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CHANGES IN RAINFALL, AGRICULTURAL EXPORTS AND RESERVES: MACROECONOMIC IMPACTS OF CLIMATE CHANGE IN ARGENTINA

Pablo G. Bortz[abc] and Nicole Toftum[ab]

Abstract

Most of the articles that analyze the macroeconomic impact of the physical risks of climate change focus on discrete, one-time events such as floods, hurricanes and draughts. This paper studies a long-term manifestation of physical risks (namely, changes in rainfalls) and its macroeconomic impacts in a developing country such as Argentina. We document a downward trend in rainfalls in the main agricultural area of Argentina, using daily data starting in 1970. We further use changes in rainfall as an instrument for on the export performance of the main agricultural complexes: soy, wheat, corn and sunflower, from 2003 to 2019. Using an instrumental variable approach, we study the impact of changes in rainfall on foreign exchange reserves, controlling for economic activity, capital flows and debt repayments. We find that drops in rainfall in the months of January (mainly) and February are significantly associated with lower reserve accumulation by the central bank. This result is robust to several specifications.

Keywords: Climate change, rainfalls, agricultural exports, foreign exchange reserves, central banks
JEL Classification: E50, F18, F31, O24, Q17, Q58.

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I. INTRODUCTION

The physical risks posed by climate change for macroeconomic performance and financial stability include both short-term, one-time events like hurricanes, floods or heat waves; and long-term changes such as increments in temperatures and changes in rainfalls, for instance. Another distinction is between acute versus chronic risks (Banxico 2020). In recent years there has been growing concern and a growing literature on the macroeconomic impacts of natural disasters, both of an acute and of a chronic nature, in the short and in the long run (Von Peter et al 2012, Kahn et al 2019, Ciccarelli and Marotta 2021). There is also increasing recognition about the effects of long-term physical risks, for productivity growth, agricultural production, export patterns, investment requirements, among other factors, particularly for Emerging and Developing Economies (EDEs) (IMF 2017). This paper adds further evidence about the macroeconomic impacts of climate change in EDEs. We focus on the effects of changes in rainfall on foreign exchange (FX) reserve accumulation through changes in exports by central banks in agricultural-exporting countries, specifically in the case of Argentina.

Agricultural output is one straightforward sector in which these physical risks could materialise (Dell et al 2014, IPCC 2018). UNCTAD (2019) shows that the 10 most vulnerable countries to climate change are commodity-dependent economies, and out of the 40 more vulnerable, 37 are commodity-dependent. This impact is not homogeneous across crops, with wheat and corn showing the largest risks. Natural disasters like floods, droughts and storms (associated with climate change) already explain substantial losses in crops and livestock (FAO 2018, Coulibaly et al 2020). In this sense, climate change will have significance influence exports and trade patterns of commodity-exporting EMEs (Oh 2017, FAO 2018, Barua and Valenzuela 2018, Dallmann 2019, among others).

But the impact will not be restricted to agricultural exports (Burke et al 2015, IMF 2017, Mittnik et al 2019). Climate change can have an impact on tax revenues and public finances, also because of the investment requirements. It will affect employment and productivity. It will have an impact on FDI and other capital flows (Osberghaus 2019). It poses severe risks to the financial system, both at the domestic and the global level (Mandel et al 2021, BCBS 2021). It can also further impact sovereign risks (Fitch 2020, Klusak et al 2021), with an impact on corporate and sovereign debt.

This paper tackles one of such effects, previously unexplored. We study the impact of changes in rainfall on foreign exchange accumulation in Argentina for the period 2003-2019, through the influence of rains on the exports of the four main agricultural complexes (soy, wheat, corn and sunflower). We adopt an instrumental variable approach with daily data of rainfalls in the core agricultural area of Argentina (in the province of Buenos Aires and Santa Fe). We include controls for domestic economic activity (influencing imports) and financial variables such as portfolio flows by residents and non-residents and public debt payments. We find that a fall in rainfalls in the months of January (mainly) and February has a negative impact on reserve accumulation, through its impact on exports. This statistically significant relation holds in all specifications. In some of these, the month of March is also statistically significant. Domestic economic activity, debt payments and portfolio flows are also significant determinants of FX reserve accumulation. Export prices, however, are neither significant determinants of export volumes nor reserve accumulation, according to our results.

The rest of the paper goes as follows. In section II, we survey the literature on the impact of physical risks on agricultural production, commodity exports and trade. We also present other studies that tackled the macroeconomic impact of climate change in Argentina, and we elaborate why it is important to focus on the unexplored impact on reserve accumulation. Section III presents the data sources and shows the trends for rainfalls, reserve accumulation and other control variables in our study. Section IV presents the main results and robustness checks through different specifications. Section V offers some conclusion remarks.

II. LITERATURE REVIEW

There is an already large and increasingly expanding literature about the impact of climate change on agricultural production[1], both in developed countries, EDEs and Least Developed Countries (LDCs). Auffhammer and Schlenker (2014), Dell et al (2014: 759) and Carleton and Hsiang (2016) review the existing literature and find

[1] For a review of modeling approaches, see Hertel (2018).

a consensus regarding the negative impact of bad weather shocks and low rainfall on agricultural output and crop yields. Lesk et al (2016) found that droughts can reduce national cereal production by 9-10%, using national data for the 1964-2007 period. Shi et al (2020) also review several studies that show negative impacts of climate change on agricultural output in the US, Europe, Africa, India, the MENA region, and China. Schlenker and Lobell (2010) predict significant losses of between 8% to 22% across a variety of crops in Sub-Saharan Africa by mid century in their preferred econometric specification. Fishman (2016) highlights the impact of fewer rainy days (in comparison to *total* rainfall) on crop yields in India for 1970 to 2003. Coulibaly et al (2020) show that natural disasters, changes in temperatures and droughts impact negatively agricultural output in Africa. However, the state of development of different African countries has a bearing on the heterogeneity of impacts and responses to climate change. UNCTAD (2018: 16) shows that climate change already explained 65% of extreme weather events in the six years prior to that report. FAO (2018) estimates at $100 billion the losses in crops and livestock production between 2005 and 2014 in developing countries due to natural hazards and disasters. Furthermore, the global impact will be different across latitudes, since northern countries will observe an increase in agricultural production (IPCC 2014, FAO 2018). Schlenker and Roberts (2009) emphasise the non-linear negative impact of climate change on yields, a finding also confirmed in studies on the US, Europe, Africa, India and South-East Asia (Carleton and Hsian 2016).

These heterogeneous impacts will have implications for international trade patterns, as shown by Carleton and Hsiang (2016), FAO (2018), Porfirio et al (2018), Dabla-Norris et al (2021), among others. Osberghaus (2019) provides a review of the effects of natural disasters and weather variations on trade. There is a consensus about the detrimental impact of higher temperatures and disasters on *exports*, both manufacturing and agricultural. Imports are relatively unaffected. These are the findings of Jones and Olken (2010), Li et al (2015), Tembata and Takeuchi (2018), Barua and Valenzuela (2018), Dallmann (2019). Barua and Valenzuela (2018) estimate that precipitations will lower agricultural exports in Latin America. In regards to higher temperatures, the results are significantly negative for Asia and Africa, and significantly positive for Australia and New Zealand.

