The Impact of Weather on Commodity Prices: A Warning for the Future

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Abstract

Drawing on the most recent advances of the panel VAR literature, we apply a framework to investigate the impact of weather on banana export prices towards the United Kingdom. This methodology can address some of the limitations of alternative approaches and it can also be generalized to assess the impact of weather on a variety of commodity markets characterized by a network structure. The results show that (i) while shocks to temperatures affect commodity prices, precipitations are less relevant; (ii) an increase in temperatures is likely to increase prices; (iii) the impact on prices is not only direct but it spills over to other exporting countries; (iv) simulating a scenario compatible with global warming we find that it is likely to lead to a substantial increase in commodity prices and spillover effects; (v) these effects are amplified if we account for a contemporaneous shock to the economy. We discuss implications for global food security, which can be useful for policy implementation.
JEL F00, C3, C5, Q1

Keywords PVAR, Commodity Price Transmission, Spillovers, Climate Change

1 Introduction

The importance of weather and climate to explain economics has been widely recognized and it is not new to the literature (Charles de Montesquieu, 1748; Dell et al., 2012a, 2014). Several studies document that climate plays a role in the determination of a series of outcomes, such as economic performance, labor productivity, the presence of conflicts, political outcomes in a country, human health among others (Mendelsohn et al., 1994; Schlenker et al., 2005, 2006; Solomon, 2007; Hsiang et al., 2011, 2013; Burgess et al., 2017; Jessoe et al., 2018).

While most of the work in economics has focused the attention on the impact of climate on the aforementioned outcomes, its role in agricultural production, rural income and dynamics in commodity markets is more recent (Jessoe et al., 2018). So far, some approaches have been developed to investigate the relation between weather/climate change and agriculture, such as the production function approach (e.g., Adams, 1989; Kaiser et al., 1993; Adams et al., 1995) and the Ricardian approach (e.g., Mendelsohn et al., 1994), followed by recent contributions that aim at addressing some limitations (e.g., Schlenker et al., 2005; Deschenes and Greenstone, 2007; Fisher et al., 2012).

In the present paper we consider the short-run impact of weather shocks on export prices of bananas, a market where producers and exporters are based in developing countries and for which developed countries are often totally dependent on imports. By studying this market the paper provides evidence about the impact of weather on commodity prices that is complementary to the existing literature; also, this choice allows us to focus on specific geographic areas which are often dependent on weather conditions and which, as developing countries, are even more subjected to the challenges imposed by extreme weather and climate change. Indeed, there is evidence on the negative impact of weather and climate on agricultural production in developing countries. Guiteras (2009), for instance, study the impact of high temperatures in India and find a negative relation between an increase in temperatures in a given year and agricultural output. Schlenker and Lobell (2010) estimate the impact of temperatures on agricultural production in Sub-Sahara and found that higher temperatures have a negative impact on yields. A similar outcome is found by Feng et al. (2010) whose results indicate that temperatures have a negative impact on agricultural production in Mexico. The results by Welch et al. (2010), who investigate the impact of higher temperatures on rice production, confirm this negative relation.

Together with temperatures, rainfalls are often used to investigate the impact of weather and climate on agricultural output in developing countries (e.g., Jayachandran, 2006, 2007; Hidalgo et al., 2010). Most of this literature agrees on the existence of a negative relation between low rainfalls and agricultural output, thus confirming the relevance of precipitations to grow agricultural products. Grounding on the most recent advances of the panel VAR literature, we collect data on the network of countries that export bananas towards the United Kingdom and present evidence on the impact of weather, specifically temperatures and rainfalls, on commodity export price transmission. Although our analysis focuses on the banana market for specific reasons explained in the next section, our framework is general and can be extended to study dynamics in other commodity markets.

The paper contributes to the literature as follows. Even though there are a few studies assessing the impact of weather and climate on agricultural production, to the best of our knowledge this is the first paper providing detailed and general insights on the matter using a methodology that allows to overcome the limitations of alternative approaches (i.e., see for instance Blanc and Reilly (2017); Blanc and Schlenker (2017); Mendelshon and Massetti (2017)). Indeed, on the one hand, the inclusion of spatial dependence and the utilization of commodity-specific data addresses some of the limitations proper of the cross-sectional approaches (e.g. the Ricardian approach

Mendelshon and Massetti (2017)). On the other hand, this framework allows to address the problem of omitted variable bias due to time-varying factors that can be correlated with the variables and weather shocks; also, the presence of time-varying coefficients permits to account for the heterogeneity of weather variation across seasons, which are limitations of panel methodologies (Blanc and Schlenker, 2017). Another important contribution is that, by estimating a panel VAR that includes country-specific macroeconomic variables (i.e., the exchange rate) and aggregate exports, this framework is more general than others used to study commodity price dynamics because it allows to account for both macroeconomic dynamics in the exporting countries and features that are market-specific, such as adaptation, namely the likelihood that production is also affected by climate change, and to study the final impact of weather on prices.

The main findings of the paper are as follows. First, we show that both direct and indirect effects are relevant and that geographic dependencies should be taken into account to unfold price dynamics. Second, since weather conditions may affect not only prices but the whole economy of procuring countries, we present preliminary evidence confirming the relevance of the agricultural sector for the economies under study; then, we simulate a contemporaneous shock to both temperatures and the economies, and we show that the effect on prices is much more substantial, suggesting that, if we generalize the framework to include macroeconomic dynamics, the impact of climate change on prices could be more worrisome than previously predicted. Finally, we show that, aside the seasonality present in both temperatures and rainfalls, the impact of precipitation is less relevant; this result is supported by previous literature (e.g., Lobell et al., 2011). So, the effect of precipitations is discarded in the econometric analysis.

The contribution of this paper is of general interest also because we show that, by simulating scenarios compatible with global warming, an increase in temperatures is likely to have, as also pointed out by the previous literature (see for instance Cashin et al., 2000), an overall negative effect (for a society) on commodity prices, which could substantially increase assuming the persistent rising of temperatures in the future. Also, in the likely occurrence of such a scenario, global warming could be detrimental not only for the market but for the whole economy and may have global consequences. The need for resilience in the food system is discussed in the final section of this paper.

