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Climate-Related Stress Testing: Transition Risk in Colombia

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Abstract

This paper builds a framework to quantify the financial stability implications of climate-related transition risk in Colombia. We explore risks imposed on the banking system based on scenarios of an increase in the domestic carbon tax by using bank- and firm-level data. Focusing on the deterioration of firms' balance sheets and the exposure of banks to different sectors, we assess the extent to which such policy shock would transmit from nonfinancial firms to the banking system. We observe that sectors are affected unevenly by a higher carbon tax. Agriculture, manufacturing, electricity, wholesale and retail trade, and transportation sectors appear to be the most important in the transmission of the risk to the banking system. Results also suggest that a large increase in the carbon tax can generate significant but likely manageable financial stability risks, and that a gradual increase in the carbon tax to meet a higher target over several years could be preferable in terms of financial risks. A gradual increase would also have the benefit of allowing for a smoother adjustment to higher carbon tax for stakeholders.

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GLOSSARY

BAU	Business-As-Usual
BUR	Biennial Update Report to the UNFCCC
BvD	Bureau van Dijk
CH4	Methane Gas
CO2	Carbon
GHG	Greenhouse Gases
ICR	Interest Coverage Ratio
IDB	Inter-American Development Bank
NDC	Nationally Determined Contributions
NGFS	Network for Greening the Financial System
UVT	Tax Value Unit

I. Introduction

"We consider climate change a systemic risk to the macroeconomy and one in which the IMF is deeply involved through its research and policy advice."
Kristalina Georgieva (Managing Director of the IMF), 2019

Climate crisis, the existential challenge of humanity, is at the door. Many countries across the globe have already been experiencing havoc in the form of loss of lives and repercussions on economies from more frequent climate-related natural disasters. The longer the world delays needed actions, the greater and more irreversible the damage to the planet. Global temperatures have increased by about 1°C since the pre-industrial period because of the accumulation of heat-trapping greenhouse gases (GHG) in the atmosphere. In the absence of decisive and swift measures to reduce emissions of GHG, temperatures can increase by an additional 2° to 5°C by the end of this century, imposing detrimental physical and economic damage and increasing the risk of catastrophic consequences across the globe (IMF, 2020a; IMF, 2020b).

Containing temperatures at safe levels requires reducing carbon (CO2) emissions substantially, and without further delays. Economic policies are the key to achieving a sizable and rapid reduction in emissions, although such policies require careful consideration (IMF, 2019a). Among those policies, carbon taxes are the most common and viewed as "the single most powerful and efficient tool to reduce domestic fossil fuel CO2 emission" (IMF, 2019b; World Bank, 2019). Moreover, an increase in the carbon tax provides revenues for governments; which "should be allocated to reorient public finances in support of sustainable and inclusive growth" (Lagarde and Gaspar, 2019).

Limiting global warming to 2°C or less, deemed as safe by scientists, requires an increase in carbon tax around the world, including an immediate global carbon tax that should reach the target of US$75 per ton of CO2 by 2030 (IMF, 2019b; Georgieva, 2019). Considering the current situation across the world, this stands out as an ambitious policy shift. As of now, only about 50 countries have a carbon pricing scheme, and the global average carbon price is about US$2 per ton, much lower than what is needed (IMF, 2019b; Gaspar and others, 2019). The vast majority of countries, therefore, have a long way—but short time—to go, leading many to consider the risks of a disorderly transition, as the Network for Greening the Financial System (NGFS) has coined such a scenario. More research on the associated costs and benefits of such policy change, along with related data, is also needed to inform policy makers.

In this regard, the IMF stress testing exercise has been adapting to the new challenges, such as the climate crisis, over the years. The IMF has incorporated macrofinancial transmission of climate-related risks into the stress testing exercises. It has become an important extension in the general stress testing framework (Adrian and others, 2020). Macrofinancial transmission of climate-related risks can be grouped into two broad categories: physical and transitions risks, where physical risks stem from damage to property and assets, while transition risks can arise from changes in policies or technologies. Physical risks can be caused by increasing temperatures or climate-related disasters, while transition risks emerge during transition to a greener economy. For the financial system, risks can materialize through the direct channel, i.e., exposures of financial institutions to nonfinancial corporates and households, or through indirect channels, i.e., the effects of climate change on the broader economy and feedback cycles within the financial system.

While physical risk analysis has been an integral part of previous IMF stress tests (e.g., Bahamas and Jamaica), this paper aims to complement the IMF's climate-related stress testing framework with the introduction of transition risk analysis. Stress testing for the transition to a low-carbon economy is a new and rapidly evolving field. It is crucial, however, since, adding climate-related transition risks into the stress testing exercises will inform policymakers on the related risks and opportunities; and in turn help them design climate mitigation policies better. In this regard, a recent example of stress testing focusing on climate-related transmission risks at the IMF is by Grippa and Mann (2020) in the case of Norway. This, however, is the first study that attempts to quantify the macrofinancial transmission of transition risks in case of an emerging market economy, Colombia, using detailed firm- and bank-level data.

In broad terms, climate-related transition risks can be summarized as the risks from the transition to a low-carbon economy that emits less GHG. Among other factors, transition risks can be driven by changes in policy (e.g., an increase in the carbon tax or introduction of other sorts of regulations), a shift on the external demand of oil (e.g., driven by higher emission taxes in the rest of the world), advances in technology (e.g., greener technologies), or a change in the public opinion, which may all go hand in hand.

In this study, we explore a specific transition risk in Colombia, namely the risk imposed on the banking system in the aftermath of a change in policy. We focus on an increase in the carbon tax, since it is the most common policy approach to reduce emissions across the globe and is viewed as effective (also considering revenues generated by governments). Based on several "what if" scenarios and a granular approach, we aim to answer two main questions: How would a sharp increase in domestic carbon pricing in Colombia affect the banking system in the short-term? How would the financial stability implications of such policy-driven transitions risks change if policymakers preferred a gradual increase in the tax to achieve a higher carbon price?

The main challenge for evaluating the transition risks is that those risks are complex, multifaceted, and in turn, hard to model with potentially second- and higher-round effects (Adrian and others, 2020). Thus, to keep the analysis tractable, we rely on several simplifying assumptions (such as no-pass-through on firms' side, and a static stress test). Furthermore, we specifically focus on the direct transmission channel through the exposure of the banking system to nonfinancial corporates. We use a rich and comprehensive firm-level dataset from ORBIS to measure the level of stress in firms' balance sheets; and bank-level data from the national authorities to evaluate the extent of banks' exposures. Our firm-level data is from 2017, and includes both small and medium-sized and large firms as well as private and publicly listed firms, with a wide coverage across sectors. It contains information on both output and balance sheet variables, which is crucial for our analysis. Our bank-level data includes banks' outstanding loans to each sector, as well as banks' total assets.

Figure 1. Colombia: Transmission Channel

Policy change higher carbon tax (scenarios)	→	Nonfinancial firms: carbon emission	→	Impact on nonfinancial firms: balance sheet weakening, higher financial stress	→	Impact on the banking: increased exposure to financially stressed firms

We build a framework to quantify the financial stability implications of transition risk, which works through banks' exposures to nonfinancial corporates (Figure 1). We rely on several "what if" scenarios of a policy shock, i.e., an increase in carbon tax, and estimate how the banking system is affected by this policy shock through its exposure to nonfinancial firms. The procedure is as follows. We start with estimating CO2 emissions at the sector-level. Second, we adjust those values based on firms' output in order to estimate the additional burden (in the form of new liabilities) imposed on firms` balance sheets by an increase in the carbon tax. We then identify firms that are under financial stress in the aftermath of an increase in the tax, where we proxy firms' financial stress using alternative measures, i.e., financial liquidity or leverage. The third step is to calculate the share of financially stressed firms in each sector. Finally, we merge this information with the bank-level exposures to each sector in order to quantify the risk imposed on the banking system by each sector, i.e., to estimate bank loans at risk due to the increase in the carbon tax.

Our results are four-fold. First, transition risks driven by a higher carbon tax are more concentrated in some sectors. Agriculture, manufacturing, electricity, wholesale and retail trade, and transportation sectors appear to be the most important in the transmission of risk to the banking system. Second, in the first scenario of a sharp US$70 per ton increase in tax (from the current US$5 per ton level) to meet the US$75 per ton target, we observe sizeable, but potentially manageable risks for the banking system. Banking loans at risk can be as large as 13.6 percent as a share of banks' total outstanding corporate loans, and 4.9 percent as a share of banks' total assets, based on different measures and methodologies. Third, we also find that risks are unevenly distributed across individual banks. Banks that are more exposed to those five sectors are much more affected by an increase in carbon tax. Finally, we quantify transitions risks under alternative scenarios with lower (US$20, US$15, and US$10 per ton carbon) increases in carbon tax. Risks are much lower in those cases (e.g., loans at risk are under 1 percent of banks` assets in some cases), as could be expected. This suggests that gradual increases over years to meet the target of US$75 per ton, instead of a one-time sharp increase, may be preferable in terms of a smoother adjustment for the financial sector and other stakeholders.

Although we attempt to account for the potential effects of the COVID-19 pandemic on transition risks to some extent, our scenario analyses do not cover the pandemic, since we use the firm-level data from 2017—the latest available. While there has been a temporary reduction in emissions in the earlier stages of the ongoing pandemic (IMF, 2020b), achieving a permanent reduction remains a priority. An assessment of climate-related transition risks gains more importance in the post-COVID-19 world since the pandemic has brought both new challenges and new opportunities for climate policies. Countries need to set the stage for a greener recovery. Climate mitigation policies can help countries achieve a sustainable growth path in the longer term (e.g., by alleviating physical risks). On the other hand, costs associated with transition to a low-carbon economy may materialize in the shorter term, when countries will be struggling to put the economy back on track. This raises the need and urgency for a detailed consideration of how climate-mitigation policies should be designed in a holistic and growth-friendly way, with protection for the poor and the most affected (IMF, 2020b). In this regard, carbon taxes provide a new tool for governments since they generate much needed revenues. A key is to manage the transition process comprehensively, which "typically involves a gradual phasing in of carbon pricing and explicit communication on the use of the associated revenue. The latter will have to balance distribution, efficiency, and political considerations" (Lagarde and Gaspar, 2019). This is even more crucial in case of emerging market economies, considering the existing social challenges and political economy constraints to deal with in the process of transitioning to a low-carbon economy.

The rest of this paper is organized as follows. Section IA reviews the literature. Section II introduces the data on carbon emissions and pricing in Colombia; as well as firm- and bank-level data. Section III explains the framework for the transmission of the stress to the banking system from nonfinancial firms. Section IV documents and discusses results from Scenario 1, i.e., a sharp US$70 per ton increase in the carbon tax. Section V considers few other scenarios with less dramatic increases in the carbon tax, such as US$20, US$15, and US$10 per ton. Section VI argues potential influence of the COVID-19 shock on the findings. Section VII concludes.