As for evidence on Argentina, the study by World Bank (2021) served as initial motivation for this paper, together with Thomasz et al (2017), Vilker (2018), Ahumada and Cornejo (2021) and González et al (2021). Thomasz et al (2017) estimate the losses in soybean crops due to two big droughts in 2008/2009 and 2011/12, up to $4.1 billion in the first case and $2.6 billion in the second case. These results are fairly in line with those obtained by Vilker (2018), who values the losses at $4.8 billion in 2008/2009 and $2.4 billion in 2011/2012. Both periods were times of recessions and balance-of-payments stress in Argentina, the first linked to the capital outflow in the Global Financial Crisis period, and to increments in domestic capital flight, respectively. These studies, as well as González et al (2021), also trace the subnational and departmental impact of the losses, concentrated on the main agricultural provinces. Ahumada and Cornejo (2021), in turn, find that droughts events associated with La Niña episodes lowered soybean yields between 1% and 2% during 1973-2015. Falling right outside the period under study, Naumann et al (2021) describe the 2019-2021 drought episode in La Plata Basin, still ongoing at the time of writing this article.

The study of World Bank (2021) is very comprehensive in its analysis of the impacts of floods and droughts, so it is important to dedicate a paragraph to its findings. The report highlights the dependency of provincial economic activity on agricultural production in Argentina. The projections for temperature and precipitation are negatively related in the case of Argentina, the former is projected to increase, the latter is projected to decrease. Droughts have a significantly higher and more negative impact than floods, though episodes of extreme precipitation have increased since the 1980s. The study estimates that the 2018 drought was responsible for half of the recession of 2.5% of GDP, while it accounted for 40% of the recession in 2009, and 80% of the recession in 2012. Their main fiscal impact is on tax revenues, not merely because of the fall in economic activity, but also because of the impact of droughts on exports, and therefore on export rights, a major source of revenue for the Treasury.

Comprehensive as it is, the report and the surveyed literature do not mention the potential impact on the balance of payments. Agricultural exports are a major source of foreign currency for the central bank. Reserve accumulation serves a number of objectives.

The literature identifies two major objectives for reserve accumulation. One view, which could be called “neo-mercantilist”, identifies a depreciated real exchange rate (RER) as an important tool to foster development of the tradable sector leading to dynamic welfare gains. In this context, FX reserve accumulation would help to smooth exchange rate volatility (Aizenman and Lee 2010, Benigno and Fornaro 2012; Korinek and Serven 2016; Rapetti et al 2012). The second argument highlights the role of reserves as a self-insurance policy, providing liquidity in times of stress (Aizenman and Lee 2007; Bastourre et al 2010; Obstfeld et al 2010,; Catao and Milesi-Ferretti 2014; Allegret and Allegret 2018, Arce et al 2019, Bianchi and Sosa-Padilla 2020). The experience during the 2008 Global Financial Crisis has vindicated the latter argument, according to Dominguez et al (2012); Bussière et al (2015); Alberola et al (2016), among others.

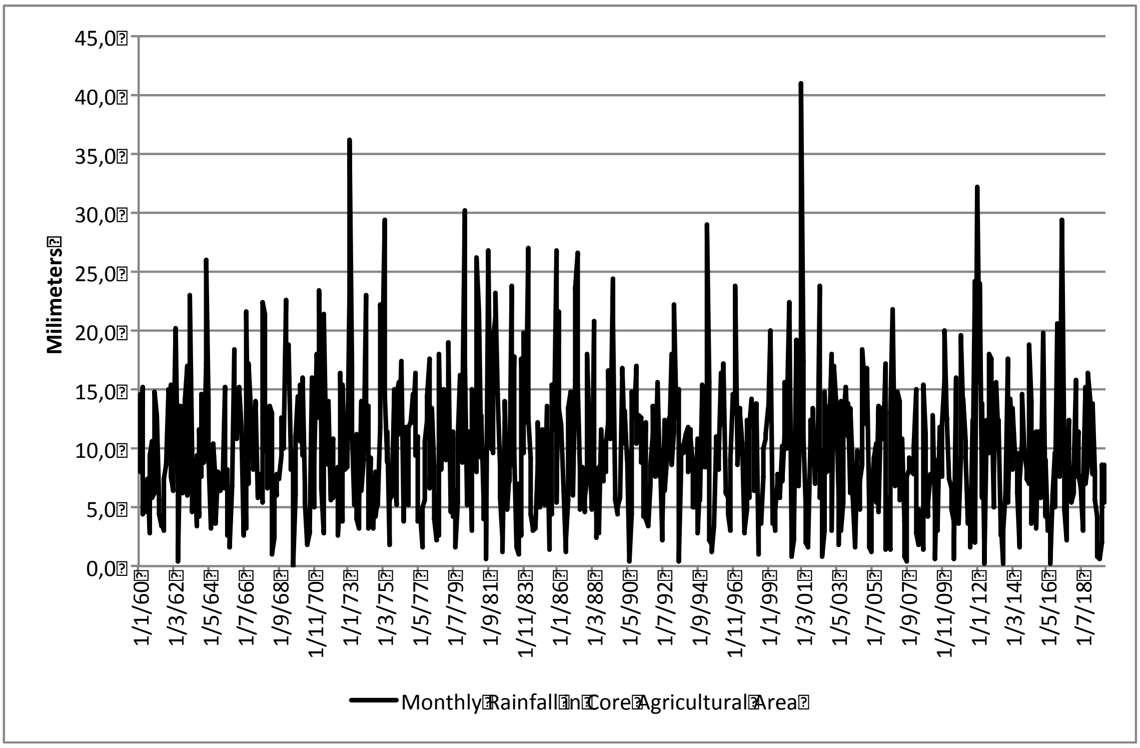
III. DATA AND TRENDS

The data used is this study was obtained from the following sources: i) Monthly rainfall values are the monthly average of the daily observations in three observational stations (9 de Julio, Junin and Pehuajó) of the National Weather Service in Argentina, located in the core agricultural zone of Argentina; ii) Monthly data on exports (in volume terms) by the four main agricultural complexes (soy, wheat, corn and sunflower) was obtained from the Ministry of Productive Development; iii) Monthly Economic Activity Estimator (EMAE, for its initials in Spanish), obtained from the National Institute of Statistics and Census (INDEC); iv) From the Central Bank of Argentina, we obtained the following monthly data (in cash criteria): changes in foreign exchange reserves, Monthly public external debt payments to the IMF, receipts from and payments to other official creditors (countries, multilateral banks, etcetera), and to private creditors, portfolio flows by non-residents, acquisition of financial external assets by the domestic private non-financial sector.

