Economics Bulletin

Volume 32, Issue 2

Impacts of climate extreme events on production and trade in four Mediterranean countries

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Abstract

The Mediterranean is one of the areas the most exposed to climate change. Setting up measures of prevention and adaptation is a priority for the region, to reduce climate costs. The aim of this paper is to highlight the economic losses already incurred by the Mediterranean countries due to extreme events. A structural VAR model allows to assess the vulnerability of the real, monetary and financial sectors of four countries in the region, characterized by different economic profiles, following periods of extreme climatic change. The analysis reveals that all countries in the sample already know significant economic losses which may increase with the strengthening of the climate change if no action is taken.

I would like to thank the anonymous referee for comments and suggestions.
Citation: Celine Gimet, (2012) "Impacts of climate extreme events on production and trade in four Mediterranean countries", *Economics Bulletin*, Vol. 32 No. 2 pp. 1755-1764.
Contact: Celine Gimet - celine.gimet@free.fr.
Submitted: January 09, 2012. **Published:** June 18, 2012.

1. Introduction

The Mediterranean is among the areas that may soon face significant physical difficulties related to climate change (Stern, 2006; IPCC, 2007; Tol, 2007; Blue Plan, 2008). A warming of about 2°C over the last forty years has been identified in the south-west Europe (IPCC, 2007), extreme events have intensified in recent decades and the percentage of surface involved has expanded. There is no standard definition of extreme events in economic literature, but they are identified as climatic movements of large amplitude which can reach and exceed maximum thresholds[1] and are characterized by their rarity and the magnitude of their negative effects. They are reflected particularly by increased periods of drought due to a high number of days during which the temperature exceeds 30°C (Giannakopoulos *et al*., 2005). Similarly, periods of flooding are becoming more violent. They evolve rapidly from a certain temperature level, creating irreparable damage (Stern, 2006). According to Smith *et al*. (2001), as part of an extreme climatic event, there is an upward shift in the distribution of temperatures and precipitations as a whole, disproportionate to the thresholds[2] defined as harmful. The effects they produce result in widespread destruction of capital (including infrastructures, but also agricultural production) but also by social and environmental catastrophic impacts (death, wounded, epidemics ...) over a period of one day, (in the case of hurricanes, for example) a few weeks (flooding) (Hallegatte *et al.*, 2007). Specifically, the global costs associated with extreme events during the second half of the twentieth century is estimated at 0.1% of GDP on average. These losses could intensify with climate change in coming years and reach 0.5 to 1% of global GDP for a temperature increase of 2°C (Stern, 2006).

These problems are exacerbated by increased demands for agricultural products, infrastructures, housing and energy linked to economic development and to the demographic evolution of the countries. This situation may create a widening inequality between the north and the south, but also within a same region. In particular, the adverse effects of extreme events may affect significantly the area's growth and create considerable difficulties in the country. Paradoxically, the economic impact of climate change in the Mediterranean countries has not been given much attention in the empirical literature. It is therefore important to focus on the costs borne by countries that may continue to grow in coming decades if no preventive measures are implemented to anticipate or limit these phenomena. This is to alert decision makers about the need to consider this problem as a whole and the importance of the implementation of adaptation policies. In addition, taking into account the upstream effects and issues of climate change in the definition of development strategies might ensure political stability in the region, in the coming years.

The objective of this paper is to highlight the costs associated with extreme events in the Mediterranean, taking into account four countries with different profiles in order to consider the main economic, social and geographical specificities that we can find in the region (a country from the north, one from the east and two from the south; one of which is an importer and another one an exporter of oil). This paper proposes a pioneering study on this subject through the implementation of a Structural VAR model, used seldomly to estimate the costs of climate change.

In section 1, the empirical analysis will be developed. In section 2, the results will highlight the different reactions of countries, the high costs incurred by each type of extreme event, and the responsiveness of each revealed by the magnitude and length of the shock.

