Spatial price dynamics in the EU F&V sector: the cases of tomato and cauliflower

Santeramo F.G.[1] and Cioffi A. [1]

[1] Department of Agricultural Economics and Policy, University of Napoli "Federico II", Portici, Italy

PAPER PREPARED FOR THE 116TH EAAE SEMINAR "Spatial Dynamics in Agri-food Systems: Implications for Sustainability and Consumer Welfare".

Parma (Italy)
October 27th -30th, 2010

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Abstract — **The paper explores the characteristics of spatial price dynamics for fresh vegetables. The analysis is carried out on selected EU prices for tomatoes and cauliflowers collected on some of the main production and consumption markets. It is based on the estimation of an time-varying threshold autoregressive econometric specification that is shown capable to underline the asymmetries in inter-Countries price transmission. The model shows that that horizontal price transmissions among net producer and net consumer markets is asymmetric and how such characteristic differs for markets closer to production areas or to consumption locations. This paper allowed to assess the average elapsing time for shocks to be transmitted among spatially separated markets, and, in particular, it shows the speed of transmission of price raises and price falls.**

Keywords— **price transmission, TVECM, vegetables**

I. INTRODUCTION

The European Union (EU) is either the largest importer and one of the most important producer in the World of fresh fruits and vegetables (F&V). The sector is dominated by elevate regional specialization such that most of the production is concentrated in a few countries (Italy, Spain, France). Furthermore a major part (almost 60%) of fresh F&V trade of the European Union is intra-regional and imports from third countries are rather limited, especially for vegetables, due to the high transportation costs of long-distance trade. Germany and United Kingdom are the largest importer of (F&V). Belgium and Netherlands play an important role in the intra EU trade: their domestic markets are of relatively small size and most of the imports are re-exported to other EU members and outside the EU.

The main peculiarities of F&V supply rely on their seasonality, perishability and sensitiveness to climate conditions. Given the importance of the F&V sector, the European Commission is really concerned about the sensitiveness to price variability. In a recent Council Regulation [9]«the production of fruit and vegetables (has been defined) unpredictable […] and surplus on the market, even if (they are) not too great, can significantly disturb the market ».

As a first result, the production variability of fresh F&V sector affects price dynamics leading to market instability (i.e. EU F&V sector is often affected by market crisis, due to factors such product perishability and production and consumption sensitiveness to climate variations [8]) and lack of sustainability. The F&V CMO reform has introduced new instruments to stabilize the markets [9] aimed at transferring price risk to other agents: the efficacy of these instruments depends on the spatial dimension of the crises. In this context the measurement of market integration, price shocks transmission and spatial dynamics (i.e. regional specialization in production, trade flows, etc.) assume relevant importance either for crisis management and prevention and for implementation of policies to increase the sector sustainability.

Despite the serious policy implications and relevance of assessing market integration and spatial price dynamics in F&V sector, the topic remains under-investigated in a few articles about U.S. F&V sector ([11], [14] and [16]) and, to the best of our knowledge, literature lacks of studies of price transmission in the EU F&V sector. Therefore, our paper aims to assess the spatial price dynamics of spatially separated markets. The interests will be to evaluate how price shocks are transmitted among EU production and consumption Regions linked by trade. More precisely we aim to explore the phenomenon of price transmission paying attention to products that differ for their degree of perishability.

The analysis is carried out using a threshold autoregressive (TAR) specification. TAR models allow testing for the presence of different regimes which occur if two conditions are satisfied: either a sufficient number of observations are attributed to each regime and the estimated coefficients of the model parameters differ in the two regimes. Although the adoption of threshold models is not new in the literature of market integration, and price transmission [12] empirical studies dealt mainly with few categories of products (in particular cereals and meat) while for many agricultural goods, especially for fruits and vegetables, the topic remains under investigated.

The analysis is concerned with tomatoes and cauliflowers, two of the main important products in EU F&V sector. In both cases we estimated the price transmission among markets of net producer and net importer EU Countries using an asymmetric threshold model.

The organization of the paper is the following: in section 2 we outline shortly the features of the EU (F&V) sector with particular focus on the two vegetables on which the study is focused; the methodology and data are presented in section 3, while results are set out and discussed in section 4; conclusions and indications for further research are developed in the last section.

II. THE EU F&V SECTOR

EU is one of the biggest global producer of F&V. Despite the recent declining trend, its production accounts for more than the 8 percent of world production (more precisely, it supplies respectively 12% and 7% fruits and vegetables of the world).