A. Literature

The disruptive consequences of physical risk stemming from climate change in Colombia, both in the recent past and in the future, are well documented. Joint work by the Colombia National Planning Department, the Inter-American Development Bank (IDB), and the Economic Commission for Latin America and the Caribbean (ECLAC) has shown that climate change can be expected to have an average impact of -0.5 percent on annual GDP growth for every year between 2010 and 2100 (BID-CEPAL-DNP, 2014). The cumulated effect of climate change at this horizon (without discounting at the present value) would then be equivalent to losing about 3.6 times the total value of the 2010 GDP. The same study looked at the impact of climate change by sectors and found heterogeneous effects, agricultural and transport industries being the most vulnerable to lose between 5.9 percent and 7.4 percent of production on average every year between 2010 and 2100.

The World Bank has also studied the macroeconomic and sectoral consequences of low-carbon development in Colombia (World Bank, 2014). In particular, the issue of "green taxes" was examined and found to have a limited impact on the economy when done through fiscal interventions that reinvest the taxes to generate jobs, while still reducing greenhouse gas emissions. Moreover, it is found that the energy sector would be most affected.

The effect of carbon taxes on the level of greenhouse gas emissions in Colombia has also been studied by Calderon and others (2016), who use both partial and general equilibrium models to simulate the way that taxes and abatement targets can achieve significant reductions in CO2 levels. Significant effects of 2 percent to 3 percent decreases in GDP are also found. Romero and others (2018) build on this work using a sectoral general equilibrium model to analyze the distributional consequences of the Colombian carbon tax; however, they find a much more limited impact, concentrated in the highest-income quintile of the population, which leads them to deem the tax progressive.

Although the interactions between climate and economic variables have been studied for a relatively long time (for a review, see Dell and others, 2014), quantitative analyses on the financial stability implications of the transition to a low-carbon economy have started to attract attention more recently. The field is still new and rapidly developing.

Some early work on modeling the effects of environmental fiscal reforms on economic conditions (but not financial stability) can be traced back to Bach and others (2002), which uses an econometric input-output model and a dynamic computable general equilibrium model to simulate the effect of increases in tax rates of gasoline, diesel, and electricity in Germany between 1999 and 2003. The authors find that energy consumption and CO2 emissions decrease while employment rises, driven by the use of the revenue to decrease pension insurance costs as part of the environmental package. Moreover, the authors find that "the impact on growth is minimal," and that fears "that the environmental fiscal reform might interfere with the goals of social and income-distribution policy are largely unjustified."

The financial stability consequences of a transition to a low-carbon economy were first analyzed by Weyzig and others (2014), who consider the exposure to fossil fuel producing firms of 20 banks and 23 pensions funds in the European Union (EU), which exceed €1 trillion. They propose a variety of scenarios regarding the speed of transition and the subsequent profitability of the fossil fuel industry. And although the authors find that a carbon bubble alone is unlikely to be a source of systemic risk, they also acknowledge that such a shock could cause significant losses for EU financial institutions and find that a slow transition would be more costly and potentially more disruptive to financial stability.

Battiston and others (2017) expanded the analysis of financial stability of banks in the Euro Area by considering not only direct exposures to fossil fuel companies, but also indirect exposures, which can propagate risk via networks of financial dependencies. These second-round losses due to the devaluation of banks' counterparties' debt obligations are found to be, on average, larger than first-round losses. The authors also underscore the importance of timing: while "an early and stable policy framework would allow for smooth asset value adjustments," sudden and late transitions could have severe adverse effects on financial stability.

Work by Vermeulen and others (2019) from the Dutch Central Bank presents a comprehensive framework for analyzing financial stress under scenarios with a disruptive transition to a low-carbon economy. Their scenarios consider both climate policy and energy technology and capture industry-specific transition risks. Applied to the balance sheets of more than 80 Dutch financial institutions, they find that financial losses can be sizeable and that authorities should closely monitor risks to financial stability from climate transition.

The closest to this study is the pioneering work by Grippa and Mann (2020), focusing on the climate-related transition risks in the case of Norway, using ORBIS firm-level data and a framework similar to this study. Their results point to a significant but manageable impact on financial stability due to transition risk arising from an increase in the carbon tax in Norway. Since we use different measures of financial risk at the firm-level (due to different variables available in the ORBIS database),[1] our quantitative results are not comparable to theirs.

To the best of our knowledge, this is the first study evaluating the financial stability implications of a climate-related transition risk (driven by a higher carbon tax) for an emerging market economy by using detailed bank- and firm-level data.

II. Data and Facts

A. Carbon Emissions

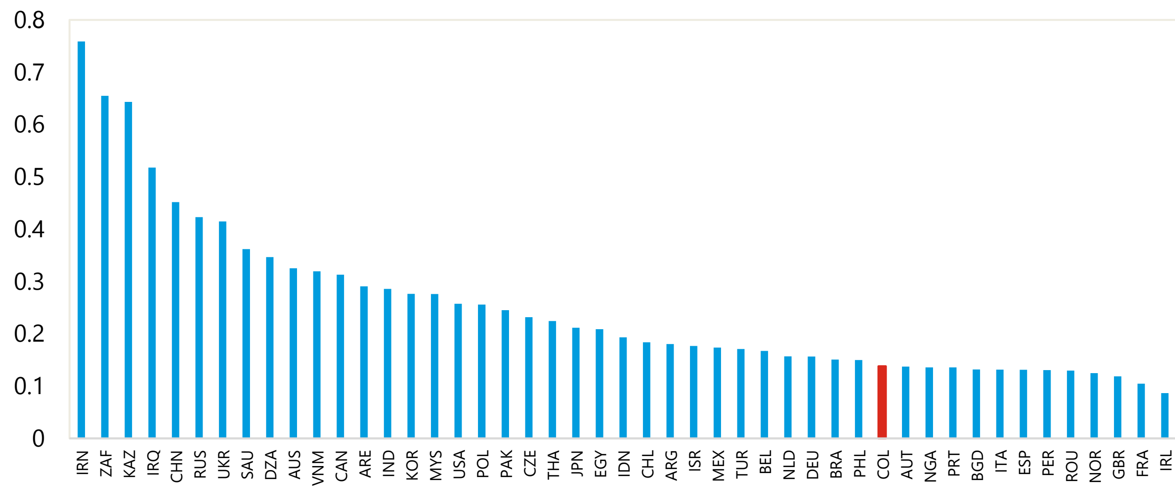
Context

According to Colombia's Second Biennial Update Report to the UNFCCC, referred to as BUR from now on, Colombia's gross greenhouse gas emissions for 2014 equaled 236 million

[1] The authors measure financial risk at the firm-level based on interest coverage ratio. However, data on interest expenses are not available for Colombian firms. Therefore, in order to proxy for firms' financial risk, we adopt leverage and financial liquidity (to be explained below) instead.

tons of CO2-equivalent (BUR, 2018). Compared to the size of its economy, however, carbon dioxide (the main GHG) emissions from Colombia are relatively low (Figure 2). This is mostly due to its extended use of hydro power for energy generation, as well as limited carbon-intensive manufacturing. Compared to peers like Brazil, Chile, and Mexico, Colombia’s emissions per unit of GDP are lower. In fact, Colombia’s emissions per output are lower than 69 percent of the countries across the world. In this sense, Colombia is likely to be better positioned to implement policies to reduce carbon emissions, which are already lower than in many countries.

Figure 2. Colombia: CO2 Emissions per Output (2019)



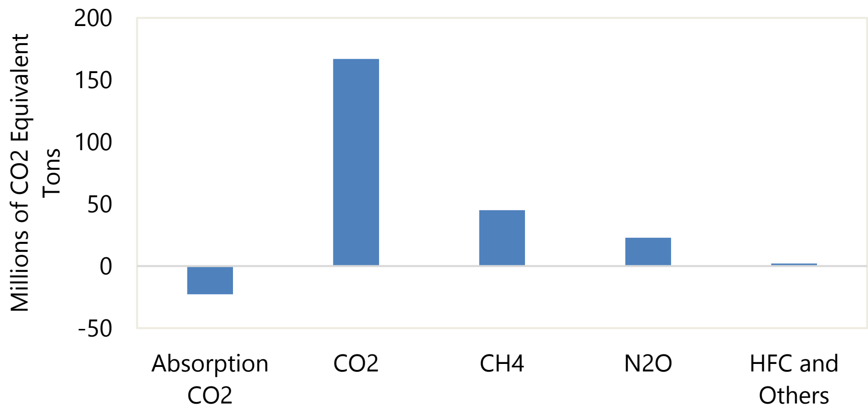
Source: Global Carbon Budget, World Bank, IMF Staff calculations.
Notes: The figure reports CO2 emissions in 2019 (kg per 2017 PPP USD of GDP) for 50 largest economies.

Greenhouse gas emissions and commitments

Despite this relatively low-carbon economy, Colombia is still aiming high in terms of carbon emission reductions. Colombia was one of 71 countries that updated its Nationally Determined Contributions (NDCs) in 2020, in accordance with the Paris Climate Agreements. Compared to its previous 2015 goal of reducing economy-wide emissions by 20 percent below business-as-usual (BAU) emissions by 2030, the updated target of reducing emissions by 51 percent by the same year is among the most ambitious in the region. The projected BAU emissions by 2030 amount to 345 megaton (Mt) CO2-equivalent, meaning the revised commitment to cap emissions at 169 Mt CO2-equivalent implies a reduction of 28 percent with respect to the 2014 emissions reported in the BUR. Although significant model and scenario-uncertainty prevent us from pinning down the exact climate policy mix at which Colombia can hope to reach its revised goals by 2030, achieving such a reduction in net emissions is likely to require the widespread adoption of aggressive carbon taxes.

Although there are many different gases that cause greenhouse effects, the most important ones for Colombia are CO2 (carbon dioxide) and CH4 (methane). Each chemical has a different heat trapping capacity[2] and as such, to compare emissions of different gases one must use equivalent measures of CO2. Figure 3 shows that CO2 emissions account for close to 70 percent of the country's gross emissions in equivalent units. Moreover, CO2 absorption offsets only 13 percent of the CO2 emitted.

