discussing fiercely over what constitutes the best policy response to tame the economic crisis triggered by the spread of the novel coronavirus. Finding an effective solution based on consensus is not only fundamental for coping with the current crisis, but is likely to shape the future of the EU.

The EU's coordinated response that emerged so far seems both comprehensive and bold. On top of issuing recommendations for a coordinated health and economic policy response to the pandemics,[4] in mid-May 2020 the European Commission has launched a 540 billion euros (4 percent of EU27 GDP) economic package to support the bloc's economy during the pandemic and help it bounce back. The package includes: (i) a Pandemic Crisis Support to help finance health-related spending up to 2 percent of 2019 GDP for each euro area country (up to 240 billion euros in total) and based on existing credit lines of the European Stability Mechanism (ESM); (ii) 25 billion euros in government guarantees to the European Investment Bank (EIB) to extend loans to companies for up to 200 billion euros, with a focus on financing capital investment of small and medium enterprises (SMEs) especially after the initial phases of the pandemic; and (iii) a temporary loan-based instrument (SURE, for State Supported Short-time work or reduced work)) of up to 100 billion euros to mitigate unemployment by protecting workers and jobs, supported by guarantees from EU Member States. The Pandemic Crisis Support from the ESM has become operational and the European Council has adopted the SURE.

Key, yet considerably more modest, measures for the EU Budget (about 37 billion euros and 0.3 percent of 2019 EU27 GDP) include creating two COVID-19 response investment initiatives (CRII and CRII+) to support investment in hospital infrastructure and smaller or hardest-hit economic players and regions; changes to the scope of the EU Solidarity Fund to accommodate public health crises; credit holidays to crisis-affected debtors; and a 3 billion euros macro-financial assistance (MFA) package to several enlargement and neighborhood partners to help them limit the economic fallout of the coronavirus pandemic. The European Commission also activated the general escape clause in the EU fiscal rules, which suspends the fiscal adjustment requirements for countries that are not at their medium-term objective and allows them to run deficits in excess of 3 percent of GDP; and has modified EU State Aid rules to make them more flexible especially for critical sectors such as aviation and tourism.

In addition to these measures, the European Council has proposed to create a 750 billion euros Next Generation EU fund meant to kick-start the European economy once the emergency is over. The NGEU, which, at the time of writing, still needs to be approved by the European Parliament, would be made up of 390 billion euros in grants and 360 billion euros in loans to be spent on green

[4] https://ec.europa.eu/commission/presscorner/detail/en/IP_20_901

and digital policies as well as increased resilience to Covid-19-type crises. About 4/5ths (312 billion euros) of the 390 billion euros will be allocated to the so-called EU Recovery and Resilience Facility. Member states will access their share of these 312 billion euros from 2021 to 2023. In order to access the grant aid, which will not have to be paid back, member states must prepare national recovery plans making certain pledges based on explicit national recovery and resilience plans for 2021-2023.[5] The rest of the 390 billion grant fund - 77.5 billion euros - will be added to existing EU budgetary programs which offer grant aid. The money would be raised on capital markets and paid back over a 30-year period between 2027 and 2058 in part with new taxes, including green and digital taxes. When adding the NGEU to the proposed size of the 2021-2027 multi-annual financial framework of 1.1 trillion, the total financial firepower of the EU budget reaches 1.85 trillion, equivalent to around 13% of EU GDP at 2019 levels.

Since a large share of the EU stimulus is expected to be allocated on the base of needs, the package involves a considerable amount of risk sharing. Besides, both loans and grants distributed to EU member states under the NGEU are expected to meet certain criteria agreed jointly at the EU level, and any request to tap into the fund will have to be signed off by the European Commission and the EU Council of Ministers to ensure that investment and reforms financed through the NGEU help countries recover in a certain direction, which is green, digital and more resilient.[6] In this sense, the NGEU also entails a certain amount of fiscal centralization from member countries to the EU in the form of the surrender of fiscal sovereignty in the decision about how to use these resources.

Alongside these fiscal instruments, in March 2020, the European Central Bank provided monetary policy support through additional asset purchases of 120 billion euros until end-2020 under the existing program (APP), as well as temporary additional auctions at more favorable conditions under the existing targeted longer-term refinancing operations (TLTRO-III) between June 2020 and June 2021. The ECB also introduced a new liquidity facility (PELTRO), consisting of a series of non-targeted Pandemic Emergency Longer-Term Refinancing Operations carried out with an interest rate that is 25bp below the average MRO rate prevailing over the life of the operation. Further measures included an additional 750 billion euros asset purchase program of private and public sector securities (Pandemic Emergency Purchase Program, PEPP) until end-2020, an expanded range of eligible assets under the corporate sector purchase program (CSPP), and relaxation of collateral standards for Eurosystem refinancing operations (MROs, LTROs, TLTROs). The ECB also announced a broad package of collateral easing measures for Eurosytem credit operations in early April 2020.

As countries embark on negotiations to seal this proposal and the EU prepares to disburse the much needed funds to its member countries, one should reflect on whether a joint stimulus package raised in large part by issuing EU bonds is an efficient policy solution for all individual member states and/or the Union as a whole, and what are, in that light, the optimal amounts of risk sharing and fiscal centralization to Brussels that should be pursued to ensure that the policy response is economically beneficial for all EU members and the Union itself as a whole.

The issue of what constitutes an efficient fiscal response for EU member countries - both collectively and individually - can be explored systematically in a framework in which fiscal integration is defined along two dimensions involving the degree of risk sharing within EU countries and the degree of

[5] As stated in a statement from the EU Council meeting which signed off the agreement, "These will need to be consistent with the country-specific recommendations and contribute to green and digital transitions. More specifically, the plans are required to boost growth and jobs and reinforce the economic and social resilience of EU countries." See https://www.consilium.europa.eu/en/meetings/european-council/2020/07/17-21/.

[6] This conditionality involves, for example, green criteria that are expected to also apply to the so-called solvency instrument aimed at shoring up companies in need of liquidity.

centralization of fiscal authority to the center. In order to design such framework, three issues need to be considered.

- *What kind of risk sharing arrangement?* Formal risk sharing entails a variety of possible arrangements that smooth the effects of (asymmetric) shocks. Such arrangements encompass, for example, common fiscal backstops for bank resolutions, EU-wide unemployment insurance programs, as well as rainy day funds. In the current emergency context, the use of the EMS, quasi-fiscal stimuli involving liquidity injections in the form of "helicopter money" (Gali 2020), and the issuance of joint EU bonds, like those postulated to finance the proposed Recovery Fund, are all mechanisms of fiscal risk mitigation. Yet, while all these three arrangements offer ways to share risk, their effect and efficiency are different because of the way they affect member countries individual sovereign debt and risks, and thereby, individual countries' fiscal sustainability (Blanchard 2020). In turn, this can affect collective equilibria, if the arrangements are per se unsustainable or lack credibility. Mobilizing funds primarily via the EMS - even unconditionally - for instance, requires an increase in a member state's individual liabilities, with potential idiosyncratic sentiment implications for sovereign risk and debt sustainability. The Spring 2020 Economic Forecast of the EU Commission projects a sinister economic recession, close to the worst-case scenario assumed in the European Banking Authority (EBA) 2020 EU-wide stress test (ESRB 2020). If this recession was to materialize, it could lead by itself to an explosion of bad loans, deteriorating assets and plummeting share prices, a scenario that could be exacerbated if use of the ESM was to increase the sovereign risk of vulnerable countries or countries hit harder by the pandemic relative to other countries (Ewing 2020). On the contrary, joint EU bonds like those proposed for the NGEU can redistribute risk across countries with different degrees of fiscal space. This way they can help lower the cost of financing for countries with less or no fiscal space, while buttressing all countries debt sustainability. In this sense EU bonds are more likely to help shelter the EU from attacks to its common currency during this particularly severe health and economic crisis.