The paper is structured as follows. In section 2 we present the motivation, in Section 3 the data and the methodology used. Section 4 reports the empirical findings and section 5 the discussion of the results and concluding remarks.

2 Motivation

Nowadays, we acknowledge that food security is a global concern and it affects all commodity markets. We choose to focus on the banana market for specific reasons. First, climate has a global impact on economies, but it is widely recognized that it has an even bigger impact on developing economies whose income sources largely on agricultural products. As a matter of fact, for several of the countries under study here banana represents one of the main export crops in terms of value: in Ecuador the banana sector is the main commodity exported (47% of total agricultural export value), for Costa Rica it is the second traded commodity (20% of total agricultural export value), and for Colombia it is the third one (11%); in terms of agricultural production value, this sector accounts for the 24 per cent of the net agricultural production in Ecuador, the 18 per cent in Costa Rica, and the 4 per cent in Colombia.[1] In addition, it is documented (see FAO (2018)) that banana exports may experience important drops due to a reduction in production caused by weather conditions; so, given the relevance covered by this sector in the economy of the exporting countries, it is important

[1] See the common facts produced and reported in FAO (2019)

to analyze how weather impact commodity price dynamics using a general frameowrk that includes both country-specific and market-specific variables.

Second, since bananas need to be grown in areas where temperatures lay within a certain range, they can only be grown in specific areas of the world (e.g., NSW, 2003), mainly in developing countries, and this gives the opportunity to look at how weather affects export prices set by developing countries towards developed countries. So, on the one hand, although the focus of the analysis is limited to only a small portion of the global trade, it sheds light on how the impact of weather and climate change may affect markets characterized by a network structure, namely, whose production is limited to a few procuring countries that supply the commodity worldwide. This allows us to provide evidence complementary to the existing one.

On the other hand, we can study the role that such export structure plays in international trade. This leads to the third motivation, that is, the choice to select the United Kingdom as importing country: we decide to investigate the banana exports towards the United Kingdom to show that the effect of weather for developing countries is relevant also for developed economies. In particular, we argue that changes in commodity markets brought about by weather and climate change may have substantial implications also for developed economies whose commodity supplies are totally dependent on imports. Thus, while other work focus the attention on the impact of climate on commodity markets (e.g., Lobell et al., 2011; Roberts and Schlenker, 2013), this is the first empirical analysis addressing this question using commodity-specifc data for commodity markets with such a network structure. Fourth, banana is a fruit with good nutritional properties (so important for the daily diet), and it is also the most favorite fruit in the United Kingdom and around the world (e.g., UNCTAD, 2016; BBC, 2017; National Geographic, 2017). Furthermore, there exist diseases that are currently threatening its production and in case of spread they could eventually threaten the survival of bananas in the entire world (e.g., UNCTAD, 2016; BananaLink, 2019). So, it is a topical commodity at the moment also because alteration to either the demand or the supply may have consequences in terms of global health.

In our empirical framework we use a panel VAR approach developed by Canova and Ciccarelli (2009) to investigate the covariation among (in order) weather, exchange rate, production devoted to exports and export prices in the seven main countries from which the United Kingdom imports the commodity. This framework allows us to study not only if weather has an effect on prices in this network of exporting countries, but also if and the extent to which there exist spillover effects in price transmission across the countries of the network. By doing this, we align to the recent literature assessing the importance of spillovers and cross-unit interdependences when analyzing international relations and outcomes (e,g, Canova and Ciccarelli, 2009; Acemoglu et al., 2015; Koop and Korobilis, 2016) and in general to the literature contributing to the identification and estimation of the climate/weather shocks on agricultural markets and commodity prices (e.g., Blanc and Reilly, 2017; Blanc and Schlenker, 2017). It also enables the researcher to account for both macroeconomic dynamics and adaptation. The countries included in the analysis altogether represent almost the totality of the banana exports towards the United Kingdom, so we can almost safely assume that the results would be robust to the addition of other minor importers.

We implement the analysis using two variables as proxies for weather in the empirical results, namely, temperature and precipitations. We use gridded data for temperatures and rainfalls of each exporting country and select the ones specific to the areas suitable for growing bananas in order to make the analysis even more reliable. We choose these two weather variables because they are the ones generally used by the literature to assess its importance on economic outcomes, among which agricultural production, in developing countries (e.g., Dell et al., 2014, 2012b; Compean, 2013; Burgess et al., 2017). They are important also for the banana market studied here, since, for instance, bananas can only be grown in settings where temperatures are neither too high nor too low (e.g., NSW, 2003).

Thus, all in all the banana market is a good example to investigate commodity price dynamics and to stress out the relevance of food security for both developing and developed economies.

3 Data and Methodology

3.1 Data

The data collected are referred to the following countries: Belize, Colombia, Costa Rica, Dominican Republic, and Ecuador, all from Latin America, and Côte d'Ivoire and Cameroon from Africa. These countries account for approximately a 90 percent of the UK banana imports, so they alone cover almost the entire network of exports towards the UK.

The data come from different sources. We collected data for four endogenous variables in the following order (relevant given the use of a Cholesky decomposition): temperatures, exchange rate (national currency per US dollars), export quantities (net weight in Kg) and prices (in US dollars). The selection of these variables allows to investigate the impact of weather on prices by taking into account changes in both the economy of the countries (through the exchange rate) and the commodity industry (through production devoted to exports). For ease of interpretation, in the descriptive analysis I use the raw data; instead, following the literature (e.g., Canova and Ciccarelli, 2009), in the econometric analysis all the variables are expressed in growth rates and data are seasonally adjusted and annualized and the variables are scaled by their standard deviation. For the preliminary descriptive part of the analysis, the data used range from 1961 till 2016, for the econometric analysis we used monthly data for the period 2011-2016 (monthly data for the commodity market are not available for earlier dates). The data for the GDP per capita and the agriculture value added as percentage of the GDP, which are in constant 2010 $, are taken from the World

Development Indicators (WDI hereafter). These two indicators are used in the descriptive preliminary analysis to investigate whether and the extent to which weather variables are somehow correlated with the economy and in particular with the agricultural sector.