We can have monthly data on reserves from the 1940s. Rainfall data can be traced back (in some observational stations) to the 1960s, and we can have monthly export data since the 1990s. However, we have restricted the period under analysis to 2003-2019 because of the limited availability of monthly data of control variables such as economic activity, external debt payments and portfolio flows by residents and non-residents.

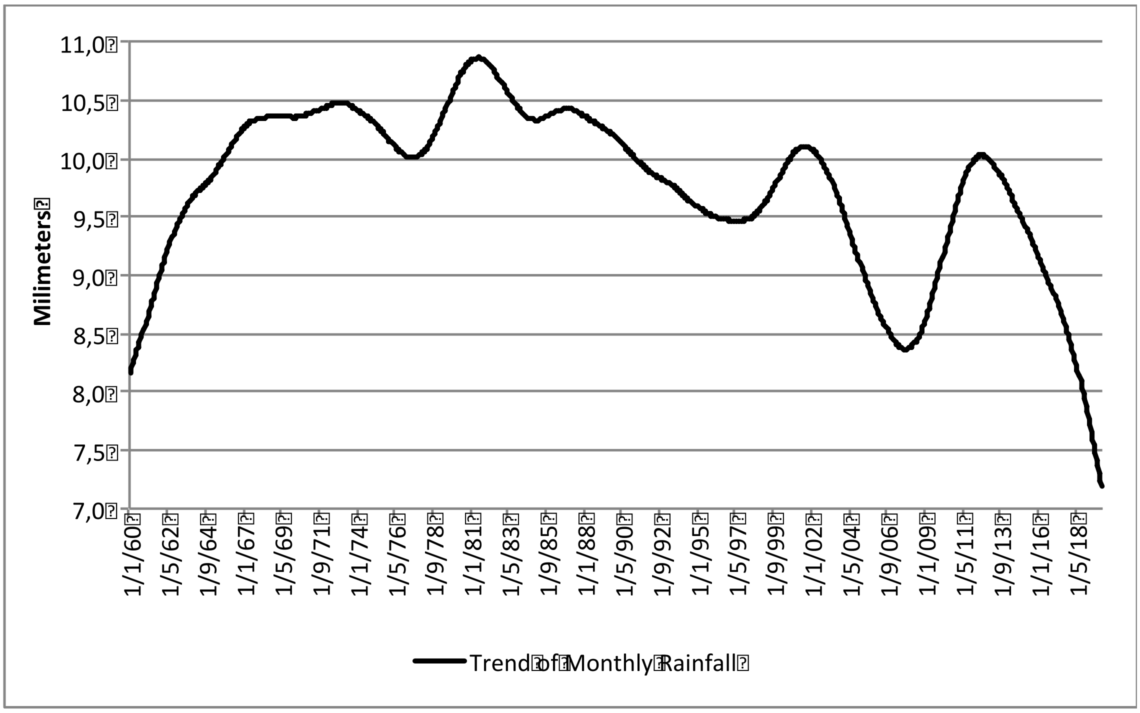
Graphs 1 shows the evolution of our measure of rainfalls, the average of monthly rainfall measured in the mentioned observational stations. To help the reader, graph 2 depicts the trend in that series, computed using the Hodrick-Prescott trend filter. Though with upswings and downswings, there is a discernible downward trend. Graph 3 and 4 show, respectively, the level of foreign exchange reserves, and its monthly changes. We assure the reader that these figures do not correspond to any record of seismic movements of techtonic plates, nor electrocardiograms, or any other measure or indicator that threatens human life. No death or injure was (directly) caused by these movements in FX reserves. Graph 3 shows that reserves increased in the 1990s and fell in early 2000s, then rose again but stagnated between 2008 and 2012, decreased until 2015, increased until 2018 (though there was a significant disbursement of an IMF loan in mid 2018), and fell throughout 2019.

Graph 1: Level of average monthly rainfall in the core agricultural area of Argentina



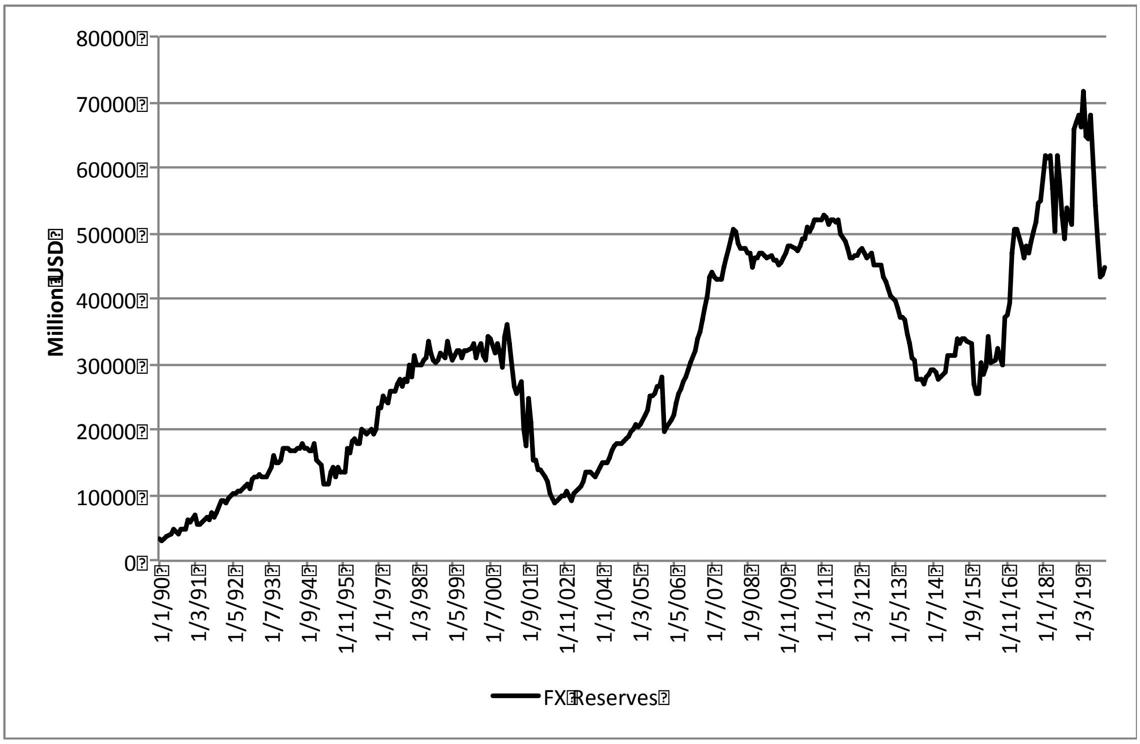
Source: Own elaboration based on National Meteorological Service. Data from the Observatory Stations of 9 de Julio, Junín y Pehuajó.