- *What degree of fiscal centralization?* European integration can come through centralization of fiscal authority. An EU-based fiscal capacity could provide area-wide public goods or long-term public investment financed by government contributions, taxes, or a combination of both (Arnold et al. 2018). While full centralization is politically impossible, some proposals towards centralization have started to emerge. For example, Grund et al. (2020) recently proposed to create a Pandemic Solidarity Instrument (PSI) that would lead to a partial sharing of the fiscal costs of the coronavirus crisis through the issuance of a one-off EU asset in the market, guaranteed by the EU budget and use it to provide disaster-relief and medical equipment. Eventually, European expenditures could be funded with a one-shot European wealth tax (Landais et al. 2020). In a sense this proposal goes in the same direction of the proposed NGEU, which essentially entails raising funds jointly at the EU level on capital markets by selling EU debt and paying this off through EU taxes.

- *Is the COVID-19 shock symmetric or asymmetric?* Beyond differences in lag and effect of different arrangements, the appropriateness of EU's fiscal policy response to the COVID-19 outbreak also depends on the degree of symmetry of the pandemic shock. Here it is important to note that while it is commonly accepted that the initial shock (namely the emergence of a global epidemic of a highly contagious disease) and the economic impact of health measures (e.g.

lockdowns and social distancing) have been fundamentally symmetric in nature, the duration and strength of the shock have been and remain variable across countries depending on, without loss of generality: (i) different severity, evolution, and duration of the contagion and, thus, necessary lock-down regulations; (ii) different pre-existing public finance conditions (which implies different fiscal spaces and costs for debt-financed fiscal spending); or (iii) different structural economic environments (e.g. prevalence of certain sectors as well as links to global supply chains). For example, a report by the IMF (2020) shows that reflecting the decline in output alone, the Greek debt/GDP ratio is estimated to rise by close to 20 percentage points, and by 15 percentage points in Italy, restricting fiscal space. Hence, as symmetric shocks could easily become asymmetric, a common insurance across the EU is needed to increase its resilience.

The aim of this paper is to identify the joint fiscal strategy for the EU and its member countries that maximizes, at once, both the EU's collective and individual member countries welfare. To that end, in the next section we develop an analytical set up to compare the trade offs between the of alternative combinations of fiscal responses of individual EU member countries and the EU, considering different risk sharing and fiscal centralization arrangements in the face of a shock similar in nature to COVID-19.

3 The Models

Building on the work of Berger et al. (2019), our models explicitly accounts for the strategic behaviour on one side of the EU and, on the other side, of one of its member countries (or a group of them) that need to spend public funds to fight the pandemic.

As public spending swells and revenues drop because of the economic slowdown caused by the measures to contain contagion, public debt increases. Individual EU countries need then to decide how much to spend to contain the contagion, to provide adequate health services, and to sustain incomes during the lockdown, considering that the more they spend, the higher the likelihood of an increase in the cost of financing their debt and the risks, eventually, of an isolated or systemic sovereign debt crisis. As stressed by (Benassy-Quere & Weder di Mauro 2020), it is in the self-interest of each member state - in principle - that the other member states have enough resources to fight the pandemic, and the pandemic does not trigger a sovereign debt crisis.[7] On the other hand, if effective at reducing contagion rates and at avoiding structural layoffs and market losses, their spending can dampen the economic slump, implying a more sustainable fiscal path characterized by lower debt service, lower future spending and higher future revenues.

The EU can smooth the trade offs faced by countries between sovereign risks and economic and health risks by supporting their emergency spending during the crisis. However, this is costly, and the financial burden that may be generated as a result of the EU-level support could be higher still in the case of a sovereign debt crisis as the welfare costs of the default for the EU (and the member countries not facing it) is increasing in the stock of sovereign debt. Crucially, offering support to individual member countries, raises the specter of moral hazard: knowing that financial help will be provided by the Union as a whole could push countries to overspend in the understanding that they would be bailed out by the EU in case of default - a problem long debated in the context of discussions for possible policy solutions to the EU's 2011 sovereign debt crisis.

[7] The risk that sovereign debt soars because of emergency spending in some member countries hardly hit by COVID-19, like Spain and Italy has been widely discussed. See, for example, Vihriala (2020), Beck (2020), and the collection in Baldwin & di Mauro (2020).

As discussed in Section 2, the extent by which EU financial support is expensive and/or risky for the Union itself and for its member countries (with different economic and health risks characteristics) depends on the amount of risk shared as support is provided from the Union to individual countries. Mutualizing sovereign risks, for example by issuing EU bonds, implies lower individual countries' debt stocks in the face of the same amount of emergency spending, capping borrowing costs at the country level and thus minimizing risks of hikes in sovereign spreads and ensuing debt defaults. Likewise, the cost and riskiness of EU support depends on the amount of delegation to the center in the decisions involved on how to spend the funds received by the Union because this can reduce moral hazard by dissuading overspending, while still providing the public goods needed to overcome the health and economic crisis (Grund et al. 2020).

To capture these dynamics, we derive two models. The first model, presented in Section 3.1, explores alternative risk sharing arrangements, while the second model, presented in Section 3.2, adds in fiscal centralization and is employed to derive the optimal fiscal integration arrangement. Several assumptions are made in the analysis:

- the EU can opt for different levels and forms of risk sharing and can decide to bailout a member country in case this is faced by a sovereign debt crisis;
- fiscal risk sharing among all member countries improves the welfare of individual ones ex ante by allowing them to deploy the same amount of resources at a lower borrowing cost, thus reducing the probability that emergency fiscal spending leads to debt sustainability problems;
- the bailout is an ad-hoc intervention, the probability of which depends (positively) on the size of the debt of the member country being bailed out and (negatively) on the level of formal risk sharing eventually agreed by the EU;[8]
- both bailouts and formal fiscal risk sharing arrangements are costly for the EU, but less so than allowing a member country to default its fiscal obligations;
- the expectation of fiscal risk sharing reduces incentives for fiscal prudence at the member country level, generating moral hazard;[9]
- fiscal authority can be enforced either at the EU or at the national level, or through some intermediate solutions, giving rise to different degrees of fiscal centralization;
- fiscal centralization to the EU reduces moral hazard and thus, the likelihood that a country faces default, but it generates administrative, legislative and political costs to the Union that increase with the amount of centralization attained,
- finally, the legislative and political costs of providing risk sharing mechanisms within the Union are negligible with respect to the costs of delegating fiscal authority.[10]

[8] In the absence of sufficient fiscal risk sharing, idiosyncratic shocks may have stronger impacts, implying higher potential costs for other EU members and thereby making a bailout more likely (Allard et al. 2013).