Grapes are the largest fruit, but most of the production is used for making wine. Italy (30%), France (25%) and Spain (22%) are the main producers, followed by Germany, Portugal and Greece. Tomatoes is the second largest product (almost 30% of the total EU vegetables production). The largest supplier, Italy (38%), is interested by a production around 6.6 million tones. Spain is the second largest producer, accounting for more than 20% of the total production.

Apples is the third most important F&V product (40% of total fruit supply), with a production around 12 million tones largely due to Italy (18%), France (17%), Poland (16%) and Germany (11%). Other Countries have minor productions: Spain, Hungary and Austria produce more than 500.000 tones.

Table 1 - Main EU F&V producers (1000 tones)

	Annual average production		
	2000-2002	**2005-2007**	**Share 2005-2007**
Italy	32523	32653	25.3%
Spain	28179	28515	22%
France	19638	16366	12.7%
Greece	8.325	7472	1.9%
Poland	7391	7383	1.9%
Romania	6076	5978	1.5%
Germany	8334	5746	1.5%
Netherlands	4260	4735	1.2%
United Kingdom	3098	3177	0.8%
Belgium	2216	2396	0.6%

Source: our calculations from EUROSTAT data.

Italy and Spain are the largest EU fresh tomatoes producer. Spanish fresh tomatoes are traded to Northern Europe, mainly towards France, United Kingdom, Germany and Netherlands. Furthermore, imports from Spain represent a large share of the total imports of Netherlands, United Kingdom, Italy, France, Germany and Belgium. In other terms, Spain play a dominant role in the fresh tomato intra-EU trade and might be certainly classified as a net producer and exporter. Almeria and Murcia are, respectively, the first and the second export provinces: the former concentrates its exports during winter, the latter shows a more stable and wider export season [6].

French production (700.000 tones per year) is rather small compared to volume of imports. Most of the production is mainly concentrated in the Southern area. In the Northern France, a large part of production is realized around the city of Chateau-Renard. Finally, the production in Belgium and United Kingdom is around 150.000 tones and the internal demand is satisfied by imports from Netherlands, Spain and Italy.

EU cauliflower production is concentrated in six Countries (decreasingly ordered for volume of production: Italy, Spain, France, Poland, Germany and United Kingdom) that account for more than 90% of the total EU production. The main production areas in Spain are Murcia, Navarra, Valencia and La Roja, where 85% of the total Spanish production take place. In United Kingdom the production takes place in areas such the Southern England as well the county of Lincolnshire.

Table 2 – Vegetables[a] most produced in EU (1000 tones)

	Annual production		
	2001	**2003**	**2003**
Tomatoes	16204	15780	15579
Carrots	5079	5088	5057
Cabbages	5434	4635	4940
Onions	4795	4559	4906
Lettuce	3275	3224	3804
Cauliflower	2114	2190	2105

[a] Includes both vegetables for direct consumption and for processing.
Source: our calculations from EUROSTAT data.

Germany is the main Italian import partner, while Spanish exports are mainly sold to United Kingdom (40%), Germany (15%), France (13%) and Netherlands (13%). The main destinations of French exported cauliflower are Germany (40%), United Kingdom (14%) and Netherlands (15%). Finally, the main foreigner partner for UK is Ireland, which absorbs more than half of its total exports, followed by Netherlands.

III. METHODOLOGY

In this section we present the non-linear econometric specification that we adopted to carry out the analysis on the EU F&V markets integration.

We follow the seminal paper of Balke and Fomby [3], who derived two interesting specific cases of threshold models from a general framework. The first model is a symmetric three-regimes TAR called BAND-TAR:

$$(1) \qquad \Delta X_t = \begin{cases} \alpha + \rho_{out} X_{t-1} + \varepsilon_t \\ \varepsilon_t \\ \alpha + \rho_{out} X_{t-1} + \varepsilon_t \end{cases} \quad if \quad \begin{matrix} X_{t-1} > \theta \\ -\theta < X_{t-1} < \theta \\ X_{t-1} < -\theta \end{matrix}$$

where ΔX_t is the first difference of the independent variable ($X_t = P_t^A - P_t^B$), α is the regime-specific mean, ε_t is an $i.i.d. \sim N(0,\sigma^2)$ error term, $[-\theta, \theta]$ represent the “inactivity band”, here assumed to be symmetric. The above specification has two types of symmetry: symmetry in the transaction costs band and symmetric behavior in the outer regimes, that is the regimes above and below the threshold share the same mean and autoregressive coefficients. ρ and α are the speed-of-adjustment parameters and are expected to satisfy the following condition: $-2 < \rho + \alpha < 0$.

