BANCO CENTRAL DE RESERVA DEL PERÚ

Financial Stress and macroeconomic fluctuations in Peru

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DT. N°. 2022-002
Serie de Documentos de Trabajo
Working Paper series
Diciembre 2021

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December 9, 2021

Abstract

We develop a reliable financial stress index (FSI) that can be included in the BCRP's toolkit for monitoring financial stability risks (which includes a financial conditions index and a heat map for the financial system, Growth-at-risk among others), using Principal Component Analysis (PCA) over a broad set of financial variables covering banking sector, capital markets, money and foreign exchange markets. To assess the accuracy of the proposed FSI, we also included in-sample and out sample model performance tests.

After estimating the FSI for the Peruvian economy, we implement a multivariate analysis to assess the impact from financial stress to the real sector variables. To do so, we perform the impulse response analysis using Linear Projection methods developed by Jordà (2005). Since financial stress impact on macroeconomic dynamics is non-linear, we applied nonlinear impulse response by linear projection developed by Gorodnichenko and Auerbach (2013). From this analysis we show that during periods of stable financial markets, macroeconomics dynamics are consistent with the Newkeynesian framework where monetary policy has a stabilizing role after a demand shock hits the economy. However, during financial stress episodes, we find that the effectiveness of monetary policy is reduced, given the same shock.

JEL: C32, E32, E52, E44, G01, G21
Keywords: Financial stress index, principal component analysis, local projection

*The authors are very thankful to Christian Brownless for the academic supervision of this paper. This research took place through the technical assistance from SECO. The views expressed in this paper are solely those of the authors and do not necessarily reflect those of the Central Reserve Bank of Peru. All errors are our own.

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1 Introduction

The Global Financial Crisis that emerged in the U.S. by the late 2000s and quickly spread to other countries highlighted the need to understand the structure and the general condition of the financial sector and the interrelation of the financial conditions with the real sector. Building an indicator of financial stress is a step forward to understand the relationship between financial and real sector, and it has grasped significant attention after the Global Financial Crisis.

An episode of financial stress is defined as a period when the financial system is under strain and its ability to intermediate is impaired. Also, financial stress can be thought of as an interruption to the normal functioning of financial markets (Balakrishnan et al., 2011; Hakkio and Keeton, 2009). More specifically, Hakkio and Keeton (2009) argue that every financial stress episode shows at least one of the following characteristics in the financial markets:

- Increased uncertainty about fundamental value of assets.
- Increased uncertainty about behavior of other investors.
- Increased asymmetry of information.
- Decreased willingness to hold risky assets (flight to quality).
- Decreased willingness to hold illiquid assets (flight to liquidity)

In recent years, there has been an increasing number of studies focusing on constructing FSI, using different methodologies. Illing and Liu (2006) was the first in constructing an indicator of stress in the financial system. They use data for foreign exchange, bond, equity markets and the banking markets to build a FSI for the Canadian financial system. The variables are aggregated using the size of each markets as weights, and extreme values of the indicator are defined as financial stress events.

Hakkio and Keeton (2009) developed a stress index for the US financial system (KCFSI) using a s set of 11 asset pricing variables that signal uncertainty about fundamental value of assets, uncertainty about behavior of investors, increasing information asymmetry, flight to quality and flight to safety. In this paper, these variables are aggregated using the principal component analysis methodology.

Cardarelli et al. (2011) identifies episodes of financial turmoil for a sample of 16 advanced economies using a FSI based on high-frequency price variables that can signal stress in the banking, securities, or foreign exchange markets. The variables then are aggregated using a variance-weighted average to get the FSI.

Holló et al. (2012) introduced a new indicator of stress in the Eurozone financial system named Composite Indicator of Systemic Stress (CISS). This paper applied the standard portfolio theory for constructing the aggregated index using a broad set of financial variables, taking into account the cross correlation among the variables besides their variances. Thus, this methodology has the advantage to identify an additional source of systemic stress when the correlation among the variables increases during financial stress events.

Huotari (2015) constructed a FSI for the Finnish financial system using information from country's money market, bond market, equity market and foreign exchange markets and the banking sector. To aggregate the variables the paper uses the variance-equal weight (VEW), principal component analysis (PCA) and portfolio theory aggregation methods (PAM).

Duprey (2020) developed a FSI for the Canadian financial system using information from equity, government, forex exchange, banking, corporate and housing sectors. This paper use the portfolio theory approach to weigh each subindex.

Financial stress indexes (FSI) are mostly calculated on a monthly basis for the developed countries. However, FSI are a relatively new topic for emerging market economies (EME) and therefore it is important to analyze the interrelation between the FSI and the real sector, considering that for an EME financial stress can arise not only from domestic developments but also from global ones. We are mainly interested in financial stress because of its potential adverse effect on the real economy. While elevated levels of financial stress are not always followed by a downturn in the real economy, we still consider a threat to the growth of the real economy as a defining feature of high financial stress. If systemic financial stress levels can be detected at an early stage, fiscal and monetary policy measures can be taken to mitigate the potential impact on the economy

The purpose of this paper is to develop a reliable financial stress index that can be included in the BCRP's toolkit for monitoring financial stability risks (which includes a financial conditions index and a heat map for the financial system, Growth-at-risk among others), using Principal Component Analysis (PCA) over a broad set of financial variables covering financial sector, capital markets, money and foreign exchange markets. We also included in-sample and out sample model performance to evaluate the accuracy of the FSI estimated.

After estimating the FSI for the Peruvian economy, we implement a multivariate analysis to assess the impact from financial stress to the real sector variables. To do so, we perform the impulse response analysis using Linear Projection methods developed by Jordà (2005). Since financial stress impact on macroeconomic dynamics is non-linear, we applied nonlinear impulse response by linear projection developed by Gorodnichenko and Auerbach (2013). From this analysis we show that during periods of stable financial markets, macroeconomics dynamics are in line with the Newkeynesian framework where monetary policy has a stabilizing role after a demand shock hits the economy. However, during financial stress episodes, we find that the effectiveness of monetary policy is reduced.

The remainder of this paper is organized as follows: section 2 explain the methodology used in the paper, Section 3 presents the data used and results from the FSI, section 4 presents the analysis of the interaction between financial stress and macroeconomic dynamics and section 5 concludes.

2 Methodology of a Financial Stress Index for Peru

To construct the Financial Stress Index for the Peruvian Economy, we select a set of different variables from the banking sector[1], domestic and foreign financial markets, money market and foreign exchange market. The selected series have been used to monitor risks to financial stability by Central Bank of Peru (i.e., those series have been used to construct the heat map for the financial system and the Growth at risk analysis included in the Central Bank of Peru's Financial Stability Report[2]).