[9] See, for example, Persson & Tabellini (1996), Hebous & Weichenrieder (2016).

[10] We intentionally leave the removal of this assumption and the discussion of the relationship between the political costs of providing formal risk sharing vis-á -vis fiscal centralization to future research.

3.1 Strategic behaviors and EU risk sharing

In the first model, we consider a sequential game (cf. Figure 1) between the EU and a representative member country ("Gov"). The country chooses to either spend to confront the health and economic emergency posed by the pandemic ("Intervention" strategy) or not ("No Intervention"). In the latter case, the health and economic fallout from the pandemic is higher.[11] After having observed the spending choice of the member country, the EU can decide either to introduce some forms of "Fiscal Risk Sharing" or not. The decision of the EU, in turn, affects the likelihood of a sovereign debt crisis hitting the member country. This event is modeled introducing a public-debt shock ("Shock"), which captures the uncertain reaction of markets to government's debt level and riskiness. More specifically, the probability of default is equal to q if no mechanism of risk sharing within the EU is in place, whereas it corresponds to p if risk sharing is present.[12] Naturally, $p < q$. Finally, if the country-EU decisions lead to a sovereign debt crisis, the EU can either bailout the country or not. In the latter case, the member country defaults on its debt obligations, causing losses also for the European Union.[13] Such sequence of events and decisions resembles well, in our view, the current European situation where, at the time of writing, the coordinated EU-level intervention has still to be defined in a great part but countries have already incurred in sizeable disaster relief spending.

The payoffs of the game reflect the assumptions listed above. The worst scenario for the member country is not spending to fight the pandemic (π_G^0 indicates the associated payoff). In case the country decides to intervene and spend, however, it gains more by overspending, going into default, and then being bailed out by the EU (π_G^h) than by sticking to a more conservative fiscal spending plan and not facing default (π_G^l). Conversely, the EU is better off when both a default and/or a bailout are avoided (π_{EU}^h). According to our assumptions, the welfare loss induced by a bailout (π_{EU}^l) are smaller than those produced by a default (π_{EU}^0). The introduction of some forms of risk sharing alters the likelihood of the country's default at the cost of imposing an additional burden c on the EU, while providing a benefit b for the member country being rescued. Finally, we assume that the country's welfare when risk is shared at the EU level and in absence of debt crisis (π_G^m) is lower than the payoff it would get in case of a default with EU bailout, i.e. $\pi_G^h > \pi_G^m > \pi_G^l > \pi_G^0$.

The game can be easily solved by backward induction.[14] Note that if there is no fiscal risk sharing and $q = 1$, the game boils down to the one in Berger et al. (2019). In this case, the "No Bailout" strategy of the EU is *not* time consistent. In our extended game, the equilibrium strategy of "Gov" implies intervening to tackle the health and economic emergency no matter what the EU decides to do. Differently, the optimal choices of the EU depend on the relative probabilities (p and q) of avoiding a sovereign debt crisis in presence of fiscal integration, the relative welfare loss of the bailout ($\pi_{EU}^h - \pi_{EU}^l$) and the costs of the risk sharing mechanism (k). In particular, the EU is better off by

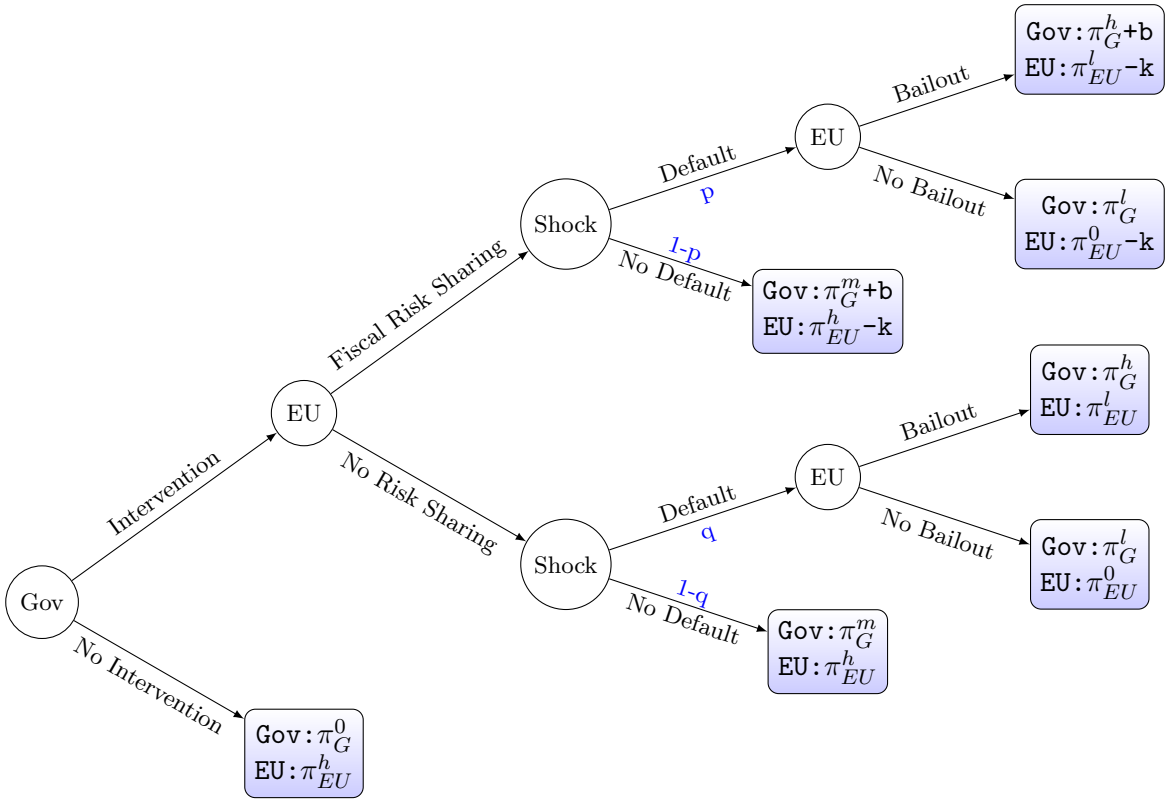
[11] In the current situation, the decision of each government to increase its debt to finance spending against the epidemics is more a necessity than a real choice between alternative options. Further, we believe that a sequential game provides a more realistic representation of the actual situation than a simultaneous one could do. The equilibrium we single out is obviously present even in the simultaneous form and it is also sub-game perfect.