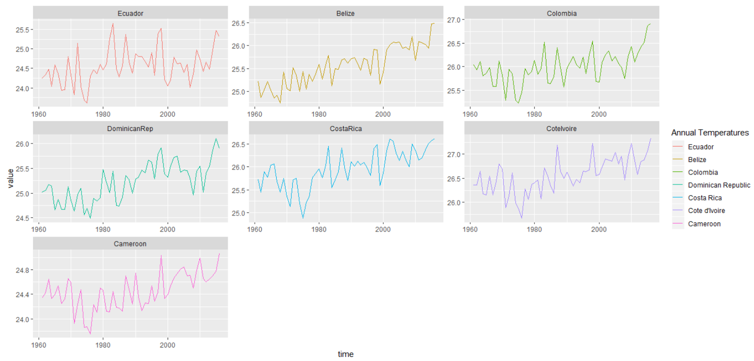
The data for both temperatures and precipitations come from the Climate Research Unit (CRU) data set at the University of East Anglia. This is the most widely used gridded data set. The use of gridded data has been advised by the recent literature (e.g., Dell et al., 2014) because it allows, among other advantages and especially in problematic countries such as developing countries, to interpolate the data when they are not available, thus offering the opportunity to have complete data sets and balanced panel in empirical studies. The temperature data used are collected and weighted for elevation, but the ones for precipitations are not because especially for short time periods (such as the one used for the econometric analysis) and in developing countries where station data are sparse, precipitation is more difficult to interpolate given also its greater spatial variation (e.g., Dell et al., 2014). In the analysis we will use both monthly and annual data. Monthly data are used in the econometric analysis as well as in the preliminary analysis, while annual data are used only in the descriptive statistics to investigate how weather correlates with annual economic data in the exporting countries.

Finally, the data on exports and prices come from COMTRADE, the data for the monthly exchange rate come from the International Monetary Fund (IMF).

3.2 Preliminary Evidence

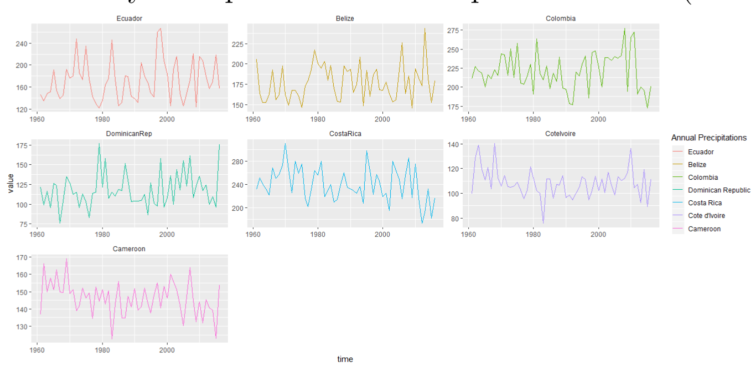
In this section we present some descriptive evidence about weather in the exporting countries of interest. Figures 1 and 2 present time series trends for, respectively, annual temperatures and precipitations in the seven exporting countries considered. As explained in the data section, they only

Figure 1: Yearly Temperatures in the Export Countries (1961-2016)



Source: Climate Research Unit and Author's calculations, years 1961-2016.

Figure 2: Yearly Precipitation in the Export Countries (1961-2016)



Source: Climate Research Unit and Author's calculations, years 1961-2016.

refer to the areas in the country where bananas can be grown (i.e., excluding mountains and in general areas with high altitudes). This allows us to give better insights about the impact of weather for the banana market. Both pictures clearly show there has been an overall increase in temperatures along the 55 years. Seasonality is evident in both figures, as expected; there is evidence of very dry seasons, especially in some countries, such as the African ones, followed by periods of high precipitations, while other countries, such as Colombia, almost never experience too dry periods. However, contrarily to what shown in figure 1, there is no clear upward trend for precipitations (figure 2), which show a relatively constant trend over the time span considered.

Since the agricultural sector is important for the economy of these countries, we also present (Table 1) the correlations between the per capita GDP, the value added of the agricultural sector and the two variables for weather (temperatures and precipitations). Clearly, this table is only a complementary evidence to support the relevance of the agricultural sector for the whole economy in the countries under study and no inference should be grounded on it. The table shows a very high correlation between GDP per

Table 1: Correlations Between Weather, GDP and Agriculture in Exporting Countries

	GDPpc	Agriculture VA	Temperature	Precipitations
GDPpc	1.00			
Agriculture VA	0.86***	1.00		
Temperature	0.30***	0.58***	1.00	
Precipitations	0.54***	0.49***	0.11**	1.00

Notes: Correlations coefficients are reported. *** indicates significance at the 1 % level, ** at the 5 % level, * at the 10 % level.

Source: COMTRADE, World Bank, IMF International Financial Statistics, Climate Research Unit and authors' calculation.

capita and the agricultural sector, as expected; in addition, both GDP and the value added of agricultural sector are positively correlated with both temperatures an precipitations in the areas where bananas are grown, while temperatures and precipitations in these areas are the only two variables showing a low degree of correlation, which is also only significant at the 5 percent level.

3.3 Methodology

Following the most recent advances of the panel VAR literature, we apply a multi-country VAR approach to investigate the impact of weather on commodity price transmission.

This literature has recently pointed out the importance to consider the presence of cross country interdependences when analyzing economic outcomes in a comparative perspective. As a matter of fact, we are living in an interconnected globalized world and every economic study should take it into account. This is even more the case for what we investigate here, since we cannot think that the commodity markets of the export countries towards the UK are completely independent one from the other.

For this reason we borrow the methodology from the multi-country VAR literature to allow for cross-country interdependences in our model. The idea that spatial dependence should be taken into account in economics and geography is not new (e.g., Anselin, 1988). In addition to the development of the spatial econometric literature, there have been very recent advances in the VAR literature (e.g., Canova and Ciccarelli, 2004, 2009; Pesaran et al., 2004; Chudik and Pesaran, 2014; Koop and Korobilis, 2016) stressing the importance of including also in time series studies the possibility for what happens in one country to have an influence on the other (nearby) countries. Allowing for cross-country interdependences is not only necessary because we cannot ignore global interdependences across countries, but it is also important because it gives the possibility to the researchers to get unbiased and consistent results. At the same time multi-country approaches should be considered overall better methods than bilateral approaches because the latter should only be used when assessing bilateral relations that are really independent on any other party (see e.g., Georgiadis, 2017; Chudik and Pesaran, 2011; Cashin et al., 2017, for a discussion on the suitability of bilateral approaches).