[1] Banking sector in Perú includes banks and other financial institutions that provides credit to the private sector

[2] For heatmap methodology see Quintana et al. (2020) and for the Growth at Risk methodology see Chicana and Nivin (2021).

The methodology for the construction of the FSI consists of three steps: (i) the selection of the relevant indicators of the Peruvian financial market, (ii) the standardization of the indicators, and (iii) the aggregation of all indicators in an index for each segments and overall, that characterizes the financial cycle.

Table 1: Methodology

I) Selection of variables		II) Standardization		III) Aggregate index
A set of 27 representative variables were selected.	⇒	Each variable is transformed to have a stationary series. Then a standardization is made using the EWMA standard deviation.	⇒	Each variable is aggregated using a PCA model for each segment and for the whole system.

2.1 Selection of indicators

The number of indicators used is representative of the broad Peruvian's financial system. The frequency of the data is monthly and updated in an period of no more than a month and a half. The series are classified into three segments : (i) capital market, (ii) banking sector, and (iii) money and foreign exchange market. In the case of banking sector indicators, the characterization of Peruvian financial cycle must be consistent with the off site analysis of the financial institutions, considering the risk thresholds for balance sheet's variables (capital adequacy, asset quality, management, earnings and liquidity). Also, for both the money and capital markets, the data set considers indicators of asset valuation, risk and liquidity premiums, extreme values and volatility.

The information of the 27 indicators and their transformation are shown in table 2.

2.2 Standardization

The treatment of the data begins ensuring the stationary of majority of the variables. Therefore, in some cases the trend component is eliminated, by calculating the annual variation of the variables that require it or using the HP filter. Only the cyclical component of the indicator is used. Subsequently, each variable x_{it} is demeaned by its sample mean μ_i and divided by its moving standard deviation (obtained from the EWMA methodology) as follow:

$$z_{it} = \frac{x_{it} - \mu_i}{\sigma^*_{it}}$$

where z_{it} represents a standarized stationary financial variable, μ_i represents its sample mean, and σ^*_{it} represents its smoothed standard deviation which is a root average between the sample variance and the variance obtained from a EWMA model:

$$\sigma^*_{it} = \sqrt{\frac{1}{2}\sigma^2_{it} + \frac{1}{2}\sigma^2_{EWMA,it}}$$

where σ^2_{it} is the sample variance and $\sigma^2_{EWMA,it}$ is the variance obtained by a EWMA model, which is calculated as:

$$\sigma^2_{EWMA,it} = 0.94\sigma^2_{EWMA,it-1} + (1 - 0.94)(x_{it} - \mu_i)^2$$

Additionally, the sign of the resulting standardized variable is modified in such a way that a higher value reflects a greater degree of vulnerability.

Table 2: Indicators

	Indicator	Measure
	I. Banking Sector	
1	Loans - Firms	Var.% 12 M
2	NPL - Firms	Var. % 12 M
3	Provisions - Firms *	Var. % 12 M
4	Loan- Households	Var. % 12 M & HP filter
5	NPL - Households	Var. % 12 M
6	Provisions - Households *	Var. % 12 M
7	Consumer average loan	Var. % 12 M
8	Financial Margin	Var. % 12 M
9	Short term foreign liabilities (% total liabilities)	Var. % 12 M
10	Liquid assets/Short term liabilities	Var. % 12 M
11	Capital surplus	Var. % 12 M
	* Only specific Provisions	
	II. Capital Markets	
12	Spread: (BTP 10 years rate - average rate CDBCRP)	Level
13	EMBIG Peru	Level
14	Foreign ownership of BTP (%)	Var. % 12 M
15	CEMBI Peru	Level
16	Private Pension Fund (Quote Fund 2)	Var. % 12 M
17	Lima Stock Exchange Index	Var. % 12 M
18	Volatility Lima Stock Exchange	GARCH (1,1)
19	Cooper-LME (USD per pound)	Var. % 12 M
20	CBOE Volatility Index	Level
21	Global Spread - MSCI	Level
22	USA Spread: (US10Y - US3M)	Level
	III. Money and FX Markets	
23	Liquid Assets of Banks	Var. % 12 M
24	Spread: Corporate rate - Interbank rate	Level
25	Exchange rate	Var. % 12 M
26	FX Volatility	GARCH (1,1)
27	Net International Reserves	Var. % 12 M

2.3 Aggregate Index

A single aggregate index is built to capture financial stress conditions of each of the financial system's segments. The literature establishes various criteria in the indicator aggregation process. The most selected methods in recent literature are market weights (Illing and Liu, 2006; Oet et al., 2015), variance-weighting (Cardarelli et al., 2011), portfolio theory (Holló et al., 2012; Duprey, 2020) and principal component analysis (Hakkio and Keeton, 2009).

For the construction of the Peruvian's FSI, we use the principal component analysis (PCA) methodology since it is a well known econometric method with a proven track record in macroeconomics and finance. Moreover, it is simple to communicate. Therefore, We proceed as follow:

Let $\{x_{i,t}\}$ be a set of k standardized financial variables and $X_t = (x_{1,t}\ x_{2,t}\ ...\ x_{k,t})'$, then the first principal component Z_t solves

$$\max_{\lambda} Var(\lambda' X_t)$$

$$s.t.\ \lambda'\lambda = 1$$

Where Z_t, estimated by PCA, is equal to the eigenvector associated with the eigenvalue with the highest value in the variance-covariance matrix of the the variables $\Sigma = E(X'X)$. The aggregation by principal components captures the joint variation of the data as well as its pattern of correlations.

3 Results

Using the indicators showed in table 2, we estimated three subindexes for the capital market, banking sector and money and FX markets. In addition, we computed the aggregated FSI as the first principal component of the broad set of variables.

3.1 Capital markets subindex

The FSI of the capital market segment shows stress conditions during the episodes of the global financial crisis of 2008 (GFC), the taper tantrum period, the Fed's tightening cycle, political uncertainty events and the Covid-19 crisis.

In the 2008 crisis, the indicators for both the fixed income and equity markets reflect significant losses, given sharp reduction of asset prices amid high volatility in those markets. Also, there were huge losses in the local stock market, as well as in the value of private pension funds (profitability Real Fund 2 registered a rate of -32% at the worst moment of the financial crisis). During this period, the risk aversion indicator in the fixed income market (EMBI) registered an average increase of 193 basis points between 2008 and 2009 with peaks of more than 600 basis points at the height of the crisis.