The model assumes that arbitrage drives the prices toward the edge of the inactivity band, where the LOP is satisfied with equality. The outer regimes follow an AR(1) process with mean α and an expected adjustment equal to $\alpha + \rho x_{t-1}$, thus the farer the deviation from the band the stronger the adjustment. The model also assumes that the inner regimes follow a random walk process, that is, the prices are not linked each other.

The second model presented in [3] is a symmetric three regimes equilibrium EQ-TAR:

$$(2) \qquad \Delta X_t = \begin{cases} \rho_{out} X_{t-1} + \varepsilon_t \\ \rho_{in} X_{t-1} + \varepsilon_t \\ \rho_{out} X_{t-1} + \varepsilon_t \end{cases} \quad if \quad \begin{matrix} X_{t-1} > \theta \\ -\theta < X_{t-1} < \theta \\ X_{t-1} < -\theta \end{matrix}$$

where the inner regime follows an AR(1) process and is expected that the parameter $\rho_{in} \approx 0$ and $\rho_{in} > \rho_{out}$, that is large deviations should be corrected faster than smaller ones. The essential difference between BAND and EQ-TAR relies on the convergence of deviations outside the band respectively towards the edge and towards the equilibrium point. From this point of view, EQ-TAR is more restrictive and not consistent with the theory of the “inactivity band”, but more linked to the Marshallian formulation of the Law of One Price.

Balke and Fomby [3] showed that, despite a local random walk is possible inside the band, the process is globally stationary.

One of the main advantages of these two formulations is that they assume a very simple first-order autoregressive process which allow to estimate the average time that the series takes to return inside the band after a deviation. The parameter *h*, called *half-life*, is the time that an exogenous shock needs to return to half of its initial value and is computed by solving the equation $m_{t+h} = \frac{m_t}{2}$ where *m* is the shock that occurs at time *t* and is halved after *h* periods (that is at time *t*+*h*). In the case of an AR(1) process the derivation of *h* is straightforward from the following equation:

$$h = \frac{\ln(0.5)}{\ln(1+\rho)}$$

A simpler way to assess the speed of adjustment from deviations is to adopt a linear AR(1) process as the following:

$$(3)\quad \Delta X_t = \rho X_{t-1} + \varepsilon_t \;,$$

where ε_t is *i.i.d.*~ $N(0,\sigma^2)$ and ρ is expected to be between zero and minus one and is called *convergence speed.* In this specification the non-linearity due to transaction costs is neglected and the process is assumed to adjust continuously to the price gap level (x_{t-1}).

This last specification ignores a large part of the phenomenon of price transmission and it has been used as a benchmark to estimate the speed of adjustment and the half-life. Conversely, both BAND-TAR and EQ-TAR take into account the potential non-linearity and give an estimate of transaction costs, identified by the width of the inner regime (*i.e.* when $-\theta < X_{t-1} < \theta$). Unfortunately, they still rely on strong assumptions: they impose fixity over time of transaction costs and symmetry of price transmission.

Many reasons tend to weak the hypothesis of fixed transaction costs when the analysis is conducted over a sufficiently long period of time: changes in transportation ways and technologies, change in trade policies, improvement in storage techniques, etc. The hypothesis of fixed transaction costs becomes even weaker when applied to perishable goods, as F&V, for which transportation costs account for a large part of their market price[1].

A second strong assumption of BAND-TAR and EQ-TAR is the symmetry of price transmission. Meyer and Cramon-Tabaudel [12] surveyed the literature on asymmetric price transmission identifying some of the possible causes of asymmetry: market power and adjustment costs [19], non-equivalence of demand and supply shocks [4], distorted price reporting process [2], asymmetric information [1].

Based on these major considerations, it seemed appropriate to estimate a model where both assumptions (fixed transaction costs and symmetric transmission) were removed. The last specification adopted in the present study is an Asymmetric Equilibrium trend-TAR (a-EQ-t-TAR). In particular, following Van Campenhout [18], we allowed the model adopted in his paper to take into account possible asymmetric price transmission.