Since in this paper we have time series of moderate length we adopt the methodology worked out by Canova and Ciccarelli (2009), which is for this reason more appropriate than other methodologies, such as the one developed by Koop and Korobilis (2016) for long time series. Besides, on of the aims of the paper is to study whether there exist spillover effects in price transmission across the network of countries exporting bananas towards the United Kingdom. Thus, our multi-country approach should be preferred to the aforementioned bilateral approaches. Furthermore, despite the availability of other additional VAR tools such as the GVAR, we still consider the methodology used here more appropriate to investigate interdependences across countries in commodity price transmission. Indeed, although in our analysis we assume that one country, Ecuador, is the leading exporter, this does not necessarily imply that the impact of weather on this leading exporter - and price dynamics it generates - should always be considered as the driver of what happens in the other countries of the network. Finally, given the econometric model specification and the presence of time-varying parameters, this approach can overcome some of the usual limitations of both cross-section and other panel data models (Blanc and Reilly, 2017; Blanc and Schlenker, 2017; Mendelshon and Massetti, 2017).

Formally, we estimate the following model:

$$y_{it} = D_{it}\left(L\right)Y_{t-1} + C_{it}\left(L\right)W_{t-1} + e_{it} \tag{1}$$

where $i = 1, ..., N$ represents the units (countries) and $t = 1, ..., T$ represent time, y_{it} is a vector of dimension $G \times 1$ (G is the number of variables, in our case equal to 4) for each country i; $Y_t = (y'_{1t}, ..., y'_{Nt})'$, W_t is a q x 1 vector that may include common variables, time-invariant variables or unit-specific variables, e_{it} is a $G \times 1$ vector representing the error terms; $D_{it,j}$ are $G \times GN$ matrices and $C_{it,j}$ are G x q matrices for each j. Interdependences across countries exist if D_{it} is not a block diagonal matrix for at least one j.

However, allowing for the presence of interdependences and time varying coefficients increases the number of coefficients to estimate and causes an overparametrization problem. Thus, we adopt the factor structure used by Canova and Ciccarelli (2009) and we impose restrictions to the coefficients, so the coefficients to estimate are reduced. The factor structure transforms the multi-country VAR into a seemingly unrelated regression (SUR) model. We are in presence of time-varying coefficients, so, given the likelihood of the SUR model, we estimate the model using Markov Chain Monte Carlo (MCMC) methods to obtain posterior distributions.

The choice of the factors depends on the application. Specifically, our benchmark model allows for the presence of a *common effect*, such as an international event that may affect all countries, of a *variable effect*, that is, effects that are specific to the variables of the system as well as the presence of *country effects*, which accounts for country-specific dynamics (i.e., fixed effects for the seven exporting countries).[2] The framework also allows for the presence of time-varying coefficients (TVC) as well as lagged interdependences, that is, the possibility, as we mentioned above, that a variable in country i at time *t-1* may affect a variable of another country at time t.

The factor structure allows the researcher to distinguish between factors in different geographic areas (e.g., in Latin America and in Africa), and to account for both country-specific factors and variable-specific factors. In our case the factor structure can be formalized as follows:

$$y_{it} = \chi_{1t}\theta_{1t} + \chi_{2t}\theta_{2t} + \chi_{3t}\theta_{3t} + \zeta_t \tag{2}$$

where $\Xi_{11t} = \Sigma_{LA}\Sigma_g\Sigma_j y_{igt-j}$, $\Xi_{12t} = \Sigma_{NotLA}\Sigma_g\Sigma_j y_{igt-j}$ and θ_{1t} is a 2×1 vector of common factors; this factor distinguishes between common factors in Latin America and in the countries belonging to a different geographic area (i.e., Africa); $\Xi_{2it} = \Sigma_g\Sigma_j y_{igt-j}$ and θ_{2t} is a $n \times 1$ vector of country-

[2]We reckon that we are using industry-specific data, however, the use of data aggregated by country (including exports) allows us to assume the presence of country fixed effects.

specific factors for the countries used in the analysis; θ_{3t} is a $g \times 1$ vector of variable-specific factors for the variables used in the analysis, where $\Xi_{3gt} = \Sigma_i \Sigma_j y_{igt-j}$; also $i = 1, ..., n$, and $g = 1, ..., g$. Following Canova and Ciccarelli (2009), we assume the factors evolve according to the following law of motion:

$$\theta_t = \theta_{t-1} + \eta_t \tag{3}$$

where $\eta_t \sim (0, B)$ and $B = diag\left(\bar{B}_1, \bar{B}_2, \bar{B}_3\right)$ and $\theta_t = (\theta'_{1t}, \theta'_{2t}, \theta'_{3t})'$.

This is our benchmark model. Nonetheless, in order to confirm our assumption on the model specification we formally test this framework against alternative models. We use the Chib's maximum likelihood method (Chib, 1995), the Schwartz approximation and the harmonic mean estimator (Newton and Raftery, 1994) and compare the models using the Bayes factor in the empirical section. We use this model as our benchmark model because this specification is more likely to reflect the dynamics of the commodity markets than alternative specifications. As a matter of fact, our methodology is particularly suitable to model a weather shock because the specification just described, by taking into account the presence of fixed effects for spatial areas (e.g., countries), variable-specific characteristics, and the presence of the common effect, assures identification is reached.[3]

Finally, before proceeding further we would like to point out that, as also stated by Canova and Ciccarelli (2009), we cannot exactly unfold the reasons for different responses across countries. However, the present structural approach, by conditionally controlling for the demand and its variation over time, and by using a factor structure and the presence of time-varying parameters, accounts for the main possible channels driving price dynamics.

[3]See Canova and Ciccarelli (2009) for further details about inference, the model specification and identification.

4 Results

4.1 Descriptive Statistics

Before proceeding with the econometric analysis, I present, in Table 2, overall descriptive statistics for the variables used in the remaining part of this section. In addition, Figures 3 and 4 report the time series for, respectively, temperatures and exports across the procuring countries.