[1] For Stern (2006), these thresholds are two standard deviations from the mean.
[2] See definition above.

2. A study of the impact of extreme events

2.1. The SVAR model

The representation of the reduced form of the vector auto-regression model VAR(q) is:

$$A(L)Y_t = e_t \qquad (1)$$

with L the lag operator and e_t a white noise. The variance-covariance matrix of the error vector has no restrictions, that is to say $E(e_t, e_t^T) = \Omega$ and $E(e_t) = 0$.

In order to obtain the shock response functions and the forecast error variance decomposition, it is necessary to write the process in the Moving Average infinite structural form. An intermediate step consists in "reversing" the canonical VAR model according to the Wold Theorem in order to obtain its moving average form:

$$Y_t = C(L)e_t \qquad (2)$$

where e_t represents the vector of canonical innovations.
Thus, the structural Moving Average representation is:

$$Y_t = \Theta(L)\varepsilon_t \qquad (3)$$

with $$e_t = P\varepsilon_t \qquad (4)$$

where P is an invertible matrix n x n which has to be estimated in order to identify the structural shocks. The short-run constraints are imposed directly on P and correspond to some elements of the matrix set to zero. The Θ_j matrix represents the response functions to shocks ε_t of the elements of Y_t. The different structural shocks are supposed to be non-correlated and to have a unitary variance $E(\varepsilon_t, \varepsilon_t^T) = I_n$. Ω is the variance-covariance matrix of the canonical innovations e_t, thus $E(e_t, e_t^T) = PE(\varepsilon_t, \varepsilon_t^T)P^T = PP^T = \Omega$. (5)

2.2. The variables

Four countries were selected as part of the analysis: Algeria, Tunisia, Turkey and France over the period 1980:1, 2011:2.

Five economic variables and two climatic shocks were selected. Regarding the economic variables, the objective is to underline the consequences of abrupt climate changes in the real, financial and monetary sectors of each country, as well as the interactions between different spheres of the economy: the indicator of output (y) was chosen according to the specialization of the countries (industrial production for France, Tunisia, Turkey, and oil in Algeria); total exports (*xpt*); the index of consumer prices (p); the share of foreign assets held by the Central Bank (*res*); and the interest rate (*interest*). These variables commonly used in literature on Structural VAR[3] facilitate the introduction of short and long term restrictions. The variable *res* has however been added to study the movements of international capital in the economy, following various shocks[4].

In the choice of climatic variable, a tenfold variation in rainfall and temperatures (*prec* and *temp*) are included in this analysis the same way that studies on this subject (Smith *et al.*, 2001; Stern, 2006; Hallegatte *et al.*, 2007; IPCC, 2007).

All the variables were used in logarithm except the interest rate of the countries and the temperatures that could take negative values. The economic variables were seasonally

[3]Among the main references we find the work of Gali (1992), Sims and Zha (1995), Cushman and Zha (1997), Kim and Roubini (2000), Mackowiak (2007).

[4] The macroeconomic and financial data are from the IMF International Financial Statistics CD-Rom (2011).

adjusted. It is not necessary to test the stationarity and the cointegration of the model's variables by following the postulate of Sims (1988) and Sims and Uhlig (1991) because a Bayesian inference is used and the model is not then affected by the presence of a unit root.

2.3. The contemporaneous restrictions

Let $Y = \begin{pmatrix} ext \\ y \\ xpt \\ p \\ res \\ i\eta terest \end{pmatrix}$ the vector of endogenous variables, and $\varepsilon_t = \begin{pmatrix} \varepsilon_{ext} \\ \varepsilon_s \\ \varepsilon_{td} \\ \varepsilon_p \\ \varepsilon_{fi} \\ \varepsilon_{ms} \end{pmatrix}$ the vector of structural shocks, where ε_{ext} represents the external shock, this means that the shock of precipitations (*prec*) or temperature (*temp*) and ε_s, ε_{td}, ε_p, ε_{fi}, ε_{ms} are respectively the real domestic shock, the trade shock, the domestic price shock, the financial domestic shock, the shock of domestic money supply.