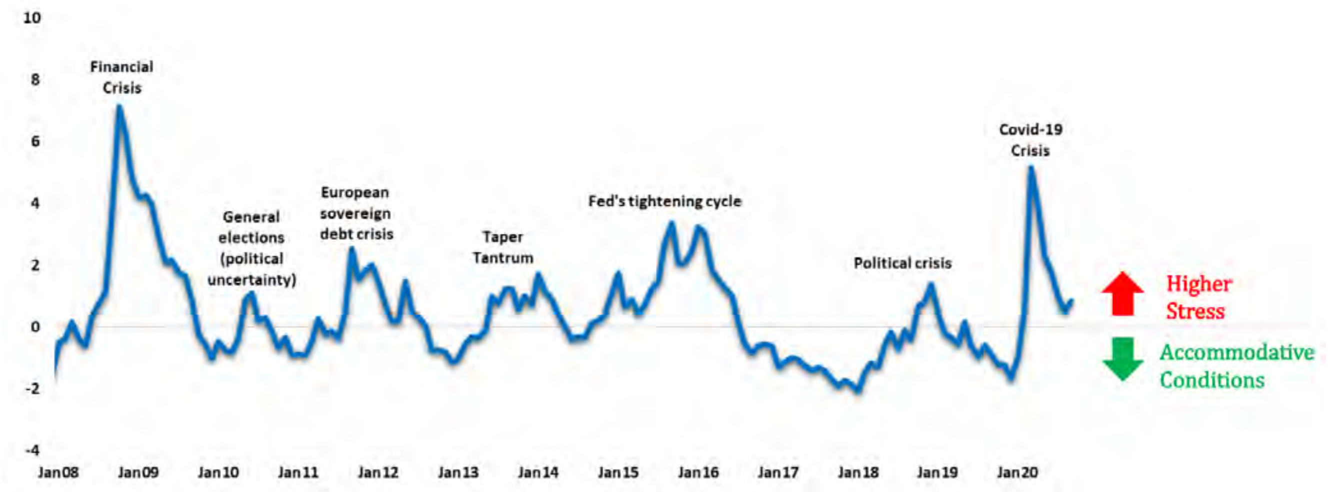
After the GFC, the capital market stress index reflects worsening conditions coinciding with two events: (i) the Fed's "taper tantrum" in 2013, after announcing the end of its monetary expansion program, which generated an adjustment in the perception of risk by international investors and volatility in financial and exchange markets in emerging economies; and, (ii) fears of a slowdown in the Chinese economy, and the consequent fall in commodity prices, affecting emerging markets exposed to the evolution of the Asian economy. However, the increase in aversion in these two episodes was less than in the

GFC episode. Unlike developed economies, the tapering episode was reflected in unusual increases in the EMBIG and CDS indicators. Likewise, lower returns were observed from the BVL and Fund 2 of the pension portfolio managed by the AFPs, in a context of greater FX volatility.

At the beginning of 2018, the index showed slack conditions in a context in which the S&P 500 index registered sustained returns. However, the threat of a rise in tariffs on products from China by the United States of America translated into increases in the VIX index as well as in falls in the S&P 500 index during 2018. In this context, the Fund 2 of the AFPs showed losses as well. This evolution was reinforced by the context of local political uncertainty that led to the resignation of the incumbent president.

Finally, after the period of high volatility registered in the first half of 2020 caused by the Covid-19 crisis, the capital market stress index showed a gradual recovery. The stabilization of international financial markets and the rise in the price of copper favored the evolution of local securities markets. Likewise, the recovery of financial markets in developed economies was positively reflected in the value of local pension funds.

Figure 1: Stress Subindex for the Peruvian capital markets



3.2 Banking sector subindex

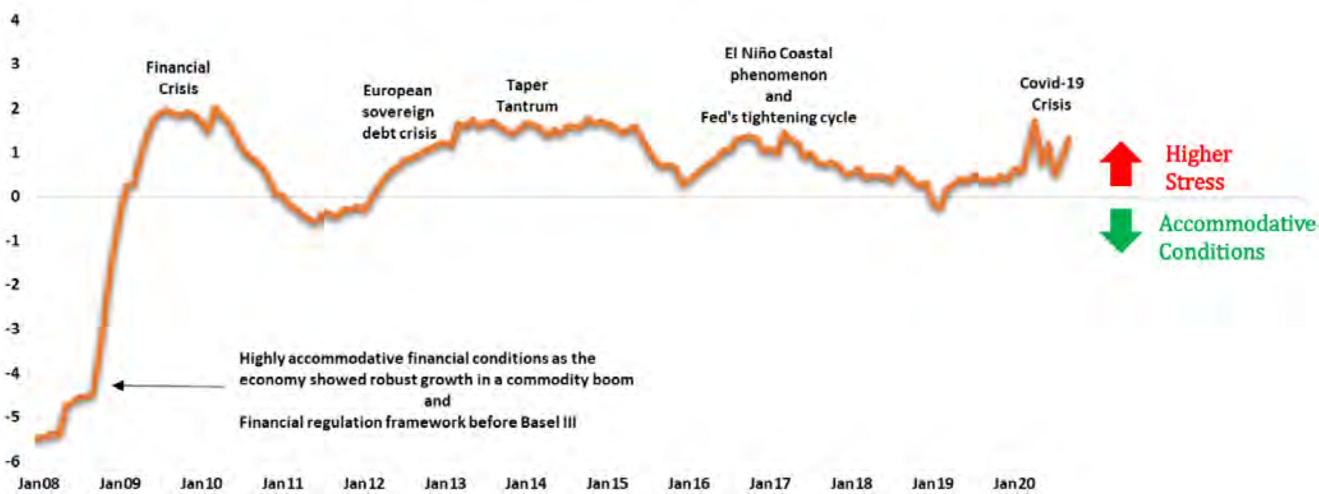
The Banking sector stress indicator also reflects the episodes of the global financial crisis of 2008, the taper tantrum period, Fed's tightening cycle, periods of political uncertainty and the Covid-19 crisis. Unlike the indicator in the capital market, a pattern of lags is observed in the case of the banking sector.

During the GFC, a rapid growth of the non-performing portfolio was observed, in line with the abrupt slowdown in domestic economic activity. This evolution caused an increase in the expense of provisions and lower profitability of the banks. As a corrective measure, local banks tightening conditions to grant credits. As a consequence, there was a rapid reduction in average consumer credit debt in the years following the crisis. However, the portfolio quality indicators continued to deteriorate towards the end of 2009.

After the international financial crisis, the banking sector did not consistently reflect slack conditions, associated with the continuous growth of delinquency indicators, although high solvency and profitability levels.