Figure 3. Colombia: Colombia's Greenhouse Emissions by Gas (2014)



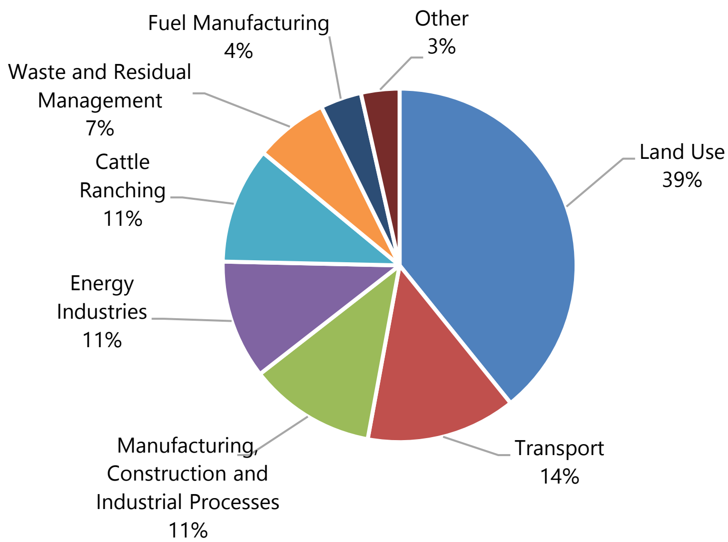
Source: BUR (2018) and IMF Staff calculations.

Greenhouse gas emissions by activity and sector

We follow closely and use as our main source the inventory of greenhouse gas emissions developed in the context of the BUR (2018), which reports individual emissions by activity. Figure 4 shows that close to 40 percent of the carbon dioxide emissions in Colombia come from the use of the land for agricultural processes, as well as land transformation related to deforestation.

[2] A ton of methane, for instance, has the equivalent effect on heat trapping in the atmosphere as 84 tons of carbon dioxide over a 20-year horizon. These equivalencies, however, are horizon-dependent. When available we have used the equivalency numbers from the IDEAM. Otherwise, the horizon used to convert between gases was 20 years.

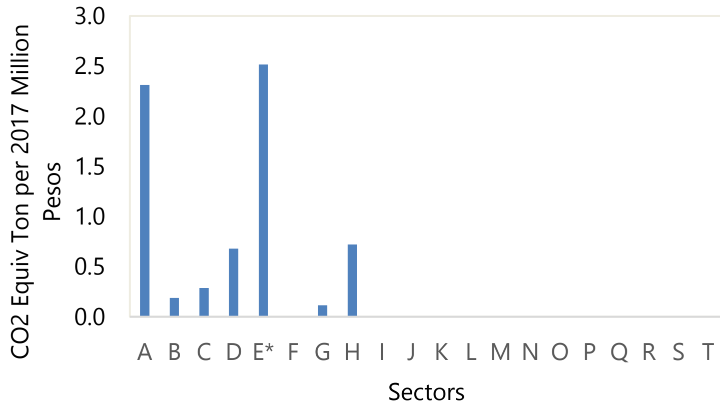
Figure 4: Net Greenhouse Gas Emissions by Activity (2014)



Source: BUR (2018) and IMF Staff calculations.
Notes: The percentages are based on the net greenhouse gas emissions expressed in CO2 equivalent tons.

We want to associate greenhouse emissions with economic activity and economic output at the sector-level and estimate individual rates of emissions per output at the sectoral or sub-sectoral levels. However, companies and sectors often emit greenhouse gases from different activities, and knowing, for example, what proportion of all transport emissions come from the transport activities of each sector is not feasible. Our solution is then to allocate emissions from each activity to the major sector (from 1-digit NACE Revision 2) associated with it. We avoid double-counting by matching each activity only to one sector (or a sub-sector when granular data is available). Then, using GDP data for 2014 we arrive at estimates of emissions per unit of output. Because the activities in the original greenhouse gas emission inventory source are mainly for the primary and secondary sectors, we only get estimates for sectors A-F and H from this source. In order to estimate emissions from tertiary sectors (such as services and retail activities), we use data from Exiobase. Exiobase reports CO2, N20, and CH4 emissions for all economic activities, including those in the services sector. However, Colombia is not covered by Exiobase. We instead use a similar country's (Brazil) to estimate the emissions per economic output in sectors G and I-T, and then convert these to estimates in Colombian pesos using the appropriate exchange rate. Figure 5 presents emissions per output for all sectors from this exercise. Note that emissions in the tertiary sectors from Exiobase are all well below 0.01.

Figure 5. Colombia: Estimated Net Emissions per Output (2014)



Source: DANE, BUR (2018), Exiobase and IMF staff calculations.
Notes: Sectors with NACE 1 codes: A - Agriculture, forestry and fishing; B - Mining and quarrying; C – Manufacturing; D - Electricity, gas, steam and air conditioning supply; E* - Sewerage, waste management and remediation activities; F – Construction; G - Wholesale and retail trade; repair of motor vehicles and motorcycles; H - Transportation and storage; I - Accommodation and food service activities; J - Information and communication; K – Financial and insurance activities; L - Real estate activities; M - Professional, scientific and technical activities; N - Administrative and support service activities; O - Public administration and defence; compulsory social security; P – Education; Q - Human health and social work activities; R - Arts, entertainment and recreation; S - Other service activities; T - Activities of households as employers of domestic personnel. For sectors A-F and H, emissions from the activities described in BUR (2018) are matched to the output of individual sectors as reported by the DANE. For sectors G and I-T, emissions per output are estimated from corresponding Brazilian data in Exiobase, doing the same exercise of matching net greenhouse gas emissions in CO2 equivalent tons to the output of individual sectors.

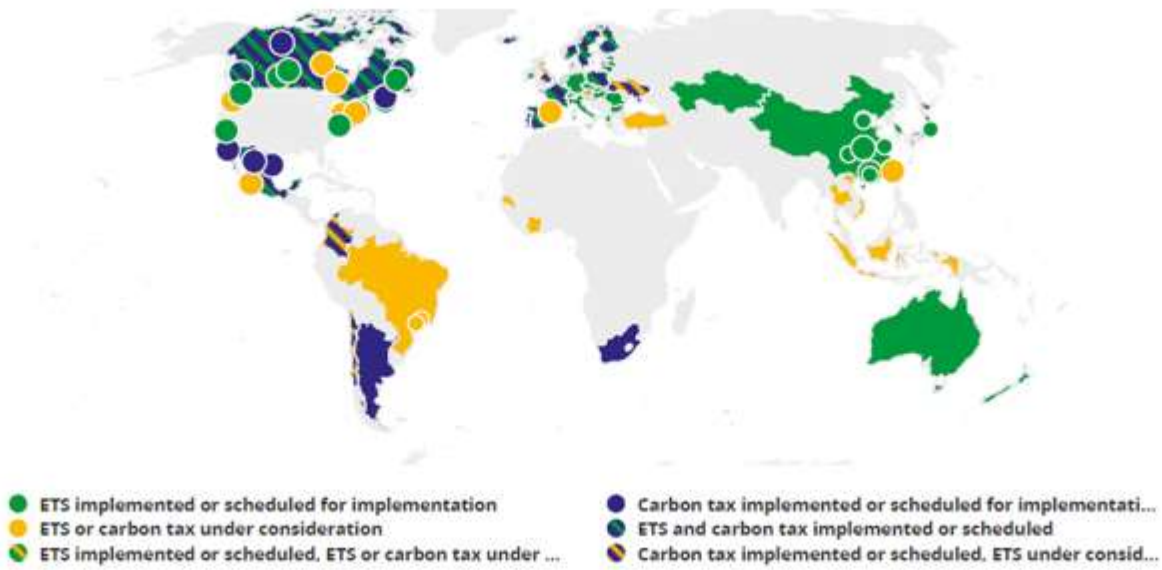
These estimates of emissions per economic activity are the basis for our stress test, as we use them to estimate new liabilities imposed on firm's balance sheets due to an increase in carbon tax. Since emissions are not available at the firm-level, the methodology assumes that firms are representative of the average emissions per output of the sector, although in reality there will be some variability within firms in the same sector.

B. Carbon Pricing in Colombia

Context

Across the world, national initiatives have been developed to tax carbon dioxide emissions, disincetivize the emission of greenhouse gases, and incentivize the transition to carbon-neutral economic activities. Despite this, no global carbon pricing scheme exists, and close to all existing intiatives fall short of the US$50 to US$100 estimated tax that would be necessary for countries to meet their commitment to the Paris Climate Agreement. According to the World Bank (2021), carbon pricing initiatives, including carbon taxes and ETS have been introduced in four countries in Latin America: Argentina, Chile, Colombia, and Mexico (Figure 6).

Figure 6. Colombia: Summary Map of Regional, National and Subnational Carbon Pricing Initiatives



Source: World Bank Carbon Pricing Dashboard.

Definition of the implemented tax

The Colombian carbon tax, known as the "Impuesto Nacional al Carbono," was one of the first among emerging market economies. It was introduced in 2017 as part of a structural tax reform. It covers the carbon content of all fossil fuels that are used for combustion, including oil and gas fuels such as gasoline, kerosene, and fuel oil. The tax burden is generated at the point of sale, withdrawal or import inside the country for consumption or sale, and is only taxed once, at the top of the sale chain during whichever event occurs first. As such, the tax causes indirect effects downstream to final users and consumers (such as households buying gasoline for their cars) via higher prices rather than direct tax collection.

Coverage, exemptions, and differences with emissions

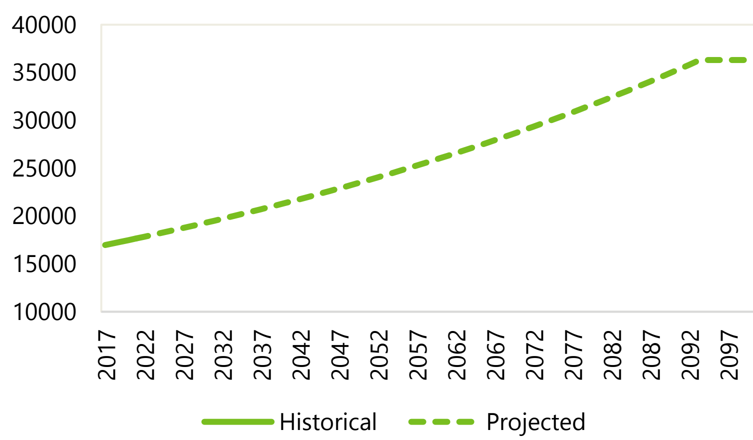
As is stated in its definition, the existing carbon tax is limited to indirectly taxing greenhouse emissions resulting from the use of oil and gas fuels through combustion. In this sense, the scope of the tax is limited—the emission of other greenhouse gases (like N2O and CH4) are not contemplated as generating a tax liability, nor is the emission of carbon dioxide stemming from other processes and practices, such as coal burning, agricultural burning, residue management, or land transformation. Moreover, certain transactions and sectors are exempt from the tax, including exports as well as carbon neutral companies; a carbon offset system was introduced in 2017, which allows companies to claim exemption status when they can prove their investments in green projects of carbon emission reductions and capture. These exemptions, it is understood, are in place in order to maintain competitiveness and incentivize innovation, as well as the participation of private companies in the green technological transition. All in all, estimates of the coverage of the Colombian carbon tax range between 24 percent (World Bank, 2021) and 40 percent (IMF 2019b) of all the country's greenhouse gas emissions.