Graph 2: Trend of rainfall in the core agricultural area of Argentina



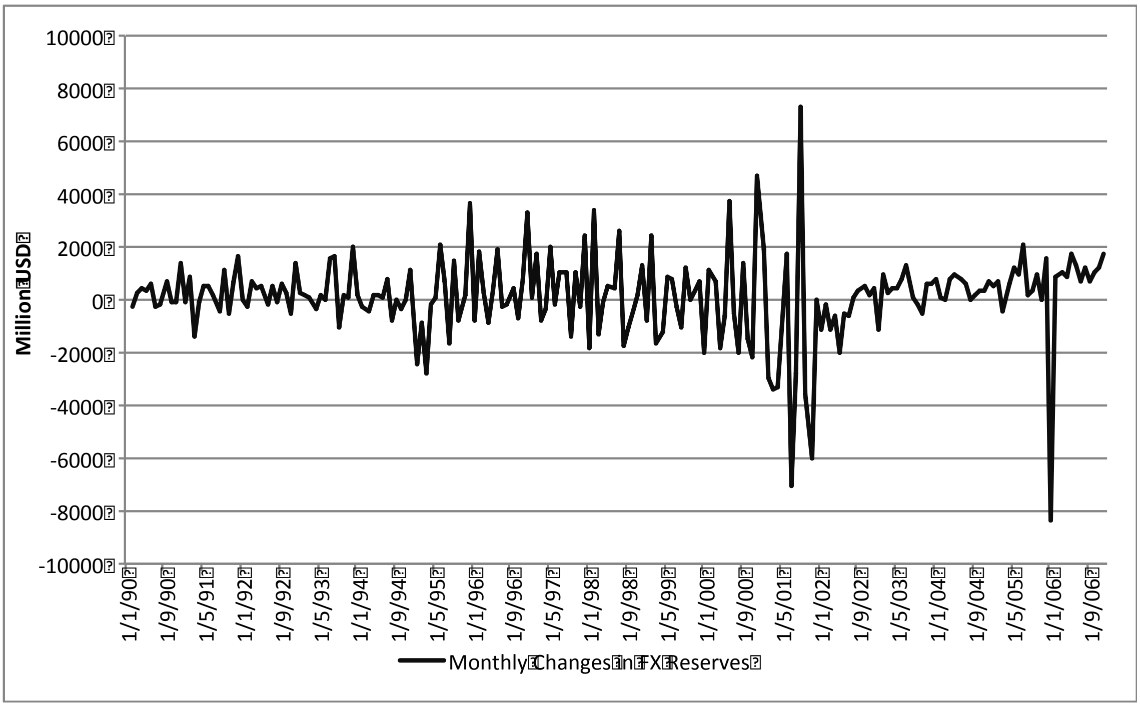
Source: Own elaboration based on National Meteorological Service. Data from the Observatory Stations of 9 de Julio, Junín y Pehuajó.

Graph 3: Level of foreign exchange reserves in Argentina



Source: Central Bank of Argentina

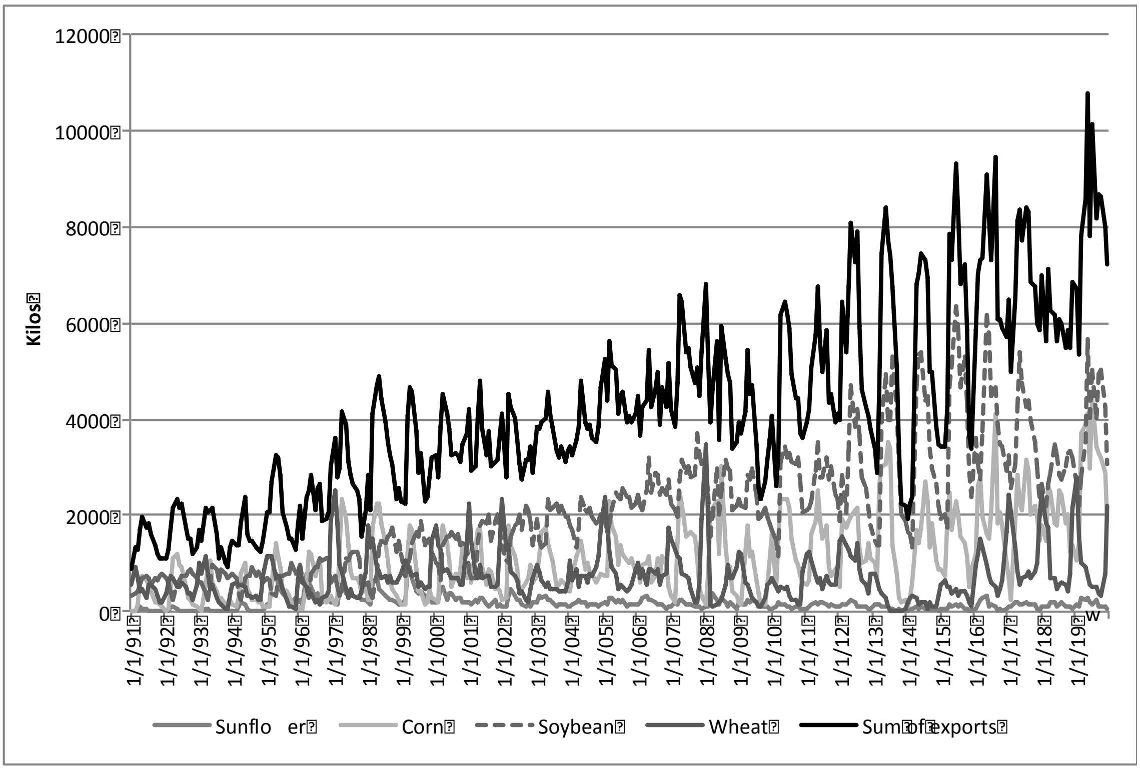
Graph 4: Monthly changes of foreign exchange reserves in Argentina



Source: Own elaboration based on Central Bank of Argentina.