In the case of the Covid-19 crisis, the indicator of the banking sector registered higher stress conditions. The strength of the financial system and the measures implemented by the authorities to mitigate the macro-financial risks derived from the crisis, specially measures to sustain the credit flows. Credit have accelerated since May 2020 and interest rates have fallen to historic lows, given Reactiva Peru Program. With this policy, the central bank provided additional liquidity to local banks in order to increase the amounts of credits to Corporate and SME businesses, using as collateral governments guarantees.

Figure 2: Stress Index for the Peruvian banking sector



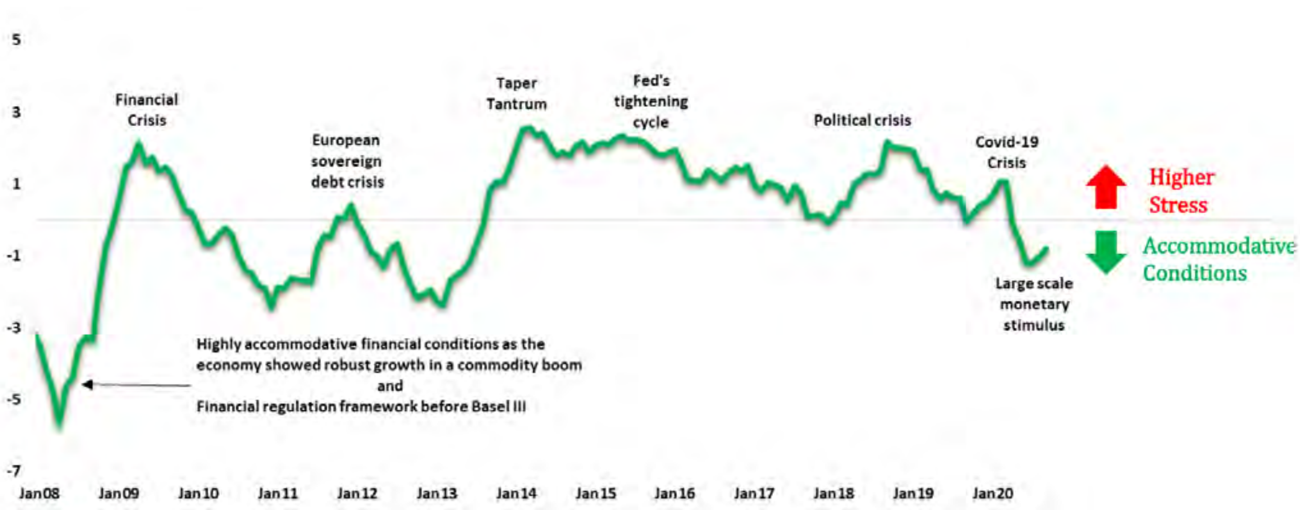
3.3 Money and foreign exchange markets subindex

The Money and FX Market indicator shows stress conditions associated with the same financial stress events. In the case of the GFC, the monetary policy of the BCRP was oriented towards maintaining its liquidity in the financial system by reducing the reserve requirements in domestic and foreign currency. Also, there was a reduction of the policy rates.

During the Fed's "taper tantrum", starting in the second half of 2013, there was an increase in volatility in financial markets. Additionally, in 2014 there was a process of substitution of credits towards those denominated in soles. In that year, credits in national currency expanded rapidly, while those in foreign currency remained stable. The BCRP injected liquidity into the system through Repurchase Agreement (Repo) using US Dollars as collateral (known as FX Swap) to contribute to the de-dollarization process of credit.

The Covid-19 crisis caused a large-scale liquidity injection by the BCRP through the implementation of the Reactiva program (equivalent to 8.2% of GDP), greater than the operations of the de-dollarization program or the international financial crisis (5.2% and 2.2% of GDP, respectively). For this reason, the MM market indicator shows slack conditions in the months following the outbreak of the health crisis.

Figure 3: Stress Index for the Peruvian money and FX market



3.4 Aggregated FSI

Figure 4 summarizes the historical evolution of stress events in the Peruvian financial market identified by the FSI. The stress episodes characterize particularly the GFC, the Taper Tantrum period that began in 2013, the El Niño phenomenon of 2016 and the beginning of the cycle of hikes in the Fed's benchmark rates, periods of political crisis and the recent Covid-19 Crisis.

In the most recent case of the Covid-19 crisis, which began in the second quarter of 2020, the lower values of the FSI in the beginning of 2021 indicates that this crisis has dissipated rapidly. The stress associated with the Covid-19 has been similar to the GFC in terms of magnitude. The shorter duration of the recent crisis in relation to previous episodes is associated with the rapid policy response to stabilize markets and liquidity expansion measures by the authorities of both developed and emerging economies. The factors that favor the decrease in the values of the aggregate index were reinforced with more favorable financial conditions in the external market and the gradual recovery of the economy.

Likewise, a normalization of the domestic capital market is observed. The indicators show a normalization process in the external sector indicators and in the local equity markets in the first quarter of 2021 in the capital market segment. The global economic recovery process, given the advances in vaccination processes and the implementation of economic policy measures to support activity, have allowed the perception of risk in financial markets to dissipate. For example, the VIX index registered values of less than 20% last March, characterizing an environment of low volatility in the markets. A similar evolution is observed in the equity market, since most indicators such as the performance of Fund 2 of the private pension system and the liquidity of the stock market have shown significant improvements compared with pre-crisis levels. On the other hand, the fixed income market has registered slight deterioration in the first quarter of 2021, given the increase in medium-term international interest rates and the increase in country risk premiums.