The objective is to identify the n^2 elements of the P matrix. Statistically it is necessary to put 21identifying constraints. Indeed, as the matrix Ω is symmetric, $n(n+1)/2$ constraints of orthogonality are already admitted. To determine the $n(n-1)/2$ remaining constraints, 15 in the model, the economic literature was used. Only short-term constraints have been chosen.

One hypothesis is that the climatic shocks are considered as exogenous (Cushman and Zha, 1997). This implies that the economies of the analysis depend significantly on the temperatures and precipitations, but do not influence the climate in the short term (Mackowiack, 2007). Therefore, $P_{12}=P_{13}=P_{14}=P_{15}=P_{16}=0$. Furthermore, the hypothesis of a delay in the response of the economic activity and of the exports to a domestic financial and monetary shock is retained (Kim and Roubini, 2000), so $P_{25}=P_{26}=P_{35}=P_{36}=0$. In addition, the response of the prices to a shock of international reserves was postponed for a month, the same as the production with a shock related to exports (Kim and Roubini, 2000). This means that $P_{45}=P_{23}=0$. Finally, many authors (Sims and Zha, 1995; Kim and Roubini, 2000) have defined the function of money supply, as the function of monetary authorities that is to say interest rates, without taking into account the influence of prices and production in the short term. This approach assumes that it is necessary to consider a reaction time of monetary policy related to insufficient information. It means the hypothesis has to be enlarged by supposing that the financial shock and the shock related to international trade will not impact the interest rates in the short term. This is translated by $P_{62}=P_{63}=P_{64}=P_{65}=0$**.**

Following the Schwartz, Akaike and Hannan-Quinn tests, two delays were selected for all models. In addition, further tests have to judge the lack of residuals autocorrelation[5].

3. Results

3.1. The economic and financial context

While interpreting the results, it must be taken into account the several factors likely to influence the reactions of economic variables. Initially it is important to consider the specialization of the production of the country. Agricultural countries are very vulnerable to extreme events that can lead to loss of crops. Adverse effects can then not only be timely but extend throughout the year. Similarly, countries whose industries require a large number of infrastructures, especially if they are located in coastal areas, may face particularly high costs

[5]Details of tests are available from the author upon request.

in cases of important extreme shocks like floods, for example. Furthermore, some activities like tourism are very sensitive to extreme variations in temperatures and precipitations, which could discourage trips and thus lead to a loss of international reserves for the country. France produces and exports mainly services. Much of the workforce is concentrated in the agricultural sector in Turkey, and Algeria. Algeria, Tunisia and Turkey have important industrial productions (mining, manufacturing, electricity, gas, water) with certain proximity between the structures of the economy of these last two countries. Algeria is one of the major exporters of oil in the world. Tunisia and Turkey have tertiary activities oriented in trade, catering and hospitality; the economy is rather focused on the development of tourism (IPCC, 2007).

Furthermore, it is important to clarify that the macroeconomic environment is very different from one country to another sample country, and this can greatly influence their vulnerability to international shocks. Firstly, countries have not begun their commercial and financial openness at the same time and so they have not even reached the same level of international integration. The reactions of the variables related to exports and international reserves may be more pronounced in countries that open their economies more prematurely. France is the first sample country to liberalize its economy. Following the oil shocks in the late '70s, the objective was to capture the international savings to boost economic activity resulting in a reduction of financial barriers. Similarly the European integration that began in the late 50s was accompanied by a gradual reduction of obstacles to international trade. For other sample countries, opening commercial trade really started in the 90s as part of the Mediterranean policy, and was reinforced by the agreements of Barcelona in 1995. However, the main partners in these countries are the European countries (trade with the rest of the world is still limited). Similarly, the financial openness, dating from 2000 is very recent for these economies.