In specification (4) we relaxes the assumptions of symmetric speed of adjustments (i.e. we allow $\rho_{\mathrm{I}} \neq \rho_{\mathrm{III}}$) and the fixity of the “band of inactivity” (that is the width θ of the band is indexed over time *t* with $\theta_t \neq k$ with *k constant*). More precisely, the specification allows for different autoregressive terms in the “above” and “below” regimes. Furthermore, the “inner” regime is not constrained to have a fixed width while could be characterized by a decreasing (or increasing, since no restrictions are imposed) trend.

$$(4)\quad \Delta X_t = \begin{cases} \rho_I X_{t-1} + \beta \Delta X_{t-1} + \varepsilon_t \\ \varepsilon_t \\ \rho_{III} X_{t-1} + \beta \Delta X_{t-1} + \varepsilon_t \end{cases}$$

$$if \quad \begin{matrix} X_{t-1} > \theta_t \\ -\theta_t < X_{t-1} < \theta_t \\ X_{t-1} < -\theta_t \end{matrix}$$

where: $\theta_t = \theta_0 + \frac{(\theta_T - \theta_t)}{T} * t$ *t= 1 , … , n*

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[1] For instance, Goodwin et. al. [10] showed that improvement in storage techniques could reinforce market integration.

Adopting specification (4) we have been able to capture heterogeneous behaviors of different markets, that is we have estimated different speeds of adjustment for deviations that exceed the higher or lower hedge of the inactivity band: in particular, the coefficients ρ are directly interpretable as speed-of-adjustments. Our results[2] are not affected by the introduction of a constant term in the outer regimes, that is if we switch to an asymmetric-BAND-trend-TAR specification. Moreover, the interpretation of coefficients in the latter model is more complex, due to the regime-specific mean[3] terms, and the computation of half-life might be cumbersome. Finally, the asymmetric-BAND-trend-TAR relies on a larger number of parameters, that would result in a loss of estimation efficiency. For all the mentioned reasons we preferred to adopt the specification (4).

In order to test if the asymmetric model is more appropriate than a symmetric one, we estimated an asymmetric-EQ-TAR[4] and performed a likelihood ratio test between the symmetric and asymmetric EQ-TAR. Under the null hypothesis, the former model is nested in the latter. If the null is rejected, the symmetric model is not nested in the asymmetric model; *vice-versa*, if we fail to reject the null, the symmetric model is nested in the asymmetric model. In this case, the coefficients of the outer regimes are symmetric and we will gain efficiency estimating them with a symmetric EQ-TAR.

The likelihood ratio (LR) test statistic is $LR = 2\left(\mathcal{L}(\hat{\omega}) - \mathcal{L}(\hat{\Omega})\right)$, where $\hat{\omega}$ and $\hat{\Omega}$ represent, respectively, the restricted and unrestricted maximum likelihood estimates of the model. In general the parameters in the restricted model are constrained by r (non linear) restrictions. The most important feature[5] of the LR statistics is that it is asymptotically distributed as a $\chi^2(r)$ hence the p-value are easy to be compared with tabulated values.

In all TAR specifications we adopted the thresholds were found through a grid search based on the values of SSR[6] while coefficients are estimated by least squares. Tsay [17] showed that, under regularity conditions, least squares estimates are consistent. In particular, if in each regime $n_j \frac{\square}{\square} n \xrightarrow{p} c_j$ holds[7], and estimated coefficients respect the OLS conditions for consistency[8], the ordinary least squares estimates are consistent. From an applied perspective, consistency of OLS greatly simplify the modeling and estimation process of TAR models.

The coefficients ρ_I and ρ_{III} of specification (4) have a clear economic interpretation being *proxies* of the forces of adjustment after that deviations from equilibrium exceed the edge of inactivity band. The lower the coefficients, in absolute value, the lower the adjustment and the higher the price *inertia* in the outer regime. Conversely, high coefficients mean that price deviations are strongly, and fast, corrected towards the equilibrium. In fact, the half-life ($h = \frac{\ln(0.5)}{\ln(1+\rho)}$) contains the coefficient ρ at the denominator, thus the higher the coefficient (in absolute value) the lower the half-life. When ΔP exceeds the band edge, say P_j falls in the lower regime, there are only two ways in which the deviations could return inside the band: 1) the price that deviated (P_j) moves in the opposite direction; 2) the other price (P_i) follows the price that deviated. The former way does not imply a price

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[2] Results using an asymmetric-trend-BAND-TAR have been omitted in the present analysis.