Tax level, evolution, and future schedule

The tax was introduced at a level of Co$15,000 per CO2 ton (adjusted individually to each fossil fuel). By law, the tax is to be revised in February each year, increasing by the previous year's inflation rate plus one percentage point until it equals 1 UVT (tax value unit, revised every year according to inflation). The tax for 2021 was set at a level of Co$17,660 or about US$4.96 per CO2 ton. For reference, in 2021 1 UVT—the eventual target level of the tax—was set at Co$36,308, or about US$10.20.

Figure 7 shows the projected schedule for the transition to the target level of 1 UVT. A very slow adjustment is planned: the target won't be reached until 2094. Moreover, even this higher level of tax is still far from the levels at which a carbon tax could support an intense process of decarbonization of the economy. Calderon and others (2016), for instance, report that a 50 percent abatement scenario (reducing emissions by half), corresponding to US$114 per CO2 ton would be required in order for Colombia to become carbon neutral by 2050 (supported in turn by the effective development and deployment of carbon capture and storage technologies). The schedules they propose are much more aggressive, starting at either US$10 or US$50, and growing at an annual rate of 4 percent after that.

Figure 7. Colombia: Colombia's Carbon Tax Projected Schedule (2021 COP per CO2 ton)



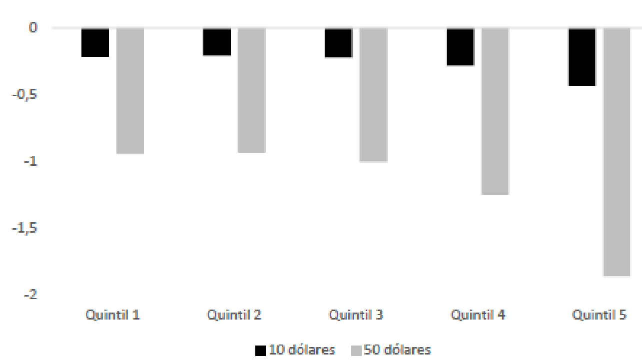
Source: IMF Staff Calculation.

Notes: The projection is made by taking the current level of the tax as announced on February 2021, and increasing it by the real rate of 1 percent as indicated in the current legislation. Because the projection is made using real units and the UVT and the tax itself are also expected to increase based on the previous years inflation, we express the tax rate in 2021 Colombian Pesos per ton of CO2.

Social considerations

As all fiscal policy, carbon taxes are often constrained by political economy factors, often in the form of social pressures. One such consideration concerns what is often described as the regressive nature of carbon taxes: as poorer families spend a higher proportion of their income on food and transport (goods directly affected by the cost of gas), the tax may become an additional burden on them. However, Romero and others (2018) investigate this possibility and find that an aggressive carbon tax, such as the one described in Calderon and others (2016) would have its highest welfare-reducing impacts on the highest quintile of the income distribution (Figure 8). In fact, the middle class would see their welfare impacted the least under their analysis, given their ability to substitute away from goods with higher price increases. Moreover, there is regional variability in the effects they find: the highest decreases in welfare are found in Bogota, while some rural regions like Arauca, Caqueta , and Vichada see relatively muted effects. These findings suggest the regressive nature of carbon tax programs may be overstated, particularly if the additional revenue from the taxes is used to target expenditures that directly or indirectly support low-income and rural households, as is often the case with environmental conservation and protection projects. The impacts of the tax, both across the income distribution and between regions (particularly, the regions that depend on carbon-intensive sectors, such as agriculture and natural resource extraction) should still be acknowledged and further studied, although they fall beyond the scope of our present analysis.

Figure 8. Colombia: Average Welfare Change under Carbon Tax Income by Quintiles (pp)



Source: Romero and others (2018).
Notes: The figure shows the average welfare change under two different carbon tax levels (US$10 and US$50) for the five quantiles of the income distribution using a general equilibrium model calibrated based on sector prices and output.

Revenues

Finally, according to the World Bank, the carbon tax resulted in US$117 million in revenues for the Colombian government in 2020, the use of which may also help address some of the previously mentioned social considerations. Although, in our analysis, we do not evaluate the impact of the fiscal porgrams supported by the new revenues stemming from the carbon tax, it should be noted that in the case of Colombia, the same law that introduced the carbon tax specifies that 25 percent of this revenue is to be destined for a specially set up fund dedicated to projects on environmental conservation and protection. The remaining 75 percent is to be used to finance the implementation of the peace agreement.[3] Insofar as the tax can support environmental and social spending programs, this could help mitigate any possible regressive effects.

Methodology

For our exercise, we consider a much more comprehensive version of the carbon tax than is currently in place. We present the effects of a carbon tax imposed on the basis of all greenhouse emissions, as shown in the estimates in Section II A. As such, they include emissions of GHG, such as N2O and CH4, as well as CO2 emissions from changes in land use, residue management, and combustion of fuels other than oil and gas derivatives, like coal. Moreover, we assume the tax burden falls ultimately on the final emitter of the greenhouse gases rather than on the producer of any particular fuel.

C. Firm-level Data, Sector Distribution, and Variables

Firm-level data is obtained from the ORBIS database, which is compiled by the Bureau van Dijk (BvD). It is a worldwide dataset with detailed information on harmonized balance sheets and income statements of firms. The vast majority of firms in the dataset are private, but there are publicly listed firms as well. With a wide coverage of private and small firms, the ORBIS is different from other datasets, such as Compustat or Worldscope, which only have large listed firms. To ensure comparability, consistency, and quality of the data across years and firms in the ORBIS requires several steps of data cleaning (Kalemli-Ozcan and others 2015; Gopinath and others, 2017). For this purpose, the methodology by Gal (2013) and Gal and Hijzen (2016) is followed.[4]

There are a few emerging market economies with large number of firms in ORBIS. Fortunately, Colombia is one of the few non-European emerging market economies with comprehensive data coverage. Although some variables are missing for the majority of firms (to be mentioned later), ORBIS provides rich enough coverage and useful information for us to analyze climate-related transition risk in Colombia.

We include all nonfinancial sectors with a good number of firms, from agriculture to mining, from manufacturing to service sectors. The sector coverage corresponds to A-S range under

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[3] Collections for carbon tax during the three-year period from 2017 to 2019 were around US$325 million. They were to be invested in environmental areas and projects related to (i) coast erosion, (ii) hydric sources conservation, (iii) ecosystems protection, and (iv) the cost of the peace agreement with FARC.

[4]We refer the reader to Gal (2013), Kalemli-Özcan and others (2015) and Gal and Hijzen (2016) for more detailed descriptions of the ORBIS dataset. We thank Federico Diaz and his unit in the Research Department of the IMF for providing the final dataset.

1-digit classification (Nace 1 Revision 2) and 1-96 range under 2-digit classification (Nace 2 Revision 2), excluding the financial services sector. The reporting in ORBIS has around a two-year lag on average. We use 2017 data, which is the latest available data.

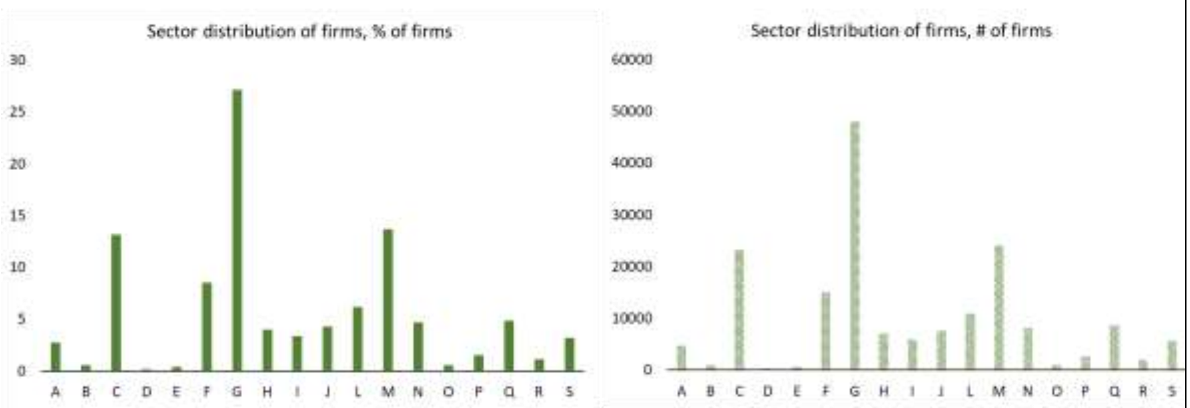
The final dataset has about 178,000 nonfinancial corporates for which the variables of interest are available. Figure 9 reports the share (Panel 1) and the number of firms (Panel 2) in each sector, respectively. The highest number of firms is in the wholesale and retail trade sectors, followed by professional/scientific/technical activies, and manufacturing and construction sectors. The distribution of firms across sectors appears to be representative for the Colombian economy.[5]

The first step in our analysis is to identify nonfinancial firms that go into the financially stressed territory following an increase in carbon tax. For this purpose, we need a proxy at the firm-level to evaluate the change in a firm's financial soundness due to an increase in the carbon tax. A standard proxy for a firm's financial health, or risk, is whether a firm can cover its interest expenses by its earnings, i.e., interest coverage ratio (ICR). This is a very intuitive measure of financial difficulties at the firm-level. Based on this measure, in our case, if the ICR was initially above 1 (i.e., earnings being greater than interest expense), but drops below 1 following an increase in the carbon tax—meaning a firm now cannot cover its interest expenses using its earnings—it would be interpreted as the firm now having financial difficulties due to the policy shock. However, the ORBIS database does not have the information on interest expenses for Colombian firms to calculate the ICR.

[5]See, for example, estimates of the number of companies in Colombia by Economia Aplicada based on data from local Chambers of Commerce available at http://economiaaplicada.co/index.php/10-noticias/1493-2019-cuantas-empresas-hay-en-colombia.

Figure 9. Colombia: ORBIS Firm-Level Data

1. Percentage of firms **2. Number of firms**



Source: ORBIS, IMF staff calculations.
Notes: Sectors with NACE 1 codes: A - Agriculture, forestry and fishing; B - Mining and quarrying; C – Manufacturing; D - Electricity, gas, steam and air conditioning supply; E - Water supply; sewerage, waste management and remediation activities; F – Construction; G - Wholesale and retail trade; repair of motor vehicles and motorcycles; H - Transportation and storage; I - Accommodation and food service activities; J - Information and communication; K – Financial and insurance activities; L - Real estate activities; M - Professional, scientific and technical activities; N - Administrative and support service activities; O - Public administration and defence; compulsory social security; P – Education; Q - Human health and social work activities; R - Arts, entertainment and recreation; S - Other service activities.