In addition, it is interesting to take into account the exchange rate regime in place, especially since it is generally linked to the country's monetary policy. France substantially fixed its exchange rates very early in the course of Monetary Snake, then the EMS since 1979. The country had to maintain its interest rates and inflation at low levels during all of the analysis period especially in the late 90s when the target was the construction of the euro zone. At the beginning of the analysis period, Algeria had opted for a fixed exchange rate regime and had undergone several devaluations. Thus, the margin for variation of interest rates was very low. Since 1996, Algeria favors a managed float with an intervention by monetary authorities to maintain some parity with the US dollar because the hydrocarbons are denominated in this currency. The country has maintained an inflation rate at a low level from the mid 90s. Since the late 80's, Tunisia has opted for an intermediate regime of crawling peg. The country chose an exchange regime with periodic adjustments to reduce inflation differentials with partnering countries and to stabilize export prices in foreign currencies. In fact, Tunisia has suffered from high inflation requiring it to maintain its interest rates relatively high. This appeared in the early 80s forcing the country to abandon its system of basket peg where the dollar was dominant. It is the same for Turkey: after a crawling peg regime in 1980-1981, the country adopted a managed floating regime until 1999, then again an intermediate regime which was abandoned following the 2001 crisis. Despite high inflation, and therefore constraints on the interest rate (the latter having been maintained at a high level during most of the analysis period), this country is still the one that has the greatest flexibility in terms of monetary policy to solve a climatic shock and stimulate economic growth.

3.2. The impact of extreme events

Regarding the countries' reactions to different types of climatic shocks, the significance of the results is judged from the figures illustrating the responses of domestic economic variables which follow a variation of a standard deviation of the external climatic variable (Appendix A.1). The confidence interval is calculated from the procedure proposed by Sims and Zha (1999)[6].

A shock in precipitation (*prec*) directly and significantly impacts the countries production (*y*). Increased precipitation may have, initially, positive effects, particularly for crops during the first month. But they quickly turn into negative impacts on economies. They are particularly important in the short term where losses are significant for all the sample countries. Turkey and Tunisia would be able to limit these effects after two months. In contrast, Algeria and France will suffer the consequences of this difficult shock for a longer period of up to one year. In addition, the negative effects are felt on exports (*xpt*) during the first months after the shock in France and in the long run in Tunisia and in Turkey, the rains would certainly damage some agricultural products. Algeria, which exports mainly oil, would not see its trade balance affected, rainfall has no impact on the structures governing the production of hydrocarbons on the one hand, and countries benefits from large stocks on the other hand. There is no impact on prices in France and in Turkey (*p*). The price would decline in Tunisia and Algeria influenced by the monetary policies of the countries to limit the general rise in prices, in particular when shocks can lead to inflationary effects. A decline in tourism may also explain this phenomenon in Tunisia. Reduced exports weigh lightly on reserves in France and in Algeria during the first month following the shock (*res*). In Algeria, this result can be explained by the fact that the exports are not affected on the one hand and numerous other barriers limit international capital outflows on the other hand. However, Turkey and Tunisia face a considerable loss of reserves in the first months after the shock and persist throughout the year at a slower pace. The monetary policies are limited by macroeconomic constraints but may result (eg in Tunisia) by a decrease in interest rates to boost economic growth (*interest*).

A shock in temperatures (*temp*) has a significant negative impact on production (*y*) in France, in Algeria and in Tunisia. In Turkey, the impact is first positive and then, beyond a certain temperature, negative. These findings converge with the conclusions of the Ricardian analysis on positive and negative consequences of increased temperatures from a certain threshold[7] (Mendelson *et al*., 2000; Kurukulasuriya *et al*., 2006). In France, in Algeria and in Tunisia the country exports (*xpt*) decrease during the first months following the shock and in Turkey they decline in the long term. Losses may accelerate in the coming years with rising temperatures leave knowing they already have a relatively high level especially in the southern countries (Stern, 2006; IPCC, 2007; Blue Plan, 2008). Prices (*p*) will react weakly in France and Turkey. However, they increase in the short term in Algeria and after the third months in Tunisia due to degradation of agricultural production, which would be felt throughout the year. The foreign currency reserves (*res*) are affected very slightly in France and in Algeria but decrease in the long term following the decline in production and exports in Tunisia and Turkey. Finally, in Turkey, the interest rate (*interest*) will suffer a slight decline from the second month onwards and, in Algeria, the interest rate decline in the long term.