[12] Modelling p and q this way offers a simple, but insightful set up to analyze the trade offs (in absence of moral hazard) that the EU faces in the scenario of setting a fiscal risk-sharing arrangement using comparative statics. In future research it would be interesting to extend the benchmark model by endogenizing the probabilities p and q as well as the cost of bailout incurred by the EU and the benefit from be bailout b received by the country in need (to better understand the interaction of these variables).

[13] In this model we implicitly model losses as lower ex-post payoffs; in section 3.2 we provide an endogenous formulation instead. Here we implicitly assume that the EU would be relatively unaffected if some of its member countries do not intervene to fight the pandemics. This is naturally unrealistic as the epidemic could spread crossing borders among EU countries. Relaxing this assumption would strengthen the results of the model.

[14] This is done, as usual, to rule out the equilibria of the normal form game that are not subgame perfect.

Figure 1: The role of fiscal risk sharing in the European Union. When the risk of insolvency critically increases in one member country, fiscal risk sharing becomes comparatively convenient to the whole Union.



introducing some fiscal risk sharing if its expected payoff under such a scenario is not inferior to the one generated in the absence of risk sharing. Such a condition holds whenever the difference in the probability of the occurrence of a debt crisis in presence or not of a risk sharing arrangement $(q-p)$ is higher than the ratio between the cost of risk sharing and the relative welfare cost of a bailout:

$$(\pi_{EU}^l - k)p + (\pi_{EU}^h - k)(1-p) \geq \pi_{EU}^l q + \pi_{EU}^h(1-q) \quad \iff \quad q - p \geq \frac{k}{\pi_{EU}^h - \pi_{EU}^l}. \tag{1}$$

A series of policy implications stem from this result. First, the greater the impact of emergency spending on the country's national debt, the higher the risk of a sovereign debt crisis (q grows), the greater the benefit to the EU from setting up a fiscal risk sharing mechanism to mitigate such risk. Moreover, the more effective the fiscal risk sharing arrangement at stabilizing the country's national debt (p decreases), the largest the incentive for the EU to introduce it. However, not all forms of fiscal risk sharing are the same: the lower the cost k to implement them, the more they are appealing for the EU. Finally, the introduction of a risk sharing mechanism becomes more desirable for the EU, as the relative welfare costs of a debt crisis for the EU ($\pi_{EU}^h - \pi_{EU}^l$) increase.

These insights, which generalize the results of Berger et al. (2019) developed to examine EU-oriented solutions for the 2011 sovereign debt crisis, show that there is merit in advancing European fiscal integration to deal efficiently with the novel coronavirus health and economic crisis. The analysis indicates that an EU risk sharing mechanism is *win-win* for both the EU and its member countries at least in the absence of moral hazard. In the next section, we explore what happens to this result when moral hazard is present.

3.2 COVID-related debt, moral hazard and EU fiscal centralization

If the EU introduces some forms of fiscal risk sharing, it must decide how much risk to share and whether, and if so to what extent, decisions on how to spend the EU-provided funds depend on conditions set by the EU's central fiscal authority. Both decisions should reflect moral hazard considerations. Here we modify the model to address such issues.

Consider a principal-agent problem between (i) the EU, which is interested in the welfare benefits from sharing risk among multiple Union members (for example, through a "rainy-day" fund), and (ii) its member countries, which can in principle exploit the fact that some of their spending is financed with joint EU resources, and therefore be inclined to overspend. The amount of risk sharing is captured by $f \in [0,1]$. The EU fixes f taking into account that its member countries need to issue additional debt to cope with the crisis. The level of EU risk sharing (f) and the increment in national debt (X) associated with the imponderable and evolving borrowing needs from the development of the COVID health emergency, where $X \in [0,1]$, affect the probability of occurrence of a sovereign debt crisis. More precisely, the probability of crisis (denoted as p_B) increases in X, as countries under increasingly stretched balance sheet face a rising likelihood to go into default, and decreases in f, as sharing fiscal risks with fellow member states reduces the fiscal burden that would otherwise have to be borne individually. It follows that p_B is equal to:

$$p_B = 1 - f(1 - X). \tag{2}$$

When $X = 0$, the model boils down to the one in Berger et al. (2019) and the likelihood of the debt crisis depends negatively only on the amount of risk sharing provided by the EU. Indeed, a higher f reduces the domestic distress from an adverse shock by lowering the interest rate paid on the national debt rates and by isolating the economy from negative spillovers coming from shocks hitting other EU countries. On the contrary, if $X = 1$, the surge in the public debt is enough to trigger a crisis, i.e. $p_B = 1$. Varying X between 0 and 1 can help study how the decision to share risk before a crisis evolves as debt increases, affecting moral hazard and the benefits of delegating fiscal authority to the center.

As in the model in Section 3.1 (and in line with Berger et al. 2019), once a sovereign debt crisis takes place, the EU has a clear incentive to bail out the country in order to minimize its losses whatever the degree of fiscal risk sharing implemented. Such an ad-hoc intervention would bring additional welfare costs for the EU which are proportional to the debt level of the country, i.e. $B = b + X$, with $b > 0$.[15] Hence, the expected welfare loss from a bailout is:

$$\hat{B} = (b + X)p_B = (b + X)[1 - f(1 - X)]. \tag{3}$$

In this framework, the expected level $\hat{f}$ of the fiscal risk sharing from the EU can be expressed as:

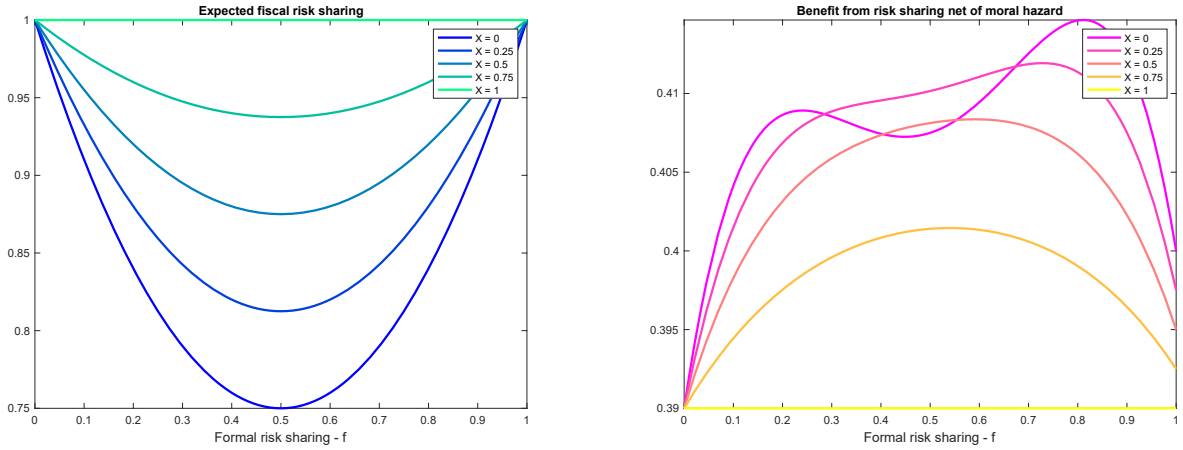
$$\hat{f} = p_B + (1 - p_B)f = 1 - (1 - X)f + (1 - X)f^2. \tag{4}$$