Table 2: Descriptive Statistics

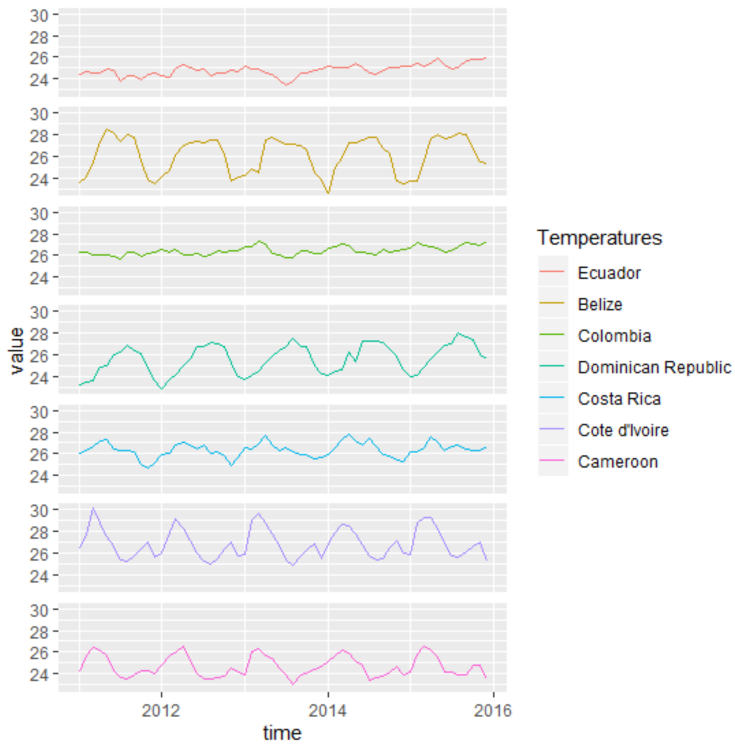
	Observations	Mean	SD	Min	Max
Exports	420	1.11e+07	6636589	417050	2.90e+07
Prices	420	.7392273	.1130117	.4430932	1.088924
Exchange Rate	420	101.8379	8.028142	63.95629	124.9272
Temperatures	420	25.8316	1.329658	22.63	30.13

Notes: Descriptive statisticsa re reported. 'SD' stays for Standard Deviation, 'Min' for minimum and 'Max' for maximum.
Source: COMTRADE, IMF International Financial Statistics, Climate Research Unit and authors' calculation.

Exports are high and they vary across countries: as reported above Latin American countries are the main exporters, of which Colombia is the principal exporter towards the UK. Instead, African countries are the ones that export the least towards the UK. Prices are not very high since bananas are cheap and this are export and not retail prices. There is some variation in the exchange rate.

Finally, the variation in temperatures is comprehensibly not high, given climate conditions in the countries under study, but there is still presence of seasonality; besides, temperatures are within the range needed to grow bananas.

Figure 3: Monthly Temperatures in the Export Countries (2011-2015)



Source: Climate Research Unit and Author's calculations, years 2011-2015.

4.2 Econometric Evidence

After getting an overall picture of weather and the correlation with the economy of the 7 countries exporting towards the United Kingdom, we proceed with the econometric study and investigate the impact of these two variables on export prices towards the United Kingdom.

In order to do this, we first test the suitability of the model specification explained in the methodological section. This is reported in Table 3. We compare four different models, that is, our benchmark model, Model 1, where we allow for the presence of a common effect, country fixed effects, variable-specific effects, lagged interdependences and time varying parameters, to other three models. Model 2 differs from Model 1 in that we do not

Figure 4: Monthly Exports in the Export Countries (2011-2015)

Source: COMTRADE and Author's calculations, years 2011-2015.

allow for the presence of lagged interdependences, Model 3 does not have country fixed effects and Model 4 does not include variable-specific factors. We compare the models using the Chib, the harmonic mean criteria and the Schwartz approach (for further details on model selection see Canova and Ciccarelli, 2009). Since none of the other three models is preferred to Model 1, and given (as explained in the methodological section) the specification in Model 1 is ideal to obtain identification in our study, we may conclude that Model 1 is the most suitable to provide econometric evidence about the impact of weather on commodity prices. From now onward, we omit the results for precipitation because the impact of rainfalls is very low compared to temperatures. This result is not surprising because for the ba-

Table 3: Model Selection

	Model 1	Model 2	Model 3	Model 4
Chib	-2,183.34	-2,307.27	-1,257.47	-2,489.19
nse	11.25	8.40	256.47	6.56
Schwartz	-2,208.26	-2,152.76	-2,201.61	-2,230.94
nse	1.89	1.19	1.34	0.96
Harmonic Mean	-2.270.50	-2.272.20	-2,323.26	-2,365.38
nse	0.44	2.13	2.17	2.69
Parameters	409	409	408	408

Notes: The number of parameters is equal to the free elements in the variance-covariance matrix plus the free elements in B. 'Nse' stays for numerical standard errors. Model 1 is the benchmark model, Model 2 is the model with no interdependences, Model 3 is the model with no country effects and Model 4 is the model with no variable effect.

nana market temperatures are much more relevant than precipitations. If anything, we expect that anomalies in precipitations and extreme weather conditions should be more relevant for banana plantations.

In Table 4 we report the impact of a 1 per cent increase in temperatures in Ecuador on prices in exporting countries. We choose Ecuador because, as explained earlier, bananas are the main exports for this country; also, Ecuador is the main global exporter of bananas (its exports represent one-third of the global banana export volume).[4] Also, we choose Ecuador because it is the leading exporting country in the banana sector and so what happens in Ecuador it is likely to affect the banana market in Ecuador as well as in the other exporting countries.