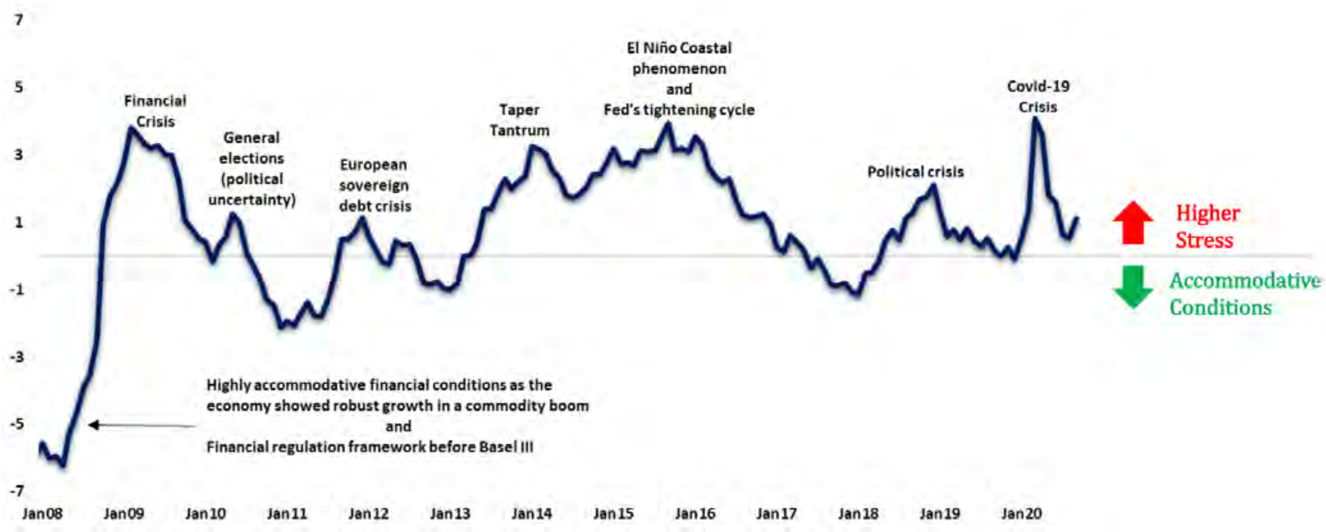
The financial system indicators have remained stable during the health crisis, given a solid initial financial position, liquidity and capital levels. In addition, local banks reduced costs to mitigate the impact of non-performing loans on profitability.

In the case of the money market, the high injection of liquidity made by the BCRP and the intervention scheme in the FX market were reflected in the rapid convergence of the aggregate index to ease conditions.

Unlike the GFC, the size of the intervention was more powerful. For example, the injection of liquidity was 8.2% of GDP, in contrast to 2.2% of GDP during the GFC. Likewise, the better position of the Peruvian economy -lower degree of dollarization, greater availability of foreign reserves, greater solvency and capital adequacy of the banking system- have contributed to absorb negative financial shocks, which have resulted in the rapid recovery of indicators in the overall FSI.

In synthesis, the aggregate Peruvian FSI summarized the relevant information from all three segments of the Peruvian financial sector. The highest values of the index, associated with heightened financial stress, are related to the Great Financial Crisis and the Covid-19 crisis. However, the latter produced a shorter period of stress due to the policy measures implemented globally and locally to stabilize financial markets.

Figure 4: Financial Stress Index for the Peruvian economy



3.5 Model evaluation

3.5.1 Internal validation

The objective of this exercise is to evaluate the relevance of FSI indicators on each of the individual variables. With this in mind, the exercise assesses whether the aggregate or segment FSI indicator lagged helps to explain each of the 27 individual variables used in the model in terms of mean square error of out-of-sample errors (one prediction period for 18 periods). The specifications are ARMA (used as benchmark) and ARMA-X are as follows:

$$x_t = ARMA(p, q)$$

$$x_t = ARMA(p, q) + \alpha_1 FSI_{t-1}$$

$$x_t = ARMA(p, q) + \alpha_1 PCA1_{t-1} + \alpha_2 PCA2_{t-1} + \alpha_3 PCA3_{t-1}$$

In general, the results in Table 3 show that adding the FSI indicator is informative for each of the variables, since the MSE is lower in most cases. The indicators of the banking system stand out, since adding the risk indicator reduces the mean square error by more than 80 % in the majority of indicators. For the case of the liquidity indicator and provision ratio, the MSE represents 30.6% and 40.2%, respectively, with respect to the benchmark case. In the case of the capital market indicators, the fixed income and equity indicators show the greatest improvements in terms of MSE when the FSI indicators are added as an explanatory variable to the ARMA specification.

Table 3: Internal Validation: MSE out of sample 1 step ahead

	MSE					AIC		
	(a) ARMA	(b) ARMA+FSI	(c) ARMA+PCA	(b)/(a)	(c)/(a)	ARMA	FSI	PCA
I. Banking System								
Loans - Firms	0,74	0,02	0,02	2,78	3,22	-51,74	-59,72	-59,52
NPL - Firms	0,24	0,01	0,01	6,02	6,18	-169,44	-171,77	-171,80
Provisions - Firms *	0,09	0,01	0,01	13,56	16,05	31,11	29,56	33,04
Loan- Households	2,88	0,08	0,08	2,94	2,91	-10,00	-10,97	-13,56
NPL - Households	0,58	0,03	0,02	4,89	4,27	-21,39	-43,68	-31,62
Provisions - Households *	1,20	0,01	0,01	0,52	0,49	-137,37	-163,07	-148,51
Consumer average loan	0,46	0,01	0,01	2,19	2,14	-137,57	-138,92	-135,05
Financial Margin	2,53	0,09	0,08	3,44	3,12	-36,45	-49,09	-42,66
Foreign debt plus deposits (% liabilities)	0,16	0,02	0,03	15,69	18,31	40,69	3,36	27,87
Liquid assets/Short term liabilities	0,70	0,21	0,21	30,59	30,39	183,74	182,37	181,51
(NPL - Provisions) / Equity *	0,14	0,05	0,06	40,19	43,65	-69,23	-73,58	-71,93
II. Capital Markets								
Spread: (BTP 10 years rate - rate CDBCRP)	0,83	0,09	0,09	11,25	11,25	88,95	87,32	87,32
EMBIG Peru	0,65	0,19	0,19	29,43	29,43	155,42	154,64	154,64
Foreign ownership of BTP (%)	1,45	0,05	0,05	3,57	3,57	32,53	33,15	33,15
CEMBI Peru	0,79	0,45	0,45	56,76	56,76	84,92	82,01	82,01
Private Pension Fund (Quote Fund 2)	0,52	0,08	0,08	15,73	15,73	-7,92	-7,39	-7,39
Lima Stock Exchange Index	0,32	0,03	0,03	9,29	9,29	10,93	15,57	15,57
Volatility Lima Stock Exchange	0,15	0,52	0,52	335,20	335,20	230,27	229,27	229,27
Cooper-LME (USD per pound)	0,27	0,10	0,10	35,05	35,05	120,19	117,87	117,87
CBOE Volatility Index	0,58	0,70	0,70	120,23	120,23	207,22	210,94	210,94
Global Spread - MSCI	0,30	0,43	0,43	143,31	143,31	118,32	120,17	120,17
USA Spread: (US10Y - US3M)	2,76	0,03	0,03	1,08	1,08	-46,43	-42,66	-42,66
III. Money and FX Markets								
Liquid Assets of Banks	0,58	0,13	0,16	23,26	26,93	138,54	136,38	125,93
Spread: Corporate rate - Interbank rate	1,14	0,12	0,12	10,62	10,31	175,07	178,28	180,71
Exchange rate	0,29	0,07	0,08	25,26	26,38	31,17	32,32	35,89
FX Volatility	0,92	0,01	0,02	1,18	2,04	-80,77	-86,00	-113,94
Net International Reserves	0,54	0,03	0,03	5,88	5,71	-46,37	-52,18	-56,08

* The PCA model consider the first PCA by each segment, whilst the FSI is the first PCA of the overall variables.