[3] Obstfeld and Taylor [13] estimated a BAND-TAR specification not imposing any restriction in the inner regime. They tested the difference between ρ_{in} and ρ_{out}. If the coefficients are not different the model collapse to a linear AR model.

[4] The model is between the asymmetric–trend-EQ-TAR and the symmetric-EQ-TAR. More precisely, the specification is the following:

$$\Delta X_t = \begin{cases} \rho_I X_{t-1} + \beta \Delta X_{t-1} + \varepsilon_t \\ \varepsilon_t \\ \rho_{III} X_{t-1} + \beta \Delta X_{t-1} + \varepsilon_t \end{cases} \quad \text{if} \quad \begin{matrix} X_{t-1} > \theta \\ -\theta \leq X_{t-1} \leq \theta \\ X_{t-1} \leq -\theta \end{matrix}$$

that is, the model is asymmetric, but the "inactivity band" is fixed.

[5] For further details [5].

[6] The algorithm adopted to estimate is the following: let fix the minimum percentage of observations that outer regimes and inner regime needs to contain (*trimming procedure*); let consider a threshold as a line connecting threshold from observation $i = 1$ to n (where n is the sample size); for each i+1 observation, let replace the threshold with the following formula: $\theta_t = \theta_0 + \frac{I(\theta_T - \theta_t)}{T} * t$, with $t = 1, \ldots, n$ if and only if SSR decreases from i to i+1; when SSR is minimized for specific of θ_0 and θ_t, let estimate the coefficients of the outer regime.

[7] n_j, n and c_j are, respectively, the number of observations in regime j, the sample size and a positive fraction such that $\sum_{j=1}^{k} c_j = 1$

[8] That is the eigenvalues of $X^T X$ tend to zero (or $(X^T X)^{-1}$ tend to infinity).

transmission, the latter does and the faster the reaction of the other price, the faster the deviation returns inside the band.

IV. DATA AND RESULTS

The analysis has been carried out using weekly prices of cauliflowers and tomatoes covering the period from 1996 to 2006. The markets were prices have been collected are located in different EU countries. In particular, markets in tomatoes sector are the followings: Almeria (Spain); Chateau-Renard (France); Den Bosch (Netherlands); Dublin (Ireland); London (United Kingdom). As far as cauliflowers are concerned, five markets have been considered: Den Bosch (Netherlands); Dublin (Ireland); La Roja (Spain); London (United Kingdom); Sint Kateljine Waiver (Belgium).

In appendix, we report descriptive statistics and correlations of the time series grouped by products. As regard tomatoes, we observe the lowest price mean and standard deviation for Almeria market, which is one of the main production center in Spain, followed by the price of Chateau Renard, one of the largest production market in France. As far as cauliflowers are concerned, the two lowest price means are observed, respectively, for La Roja and London. In our analysis these four markets are considered as net exporters and price transmission is computed among them and the other European locations.

Among tomatoes markets the correlation of Almeria price and the others is the lowest. The main reason that might lead to such situation is the large distance of Almeria from the other markets which, as a consequence, implies larger transaction costs (i.e. a wide “inactivity band”). A different situation is detected for Chateau Renard: the correlations are almost 0.7 with respect all but Almeria price for which we observe a value of 0.59 (a possible explanation of such low correlation is that these markets, both production and export centers, are scarcely integrated). As regard cauliflower, La Roja and London have the highest correlation among themselves and with respect Dublin, while the coefficients related to Den Bosch and Sint Katelijine Waiver are very low (respectively, 0.21 and 0.25 for La Roja, 0.36 and 0.30 for London). In line with these findings, the analysis conducted by TAR models show that for Den Bosch and Sint Katelijine Waiver we estimated the widest bands and the highest half-lives, that is they are the least integrated with La Roja and London.

The estimation results of the TAR model for tomatoes markets are collected in table 3. In general, we show that price transmission is asymmetric and the adjustments are faster in the third regime rather than in the first regime.

Price transmission between Almeria (Spain) and the other markets is generally asymmetric[9]. In particular, the adjustments are weaker in the first regime than in the third ($\rho_I < \rho_{III}$) while the deviations from equilibrium are far more frequent in regime I (*i.e.* price spikes): the share of prices deviations toward the lower regime are lower than 1% in all but one case, the transmission between Almeria and Chateau-Renard, for which the percentage is slightly larger (3.27%). These results might be largely explained by the unidirectional trade between Almeria and the other markets with the first playing the role of production market and the latter of consumption markets. Finally, the estimated half-lives in the first regime range from 2.07 to 3.09, that is deviations from the equilibrium are corrected in less than 2 or 3 weeks. Not surprisingly the estimated “inactivity band” is large, certainly due to the considerable distance between Almeria and the other locations. In all cases, the band shrinks over time, that is the transportation costs decreases more and more.