[4]FAO (2019)

Table 4: Effect on Export Prices of a Temperature Increase Only in Ecuador

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Ecuador	0.052	0.068	0.045	0.031	0.021	0.014	0.009	0.006
	(-0.115; 0.220)	(0.013; 0.126)	(0.013; 0.085)	(0.011; 0.064)	(0.007; 0.047)	(0.004; 0.035)	(0.002; 0.025)	(0.001; 0.019)
Colombia	0.045	0.043	0.039	0.027	0.018	0.012	0.008	0.005
	(-0.182; 0.270)	(-0.007; 0.100)	(0.009; 0.077)	(0.008; 0.058)	(0.006; 0.042)	(0.003; 0.032)	(0.002; 0.023)	(0.001; 0.017)
Belize	-0.036	0.056	0.045	0.032	0.021	0.014	0.009	0.006
	(-0.273; 0.198)	(-0.001; 0.114)	(0.013; 0.087)	(0.011; 0.065)	(0.007; 0.048)	(0.004; 0.036)	(0.003; 0.026)	(0.001; 0.019)
Costa Rica	0.028	0.056	0.044	0.031	0.021	0.014	0.009	0.006
	(-0.162; 0.218)	(0.001; 0.114)	(0.012; 0.085)	(0.011; 0.063)	(0.007; 0.047)	(0.004; 0.034)	(0.003; 0.025)	(0.001; 0.019)
Dominican Republic	0.182	0.053	0.043	0.031	0.021	0.014	0.009	0.006
	(-0.010; 0.376)	(-0.004; 0.111)	(0.012; 0.085)	(0.011; 0.063)	(0.007; 0.047)	(0.004; 0.034)	(0.003; 0.025)	(0.001; 0.018)
Côte d'Ivoire	0.103	0.041	0.024	0.016	0.011	0.007	0.005	0.003
	(-0.082; 0.293)	(-0.001; 0.090)	(0.006; 0.050)	(0.005; 0.033)	(0.004; 0.024)	(0.002; 0.018)	(0.001; 0.013)	(0.001; 0.009)
Cameroon	0.048	0.037	0.026	0.018	0.012	0.008	0.005	0.003
	(-0.136; 0.233)	(-0.004; 0.085)	(0.007; 0.051)	(0.006; 0.035)	(0.004; 0.025)	(0.003; 0.018)	(0.002; 0.013)	(0.001; 0.010)

Notes: Median responses of export prices to a 1% increase in temperature in Ecuador. 95% posterior bands are reported in parentheses.

As shown in the table, the impact of a temperature increase does not significantly affect prices in Ecuador or in any of the other countries of the network in the first period. This is not surprising because the effects of weather are likely not to have an immediate impact on prices. In the second period an increase in temperatures in Ecuador leads to an increase in prices in Ecuador by 0.068%, but also in Costa Rica (by 0.056%) and in Côte d'Ivoire (by 0.041%); this effect propagates to the other countries of the network starting from the third period onward. By the time of period 8, that is, almost after 1 year, the effect tends to disappear. Thus, we can conclude that, since a shock in only Ecuador has effects on prices also in other countries, we can infer that there exist spillover effects in price transmission across the exporting countries in the network and for this reason they should always be taken into account when analyzing the market.

In Table 5 we generalize the shock by extending it to all the countries in the network, so this scenario is compatible with the effect of global warming on commodity markets.

Although this is a short period analysis, we can imagine that extending

Table 5: Effect on Export Prices of a Contemporaneous Increase in Temperature in All the Export Countries

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Ecuador	0.097	0.210	0.151	0.105	0.070	0.046	0.030	0.019
	(-0.279; 0.447)	(0.092; 0.340)	(0.073; 0.248)	(0.049; 0.189)	(0.029; 0.142)	(0.017; 0.106)	(0.009; 0.080)	(0.005; 0.059)
Colombia	-0.240	0.153	0.131	0.091	0.062	0.040	0.026	0.017
	(-0.687; 0.201)	(0.031; 0.289)	(0.057; 0.227)	(0.038; 0.170)	(0.024; 0.128)	(0.014; 0.096)	(0.008; 0.072)	(0.004; 0.053)
Belize	0.250	0.220	0.157	0.109	0.073	0.048	0.031	0.020
	(-0.245; 0.745)	(0.102; 0.350)	(0.077; 0.256)	(0.051; 0.194)	(0.031; 0.146)	(0.018; 0.110)	(0.010; 0.082)	(0.005; 0.060)
Costa Rica	0.046	0.209	0.152	0.106	0.071	0.046	0.030	0.019
	(-0.341; 0.430)	(0.096; 0.338)	(0.076; 0.249)	(0.051; 0.187)	(0.030; 0.141)	(0.017; 0.106)	(0.010; 0.078)	(0.005; 0.058)
Dominican Republic	0.421	0.199	0.150	0.104	0.070	0.046	0.030	0.019
	(0.008; 0.808)	(0.081; 0.326)	(0.073; 0.246)	(0.049; 0.185)	(0.029; 0.140)	(0.017; 0.105)	(0.009; 0.078)	(0.005; 0.057)
Côte d'Ivoire	0.233	0.064	0.066	0.052	0.037	0.025	0.016	0.011
	(-0.155; 0.627)	(-0.026; 0.159)	(0.026; 0.118)	(0.025; 0.090)	(0.017; 0.070)	(0.010; 0.052)	(0.006; 0.039)	(0.003; 0.029)
Cameroon	0.395	0.054	0.068	0.055	0.039	0.026	0.017	0.011
	(0.017; 0.780)	(-0.036; 0.149)	(0.027; 0.123)	(0.027; 0.094)	(0.018; 0.072)	(0.011; 0.054)	(0.006; 0.041)	(0.003; 0.031)

Notes: Median responses of export prices to a 1% increase in temperature in all UK export countries. 95% posterior bands are reported in parentheses.

this scenario to the medium and long-run allows to fully capture the long term effects of global warming. Looking at the table, we can notice that, once again, a shock to temperatures will take a few months to propagate to the entire market. Of the seven countries in the network, only Dominican Republic will be significantly affected (with a peak of price increase by 0.421% in the first period) in all the eight periods reported, the majority of countries will experience the change in prices starting from the second period and all the countries will definitely be affected by the shock by the third period: in this period the export prices will experience an increase ranging from 0.066% in Côte d'Ivoire to 0.157% in Belize. Besides, by comparing Tables 4 and 5, it is clearly evident that the impact on export prices of bananas towards the UK would be much higher the higher the number of countries involved in the shock. Also, both tables show that the increase in prices would be more pronounced in Latin American countries than in African countries, suggesting the presence of geographic effects. Although a more detailed analysis is needed, these dynamics should probably be attributed to differences in the market shares represented by the countries of the network.