Therefore, we use two alternative proxies for a firm’s balance sheet stress. First, we calculate leverage as the ratio of total liabilities to total assets. Second, we calculate what we call (inverse of) financial liquidity, the ratio of current liabilities to current assets. The higher the leverage or the financial liquidity measures, the higher the financial stress. These proxies are still intiutive and are used by the literature to evaluate financial stress or vulnerabilities at the firm-level (among others, see Duval and others, 2020; Ahn and others, 2020; Uras, 2014). For each of these measures, once the ratio becomes higher than 1 in the aftermath of an increase in the carbon tax (from below 1 initially), we identify a firm as financially stressed due to the policy change. Although these are not perfect (or holistic) measures of firm`s financial health, we consider them the best, given the data constraints.

Once we calculate these ratios at the firm-level before the policy change, we incorporate the estimates for carbon emission (per unit output) that we obtain for each sector as described before.[6] In particular, we impose the additional cost (in the form of new short-term liabilities) from an increase in carbon tax faced by each firm. We assume “no-pass-through” (and no further adjustment) and multiply the difference between new and old carbon prices per peso of output with each firm’s output. Therefore, leverage and financial liquidity now change, where both ratios increase with new liabilities stemming from a higher tax. This would

[6]Note that this is due to data limitations. If we had carbon emission data at the firm-level, it would be ideal to use. However, we can only get estimates of carbon emission at the sector-level. Therefore, we need to assume that all firms in each sector emits the same amount of carbon per unit output. Therefore, if any, the effect of within-sector (across-firms) variations in emissions are not captured.

potentially generate a higher number of firms under stress in each sector, relative to pre-policy-change. The extent to which this stress in nonfinancial corporates would transmit to the banking system is crucial for our analysis. For this purpose, we aggregate these firm-level stress measures into the 1-digit sector-level using different approaches (see Section III) and match that information with the banking exposures to sectors, as we discuss in the next section.

Before going into the details of the banking data, we would like to emphasize what the "no-pass-through" assumption means for our analysis. To calculate the effect of a higher carbon tax on firms' balance sheets requires assumptions about the pass-through of the burden. In practice, following an increase in the carbon tax, firms can adjust the quantity and price of their output, and also possibly the relative use of their inputs, thus alleviating the burden from a higher tax.[7,8] The extent to which the increase in the tax is passed on to customers would also change the effect of such higher carbon price. There may be second-round effects through demand, potential changes in production chains, or behavioral changes in responses by firms and consumers. However, without a general equilibrium framework, with firm and consumer optimization problems, it is not feasible to adjust for such mechanisms. This points to the degree of complexity in fully accounting for transition risk, as mentioned above. Thus, we follow "no-pass-through" and no adjustment assumptions: Firms absorb the increased costs fully in the form of higher liabilities. In theory, this corresponds to perfectly elastic demand or perfectly inelastic supply under perfect competition with profit-maximizing agents. The implication of this assumption in our analysis is that our findings in terms of the financial risk should be viewed as an upper bound and are likely to be lower in practice.

D. Banking Data and Exposures to Sectors

As mentioned in the previous section, in order to calculate the extent of the transmission of financial stress in nonfinancial sectors to the banking system, we need information on banks' exposure to each sector. The banking dataset used for our analysis was provided by the Colombian authorities. It has information on each bank's outstanding loans to each sector (NACE 1 Revision 2) as of end-2017, as well as bank's total assets (with 56 individual banks in the dataset). Together with the degree of the financial stress in each (nonfinancial) sector, the exposure of the banking system to those sectors would be a crucial determinant of the

[7] This effect can be heterogeneous across sectors. For instance, sectors producing non-tradable goods, or with monopolistic firms, are likely to be relatively less affected, since they may be able to pass on higher carbon tax to consumers by increasing their prices to a larger extent.

[8] We note that there are various other short-term effects that we do not account for in this study. An example is that an increase in domestic carbon price (with no change in the rest of the world) can affect exporters differently, due to its effect of competitiveness among Colombian exporters. Indeed, such concerns underpin the exemption for exports that the carbon tax currently in place includes. On the other hand, there are potential positive effects that are more likely to materialize in the medium term. For instance, firms (including exporters) can invest in green technologies and innovate, which can also spur firm productivity (and competitiveness). In that sense, as we consider medium-term effects, some firms with industries can be "winners," rather than being affected negatively by an increase in carbon tax.

banking stress arising from an increase in carbon tax. As firms in a sector become financially more stressed following an increase in the tax, this stress would transmit to the banking sector more intensely, if banks are more exposed to that sector ex ante.

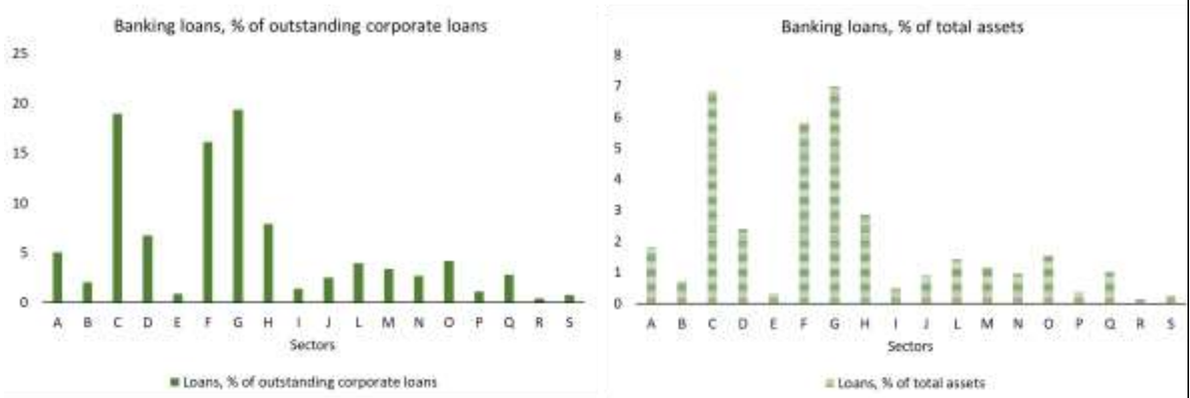
Figure 10 reports the exposure of the banking system as a whole to each sector. It documents the outstanding loans extended to each sector as a share of banks` total outstanding corporate loans (Panel 1) and as a share of banks' total assets (Panel 2). Wholesale and retail trade (G) has the largest share with the amount of 19.4 percent of banks' total outstanding corporate loans and 7 percent of banks' total assets. Manufacturing (C) has the second largest share with 19 percent of banks' total outstanding corporate loans and 6.9 percent of banks' total assets. Total outstanding loans to construction (F) follows with 16.2 percent of banks' total outstanding corporate loans and 5.8 percent of banks' total assets. Transportation (H), electricity (D), agriculture (A), public administration (O), real estate (L), professional/ scientific/technical activities (M) are other sectors with relatively high loans from the banking system.

Although the exposure of the banking system to each nonfinancial sector affects the level of aggregate stress in the banking system, it can mask differential effects on individual banks. With this in mind, Figure 11 documents exposures of individual banks to each sector, instead of the banking system as a whole. Panel 1 shows a bank's outstanding loans to each sector, focusing on highly exposed banks (ninetieth percentile), less exposed banks (tenth percentile), and banks at the median for each sector, as a share of each bank's total outstanding loans to the nonfinancial corporates. Panel 2 does the same as a share of each bank's total assets, instead of as a share of total outstanding corporate loans.

There is substantial heterogeneity across banks, meaning that banks are differently exposed to different sectors. For instance, as shown by Figure 10 (Panel 1) above, wholesale and retail trade (G) account for 19 percent of total outstanding corporate loans in the banking system, but the exposure is much higher for the bank at the ninetieth percentile, with above 50 percent of total outstanding corporate loans (Figure 11, Panel 1). Or, Figure 10 (Panel 2) reports that manufacturing (C) loans is about 6.9 percent of the total assets in the banking system; however, Figure 11 (Panel 2) shows that it is above 13 percent of total assets for some banks. Hence, while focusing on the stress in the banking sector as a whole, one should also keep an eye on banks' different exposures to specific sectors, which is important in order to measure whether the risk is concentrated among some banks. We will discuss this issue further in the coming sections.

Figure 10. Colombia: Exposure of the Banking System to Different Sectors

1. As a share of banks` total corporate loans** **2. As a share of banks` total assets

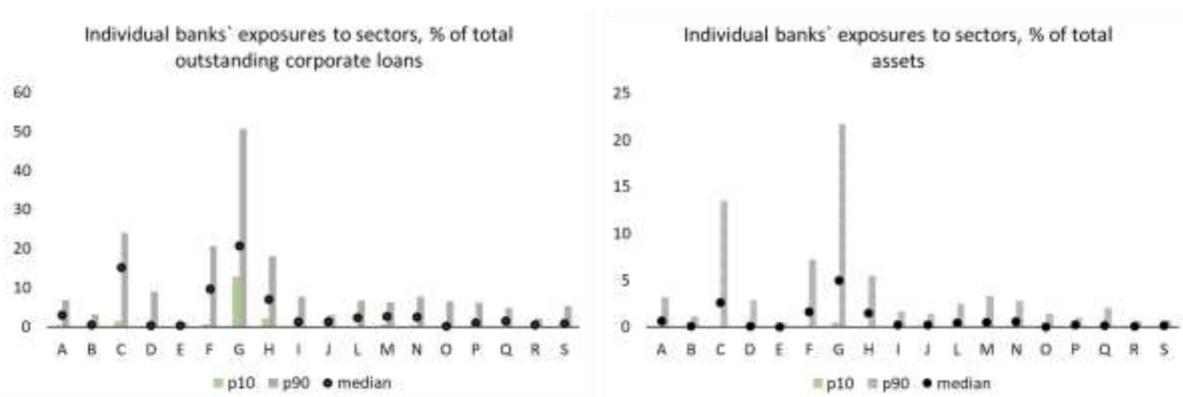


Source: National authorities, IMF staff calculations.

Notes: Sectors with NACE 1 codes: A - Agriculture, forestry and fishing; B - Mining and quarrying; C – Manufacturing; D - Electricity, gas, steam and air conditioning supply; E - Water supply; sewerage, waste management and remediation activities; F – Construction; G - Wholesale and retail trade; repair of motor vehicles and motorcycles; H - Transportation and storage; I - Accommodation and food service activities; J - Information and communication; K – Financial and insurance activities; L - Real estate activities; M - Professional, scientific and technical activities; N - Administrative and support service activities; O - Public administration and defence; compulsory social security; P – Education; Q - Human health and social work activities; R - Arts, entertainment and recreation; S - Other service activities. Charts represent the exposure of the banking system to each sector as a share of banks` total outstanding loans and as a share of banks` total assets.

Figure 11. Colombia: Exposures of Individual Banks to Different Sectors

1. As a share of bank`s total corporate loans** **2. As a share of bank`s total assets



Source: National authorities, IMF staff calculations.