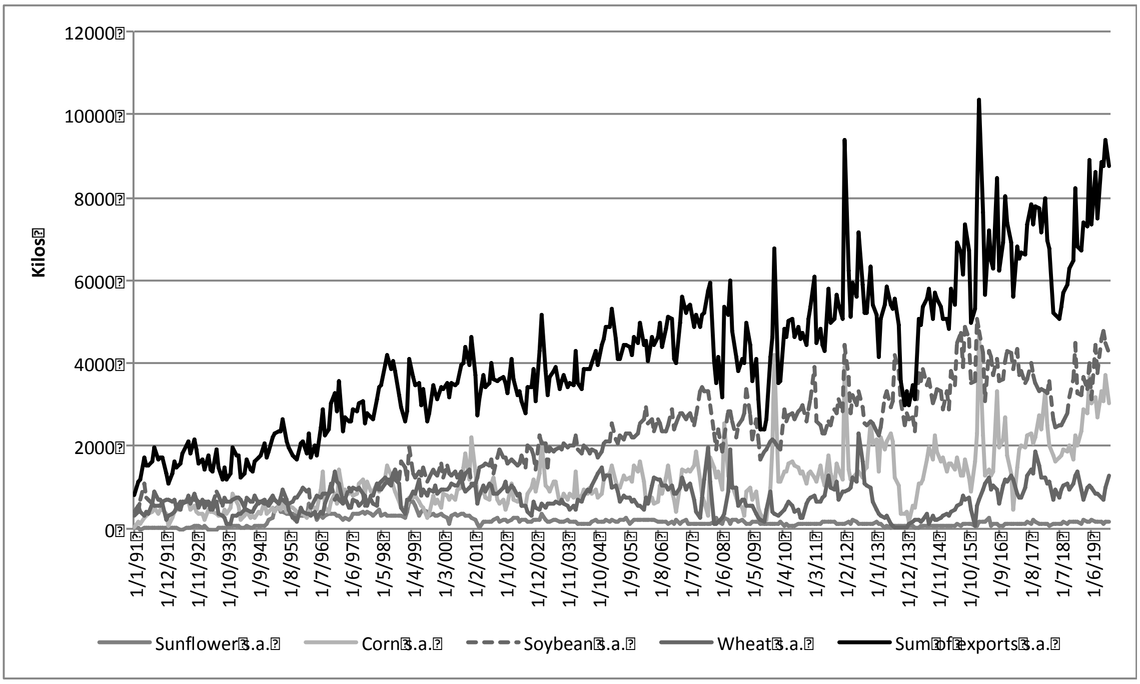
Graph 5 and 6, in turn, show the level and the seasonally adjusted values of agricultural exports, distinguishing the four complexes. While soy and corn show an increasing trend (in the latter, particularly after 2014), wheat observes fluctuating but stagnated levels, and sunflower output decreased until 2014 and started to recover afterwards. Soy is the most important crop. While corn and wheat were relatively similar in terms of volume in the 2000s, corn outpaced wheat in the 2010s. Sunflower crop constitute the smallest share of the group.

Graph 5: Level of Agricultural Exports by complex (in volume)



Source: Ministry of Productive Development

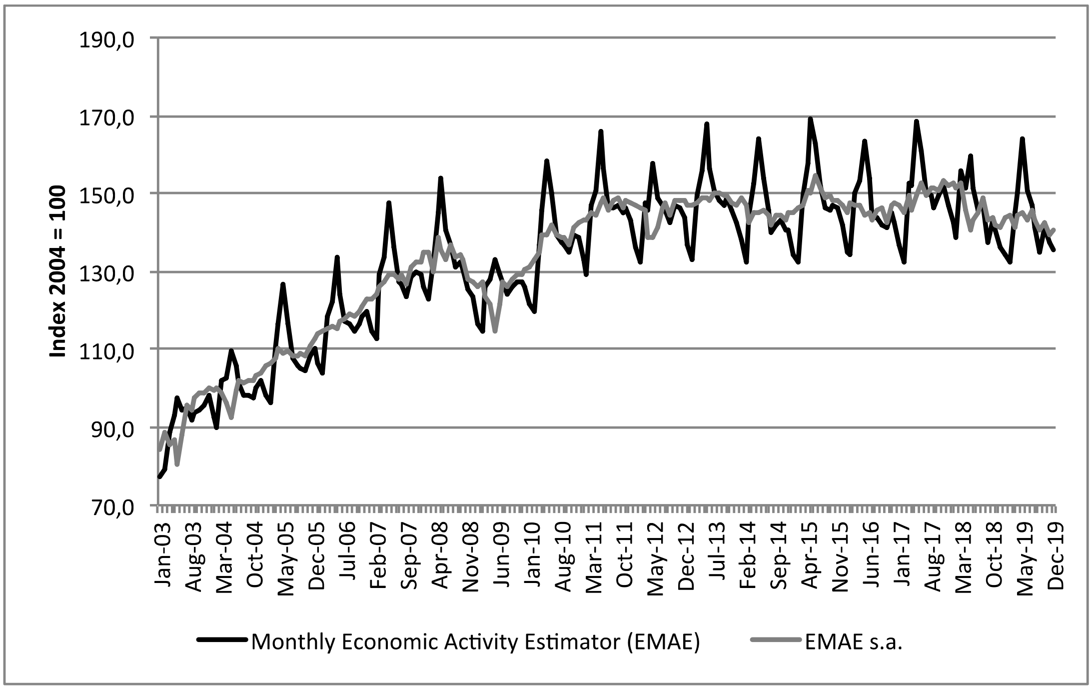
Graph 6: Agricultural exports by complex, seasonally adjusted (in volumes)



Source: Own elaboration based on Ministry of Productive Development.

Graph 7 shows the evolution and the seasonally adjusted value of the EMAE. While the 2000s was mostly a decade of recovery (after the 2001 crisis), the 2010s was basically a decade of stagnation, reflected as well in variables like the GDP per capita.

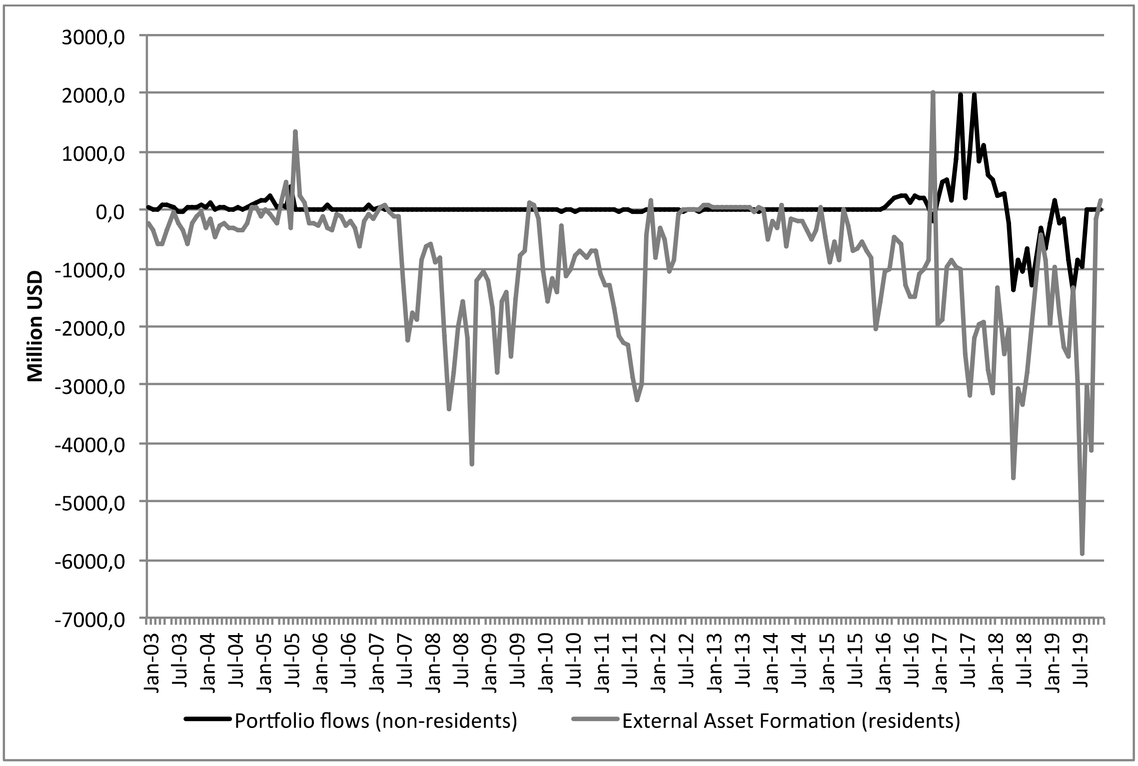
Graph 7: Level and seasonally adjusted Monthly Estimator Economic Activity (EMAE)



Source: Own elaboration based on National Institute of Statistics and Census.