On the other hand, for the risk aversion indicators (Stock volatility, VIX index and global spread) the MSE is higher when the FSI indicators are added. This result is usual in other applications, since the errors of volatility indicators are not well behaved and the ARMA-X specifications do not show high fit. For this type of variables, a comparison could be made with specifications that consider regime switching, since they can be modeled with non-linear specifications.

3.5.2 External validation

The financial cycle can have negative effects on economic activity. For example, lower asset prices and higher premiums for liquidity and insolvency risk lead to a reduction in the value of the families' portfolio and, therefore, their consumption and investment levels.

We evaluate the effects of the FSI on the real economy. First, the cyclical component of the monthly GDP indicator is used as dependent variable as a function of its own lags as well as alternative measure of the FSI (ARMA-X) as shown in Table 4.

Table 4: Out of sample error of y_t, given specifications

	Model	MSE	AIC
1	$y_t = ARMA(1,3)$	2.6647	151.2
2	$y_t = ARMA(1,3) + \alpha_1 PCA1_{t-1} + \alpha_2 PCA2_{t-1} + \alpha_3 PCA3_{t-1}$	1.4438	161.8
3	$y_t = ARMA(1,3) + \alpha_1 BS1_{t-1} + \alpha_2 MK1_{t-1} + \alpha_3 MM3_{t-1}$	1.5267	146.3
4	$y_t = ARMA(1,3) + \alpha_1 PCA1_{t-1}$	1.5350	149.7

The first specification does not include any FSI indicator. This ARMA model is used as a benchmark. In the rest cases, the ARMA specification includes exogenous variables of measures of the FSI (PCA aggregated or by segments). The evaluation is carried out by comparing the squared error of the out-of-sample errors. Thus, the initial cut-off date corresponds to September 2018 and the one period errors ahead are computed for the following 15 periods (until March 2020). The results for the out-of-sample MSEs as well as the AIC information criteria are presented in table 4.

The MSE show that the FSI indicator outperforms the benchmark model in all the 3 different specifications that includes a measure of FSI. While according to AIC, including either the three financial stress sub-indexes or the agreggated FSI outperform the best univariate process for GDP.

Alternatively, the MSE errors will be evaluated for 12 periods ahead without widening the sample window. Considering September 2018 as the cut-off date, the results of Figure 5 indicate that the specification of Model 4 shows the lowest mean square errors out of the sample for all prediction horizons. In the rest of the specifications, the biases of ahead errors are not so different with respect to the benchmark specification. Therefore, these results support the need to use the FSI to explain the dynamic of economic growth.

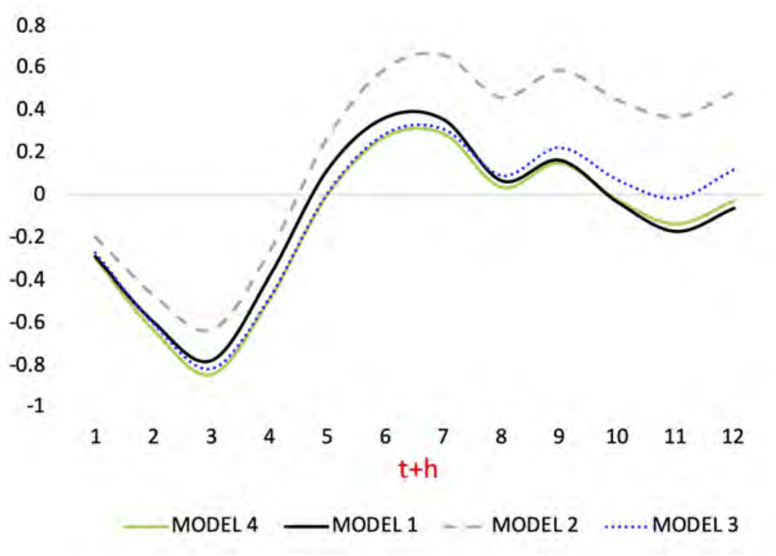


Figure 5: Out of sample error $t + h$ steps ahead of the GDP cyclical component, given model

4 Financial Stress and Macroeconomic Dynamics

The previous sections were dedicated to the construction of a financial stress index for Peru. It is important to monitor the conditions in the financial sector since it tends to amplify negative shocks to the real economy. Thus, in this section, we focus on the relationship between financial stress and macroeconomic outcomes.

We provide a simple framework to illustrate the negative relationship between financial stress and macroeconomic dynamic. Since during calm times standard macroeconomic model can explain real sector dynamic while during stress episodes amplification effects occur, impairing the response of output to real and financial shocks. Therefore, recent literature has taken into account this nonlinear effect of financial shocks to the macroeconomy.

Traditionally, an analysis of impulse-response from a structural vector autorregression (SVAR) model has been used to assess the impact of financial development to the real sector. However, to capture nonlinear effects of financial shocks, recent literature have focused mainly in two methodologies: Threshold Structural Verctor Autorregressions (TVAR) and Markov Switching Vector Autorregressions (MS-VAR).

Davig and Hakkio (2010) use a MSVAR model in order to assess the nonlinear dynamics between high and low financial stress regimes within the United States and find that during high stress regime the decline in real activity is 50% larger and longer lasting than within the low stress regime. Also, Hubrich and Tetlow (2015) uses a MSVAR that allows for two regimes, calm times and stress times, and find that a shift to a stress event is highly detrimental to the outlook for the real economy, and that conventional monetary policy is relatively weak during such periods.

Alternatively, Li and St-Amant (2010) use a TVAR model in order to assess the impact of shocks to Canadian financial stress on the real economy as well as the asymmetric effects of monetary policy within both a low and high Canadian stress regime. They find that monetary policy actions have stronger effects when financial stress is high and that tightening monetary policy tends to have more impact than easing. Also, Duprey (2020) uses a Bayesian TVAR model that allows for macroeconomic dynamics to differ across regimes, identified by the level of an observed threshold variable (which is the FSI). He shows how financial stress and worsening macroeconomic conditions amplify each other, arguing that episodes of elevated financial market stress show a deeper correction of GDP.