Notes: Sectors with NACE 1 codes: see previous Figure.
Charts represent the exposure of individual banks (low, medium and high exposures with 10th, 50th and 90th percentile, respectively) to each sector as a share of banks` total outstanding loans and as a share of banks` total assets.

III. Transmission of the Stress to the Banking System

Our goal is to establish the transmission channel of stress from the real sector to the banking system. We need to estimate (1) the additional costs and financial difficulties imposed on nonfinancial firms from a higher carbon price, thereby generating risks in firms' balance sheets; and (2) the transmission of those risks to the financial sector through lending relationships. For this purpose, we use information both from the firm- and bank-level data, as well as sector-level carbon emissions. As discussed in Section II C, we identify a firm in a given sector as under stress if (1) current liabilities exceed current assets—the financial liquidity measure exceeding 1—, or (2) total liabilities exceed total assets—leverage exceeding 1. We first quantify the effect of an increase in the carbon tax (in the form of new additional liabilities) on firms' balance sheets using the carbon estimates and the firm-level data. In each sector, we identify firms that were not under financial stress ex ante, but fall into this category (based on financial iquidity or leverage measure) in the aftermath of the tax, due to the additional burden as discussed.

Next, we need to use banking data (as described in Section II D), since the exposure of the banking system to each sector determines the extent to which the risk is transmitted to the banking sytem. For instance, if half of the firms in a specific sector are having financial difficulties due to the policy change, and if the banking system is highly exposed to this sector ex ante, the risk imposed on the banking system (coming from this specific sector) would be large. Another example would be that, say, half of the firms in a sector are severely affected, but the banking system had very low exposure to that sector. In that case, such high risk in firms' balance sheets in that sector would not be transmitted to the banking system through the direct channel.[9]

To measure the level of stress in the banking system, we first calculate the share of firms in each sector that are now financially at risk. It is straightforward to use the number of firms to calculate the share of such firms in each sector (nonweighted). This is our first approach. However, this may be misleading, since some firms have larger liabilities ex ante. If such firms go under stress, this would mean larger risk to the banking system (assuming most of those liabilities are to banks). To account for the degree of existing linkages, we also calculate the share of firms (in each sector) under stress, using existing liabilities as weights (weighted approach). Therefore, we evaluate the risk contribution of each sector to the banking system in four different ways: (1) Firms that are under stress are identified based on either the financial liquidity or leverage measure (two sets of results), and (2) sector share of firms under stress is calculated by either the nonweighted or weighted approach (two sets of

[9] Note that it would be ideal to have data on banking loans at the firm-level. In that case, we would merge bank-firm data, and estimate the risk contribution of each individual firm. However, we only have data on the sector-level loans for the overall banking system. This is why we calculate shares of firms under stress within each sector, and aggregate financial stress measures to the sector level. Then, we merge this with the banking data, since both kinds of information are at the (1-digit) sector-level.

results). Note that the sector share of firms under stress will basically be driven by the following factors: estimates for sector-level carbon emission, amount of the increase in the carbon tax, and firms' initial balance sheet strength.

Once we calculate the share of firms facing financial difficulties, we then build the channel between the real and banking sectors. We want to observe how much risk arises from each sector, as well as the aggregate risk. The banks' exposure to each sector is the crucial determinant: to calculate the financial risk arising from each individual sector, we multiply the share of stressed firms in each sector with the exposure of the banking system to that sector. The exposure of the banking system to each sector is calculated based on total loans or total assets, as shown by Figure 10, Panel 1 and Panel 2. Hence, we have two sets of results: banking stress stemming from each individual sector, as a share of (1) banks' total outstanding corporate loans; and (2) banks' total assets. The former is the share of outstanding loans to each sector divided by the total outstanding corporate loans of the banking system. The latter is the share of outstanding loans to each sector divided by the total assets of the banking system.

For instance, 50 percent of the firms go under stress in a sector (say, based on the financial liquidity measure and nonweighted approach) following a higher carbon tax. The outstanding loans of the banking system to this sector was 10 percent of the total outstanding corporate loans. For the banking system, this means that 5 percent of total outstanding corporate loans are under stress coming from this specific sector only. At the same time, if the outstanding loans of the banking system to this sector was 4 percent of the banks' total assets, this would mean that 2 percent of banks' total assets are under stress arising from the stress in this sector. These numbers are the contribution to the banking risk by this specific sector, based on financial liquidity measure and nonweighted approach. There are three additional calculations represented in our results, based on alternative financial measures and approaches; namely, financial liquidity measure and weighted approach, leverage and nonweighted approach, and leverage and weighted approach.

We repeat this exercise for each sector. Therefore, we are able to observe the risk imposed on the banking system by individual sectors. Moreover, we also report the aggregate risk transmitted to the banking system. Finally, we report the risk imposed on individual banks to shed light on the importance of heterogenous exposures to sectors.

We explore several hypothetical scenarios in our analyses.[10] First, we assume a sharp US$70 increase in the carbon tax from US$5 to US$75 per ton carbon-equivalent. This is to the mid-point of the range estimated by the High-Level Commission on Carbon Prices (2017), seen as

[10] We reiterate that these are simply "what if" scenarios of an increase of carbon tax, and not the most likely or feasible ones.

necessary to achieve the Paris Climate targets, and also reported by the IMF.[11] Second, instead of a one-time and sharp increase, policy makers may prefer a gradual approach to smooth financial impact and reach the US$75 target over several years. In this regard, the scenario analyses explore the risks in the financial system in case of lower US$20, US$15, and US$10 increases in the carbon price.

IV. Scenario 1: US$70 Increase in Carbon Tax

A. Firms Under Stress

Following a sharp US$70 increase in carbon tax (to US$75 per ton), sectors are affected differently. Figure 12 shows the share of firms in each sectors that are driven into the stress territory by the US$70 increase in tax. Panel 1 shows the share of financially stressed firms in each sector, based on the financial liquidity measure using simply the number of firms (nonweighted). Panel 2 does the same for the leverage measure using the number of firms (nonweighted) to calculate the shares. Panel 3 (based on the financial liquidity measure) and Panel 4 (based on the leverage measure) illustrate shares calculated using liability weights (weighted approach).

Panel 1 in Figure 12 shows that water supply (E, 66.2 percent), agriculture (A, 46.2 percent), transportation (H, 31.6 percent), electricity (D, 24.4 percent), manufacturing (C, 15.7 percent), and accomodation (I, 11.4 percent) are the most affected sectors, with more than 10 percent of all firms within the sectors falling into financially stressed category (as shown in parantheses). Note that these are the shares of firms that were initially not under stress but fall into the financially stressed category following an increase in the carbon tax. When we switch to the leverage measure as a proxy for firm stress (Panel 2), effects are somewhat milder, but the list of most affected sectors remains similar.

Panels 3 and 4 illustrate that the stress in many sectors would be lower relative to the non-weighted shares for both the financial liquidity and leverage measures. These differences (between Panel 1 vs Panel 3; Panel 2 vs Panel 4) suggest that the stress is more concentrated among small firms, with levels of liabilities being relatively high compared to their small size of assets.

[11] A $75 per ton of CO2 tax is incidentally the level at which Calderon and others (2016)’s proposed high CO2 price scenario would be by 2030 (assuming a tax of $50 was introduced in 2020 and were to grow at a rate of 4 percent per year). This, in two of the three models they report, is consistent with close to a 50 percent reduction in GHG emissions by 2030—which is in turn Colombia’s revised NDC goal.

Figure 12. Colombia: Shares of Firms under Stress Across Sectors

1. Based on number of firms, financial liqudity

2. Based on number of firms, leverage

3. Based on liability weights, financial liqudity

4. Based on liability weights, leverage

Source: IMF staff calculations.

Notes: Sectors with NACE 1 codes: A - Agriculture, forestry and fishing; B - Mining and quarrying; C – Manufacturing; D - Electricity, gas, steam and air conditioning supply; E - Water supply; sewerage, waste management and remediation activities; F – Construction; G - Wholesale and retail trade; repair of motor vehicles and motorcycles; H - Transportation and storage; I - Accommodation and food service activities; J - Information and communication; K – Financial and insurance activities; L - Real estate activities; M - Professional, scientific and technical activities; N - Administrative and support service activities; O - Public administration and defence; compulsory social security; P – Education; Q - Human health and social work activities; R - Arts, entertainment and recreation; S - Other service activities. Charts represent the sector share of firms under stress following a US$70 increase in the carbon tax, based on (i) different financial stress measures at the firm-level (financial liquidity versus leverage) , and (ii) different approaches in the calculation of the sector share of firms under stress (weighted versus nonweighted). pp= percentage points.

B. Contribution to the Banking Stress

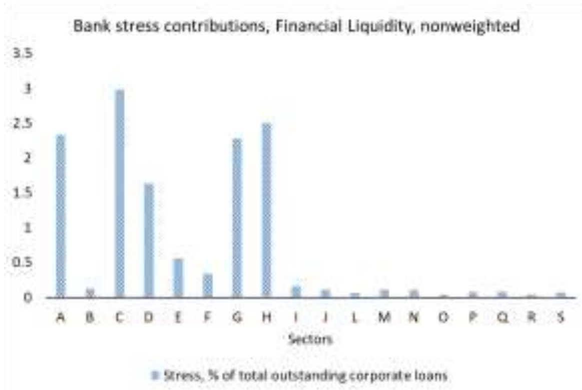
Once we calculate the share of firms falling into financial stress following a US$70 increase in the carbon tax, we build the link to the banking system, as described previously. Figure 13 shows the risk in the banking system imposed by each sector, as shares of banks' total outstanding loans to nonfinancial corporates. Based on the financial liquidity measure and nonweighted calculations (Panel 1), the largest risk is from manufacturing (C) sector: 3.0 percent of total corporate loans fall into at-risk category coming from the increased stress in the manufacturing. Transportation (H, 2.5 percent), agriculture (A, 2.3 percent), wholesale and retail trade (G, 2.3 percent) and electricity (D, 1.6 percent) sectors are others that generate relatively large risks on the banking system.

Panel 2 illustrates the risk contributions based on the leverage measure with nonweighted calculation (using the number of firms). Although the numbers are lower, the manufacturing (C, 2.1 percent), wholesale and retail trade (G, 2.0 percent), agriculture (A, 1.9 percent), transportation (H, 1.8 percent), and electricity (D, 1.0 percent) sectors still pose the largest risks for the banking system.

Panel 3 (financial liquidity measure) and Panel 4 (leverage measure) in Figure 13 show the results when we follow the weighted approach in the calculation of firm shares. Consistent with Figure 12, risks in general are lower for each measure, relative to the nonweighted approach. The five sectors with the largest risk (agriculture, manufacturing, electricity, wholesale and retail trade, and transportation) stay similar though.