Graph 8 shows external financial asset formation by the private non-financial sector and portfolio flows by non-residents. The former reflects outflows almost uninterruptedly throughout the period. Portfolio flows, in turn, show almost brief and small entries in 2003-2005, then close to zero for a decade. During this period Argentina was essentially excluded from financial markets because of the lingering conflict with "holdouts" of the 2001 default. The country returned again after 2015. We see a significant increase in portfolio inflows in 2016 and 2017, and a sharp reversal in 2018 and 2019.

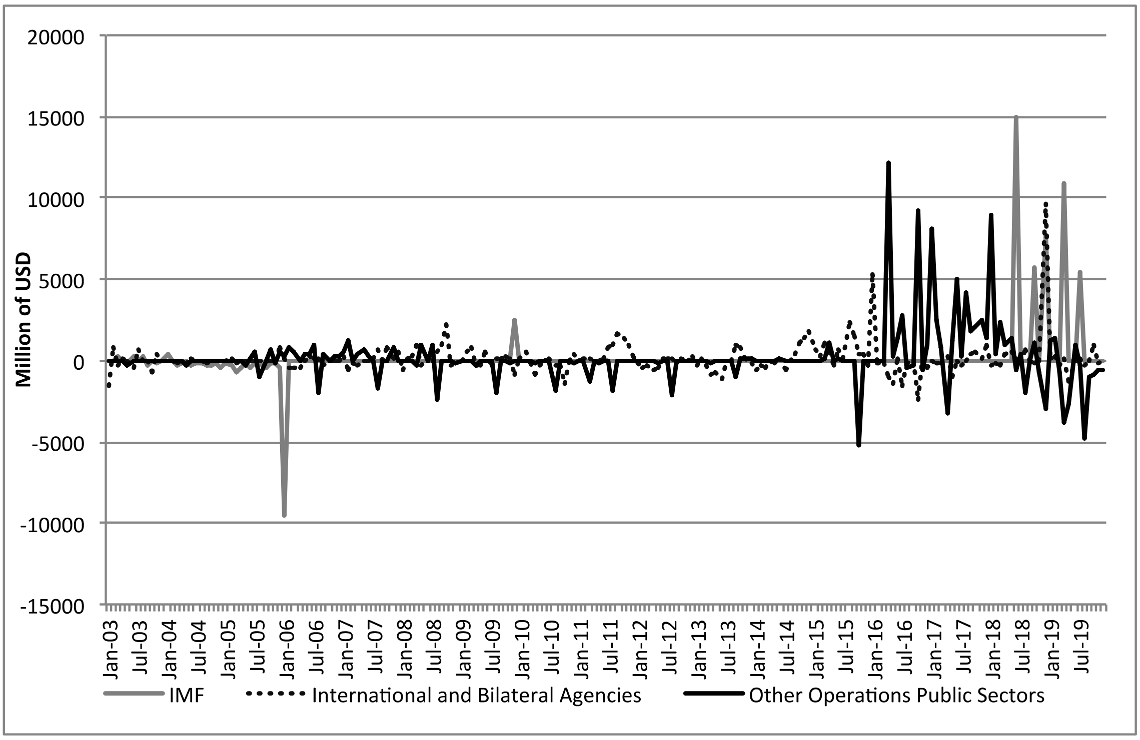
Graph 8: Portfolio flows by non-residents and external financial asset formation by residents



Source: Central Bank of Argentina

Graph 9, finally, shows receipts from and payments to official creditors (international and bilateral agencies), other operations of the public sector (mainly debt payments to private creditors) and receipts from (and payments to) the IMF. The relationship with the IMF was more "infrequent": Argentina cancelled its obligations in 2005, and got into a new agreement in 2018. It received $44 billion in 2018 and 2019. Payment begins in 2021. Table 1 presents the descriptive statistics of the variables included in the econometric analysis.

Graph 9: Flows from (and to) IMF, International and Bilateral Agencies, and other operations of the public sector



Source: Central Bank of Argentina

Table 1: Descriptive Statistics of selected variables

Variables/Stats	Mean	Standard Dev.	SE (mean)	Min	Max
Reserves	38507.5	14007.8	980.7	9325.6	71662.5
Exports (sum)	5287.8	1738.2	121.7	1944.5	10750.8
Rainfall	9.0	5.6	0.4	0.2	32.2
Agricultural Prices (mean)	417.7	122.0	8.5	219.6	717.4
EMAE	133.0	19.6	1.4	77.2	168.9
External Asset Formation	-923.3	1091.8	76.4	-5908.6	2014.5
Portfolio Non-Resid Flows	13.4	352.7	24.7	-1409.6	1978.4
IMF	157.0	1653.9	115.8	-9530.0	14955.9
International & Bilateral Agencies	112.9	965.4	67.6	-2463.5	9668.7
Other Public Sector Operations	180.7	1725.4	120.8	-5209.9	12166.7

Source: Own elaboration

A curious reader may ask why did we not use the exchange rate as the dependent variable, instead of reserve accumulation. The main explanation is that, since 2012 and until 2015, the government implemented a variety of (increasingly strict) capital controls. These led to the development of parallel markets, and a widening gap between the official and parallel exchange rates of up to 60%. These controls were lifted in December 2015, and reinstalled in October 2019 (see Bortz et al 2021). The volumes traded in these parallel markets were generally small, but the influence of the parallel exchange rate upon economic activity, prices and financial variables is open to debate. Instead, paraphrasing the popular singer Shakira, "reserves don't lie".