Appendix A.2 highlights the involvement of climatic shocks in the total variation in each indicator. The study underlines the fact that in the 80s, 90s and at the beginning of 2000s, climatic shocks were already responsible for a change often exceeding 15% of the production

[6] Bayesian Monte-Carlo integration method proposed by Sims and Zha (1999) outperforms other procedures for short horizons (Kilian and Chang, 2001).

[7] This type of analysis assumes that all sectors sensitive to climate, there is a temperature that maximizes the welfare of this sector. Below that threshold growth temperatures resulting in increased production. Beyond this maximum, then the sector undergoes significant losses.

of various countries in the short and medium term. The extreme shocks explain the decreased production over the discussed period (8 months). They play a particularly important role in Tunisia, Turkey and France. Similarly, one can assign nearly 10% of the variation in exports and sometimes over 10% of the variation in prices and in foreign currency reserves, particularly in Tunisia. Only changes in interest rates are not directly related to the climate. From these tables, it shows a vulnerability of all the economies in the region to climate variability. Tunisia, however, seems to be the country whose production and exports are most dependent to climate while Algeria, which is specializing in the oil sector, seems slightly less sensitive. France and Turkey are in an in-between position, although, Turkey is relatively less dependent on the climate.

The results of the analysis converge with those of economic literature. The impact of shocks has been standardized to make it possible to measure the variables from a shock in a unit of the climatic variable (Appendix A.3). Thus, a sharp increase of 10% of precipitation that can be associated with the flood periods is likely to generate a cost close to 0.32% of the total production of the four countries in the years 1980-2011 during the 4 months which followed the disturbance. The countries most affected are Turkey (0.4% of the production) and Tunisia (0.2% of the production) during the year following the shock. The countries exports can decrease by 0.1% in France, 0.12% in Tunisia and 0.06% in Turkey. In relation to the temperatures, a harsh increase of 5°C, more than the normal temperatures for the season (approximately one standard deviation from the mean), which may be associated with a heat wave which has resulted in a decrease in country production of 0.03% in the first month following the shock for the period of 1980-2011.

4. Conclusion

All countries suffer adverse effects of an extreme variation in temperatures and precipitations. This is reflected particularly by the decrease of production in these countries. Consequently their exports drop significantly, especially in the agricultural sector. In addition, the decrease in production can lead to an increase in prices, especially commodities. This situation may concern particularly the poorest people who are already experiencing difficulties to find food sources. This can lead to epidemics and mass population movements from rural to urban, where they are not always equipped to handle a large influx of people. Beyond economic impacts, social consequences are also important. A decline in exports can have a drying effect on the international reserves of the country. This poses problems especially when they have chosen a fixed or quasi-fixed exchange rate regime.

The fact that all the countries are impacted and the effects are significant regardless of the geographical location and specialization of the countries shows that they are not really prepared to cope with future changes in the climate. This study shows the lack of adaptation policies from all the countries in the sample, to prevent or limit climate shocks. A regional cooperation could be organized to strengthen the countries capacities to deal with such shocks by adopting concerted policies across the area.