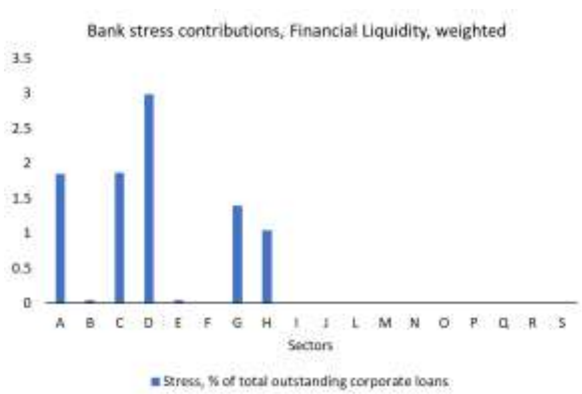
Figure 13. Colombia: Contribution to Banking Stress, Share of Corporate Loans

1. Based on number of firms, financial liqudity

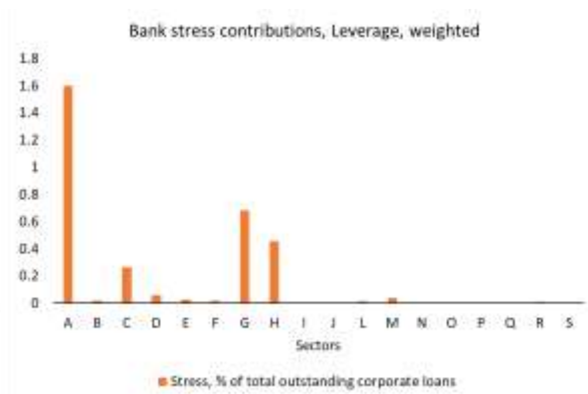


2. Based on number of firms, leverage

3. Based on liability weights, financial liqudity



4. Based on liability weights, leverage



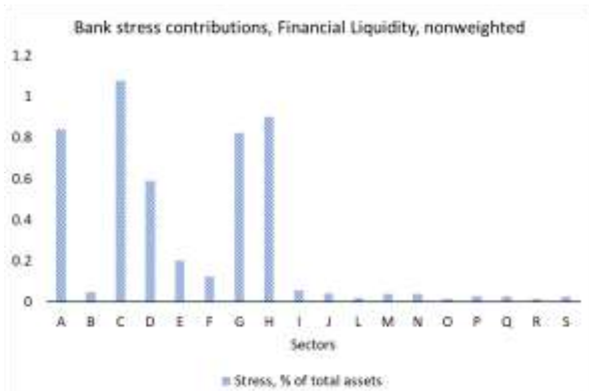
Source: IMF staff calculations.

Notes: Sectors with NACE 1 codes: A - Agriculture, forestry and fishing; B - Mining and quarrying; C – Manufacturing; D - Electricity, gas, steam and air conditioning supply; E - Water supply; sewerage, waste management and remediation activities; F – Construction; G - Wholesale and retail trade; repair of motor vehicles and motorcycles; H - Transportation and storage; I - Accommodation and food service activities; J - Information and communication; K – Financial and insurance activities; L - Real estate activities; M - Professional, scientific and technical activities; N - Administrative and support service activities; O - Public administration and defence; compulsory social security; P – Education; Q - Human health and social work activities; R - Arts, entertainment and recreation; S - Other service activities. Charts represent the contribution to the banking risk (as a share of banks` total outstanding corporate loans) by each sector following a US$70 increase in the carbon tax, based on (i) different financial stress measures at the firm-level (financial liquidity versus leverage) , and (ii) different approaches in the calculation of the sector share of firms under stress (weighted versus nonweighted).

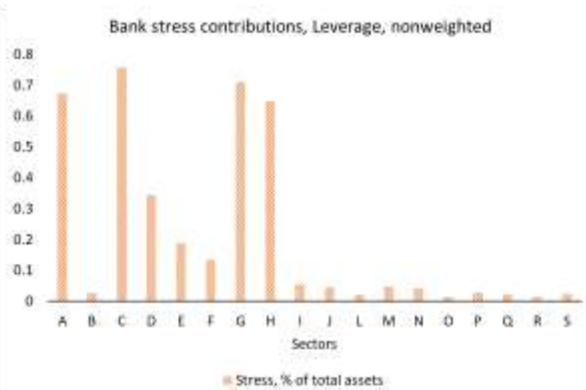
Figure 14 replicates Figure 13, except that it normalizes the banking stress with banks' total assets, instead of the total outstanding corporate loans. Note that, by construction, charts in Figure 14 are the scaled versions of charts in Figure 13, where the scale is the ratio of banks` total outstanding corporate loans to the banks' total assets.

Figure 14. Colombia: Contribution to Banking Stress, Share of Total Assets

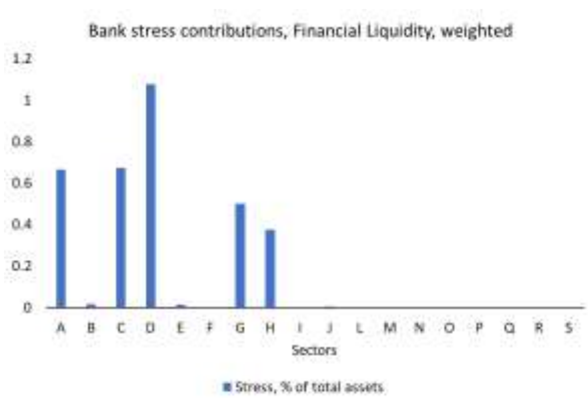
1. Based on number of firms, financial liqudity



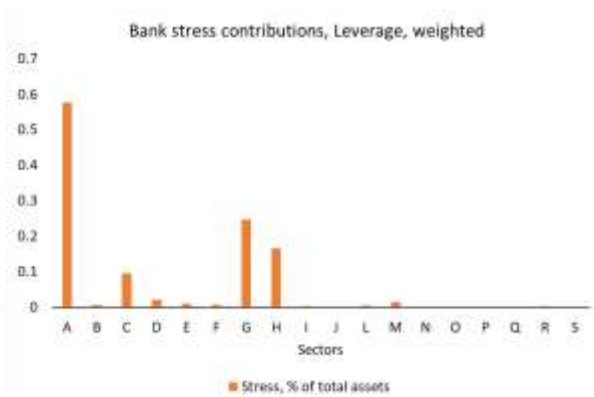
2. Based on number of firms, leverage



3. Based on liability weights, financial liqudity



4. Based on liability weights, leverage



Source: IMF staff calculations.

Notes: Sectors with NACE 1 codes: A - Agriculture, forestry and fishing; B - Mining and quarrying; C – Manufacturing; D - Electricity, gas, steam and air conditioning supply; E - Water supply; sewerage, waste management and remediation activities; F – Construction; G - Wholesale and retail trade; repair of motor vehicles and motorcycles; H - Transportation and storage; I - Accommodation and food service activities; J - Information and communication; K – Financial and insurance activities; L - Real estate activities; M - Professional, scientific and technical activities; N - Administrative and support service activities; O - Public administration and defence; compulsory social security; P – Education; Q - Human health and social work activities; R - Arts, entertainment and recreation; S - Other service activities. Charts represent the contribution to the banking risk (as a share of banks` total assets) by each sector following a US$70 increase in the carbon tax, based on (i) different financial stress measures at the firm-level (financial liquidity versus leverage); and (ii) different approaches in the calculation of the sector share of firms under stress (weighted versus nonweighted).

C. Aggregate Banking Stress and Individual Exposures

The next step is to estimate aggregate banking stress by adding the sector-level numbers as we find above. Table 1 reports the aggregate banking stress based on different measures of firm stress and as shares of total loans and assets following a US$70 increase in the carbon tax. Consistent with the sector-level numbers, the financial liqudity measure gives higher numbers relative to the leverage measure, both with weighted and nonweighted approaches. The total loans in stress is 13.6 percent (4.9 percent) of total outstanding corporate loans (of total assets) when we use the financial liquidity measure through the nonweighted approach. When we calculate shares of firms under stress based on the weighted approach, it is 9.3 percent and 3.3 percent, respectively.

The leverage measure generates lower stress in the banking system with 10.5 percent of total loans and 3.8 percent of total assets, when we calculate sector-level stress through the nonweighted approach. A large difference emerges when we use the weighted approach with the leverage measure, generating much lower numbers in terms of banking risk, due to the high number of small firms with liabilities higher compared to the small size of assets.

Table 1. Colombia: Aggregate Banking Stress

Banking stress, percent of	Financial Liquidity, nonweighted	Financial Liquidity, weighted	Leverage, nonweighted	Leverage, weighted
Total corporate loans	13.6	9.3	10.5	3.2
Total assets	4.9	3.3	3.8	1.2

Source: IMF staff calculations.

Notes: Table represents aggregate risk imposed on the banking system following a US$70 increase in the carbon tax, based on different financial stress measures at the firm-level (financial liquidity versus leverage) and different approaches in the calculation of the sector share of firms under stress (weighted versus nonweighted). The first and second rows illustrate banking loans under stress as a share of banks` total outstanding corporate loans and bank` total assets, respectively.

Table 1 shows that the aggregate stress transmitted to the banking system can be large. However, these risks can be manageable, especially considering that our estimates should be viewed as an upper bound due to the simplifying assumptions (e.g., no-pass-through) in our analysis.[12] However, it may not be ideal to impose such a high US$70 increase in the carbon tax in one step. An alternative policy change could aim to reach the US$75 tax in several steps with a lower hike at a time. To analyze the extent of the stress imposed on the banking system in that case, we next analyze the financial stress due to lower US$20, US$15, and US$10 increases in the carbon tax.

[12] Moreover, we would like to emphasize that the amounts of loans under risk do not correspond to nonperforming loans (NPLs) one to one. Those can also be viewed as an upper bound for NPLs in bank balance sheets.

Before moving to the next scenario analysis, we explore the effects on the highly exposed banks. Figures above suggest that risks are more concentrated in a few (actually five) sectors. Hence, for this exercise we consider those five sectors that appear to be most important for the banking stress: agriculture (A), manufacturing (C), electricity (D), wholesale and retail trade (G), and transportation (H). We identify banks that are most exposed to these five sectors as a whole. Based on the share of total corporate loans, five banks seem to be highly exposed, with above 90 percentile of exposure to those sectors. Looking at the share of total assets, six banks appear to be highly exposed, with above 40 percent of their assets. Table 2 reports the stress contribution from those sectors in these highly exposed banks on average. The numbers are higher than the aggregate levels in Table 1, meaning that, although the stress in the banking system as a whole is important, one must pay attention to the individual exposures to high-risk sectors as well.

Table 2. Colombia: Stress in Highly Exposed Banks

Bank stress, percent of	Financial Liquidity, nonweighted	Financial Liquidity, weighted	Leverage, nonweighted	Leverage, weighted
Total corporate loans	24.3	20.9	17.8	8.1
Total assets	13.1	11.3	9.6	4.4

Source: IMF staff calculations.