IV. RESULTS

We perform a Two-Stage Least Squares (TSLS) approach. This approach is useful when one of the alleged explanatory variables is endogenous itself. In equation terms:

(1) $y = \alpha_x X_{ex} + \alpha_n X_{en} + e$

(2) $X_{en} = \gamma_x X_{ex} + \gamma_n Z_{iv} + u$

With y is a nx1 vector of dependent variables; X_{ex} is a nxk_{ex} matrix of exogenous variables; X_{en} is a nxk_{en} matrix of endogenous regressors; Z_{iv} is a nxk_{iv} matrix of of instrumental variables; $\alpha_x, \alpha_n, \gamma_x$ and γ_n are vectors of parameters, and e and u are error vectors. In our case, the relevant equations are (3) and (4):

(3) $Reserves = \beta_1 expo + \beta_2 prices + \beta_3 activity + \beta_4 portfolio + \beta_5 EAF + \beta_6 IMF + \beta_7 IB + \beta_8 other + u$

(4) $Expo = \gamma_1 rain + \gamma_2 pr + \gamma_3 a + \gamma_4 po + \gamma_5 EAF + \gamma_6 IMF + \gamma_7 IB + \gamma_8\, other + u$

Where *reserves* stands for international reserves of the central bank, stands for the monthly sum of exports in volume (kilos) of the four main agricultural complexes in Argentina (soya, wheat, corn and sunflower), *prices* stands for the weighted mean of prices of those four crops, *activity* stands for the EMAE, *portfolio* stands for portfolio flows by non-residents, *EAF* stands for external asset formation by residents, *IMF* stands for receipts (and payments) from (and to) the IMF, *IB* stands for receipts (and payments) from (and to) international and bilateral agencies, *other* stands for other financial movements of the public sector, and *rain* stands for monthly rainfall.

Table 2 presents the results of the first and second stage of the main specification of the first and second stage of the regressions. In this specification, we chose as our dependent variable the monthly variation of the log of international reserves. In further robustness checks we will analyse other specifications. As our endogenous regressor, we firstly adopt the detrended log of the *sum* of seasonally-adjusted monthly exports, in volume terms. In some of the specifications we include the first lag of the dependent variable. *Prices* are specified as the variation of the weighted mean of agricultural prices. *Activity* is specified as the detrended EMAE. As for our instrument, monthly rainfall, we present at first three different specifications, given the nature of the crops. As shown in graphs 5 and 6, soy and corn are the main agricultural complexes. The volume of the harvest is significantly determined by rainfall in the (southern) summer time. That is why we test different alternatives, as shown in table 2.

Table 2: 2SLS results with monthly variations of log of international reserves

First Stage. Dependent Variable: detrended log of sum of seasonally-adjusted exports						
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Reserves (-1)		0,3076178		0,2776758		0,3024291
Prices	-0,0004733	-0,000449	-0,0004881	-0,0004604	-0,0004823	-0,0004531
Activity	0,0118438***	0,0118765***	0,0123696***	0,0123971***	0,0123693***	0,0123969***
Portfolio	0,0000572	0,0000529	0,0000601	0,0000563	0,0000602	0,0000562
EAF	0,0000216**	0,0000219**	0,0000192*	0,0000187*	0,000016	0,0000154
IMF	-6,87e-06	-4,96e-06	-7,57e-06	-5,80e-06	-7,35e-06	-5,47e-06
IB	0,0000129	0,0000127	0,0000121	0,0000118	0,0000137	0,0000121
Other	-3,46e-06	-3,44e-06	-5,92e-06	-5,77e-06	-5,20e-06	-5,08e-06
S.A. January rainfall	0,0047063**	0,0045496**				
Mean of S.A. January and February rainfall			0,0013235**	0,0033344**		
Mean of S.A. January, February and March rainfall					0,0028572**	0,0024734

Second Stage. Dependent variable: Monthly variations of log of international reserves.						
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Expo	0,20485093***	0,19964309**	0,33830235**	0,33470291**	0,43960775*	0,45494044
Reserves (-1)		0,06165669		0,01682541		-0,02308581
Prices	0,0001042	0,00010698	0,00016738	0,00016678	0,00021534	0,00022002
Activity	-0,0032895**	-0,00322653**	-0,00495503**	-0,00491388**	-0,00621937*	-0,00641604
Portfolio	6,982e-06	6,437e-06	-1,440e-06	-1,433e-06	-7,834e-06	-8,439e-06
EAF	0,00001164***	0,00001184***	0,00001105***	0,00001111***	0,0000106**	0,00001045**
IMF	0,00002293***	0,00002327***	0,00002395***	0,00002401***	0,00002472***	0,00002468***
IB	0,00001516***	0,00001529***	0,0000135**	0,00001364**	0,00001224*	0,00001217*
Other	0,00002109***	0,00002108***	0,00002173***	0,00002173***	0,00002222***	0,0000223***
Obs.	203	202	203	202	203	202
F-statistic	5,14***	4,84***	4,20***	3,95***	3,85***	3,65***
Adjusted R2	0,1402	0,1461	0,1120	0,1160	0,1010	0,1057

Legend: *p<0,1; **p<0,05; ***p<0,01.

We tried three different specifications of seasonally-adjusted monthly rainfall: the month of January alone, the mean of January and February, and the mean of January, February and March, with and without the lag of the dependent variable (monthly variations of the log of international reserves). The three specifications of rainfall were statistically significant at 95% of confidence in the first and in the second stage, with the exception of the mean of January, February and March, when we include the lag of the dependent variable.

Based on these results (and in other specifications, to be presented below), we can affirm that rainfall in the Argentine summer is a good instrument for exports of the agricultural sector, and it has a significant influence on reserve accumulation. In the second stage, economic activity was statistically significant in five out of the six specifications, at 95 % (in models 1 to 4) and 90% (model 5). External asset formation was statistically significant and with the expected signs in all six specifications, though with different thresholds of confidence. The same applies to receipts from (and payments to) the IMF, from (and to) international and bilateral agencies, and other financial movements of the public sector. A surprising factor is that agricultural prices are not significantly explanatory variables of reserves, nor of agricultural exports.

We also ran a regression with agricultural exports as the dependent variable, and included rainfall (in the mentioned months), agricultural prices and two different measures of global economic activity: the US PMI composite index (obtained from Nasdaq) and the Global Real Economic Activity Index, compiled by the Federal Reserve. Only rainfall had statistically significant results.

Tables 3 and 4 present the second-stage results of alternative specifications of the dependent variable and the endogenous regressor. The instrumental variables in both tables are seasonally-adjusted January rainfall (models 1 and 2), seasonally-adjusted January and February rainfall (models 3 and 4) and seasonally-adjusted January, February and March rainfall (models 5 and 6). In Table 3, as dependent variable we use the monthly variation of international reserves, and as dependent regressor we use the sum of detrended seasonally-adjusted exports. In Table 4, we also use the monthly variation of international reserves as dependent variable, but we adopt a different endogenous regressor: the detrended log of the *mean* of seasonally-adjusted exports (instead of the sum). Results are mostly coincident with those of table 2. Significance for exports as determinant of reserve accumulation is lost when we include the month of March within our instrumental variable of rainfall. As mentioned above, it is rainfall during certain, key months that is relevant for agricultural output and exports. Another difference is the loss of significance of the *activity* variable in models (5) and (6).