Tables 6 and 7 replicate the results of the shocks imposed, respectively, in Tables 4 and 5, but in addition to the 1 percentage increase in temperature we also simulate a 1 percentage increase in the exchange rate. Indeed,

Table 6: Effect on Export Prices of a Contemporaneous Increase in Temperatures and Exchange Rate in Ecuador

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Ecuador	-0.062	0.090	0.064	0.043	0.029	0.019	0.012	0.008
	(-0.365; 0.235)	(-0.008; 0.193)	(0.009; 0.131)	(0.009; 0.096)	(0.007; 0.071)	(0.004; 0.052)	(0.003; 0.038)	(0.001; 0.028)
Colombia	-0.493	0.076	0.050	0.037	0.025	0.016	0.011	0.007
	(-0.844; -0.120)	(-0.015; 0.171)	(-0.001; 0.114)	(0.007; 0.087)	(0.005; 0.063)	(0.004; 0.046)	(0.002; 0.034)	(0.001; 0.025)
Belize	0.071	0.077	0.066	0.045	0.030	0.019	0.013	0.008
	(-0.327; 0.468)	(-0.021; 0.182)	(0.009; 0.135)	(0.010; 0.101)	(0.007; 0.074)	(0.005; 0.053)	(0.003; 0.039)	(0.002; 0.029)
Costa Rica	-0.163	0.066	0.063	0.043	0.029	0.019	0.012	0.008
	(-0.486; 0.157)	(-0.029; 0.167)	(0.008; 0.130)	(0.010; 0.095)	(0.007; 0.070)	(0.005; 0.052)	(0.003; 0.038)	(0.002; 0.028)
Dominican Republic	-0.158	0.061	0.061	0.043	0.029	0.019	0.012	0.008
	(-0.477; 0.153)	(-0.036; 0.160)	(0.007; 0.129)	(0.009; 0.096)	(0.007; 0.070)	(0.004; 0.051)	(0.003; 0.037)	(0.001; 0.027)
Côte d'Ivoire	0.153	-0.025	0.018	0.020	0.015	0.010	0.006	0.004
	(-0.175; 0.484)	(-0.100; 0.047)	(-0.016; 0.055)	(0.001; 0.045)	(0.003; 0.035)	(0.002; 0.026)	(0.002; 0.019)	(0.001; 0.014)
Cameroon	0.077	-0.014	0.020	0.021	0.015	0.011	0.007	0.005
	(-0.252; 0.383)	(-0.091; 0.057)	(-0.014; 0.058)	(0.002; 0.047)	(0.003; 0.036)	(0.003; 0.027)	(0.002; 0.020)	(0.001; 0.015)

Notes: Median responses of export prices to a 1% increase in both temperature and exchange rate in Ecuador. 95% posterior bands are reported in parentheses.

since the agricultural sector in these countries still represents a large part of the economy, it is likely that global warming and every (structural) change or shock that has an impact on agriculture will have consequences for the economy as a whole. A 1 percentage change in the exchange rate, which represents country-specific macroeconomic dynamics, may reflect such changes.

We can notice (Table 6) once again the shock is only significant after a few periods and it becomes significant in all exporting countries only in period 4, as expected. Again, we find evidence of spatial patterns because while the shock becomes significant in all Latin American countries at the third period, it has a significant effect on prices in African countries only starting from the fourth period. However, the effect on prices is present in all countries. As a matter of fact, it ranges from 0.064% in the third period in Ecuador itself, to similar results for the other Latin American countries, to lower effects (about 0.020%) for the African countries. So, once again the shock imposed in the leading exporting country in Latin America spills over to other exporting countries and generates an overall increase in export prices of bananas towards the UK.

Besides, by comparing Tables 4 and 6 we notice that while in both Tables the impact of the shock takes a few periods to have effect, the magnitude of the increase in prices is higher when we impose a 1 percentage change in the exchange rate (Table 6). Indeed, while for instance in Table 4 the shock leads to an increase in banana export prices in Ecuador by 0.045% in the third period, in the same period the shock in Table 6 implies an increase in prices by 0.064%. A similar trend is followed by the other countries of the network. The presence of spillovers is also confirmed. Comparing Tables 5

Table 7: Effect on Export Prices of a Temperature and Exchange Rate Increase in All the Export Countries

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Ecuador	0.034	0.400	0.269	0.178	0.114	0.074	0.047	0.030
	(-0.546; 0.616)	(0.211; 0.596)	(0.146; 0.424)	(0.087; 0.312)	(0.049; 0.226)	(0.027; 0.164)	(0.015; 0.120)	(0.008; 0.089)
Colombia	0.078	0.350	0.233	0.156	0.101	0.065	0.042	0.027
	(-0.648; 0.711)	(0.167; 0.541)	(0.114; 0.385)	(0.071; 0.284)	(0.041; 0.205)	(0.023; 0.151)	(0.012; 0.110)	(0.007; 0.081)
Belize	1.235	0.426	0.278	0.182	0.118	0.076	0.049	0.031
	(0.494; 1.996)	(0.234; 0.626)	(0.153; 0.437)	(0.090; 0.319)	(0.051; 0.234)	(0.028; 0.169)	(0.016; 0.123)	(0.008; 0.091)
Costa Rica	-0.341	0.392	0.270	0.177	0.115	0.074	0.047	0.030
	(-0.991; 0.285)	(0.203; 0.589)	(0.149; 0.427)	(0.090; 0.312)	(0.051; 0.227)	(0.028; 0.165)	(0.015; 0.120)	(0.008; 0.088)
Dominican Republic	0.255	0.392	0.270	0.177	0.114	0.073	0.047	0.030
	(-0.387; 0.871)	(0.199; 0.586)	(0.143; 0.423)	(0.087; 0.306)	(0.049; 0.224)	(0.027; 0.163)	(0.015; 0.120)	(0.008; 0.088)
Côte d'Ivoire	0.407	0.190	0.137	0.093	0.061	0.040	0.026	0.016
	(-0.272; 1.058)	(0.049; 0.343)	(0.067; 0.227)	(0.048; 0.161)	(0.029; 0.118)	(0.016; 0.086)	(0.009; 0.062)	(0.005; 0.045)
Cameroon	0.651	0.189	0.143	0.098	0.065	0.042	0.027	0.017
	(0.039; 1.261)	(0.051; 0.342)	(0.073; 0.236)	(0.051; 0.168)	(0.031; 0.123)	(0.018; 0.089)	(0.010; 0.065)	(0.005; 0.047)

Notes: Median responses of export prices to a 1% increase in both temperatures and exchange rates in all export countries. 95% posterior bands are reported in parentheses.

and 7 leads to similar conclusions.