Equation (4) formalizes that support from the EU can come in two forms: through formal risk sharing, f, that reduces the probability of default or through posthumous and not-previously-agreed interventions. The latter will be more expensive from a welfare point of view than support agreed ex

[15] For simplicity, we assume that the bail out requires the same level of support as the maximum formal risk sharing, i.e. $f = 1$.

ante through formal risk sharing arrangements, because the will normally be delivered at the latest stage in the game and typically only when the EU has realized that the risk of a regional crisis becomes a reality and more support than what was originally envisaged is needed to contain the losses of the Union. With this in mind, to keep things simple, as in Berger et al. (2019), we assume that the latter intervention requires the same level of support of the maximal risk sharing ($f = 1$). The expected support that a member country can receive is then a non-linear, U-shaped function of f (see left panel of Figure 2).[16] Higher levels of COVID-related debt (X) make the amount of risk sharing that countries eventually expect less sensitive to the level of risk sharing agreed before the shock because the higher the debt the more likely a default and, therefore, more likely the probability of full risk sharing, independently of previous agreements. Intuitively, additional debt raises the probability of default vanishing the insurance-effect of f.

Figure 2: Expected support from the EU and expected welfare gain from risk sharing (net of moral hazard) for varying level of formal risk sharing and selected levels of COVID-related debt.



(a) Expected risk sharing.

(b) Welfare gain from risk sharing (net of moral hazard).

In the presence of an EU risk sharing mechanism, member countries can have an incentive to lessen or deviate from a path of fiscal discipline and/or create an extra amount of debt that is unrelated to the spending necessary to deal with the health and economic crisis from the pandemic.[17] However, centralization can mitigate the risk that member countries engage in profligate fiscal policies. As mentioned in Berger et al. (2019), delegation of fiscal authority to the EU - which fundamentally entails a form of migration of sovereignty from individual member states to the center - can take various forms. Here, we interpret it as a partial transfer of fiscal (and other) policy responsibilities to Brussels in order to facilitate a better coordinated pursuit of jointly accepted goals. Indeed, when fiscal authority is more centralized, governments have a less tight control over taxes and expenditures. Thus, the moral hazard (MH) associated to countries' debt is an increasing function of the expected formal risk sharing ($\hat{f}$) and depends negatively on the degree of power centralization, $d \in [0, 1]$. Moral

[16] This is a convex function in f and linear in X. If $X = 0$ it has a minimum at $f = 1/2$, while if $X = 1$ it reaches the maximum level $f = 1$.

[17] See, for example, the discussion in Wyplosz (2020).

hazard is just equal to:[18]

$$MH = \hat{f}(1-d) = [1-(1-X)f+(1-X)f^2](1-d). \tag{5}$$

In addition, in the case of a complete fiscal union where all decision are delegated to the center ($d=1$), the MH is zero. We assume that the delegation of fiscal powers to a central authority is costly and increasing in the degree of centralization:

$$C = c\frac{d^2}{2}, \tag{6}$$

with $c > 0$. Centralization costs reflect expenses associated with the administrative, legislative and political processes and procedures necessary to attain and operate fiscal centralization from member countries to Brussels. In line with the list of assumption introduced at the beginning of Section 3 and with Berger et al. (2019), we assume that the political and legislative costs of formalizing risk-sharing clauses within the Union are negligible with respect to those of centralizing fiscal authority.

In order to jointly determine the optimal level of European risk sharing (f) and fiscal delegation (d) to the EU for different level of countries' debt, we derive the social planner's welfare function:

$$\begin{aligned} W &= (1-MH)\hat{f} - \hat{B} - C = \\ &= \{1-[1-(1-X)f+(1-X)f^2](1-d)\}[1-(1-X)f+(1-X)f^2] + \\ &- (b+X)[1-f(1-X)] - c\frac{d^2}{2}. \end{aligned} \tag{7}$$

The first terms captures the net benefit of risk sharing taking into account the possible moral hazard behavior of member countries, while the second and third terms represent the costs of bailout ($\hat{B}$) and the costs of centralization (C) respectively.[19] As shown in the right panel of Figure 2, the net benefit of risk sharing is a non-linear function of f and X (once other variables are fixed). In particular, when X increases the trade off between very high and very low f becomes weaker, and formal risk sharing offers increasingly lower benefits in the face of its moral hazard costs.

To study such interconnected system, we start computing the first order condition for the fiscal centralization (d):

$$\frac{\partial W}{\partial d} = 0 \iff [1-(1-X)f+(1-X)f^2]^2 - dc = 0. \tag{8}$$

The optimal level of fiscal delegation to the center (d^*) is equal to:[20]

$$d^* = \frac{[1-(1-X)f+(1-X)f^2]^2}{c}. \tag{9}$$

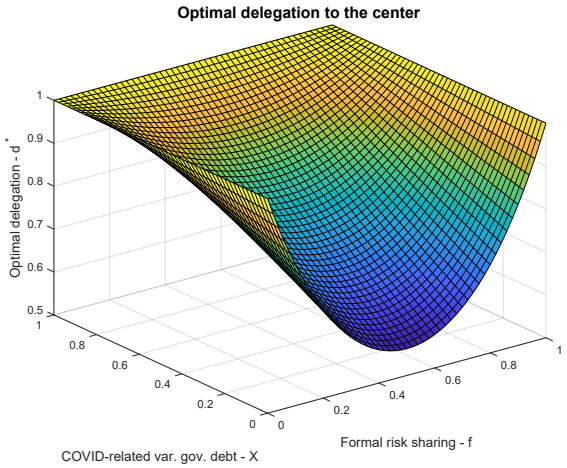
The function is concave in the degree of risk sharing, reaching its maximum when$f = 0$ or $f = 1$, reflecting the role played by moral hazard: when MH is stronger, that is when risk sharing is

[18] We describe moral hazard indirectly: rather than modelling the country's effort at running fiscal policy with discipline, we focus on those mechanisms that might affect the outcome of such process. Expected formal risk sharing lessens fiscal discipline, while centralization transfers fiscal authority, de facto reducing the ability of a country to incur in additional spending and deficits. Hence, moral hazard in our context can be interpreted as the incentive of a national government to (i) spend excessively while coping with the health emergency (i.e. without taking into account the impacts on sovereign risk and its spillovers) or, alternatively, (ii) unduly represent as emergency spending other forms of spending, unrelated to the health emergency.