Table 3: 2SLS results with monthly variation of international reserves

Second Stage. Dependent variable: Monthly variations of log of international reserves.						
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Expo	2,0795964**	2,0860359**	3,2720529*	3,215013*	3,697218	3,608747
Reserves (-1)		0,06088408		0,03962339		0,0322087
Prices	4,1369769	4,3857663	6,440871	6,5053997	7,088429	7,244628
Activity	-141,49644**	-143,88961**	-241,93334*	-213,16599*	-235,5743	-237,3263
Portfolio	0,28679473	0,25126615	-0,22562698	-0,22044511	-0,3696539	-0,3849557
EAF	0,59014692***	0,59589052***	0,55861791***	0,5633136***	0,549756***	0,5519523***
IMF	1,0505491***	1,0680389***	1,0757209***	1,0860264***	1,082796***	1,0923***
IB	0,86031663***	0,87021238***	0,84793269***	0,85226388***	0,8444519***	0,8460043***
Other	0,92274538***	0,92470415***	0,97998143***	0,97788729***	0,9960688***	0,9964351***
Obs.	204	203	204	203	204	203
F-statistic	5,29***	4,76***	4,73***	4,23***	4,57***	4,11***
Adjusted R2	0,1440	0,1428	0,1276	0,1254	0,1229	0,1211

Legend: *p<0,1; **p<0,05; ***p<0,01.

Table 4: 2SLS with detrended log of the mean of s.a. Exports

Second Stage. Dependent variable: Monthly variations of log of international reserves.						
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Expo	0,2048508***	0,2051565***	0,33830195**	0,33031359**	0,43960687*	0,43673061*
Reserves (-1)		1,8844e-06		1,264e-06		7,703e-07
Prices	0,0001042	0,00011115	0,00016738	0,00016826	0,00021534	0,00021682
Activity	-0,00328949**	- 0,00334634***	-0,00495502**	-0,00489166**	-0,00621935*	-0,0062056*
Portfolio	6,982e-06	5,937e-06	-1,440e-06	-1,639e-06	-7,834e-06	-8,081e-06
EAF	0,00001164** *	0,00001183***	0,00001105***	0,00001121***	0,0000106**	0,00001069**
IMF	0,00002293**	0,00002346***	0,00002395***	0,00002425***	0,00002472***	0,00002492***
IB	0,00001516** *	0,0000155***	0,0000135***	0,00001384**	0,00001224*	0,00001242*
Other	0,00002109** *	0,00002114***	0,00002173***	0,00002173***	0,00002222***	0,00002223***
Obs.	203	203	203	203	204	203
F-statistic	5,14***	4,68***	4,20***	3,80***	3,85***	3,51***
Adjusted R2	0,1402	0,1401	0,1120	0,1103	0,1010	0,1001

Legend: *p<0,1; **p<0,05; ***p<0,01.

To check the robustness of the results under a different setting, we conducted a series of VARs. In table 5, we show the results of a one-lag VAR that includes exports and summer rainfall, under different specifications. The export variable included in models (1) to (3) is the detrended log of the sum of seasonally-adjusted exports, while in equations ((4) to (6) we include the detrended log of the mean of seasonally-adjusted exports. The results corroborate the significant influence of rainfall, particularly in the month of January, as an explanatory variable for agricultural export performance.

Table 5

	Detrended log of the sum of s.a. exports			Detrended log of the mean of s.a. exports		
	(1)	(2)	(3)	(4)	(5)	(6)
Expo (-1)	0,54960436***	0,56231469***	0,57129762***	0,54960428***	0,56231461***	0,57129751***
S.A. January rainfall	0,00492836***			0,00492836***		
Mean of S.A. January and February rainfall		0,0064223**			0,00642231**	
Mean of S.A. January, February and March rainfall			0,00617032**			0,00617033**
Constant	-0,0407753**	-0,05886428**	-0,05733345*	-0,0407753**	-0,0588643**	-0,05733351*
Obs	203	203	203	203	203	203
AIC	-0,997242	-0,9842911	-0,9749677	-0,9972422	-0,9842813	-0,974968
HQIC	-0,9774332	-0,9644824	-0,955159	-0,9774334	-0,9644826	-0,9551592
SBIC	-0,9482783	-0,9353275	-0,9260041	-0,9482785	-0,9353277	-0,9260043
R squared	0,3896	0,3817	0,3759	0,3896	0,3817	0,3759
chi2	129,5835***	125,3041***	122,2574***	129,5835***	125,304***	122,2574***

Legend: *p<0,1; **p<0,05; ***p<0,01.

Afterwards, we perform two one-lag VARs with the same variables included in the second stage of our previous 2SLS exercise, in tables 2-4. The variable *Reserves* is captured by the monthly variations of the log of international reserves. The difference between the two VARs is the indicator for *exports*. While in the VAR (1) we use the detrended log of the sum of seasonally-adjusted exports, in the second we use the detrended log of the *mean* of seasonally-adjusted exports. Results are shown in table 6. Results are consistent with previous tests. The main difference is that now portfolio flows by non-residents are statistically significant with a 90% degree of confidence as an explanatory variable for reserve accumulation.

Table 6: Results of VARs

	(1)	(2)
Reserves (-1)	0,117856***	0,11785601***
Expo	0,03033565**	0,03033564**
Prices	0,00003201	0,00003201
Activity	-0,00111132	-0,00111132
Portfolio	0,0000163*	0,0000163*
EAF	0,00001277***	0,00001277***
IMF	0,00002233***	0,00002233***
IB	0,00001736***	0,00001736***
Other	0,00002028***	0,00002028***
Obs	202	202
AIC	-3,674125	-3,647125
HQIC	-3,587487	-3,587487
SBIC	-3,499727	-3,499727
R squared	0,6425	0,6425
chi2	362,9895***	362,9895***

Legend: *p<0,1; **p<0,05; ***p<0,01.

V. CONCLUSION

The paper has explored one channel by which the manifestations of the physical risks posed by climate change can affect central bank objectives. We present evidence which shows that changes in rainfall patterns (linked to climate change) can have a negative influence on reserve accumulation in an emerging commodity-exporting economy like Argentina. From the study, we draw several conclusions for central bankers. First, central banks should incorporate climate-related changes in several "real" and "financial" variables in their projections of scenarios for monetary policy design and implementation. Changes in export patterns can affect exchange rates, interacting with changes in market sentiments. This is particularly the case for agricultural-exporting economies such as Argentina, which are exposed to the kind of physical risks explored in this article. But other commodity-exporting countries can be affected (for better or worse) by transition risks, such as changes in global energy consumption patterns, or by higher demand for commodities required for the energy transition.

Second, though not covered in this study, the impact of changes in rainfall and exports have consequences for other dimensions of monetary policy. For instance, the losses due to droughts and floods can deteriorate the balance-sheet of specific sectors, as well as increasing liquidity demand. By its very nature, with significant time lapses between expenditures in inputs and receipts from sales, the agricultural sector is very credit-intensive. It also has linkages with numerous productive sectors, such as chemicals, machinery, engineering and others. Disruptions in income flows can have widespread effects on firms and creditors.

Finally, the macroeconomic effects of climate change go beyond the concerns of central bankers. Referring specifically to conclusions from this study, our results point towards the necessity of diversifying the export basket of agricultural-exporting countries to reduce the exposure of the balance-of-payments to climate-related changes in environmental conditions.

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