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Appendix

A.1. Country responses to climate shocks

Figure 1. Responses to a shock of precipitations (*prec*)

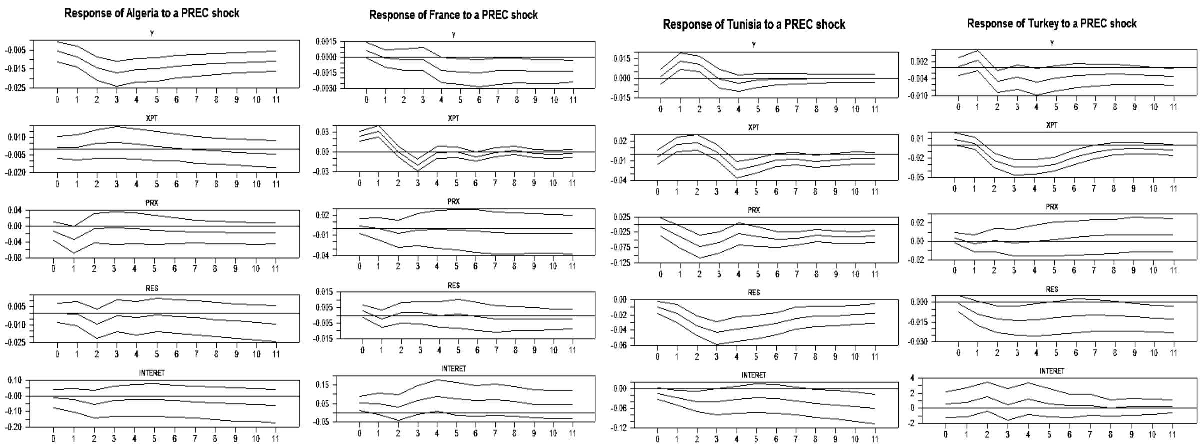
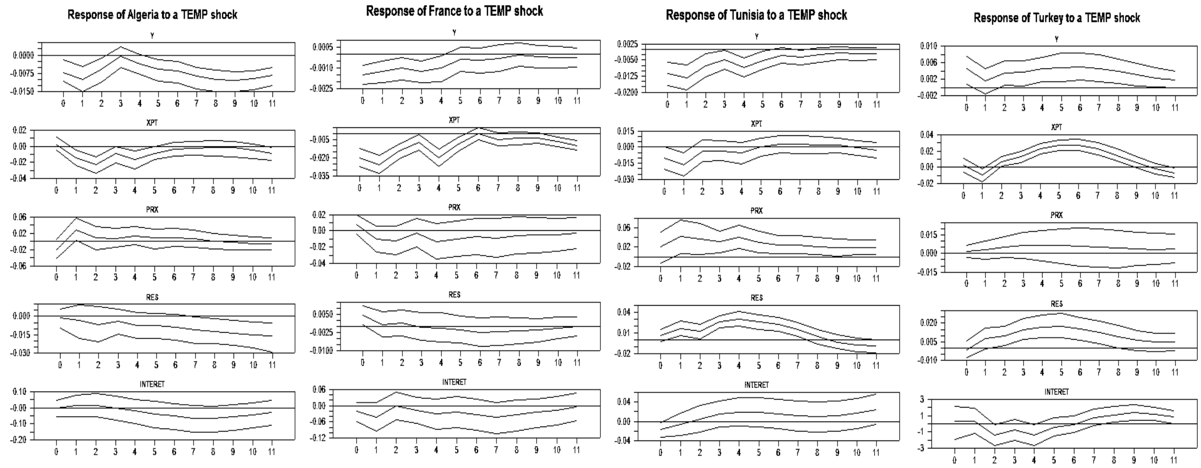


Figure 2. Responses to a shock of temperatures (*temp*)



A.2. Variance Decomposition

Table1. Decomposition of variance following a shock in precipitations (*prec*)