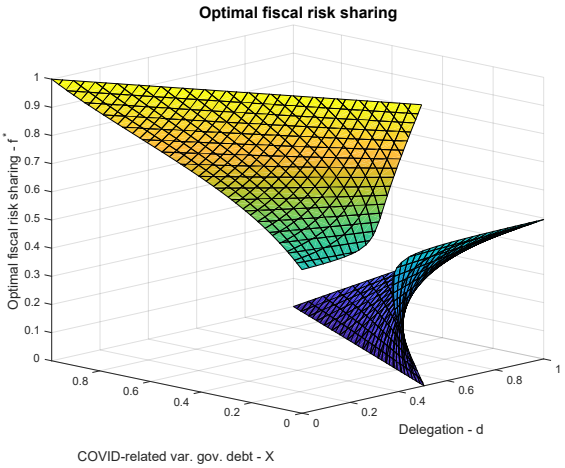
[19] As in Berger et al. (2019), we assume that moral hazard proportionally cuts the gross welfare benefits from risk sharing. Further, if moral hazard is maximal, the positive effect of risk sharing vanishes.

[20] The algebraic passages to obtain d^* and f^* are spelled out in the Appendix.

Figure 3: Optimal centralization of fiscal authority and optimal risk sharing as functions of the surge in debt induced by the pandemics. Parameter configuration: relatively low costs of centralization ($c = 1$) and of sovereign bailout ($b = 0.01$).



(a) Centralization as function of X and f



(b) Risk sharing as function of X and d

either minimal or extensive, centralization is more desirable. Figure 3a shows the optimal level of centralization as a function of the surge in sovereign debt (X) related to the pandemics and the degree of risk sharing f. The shape of the three-dimensional graph indicates that, as the response to COVID-19 induces individual countries to borrow more and more, the optimal level of centralization is relatively high when formal risk sharing is at its extreme values (0 and 1), but declines when some formal risk sharing is in place. The rationale is clear: the EU needs a tighter control on the public finances of those member countries with higher level of national debts because fiscal profligacy in these countries would increase disproportionately the risks of their debt default. Indeed, in the limit case when a default is certain ($X = 1$), the optimal delegation to the EU is unique and envisages a maximal centralization, i.e. $d^* = 1/c$. The optimal centralization depends also on the cost of transferring power to the center. When $c \leq 1$, the marginal costs of transferring fiscal authority to the center rise less than the benefits of centralization obtained by the EU through it. In this case, the need of extraordinary and potentially un-repayable debt to fight the COVID-19 shock supports a process of fiscal integration through a central EU fiscal authority. On the contrary, when delegating to Brussels is more expensive ($c > 1$), the optimal level of centralization is lower, but needs to be compensated by larger fiscal risk sharing. To see this, one needs to compute the optimal level of risk sharing f^*.

The first order condition for the degree of fiscal risk sharing in the European Union is equal to:

$$\frac{\partial W}{\partial f} = 0 \iff (1 - X)\{(1 - 2f)[2\hat{f}(1 - d) - 1] + b + X\} = 0. \tag{10}$$

The optimal degree of formal risk sharing, f^*, depends on the level of COVID-related debt, X, the impact of a potential debt bailout on welfare and the degree of delegation to the center d. As shown before, the optimal amount of centralization, $d*$, depends on formal risk sharing, f, the level of COVID-related debt, X and centralization costs, c.

Figure 3a and 3b show conditions (8) (10), respectively, by expressing d^* as a function of X and f, as well as f^* as function of X and d. Three broad results emerge. First, in a more general setting that allows for a variations in the level of public borrowing in response to the COVID-19 health emergency

in individual EU countries, we confirm the result of Berger et al. (2019): a positive amount of fiscal risk sharing improves the welfare of both the EU and its member countries even when COVID-related debt (X), and the implied cost of a bailout (B), are very low.[21] This result is in line with the intuition provided in Section 3.1: when there are tangible risks of a sovereign debt crisis, the presence of a risk sharing mechanism is desirable for the EU, independently from the size of the crisis itself, because its activation reduces overall costs to the EU of ex post fiscal support.

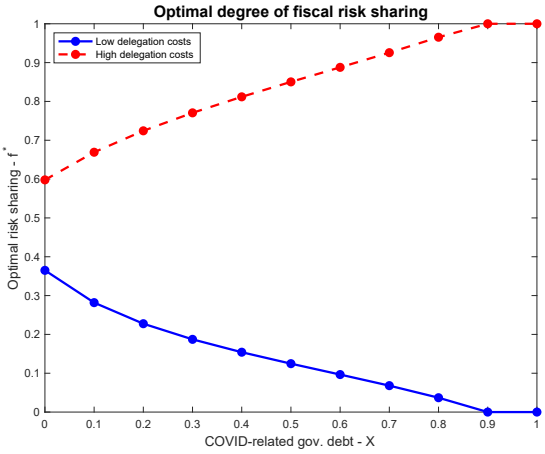
Second, we show that the relationship between optimal risk sharing and optimal centralization depends on how much debt a country eventually contracts in order to address the health emergency (Figure 3). Specifically, the higher the debt, the lesser the responsiveness of expected risk sharing to formal risk sharing, as any ex ante sharing arrangement becomes irrelevant when a country's probability of default come close to one and ad-hoc support becomes more and more likely. Indeed, a larger X requires a monotonically higher degree of centralization. However, transferring of fiscal authority is a costly process, and the maximal level of centralization at the optimum is constrained by the size of such costs (cf. equation (8)). When centralization is low, risk sharing must be rather large ($f^* > 1/2$) and a surge in COVID-related debt requires increasing the degree of risk sharing. On the contrary, when centralization is high, risk sharing is low ($f^* < 1/2$) and a further increase in X makes f^* shrinking further. To understand this better imagine that X is at or close to 0 and f is low; hence, increasing f reduces the probability of ad-hoc support and the associated welfare loss from moral hazard by more than it lowers the expected level of risk sharing. However, when X rises, the effect of raising f on the likelihood of a sovereign crisis vanishes, and it becomes optimal to reduce the degree of formal risk sharing.

This leads to our third result: the level of debt incurred by any given country in fighting the pandemic also bears on how the costs of centralization affect the optimal risk sharing/delegation combination (Figure 4).[22] When centralization is relatively expensive, because of administrative costs or lack of political buy-in for example, centralization of fiscal authority is heavily constrained, and it is optimal for all member countries to agree on a high degree of risk sharing ($f^* > 1/2$) to offset the consequences of a possible default in any member country. In such circumstances, the optimal degree of risk sharing increases as COVID-related debt surges: a higher f reduces the increasing expected costs of a sovereign default by more than it raises moral hazard costs. Since the sensitivity of moral hazard costs to f diminishes as X gets larger (see the left panel of Figure 2 and Equation (5)), setting a high level of risk sharing upfront proves increasingly effective when more debt is needed to face the pandemic. This is because the reduction in EU losses attainable through greater risk sharing is larger than the reduction that would accrue through an expensive centralization of fiscal powers. By converse, when centralization is cheap, it pays to transfer more fiscal powers and share less fiscal risks ($f^* < 1/2$). For larger debt, both the likelihood of a sovereign default and moral hazard increase. Thanks to the low transferring costs of fiscal authority, moral hazard can be largely off set by stronger centralization. However, additional debt diminishes the sensitivity of moral hazard to f (symmetrically to the case of high centralization costs), inducing also an adjustment in the level of

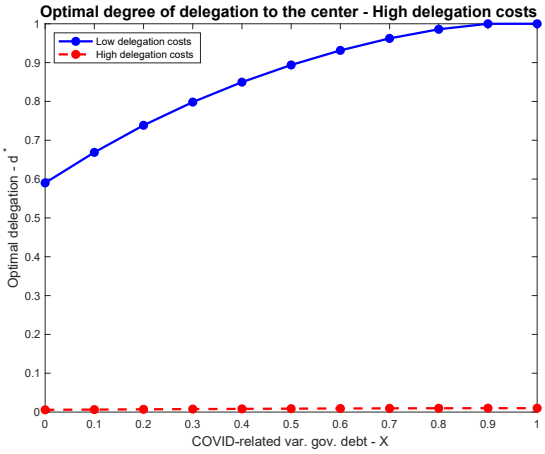
[21] Assuming that b and X are positive but close zero, then the first-order condition for d implies that the planner sets f^* close to $1/2$.