Notes: Table represents average risk imposed on the banks that are most exposed to five sectors (agriculture, manufacturing, electricity, wholesale and retail trade and transportation) following a US$70 increase in the carbon tax, based on different financial stress measures at the firm-level (financial liquidity versus leverage) and different approaches in the calculation of the sector share of firms under stress (weighted versus nonweighted). The first and second rows illustrate banking loans under stress as a share of banks` total outstanding corporate loans and bank` total assets, respectively.

V. Other Scenarios

In Section IV, we examined the financial stability implications of a sharp US$70 increase in the carbon tax to meet the US$75 target. As Table 1 shows, such dramatic increase in the tax can yield large, although potentially still manageable, risks to the banking system. Instead of the one-step sharp increase, what happens if lower gradual increases in the carbon tax are considered in order to achieve the US$75 target over years? The main point here is to act earlier rather than later and start the process. To provide an insight on the potential aggregate risks imposed on the banking system in such cases, we explore three scenarios with a US$20, US$15, and US$10 (per ton) increase in tax in a year. Table 3 represents the associated risks in those three scenarios.

Table 3. Colombia: Aggregate Banking Stress in Case of Different Scenarios

Panel A: A 20 USD increase in tax				
Banking stress, percent of	Financial Liquidity, nonweighted	Financial Liquidity, weighted	Leverage, nonweighted	Leverage, weighted
Total corporate loans	6.9	4.6	5.6	0.9
Total assets	2.5	1.7	2.0	0.3
Panel B: A 15 USD increase in tax				
Banking stress, percent of	Financial Liquidity, nonweighted	Financial Liquidity, weighted	Leverage, nonweighted	Leverage, weighted
Total corporate loans	6.2	3.6	5.1	0.7
Total assets	2.2	1.3	1.9	0.3
Panel C: A 10 USD increase in tax				
Banking stress, percent of	Financial Liquidity, nonweighted	Financial Liquidity, weighted	Leverage, nonweighted	Leverage, weighted
Total corporate loans	5.3	1.4	4.6	0.5
Total assets	1.9	0.5	1.7	0.2

Source: IMF staff calculations.

Notes: Table analyzes the risk in the banking system following a 20 (Panel A), 15 (Panel B), and 10 (Panel C) USD increase in the carbon tax. Each panel represents aggregate risk imposed on the banking system based on different financial stress measures at the firm-level (financial liquidity versus leverage) and different approaches in the calculation of the sector share of firms under stress (weighted versus nonweighted). The first and second rows in each panel illustrate banking loans under stress as a share of banks` total outstanding corporate loans and bank` total assets, respectively.

As expected, Table 3 shows that associated risks from a 20 (Panel A), 15 (Panel B), and US$10 (Panel C) dollar increase in the carbon tax are much lower compared to the sharp US$70 increase (Table 1).[13] For instance, a US$10 increase generates risks in the financial system lower than 1–2 percent of total outstanding corporate loans or assets in weighted calculations, and about 5 percent of total corporate loans in case of the nonweighted approach. Similarly, a US$15 increase yields numbers lower than or about 5–6 percent. Such milder financial stability effects imply that a gradual approach could be preferable.

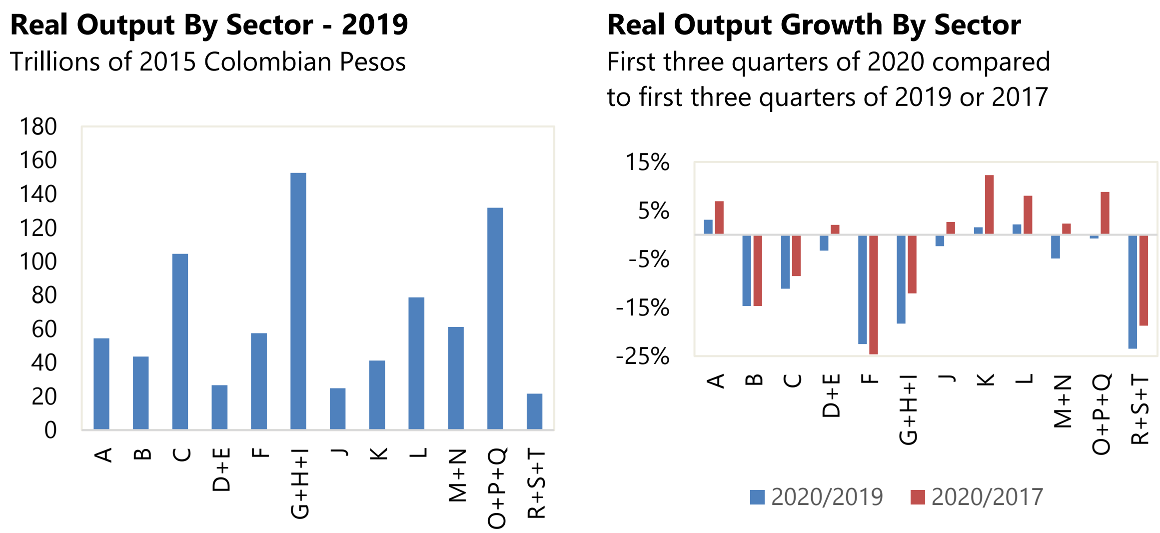
VI. Considerations on the Effects of the COVID-19 Pandemic

Due to reporting lags in the firm-level as described before, our exercise is performed on balance sheet data corresponding to 2017. However, major shocks have ocurred since then. Figure 15 intends to give a better picture of the more recent state of the Colombian economy by sector. Although some sectors, like manufacturing, had increased their real output

[13] The list of five sectors generating relatively large risks in the banking (i.e., sectors that are most affected) stays the same across these scenario analyses, as expected. However, since each sectors yields less risk, we observe lower risks on aggregate.

between 2017 and 2019, the COVID-19 crisis has negatively affected most of them since. The hardest hit sectors have been construction, wholesale and retail trade, transportion, accommodation, arts, recreation, and other services. Among those, wholesale and retail trade and transportion are the sectors that emit more carbon and are found to be important for the transition risk by our analysis. Another sector that appears to be crucial in the tranmission of risk to the banking system, the agricultural sector, has been hit to a lesser extent: even during the first three quarters of 2020 it saw some modest growth compared to the previous year.

Figure 15. Colombia: Sector-Level Growth Rates in 2019 and 2020Q1



Source: Banco de la Republica and IMF staff calculations.

Notes: Sectors with NACE 1 codes: A - Agriculture, forestry and fishing; B - Mining and quarrying; C – Manufacturing; D - Electricity, gas, steam and air conditioning supply; E - Water supply; sewerage, waste management and remediation activities; F – Construction; G - Wholesale and retail trade; repair of motor vehicles and motorcycles; H - Transportation and storage; I - Accommodation and food service activities; J - Information and communication; K – Financial and insurance activities; L - Real estate activities; M - Professional, scientific and technical activities; N - Administrative and support service activities; O - Public administration and defence; compulsory social security; P – Education; Q - Human health and social work activities; R - Arts, entertainment and recreation; S - Other service activities.

Combining these results with those of the stress test, one can infer that the greatest pressure is in the sectors of wholesale and retail trade, as well as transportion, which would be significantly impacted negatively by a sharp increase of the carbon tax, and are currently in a more vulnerable position after the COVID 19 crisis. However, to get a more complete picture, looking at the impact of the pandemic on firms’ balance sheet is also crucial once the data is available.

VII. Concluding Remarks

This study proposes a framework to evaluate the financial stability implications of climate-related transition risk. Using comprehensive bank- and firm-level data for Colombia, we attempt to quantify the extent to which transition risks driven by a policy shock (i.e., higher carbon price) transmits nonfinancial corporates to the banking system. We explore hypothetical scenarios in which a higher carbon tax would generate risks in the nonfinancial firms' balance sheets, and such risks would be transmitted to the banking system through banks' exposure to those firms.

The results suggest that, among others, five sectors, i.e., agriculture, manufacturing, electricity, wholesale and retail trade, and transportation seem to be more conducive to the transmission of the risk to the financial system. Moreover, a sharp US$70 increase in the carbon price is found to lead to significant, but still manageable risks in the banking system. The risks are highly uneven among individual banks, based on different exposures to those five sectors. Finally, alternative scenarios suggest that a gradual increase in carbon price over several years could be preferable in terms of financial risks and smoother adjustment for stakeholders. Policymakers, however, should act sooner rather than later.

It is worth noting that climate-related stress testing and transition risks are still a new and developing area in the realm of financial stability analysis. While our analysis relies on strong, simplifying assumptions and a static stress test perspective, and only accounts for the direct channel at play, it offers an insight for climate-related transition risks due to policy change in the case of Colombia. To the best of our knowledge, this study is the first providing a detailed firm-level analysis on climate-related transition risks for an emerging market economy.

This study particularly focuses on financial stability implications of a shift in carbon tax, since carbon taxes are viewed as an important and efficient tool to achieve the emissions at the desired pace and level, aforementioned. Potential implications of the use of new revenues generated by a higher carbon tax on transition risks are left for future research. In particular, how new fiscal revenues are used by governments can lower the short-term financial risks; for instance, if they are allocated to subsidize the sectors that are more affected so that they adopt or develop greener and/or more productive technologies. On the other hand, it is important to note that, whenever those revenues are used for purposes such as fossil fuel subsidies, they can impede the effectiveness of a higher carbon tax in reducing emissions. Therefore, a comprehensive policy approach is needed by also considering how new revenues raised by governments would be used to support the climate ambition and to mitigate related financial risks at the same time.

While our paper specifically focuses on the effect of an increase in the domestic carbon price on financial stability risks, there are other triggers of transitions risks that are important to explore in future research. For example, the adoption of new technologies to achieve a greener economy can also impose financial risks as well as new opportunities. An increase in carbon price in the rest of the world (which could potentially coincide with an increase in the domestic tax) brings transition risks through the external demand channel for oil, through higher tax burdens on Colombian firms operating abroad, and also considering the costs of goods. Moreover, climate mitigation policies in the rest of the world could generate transition risks in Colombia through value chains, other import/export trends, and labor movements. Transition risks can also be triggered by shifts in public opinion or market sentiment. These are very relevant for Colombia, being an oil exporting country, and require further research on the financial stability implications of climate-related transition risk. More generally, climate-related stress testing provides interesting avenues for further research in the field of financial stability analysis (Grippa and Mann, 2020).

Last, but not least, costs and benefits of climate mitigation policies should be considered in a holistic view of physical and transition risks together, along with a consideration of the use of new fiscal revenues. Relatively milder and limited short-term risks, or costs, of climate mitigation policies, such as an increase in carbon tax, could generate much larger medium- to longer-term benefits for the whole economy by alleviating physical risks. Moreover, as discussed before, the efficient and transparent use of the new revenues generated by a higher carbon tax could help many countries across the globe set the stage for a greener, resilient, sustainable, and inclusive growth path.

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