Period	Algeria	*y*	*xpt*	*prx*	*res*	*interest*
1		0.653	0.011	0.113	0.126	0.023
2		1.012	0.008	0.07	0.287	0.249
5		8.258	0.024	0.085	0.195	1.736
8		10.85	0.223	0.282	0.265	1.895
12		12.037	1.015	0.675	0.243	2.608
	France	*y*	*xpt*	*prx*	*res*	*interest*
1		5.22	5.166	0.059	0.253	0.936
2		3.88	14.725	0.094	0.495	1.021
5		7.97	12.506	0.047	0.252	5.455
8		13.17	10.465	0.039	1.253	7.726
12		17.25	8.738	0.045	2.329	6.301
	Tunisia	*y*	*xpt*	*prx*	*res*	*Interest*
1		0.044	0.071	0.042	0.911	0.554
2		5.58	0.549	2.432	1.758	0.463
5		12.491	8.488	3.076	13.214	1.186
8		9.439	7.832	3.49	16.17	1.344
12		8.818	10.304	4.491	15.525	2.027
	Turkey	*y*	*xpt*	*prx*	*res*	*interest*
1		0.01	0.481	1.36	0.019	0.051
2		0.11	0.676	1.19	0.723	0.074
5		7.66	7.976	2.32	1.538	1.022
8		5.82	8.443	1.39	1.689	1.291
12		5.82	7.162	0.91	2.053	1.353

Table 2. Decomposition of variance following a shock in temperatures (*temp*)

period	Algeria	*y*	*xpt*	*prx*	*res*	*interest*
1		1.153	0.063	0.331	0.012	0.002
2		1.388	0.252	0.544	0.026	0.002
5		0.891	2.732	0.464	0.082	0.067
8		1.07	2.189	0.423	0.125	0.227
12		2.475	1.77	0.542	0.171	0.325
	France	*y*	*xpt*	*prx*	*res*	*interest*
1		21.98	3.498	0.213	0.645	0.226
2		20.23	5.404	0.905	0.335	0.495
5		20.98	7.45	0.638	0.262	0.315
8		14.36	6.66	0.387	0.64	0.34
12		10.11	5.792	0.241	0.629	0.386
	Tunisia	*y*	*xpt*	*prx*	*res*	*interest*
1		2.361	0.592	0.231	0.304	0.711
2		4.743	3.949	1.916	0.726	0.369
5		4.848	3.408	2.821	3.032	2.512
8		4.535	3.431	3.898	3.133	3.873
12		4.245	3.365	4.587	3.623	3.88
	Turkey	*y*	*xpt*	*prx*	*res*	*interest*
1		9.14	0.057	0.49	0.076	0.03
2		7.53	0.901	0.8	0.834	0.027
5		6.46	1.147	0.4	2.883	0.446
8		8.01	3.539	0.37	2.933	0.514
12		9.11	3.424	0.32	2.116	0.969

A.3. Impact of standardized shocks

Table 3. Impact of increased precipitation by 10% during the period 1980-2011

prec	Algeria	France	Tunisia	Turkey	Algeria	France	Tunisia	Turkey
	y	*y*	*y*	*y*	*xpt*	*xpt*	*xpt*	*xpt*
1	-0.019374	-0.0979	0.07469	-0.05461	0.009992	0.024963	0.06286	-0.038636
5	-0.024368	-0.0127	-0.071	-0.054192	0.002131	-0.019104	-0.04972	-0.096987
8	-0.020919	-0.001086	-0.0365	-0.044938	-0.005177	-0.013565	-0.0653	-0.0904

Table 4. Impact of a temperature increase of 1°C over the period 19980-2011

temp	Algeria	France	Tunisia	Turkey	Algeria	France	Tunisia	Turkey
	y	*y*	*y*	*y*	*xpt*	*xpt*	*xpt*	*xpt*
1	0.000723	-0.00172	-0.001353	0.000264	-0.002227	-0.003078	-0.001834	-0.000812
5	0.001586	-0.0028	-0.002	0.00115	-0.00409	-0.000041	0.003557	0.007363
8	0.000132	-6.10E-06	0.001045	0.001108	0.002979	0.000663	0.005814	0.004911