[22] We rely on two scenarios with *low* ($c = 1$) and *high* ($c = 100$) costs of centralization, fixing $b = 0.01$. Such settings are representative of two distinct behaviours of the optimal fiscal integration arrangements that are possible in our setting, and sensitivity analysis is performed in the Appendix (see Figure 6 and 7). The *low cost scenario* is calibrated such that that the cost of full centralization would be slightly lower than the welfare cost of a sovereign bailout, while the *high cost scenario* implies that full centralization would cost 100 times the bailout. The results discussed in the text hold qualitatively when we calibrate b and c differently, as shown the Appendix.

Figure 4: Optimal variation of fiscal risk sharing and delegation to the center for rising COVID-19 related debt of a member country. Parameter configuration: $c_{low} = 1$, $c_{high} = 100$, $b = 0.1$.



(a) Optimal fiscal risk sharing



(b) Optimal centralization of fiscal authority

risk sharing. In practice, the EU can thus improve welfare by raising the expected support to the member country, which requires to diminish the level of f (see Figure 2), and compensate the double effect of changes in X and f on moral hazard by leveraging on (cheap) centralization.

4 Discussion and conclusions

In this paper we have employed the framework of Berger et al. (2019) to study whether there is merit in pursuing greater EU fiscal integration to respond to the health and economic crisis triggered by the COVID-19 pandemic. To that end, we have examined alternative strategic policy interactions between the EU and a representative member country that needs to decide the size of its fiscal response. The country faces a trade off: a weak fiscal response may be insufficient to halt the pandemic and support the economy, while a stronger response may be out of reach if fiscal space is limited.

We show that fiscal integration is a desirable characteristic of the EU response to the COVID-19 crisis: the magnitude of the shock and its asymmetric nature imply a dispersion in the ability of countries to respond and, thus, a heightened probability of sovereign debt crises in the EU absent mutualized support from the center. The analysis indicates that in this case the EU Treaty's "no-bail-out" clause becomes not credible (in line with Berger et al. 2019), while the introduction of some sort of fiscal risk sharing is welfare improving.

In this scenario, it is key to devise ways to ensure that mutualizing fiscal risks at the EU level does not give rise to moral hazard - the incentive for individual countries to overspend, freeriding on the risk sharing arrangements. Innovatively, we show that a strong centralization of fiscal authority to the EU is needed when moral hazard is high, but the optimal amount of fiscal risk sharing and centralization depend on the amount of COVID-related debt incurred by any given country. When a country has high public borrowing needs, the amount of support that the country expects to receive in the case of a shock is less responsive to commitments to shared risk ex ante. In this case, even a modest amount of formally-arranged risk sharing can go a long way in maximizing the EU economic benefits by containing both the probability of a bailout and the actual losses in cases a default becomes inevitable. As earlier literature, we reaffirm that additional economic gains in minimizing losses can be attained

by combining risk sharing with outright delegation of some national fiscal spending decisions to the EU itself, for example through a mechanism that conditions delegation to the pursuit of some common EU goals. The benefits of centralization depend on the costs of transferring power to the center, as shown by earlier literature as well. In this respect, we demonstrate that when fiscal centralization costs are elevated, because of administrative costs or lack of political buy in for example, risk sharing should do the lion share in the risk/sharing/centralization mix and that such degree of risk sharing and centralization increases as COVID-related debt surges. The opposite is true when delegation is inexpensive: a social planner would substantially strengthen fiscal centralization at the EU level and increasingly commit to an ad-hoc intervention in case of sovereign default.

While stylized, our results provide basic insights on the relative costs and benefits of risk sharing versus fiscal delegation in the context of the current EU debate. The EU response so far has been broadly in the direction of providing a fiscally integrated response to the COVID crisis: as discussed in Section 2, both the SURE, the Recovery Fund and the ECB's quasi-fiscal stimulus involve substantial risk sharing. At the same time, conditionality both under SURE and the Recovery Fund mimic a mechanism of fiscal delegation, whereby Brussels decides the way monies should be spent at the country level and monitors deployment. Against that background, our findings tentatively indicate that aiming for more or less rigid spending conditions (i.e. a weaker or stronger delegation), should reflect the administrative and political costs of fiscal conditionality that comes with the funds. Finally, the benefits from delegation will depend on the economic and social returns of fiscal conditionality. While examining this is beyond the scope of this paper, it is plausible to expect that ensuring that monies are spent on projects capable of making the recovery more durable and more sustainable should reinforce the benefits of delegation.

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Appendix

First order conditions - analytical passages

Here we report the passages leading to the conditions from which we derive the optimal degree of delegation to the center d^* and optimal level of formal fiscal risk sharing f^* (see section 3.2). The welfare function of the social planner is given by

$$\begin{aligned} W &= (1-MH)\hat{f} - \hat{B} - C \\ &= \{1-[1-(1-X)f+(1-X)f^2](1-d)\}[1-(1-X)f+(1-X)f^2] - (b+X)[1-f(1-X)] - c\frac{d^2}{2}. \end{aligned}$$

We start by evaluating the first order con with respect to d:

$$\begin{aligned} \frac{\partial W}{\partial d} &= [1-(1-X)f+(1-X)f^2][-1+(1-X)f-(1-X)f^2](-1) - dc \\ &= [1-(1-X)f+(1-X)f^2]^2 - dc = 0, \end{aligned}$$

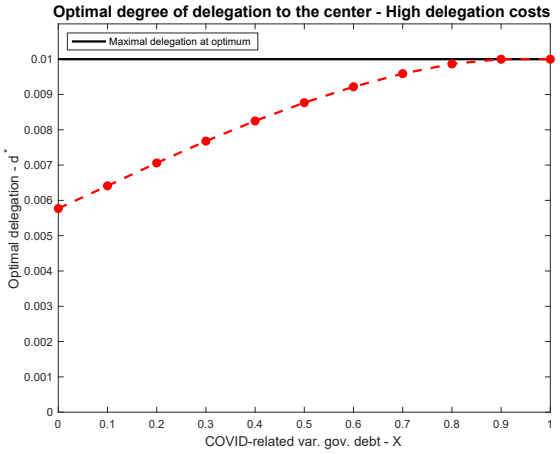
from which Equation (9) is immediate. The first order condition with respect to f implies

$$\begin{aligned} \frac{\partial W}{\partial f} &= [-(1-d)(1-X)+(1-d)(1-X)2f]\hat{f} + [1-\hat{f}(1-d)][-(1-X)+(1-X)2f] + (1-X)(b+X) && (11) \\ &= -(1-X)(1-d)[-1+2f]\hat{f} + [1-\hat{f}(1-d)](1-x)(-1+2f) + (1-X)(b+X) && (12) \\ &= (1-X)\{-(1-d)(-1+2f)\hat{f} + [1-\hat{f}(1-d)](-1+2f) + b + X\} && (13) \\ &= (1-X)\{(-1+2f)[-(1-d)\hat{f}+1-\hat{d}(1-d)] + b + X\} && (14) \\ &= (1-X)\{(2f-1)[1-2(1-d)\hat{f}] + b + X\} = 0, && (15) \end{aligned}$$

where $\hat{f} = 1-(1-X)f+(1-X)f^2$.