Furthermore, a comparison of the two sets of tables (4 and 6 versus 5 and 7) shows that, once again, imposing the shocks to all countries of the network would amplify even more the impact on prices: the magnitude of the impact in Table 7 is from four to six times higher than in Table 6, providing evidence that a global shock would have a much higher overall impact on prices. In addition, tables 5 and 7 show that accounting for the shock to the economy and not only to temperatures may double the effect of the shocks on prices.

All in all, the results indicate that a temperature increase in the banana exporting countries is likely to affect export prices towards the United Kingdom and that there exist spillovers in the network of exporting countries, namely, weather and climate change (in the long-run) in a country are likely to affect not only prices in the country itself, but also prices in the other exporting countries of a commodity network. Besides, the size of the shock is likely to depend on the countries affected by the shock. Finally, assuming a contemporaneous shock to both temperature and the economy, we find that the shock would have much larger effects on export prices. Thus, we may conclude that, assuming the perpetration of such shocks over longer time periods, climate change, and global warming more specifically, would have a positive impact (i.e. prices would rise) on export prices of bananas, which could however represent a net negative impact for a society.

5 Discussion and Conclusions

Understanding how and the extent to which weather affects commodity market dynamics is crucial to prevent the likely negative consequences that may arise from both present and future global scenarios.

In this paper we have provided new evidence on the relation between weather and commodity prices. We have investigated the effect of weather on commodity price dynamics by looking at how temperatures and precipitations, the two most commonly used variables to investigate how weather affects economic outcomes, impact exporting prices of bananas towards the United Kingdom.

Since we are aware that not only temperature matters but also precipitations are important determinant for commodity markets (Dell et al., 2014) we also run the analysis using precipitation, but we found less sizeable results. This result, which is supported by some of the previous literature (e.g., Jones and Olken, 2010; Lobell et al., 2011) is not surprising. As a matter of fact, on the one hand, the descriptive statistics show there have not been significant changes in the trends of precipitation over the time span considered; on the other hand, it is more likely that it is not rainfalls *per se* that matter, but the increase (also due to climate change) in extreme weather conditions and precipitation anomalies that is likely to have a negative impact on agriculture. While in this paper we wanted to investigate the impact of two different weather variables that are generally considered important for commodity prices, the impact of extreme weather and anomalies will be considered in future research.

The descriptive statistics suggest that the agricultural sector is still important in the seven exporting countries under study. In the econometric analysis we show that an increase in temperatures leads to an increase in export prices of bananas. By imposing the shock on Ecuador, which is the worldwide lead banana exporter, we showed that these price increases are experienced not only by Ecuador, but they spill over to other countries, so our results are in line with the recent literature pointing out the need to account for cross country interdependences and indirect effects in the determination of international economic outcomes (e.g., Canova and Ciccarelli, 2009; Acemoglu et al., 2015; Koop and Korobilis, 2016). Furthermore, when we extend the shock not only to a country but to all the countries in the network, thus simulating the effect compatible with global warming, the impact of an increase in temperatures is much more substantial. Also, the results are consistent with the presence of spatial geographic dependence. This result is also a consequence of the environment needed by banana plantations to grow and it is consistent with the literature according to which an increase in temperatures in already warm places may potentially be detrimental to the economy (e.g., Brown and Funk, 2008).

Furthermore, the multi-country VAR structure allows to compare these scenarios to alternative scenarios where the shock is imposed contemporaneously to both temperatures and the economy. The comparison allows us to conclude that if we assume that a contemporaneous shock could happen to both weather and the economy at the same time, the increase in prices emerging from the econometric study would be even larger in magnitude. This finding is not unrealistic if we think that countries in the network are developing countries and an increase in temperatures would eventually be accompanied by a shock to their economy as a whole. So, all in all, the findings suggest that the impact of weather and climate change on prices may be even more worrisome if we account for the fact they may also affect the economy of procuring countries, especially if the commodity markets are characterized by a network structure.

This increase in prices could be beneficial to the supply side of the whole industry. However, it would have a series of negative consequences for both the exporting and importing countries. On the one hand, the increase in export prices could benefit the whole banana industry in exporting countries. Nonetheless, this benefit could be overridden by the costs necessary to adjust to weather conditions and shocks (e.g., Cashin et al., 2000). So, overall, the need to be resilient to climate change for producers and exporters may offset the benefits of selling the products at higher prices. On the other hand, consumers will also probably have to face and react to changes in the market. Consequently, an increase of commodity prices may lead some (especially poorer) consumers to either substitute the commodity with other products or to consume less of it. This alteration of the daily diet may also have health consequences. Then, as pointed out also by the previous literature (e.g., Brown and Funk, 2008; Lobell et al., 2008) weather and climate change constitute a threaten to food security of both developed and developing countries. As a matter of fact, if we had to generalize the results to other commodity markets or countries, we would have a future where developing economies should find a way to be resilient to weather shocks (and more generally climate change) and to build strategies to face both national and international constraints (e.g., Swinnen, 2007; Swinnen et al., 2015; Jessoe et al., 2018) and developed/importing countries should be able to face supply shortages and/or increase in prices of agricultural products, such as fruits and vegetables, imported from developing countries.

It could be questioned that, in many countries, among which the United Kingdom, the negative shocks to banana prices are often absorbed by retailers and consequently consumers should not be much affected. However, the threaten of global warming and climate change are not specific to the banana sector, so if we consider a likely scenario where climate change will have a deep impact on prices of all commodities it becomes clear that retailers will not be able to face the global and overall implications of this future scenario. Thus, consumers in the UK and other economies will be threatened as well because they would have to bear themselves changes in commodity prices and supply.

In conclusion, our study can be used as general evidence about the impact of weather on commodity prices. Although we restrict the analysis to the banana market, the framework can be used to investigate the impact on other commodity markets. So, while the findings presented here may be specific to this market (e.g., relevant weather variables and conditions may vary depending on the commodity under study and the characteristics of the countries that grow it), the methodology can be used to investigate the effect of weather on other similarly structured commodity markets and may be useful to policy-makers.

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