Instead of using MSVAR or TVAR, our main contribution is capture the nonlinear effect of financial stress using state dependent impulse response from a linear projection model as suggested by Gorodnichenko and Auerbach (2013) and Barnichon and Brownlees (2019). The first paper focused on estimate the state contingent response of fiscal policy during expansions and recessions, while the second paper focused on analyze how different is the effect of monetary policy during economic expansion and recessesion. In our paper, we focused on episodes of financial stress and calm times, and how these regimes affects the interrelation between macroeconomic variables.

State dependent IRFs using linear projection methods have several advantages over TVAR and MSVAR models. First, IRFs by linear projection methods do not use a VAR structure and therefore it is more flexible to capture the evolution of macroeconomic variables especially when the relationship among the variables is nonlinear. Moreover, State dependent IRFs using linear projection do not assume that the economy stays in th current state over the horizon in which the impulse responses are calculated, which is the case of TVAR. Also, with linear projection IRF we can only focus in the response of the variable we are interested in, instead of estimate the whole system as in the case of using VAR IRFs.

4.1 Estimation of Impulse Responses by Local Projection

4.1.1 Methodology

Let $Y_t = (g_t, \pi_t, i_t, e_t)'$ a vector of macroeconomics variables for a small open economy, where g_t is growth rate of GDP, π_t is inflation, i_t is monetary policy rate and e_t is effective real exchange rate. Following Jordà (2005) and Barnichon and Brownlees (2019) we define the linear projection model model:

$$y_{t+h} = \alpha_{(h)} + \beta_{(h)} x_t + \sum_{k=1}^{K} \gamma_{k(h)} w_{k,t} + u_{(h)t+h}$$

Where y_t is the response variable, x_t is the impulse variable and $w_{k,t}(k = 1...K)$ is a set of control variables (which included lagged values of y_t and x_t). Then the impulse response function (IRF) of y_t to a shock on x_t of size δ is:

$$IRF(h, \delta) = \beta_{(h)} \delta$$

To incorporate the effect of financial stress on macroeconomic dynamics, we follow Gorodnichenko and Auerbach (2013) and define the state dependent linear projection model:

$$y_{t+h} = \alpha_{(h)} + [1 - F(z_{t-1})] \left[\beta_{(h),R1} x_t + \sum_{k=1}^{K} \gamma_{k(h),R1} w_{k,t} \right] + F(z_{t-1}) \left[\beta_{(h),R2} x_t + \sum_{k=1}^{K} \gamma_{k(h),R2} w_{k,t} \right] + u_{(h)t+h}$$

where z_t is an indicator of financial stress, normalized to have zero mean and unit variance. The weights assigned to each regime for a given observation vary between 0 and 1 according to weighting function $F()$ which depends to the state of financial stress.

$$F(z_t) = \frac{e^{-\gamma z_t}}{1 + e^{-\gamma z_t}}$$

Then, the state dependent IRF is calculated as follows:

$$IRF(h, R1, \delta) = \beta_{(h),R1}\delta$$

$$IRF(h, R2, \delta) = \beta_{(h),R2}\delta$$

where $IRF(h, R1, \delta)$ represent the impulse response function during normal times and $IRF(h, R2, \delta)$ represents the impulse response function during episodes of financial stress.

4.1.2 Estimation for the Peruvian Economy

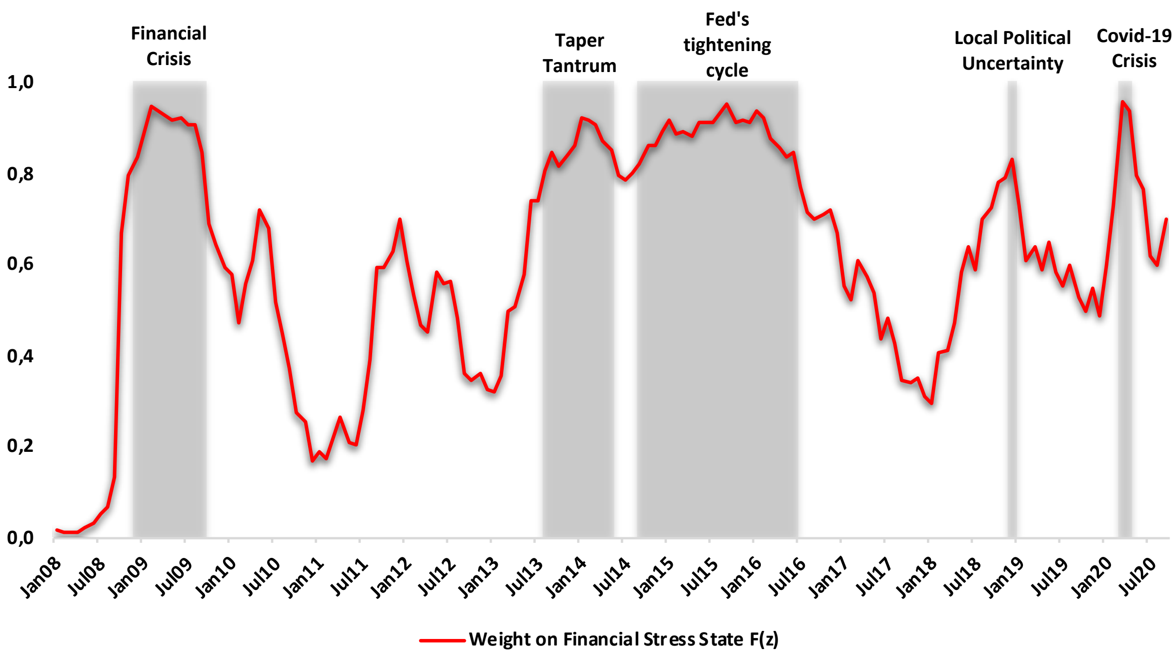
We use monthly data from September 2007 to September 2020 with four endogenous variables in the system. The annualized growth rate of real GDP, the annualized CPI inflation rate, the monetary policy rate, and the annualized variation in the real effective exchange rate which summarizes the relevant external conditions for Peru. A simple first baseline estimation is conducted with these variables. The specification includes two lags as suggested by the information criterion.

The system described above is extended to include a nonlinear framework with two regimes in order to incorporate the macroeconomic impacts of financial stress,. Therefore, the estimation has two macroeconomic dynamics: **State 1** that can be considered as normal times, and **State 2** which contains the periods of elevated financial stress. The Financial Stress Index is the variable z_t in the logistic function $F()$ that computes the state probabilities. We fix $\gamma = 0.8$ so that about 30 percent of the time are periods of high financial stress (probability of 80 percent or higher to be in **State 2**)[3].