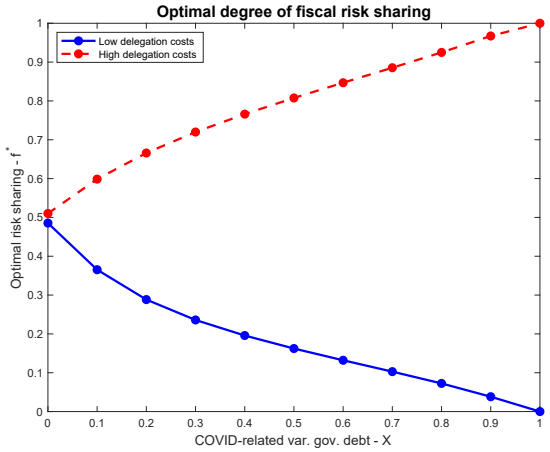
Optimal delegation with high delegation costs

Figure 5: Optimal delegation to the center. This is a zoom of figure 4b. The maximal delegation at the optimum corresponds to $d^* = 1/c = 0.01$.

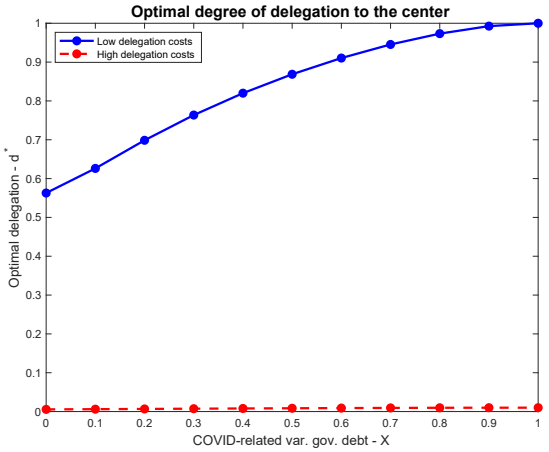


Sensitivity

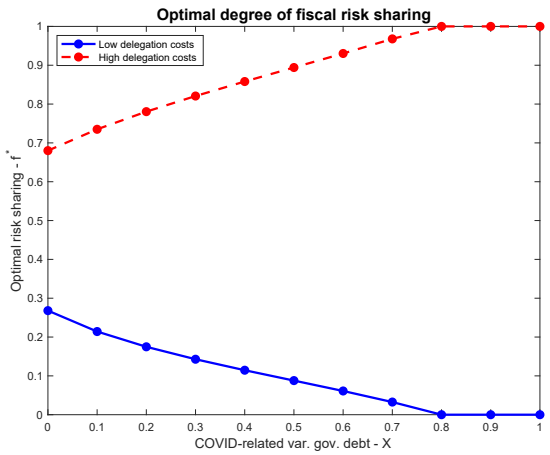
Figure 6: Sensitivity of the optimal fiscal risk sharing and delegation to the center to b (welfare costs of bailout). Parameter configuration: $c_{low} = 1$, $c_{high} = 100$.



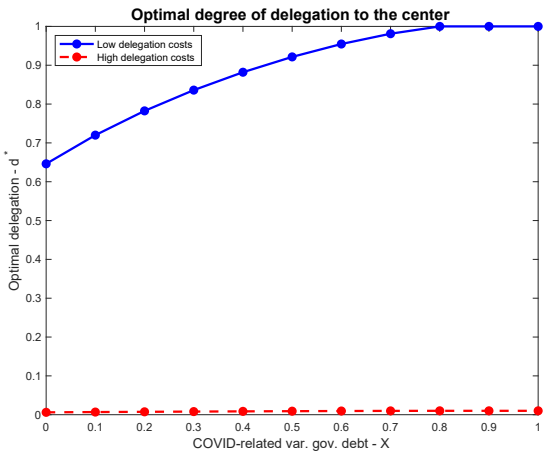
(a) $b = 0.01$



(b) $b = 0.01$

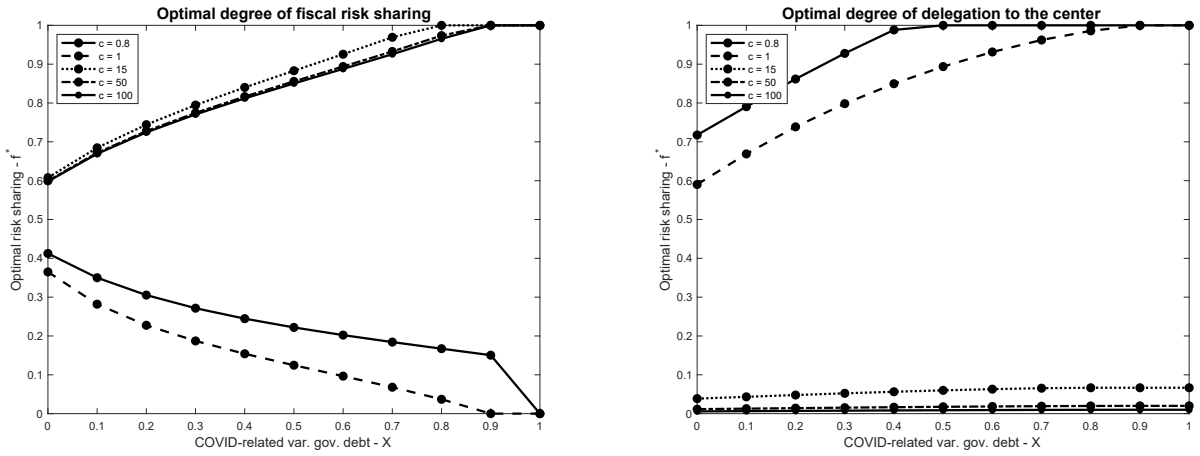


(c) $b = 0.2$



(d) $b = 0.2$

Figure 7: Sensitivity of the optimal fiscal risk sharing and delegation to the center to c (cost of delegation). Parameter configuration: $b = 0.1$.



(a) Optimal fiscal risk sharing

(b) Optimal delegation to the center