[3] We also considered different reasonable values for γ and obtained similar results.

Figure 6 shows the weighting for the financial stress state. It captures five relevant periods: two related to the Federal Reserve monetary policy normalization (taper tantrum and Fed's tightening cycle), two global crises (the 2008 financial crisis and the Covid-19 crisis), and one related to a local political turmoil period. External factors are relevant for the Peruvian financial sector, especially those linked to US dollar interest rates.

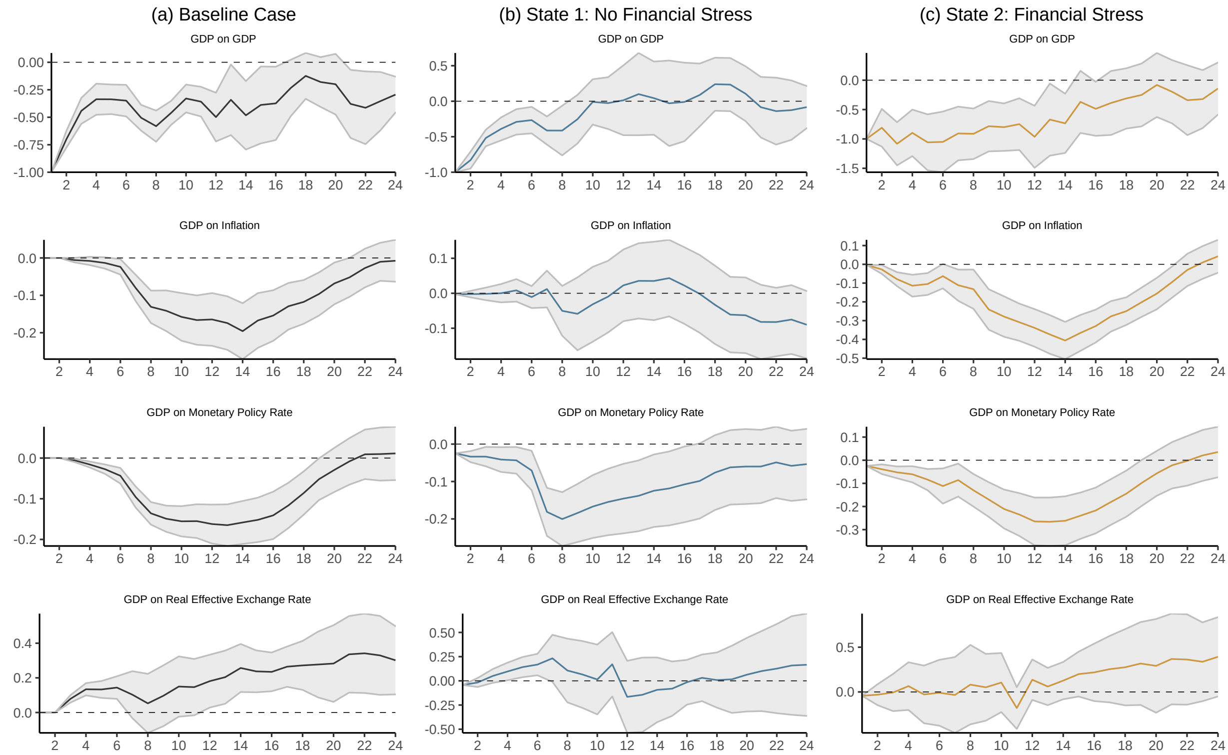
Figure 6: Weight on Financial Stress State and Relevant Periods



4.2 Financial Stress and its Effects on Macroeconomic Outcomes

Our results for a negative one percentage point shock to GDP with monthly data and 68 percent confidence intervals are summarized in Figure 7. Panel (a) shows the impulse responses for the baseline case where no considerations regarding financial stress are addressed. However, the main interest in this section is to analyze if financial stress affects macroeconomic dynamics. Panel (b) and (c) show the results for this case.

Figure 7: Impulse responses to a negative one percentage point shock to GDP



Note: Impulse responses with 68 percent confidence intervals. X-axis units in panels are months and Y-axis units are percentage points.

The overall result is in line with macroeconomic theory. In all cases, when a negative shock hits GDP, the system reacts as expected for a small open economy with a reduction in inflation, monetary policy becomes expansive, and the exchange rate depreciates. However, there are significant differences in the dynamics of the variables if the financial system is under stress or not.

In the case of no financial stress, panel (b) from the previous figure, conventional monetary policy is a powerful stabilizing tool and the system behaves in the desired manner as in the standard Newkeynesian Model. It takes fewer periods to recover from the negative shock to GDP, monetary policy needs to be expansionary for a shorter time, the exchange rate properly works as a shock absorber, and there is a limited impact on inflation.

Contrary to the previous case, it is a prolonged process to recover from the negative shock to GDP when the financial system is under stress, as panel (c) from the previous figure shows. In this scenario, the effectiveness of conventional monetary policy is reduced, despite the need to be more expansionary, and the impact of the shock on the inflation rate is considerable.

The results in this section highlight two main points:

1. Financial stability has a relevant role for the central bank to accomplish its objectives. That is straightforward since the central bank uses the financial system as an intermediary for its monetary policy. However, our contribution is to quantify how different macroeconomic outcomes can be in the presence or absence of financial stress for the Peruvian economy.

2. It is important to have a range of policy instruments in order to control the shocks to the economy in different scenarios. Conventional monetary policy is not enough when the financial sector is under stress. In this scenario, other monetary policy tools and coordination between fiscal and monetary policy become more relevant. Recently, the Covid-19 crisis provides a clear example in the case of Peru.

5 Conclusions

The Financial Stress Indicator estimated in this paper provides a relevant tool for monitoring the vulnerabilities and risks to financial stability in the Peruvian Economy and therefore can be included in the BCRP's toolkit for monitoring financial stability risks (which includes a financial conditions index and a heat map for the financial system, Growth-at-risk among others). Through this FSI policymakers can have additional information about the building up of financial stress and identify its determinants in order to take action to preserve financial stability and mitigate the impact on the economy.

Moreover, this paper highlights the importance of realizing that the economy react differently depending the state of financial market. Using state dependent IRFs from linear projection methods, we show that during periods of stable financial markets, macroeconomics dynamics are consistent with the newkeynesian framework where monetary policy has a strong stabilizing role after a demand shock hits the economy. However, during financial stress episodes, we find that the effectiveness of monetary policy is reduced. This results reinforce the use of additional policy instruments to stabilize the economy during an episode of financial stress.

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