As far as price transmission between Chateau-Renard (France) and the other markets is concerned, a remarkable difference consists in a less evident asymmetry[10], although, as mentioned for Almeria, the adjustments seems to be weaker in the first regime than in the third ($\rho_I < \rho_{III}$). The deviations are unevenly distributed among the regimes. In particular, price deviations in the first regime account for a large share in the cases of price transmission with Dublin (Ireland) and London (United Kingdom), for which the percentage is, respectively, 50% and 43%. In all

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[9] In all but one case, the price transmission between Dublin and Almeria, the likelihood ratio tests reject the null hypothesis at 5% significance level.

[10] In none of the cases under analysis LR tests are rejected at 5% significance level, but for London and Sint Katelijine Waiver the test is rejected at 10% level.

three cases the observations in the third regime occur with the lowest frequency (ranging from 6 to 25%). The average time required for deviations to return into the "inactivity band" is lower than one week for deviations in the third regime (price falls) and from 0.8 to 1.8 for deviations in the first regime (price spikes). The estimated "inactivity band" is tiny in all but one case, the price transmission between Chateau Renard and Dublin. Moreover, the transaction costs increase over time.

Table 3 Price transmission in tomatoes markets

	Cht - Alm	Dub - Alm	Lon - Alm	SKW - Alm	Dub - Cht	Lon - Cht	SKW - Cht
B	-.55 (.065)	-.01 (.063)	-.039 (.064)	-.14** (.062)	-.042 (.065)	-.118 (.062)	-.054 (.591)
ρ_I	-.284*** (.48)	-.206*** (.035)	-.201*** (.032)	-.279*** (.035)	-.475*** (.073)	-.307*** (.048)	-.545*** (.060)
ρ_{III}	-.679*** (.19)	-.251^{a} (.316)	-	-.965$^{a\ ***}$ (.332)	-.623*** (.123)	-.582*** (.233)	-.527*** (.109)
% obs. (regime I)	36.45	32.24	28.97	30.84	50.47	42.99	28.04
% obs. (regime III)	3.27	< 1	-	< 1	25.23	6.07	18.59
Half-life regime I (weeks)	2.07	2.99	3.09	2.11	1.08	1.88	0.87
Half-life regime III (weeks)	0.61	-	-	-	.71	.79	.92
θ^T (% w.r.t $\overline{PA}$)	27.34 (32.3%)	39.38 (42.6%)	62.8 (58%)	31.28 (34.5%)	43.62 (51.5%)	8.28 (9.0%)	8.93 (8.2%)
Δθ: $\frac{(\theta^0 - \theta^T)}{\theta^0}$	-39.3 %	-21.1 %	-6.2 %	-40.4 %	6.4 %	344.6 %	-59.2 %
N. obs.	207	207	207	207	207	207	207

[a] The results rely on very few observations.

In table 4 we collect the estimation results of the TAR model for cauliflower markets. In general, we show that price transmission is asymmetric and the adjustments are faster in the third regime rather than in the first regime.

Price transmission between La Roja (Spain) and the other markets is clearly asymmetric[11]. In particular, the adjustments, when they occur, are stronger in the third regime than in the first ($\rho_I < \rho_{III}$). Moreover, the share of prices deviations toward the lower regime are rare: lower than 1% in all but one case, the transmission between London and La Roja, for which the percentage is 2.78. Similarly to the explanation we provided for price transmission among tomatoes markets, these results might be explained by the mainly unidirectional trade among La Roja and the other markets with the first playing the role of

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[11] The estimates of the asymmetric and symmetric models with fixed band used to compute the LR test for La Roja sensibly differ from those obtained from specification (4). In particular the formers attribute almost the same share of deviations to regime I and III. In this framework the results of LR test which fail to reject the null hypothesis is not surprising but its interpretation might have poor value for inference on the asymmetry we observe with specification (4). In all other cases for regime III the coefficient ρ cannot be estimated due to the lack of a sufficient number of observations: the asymmetry relies on the uneven distribution of deviations from equilibrium.

production market and the latter the consumption markets. The estimated half-lives in the first regime cover the range from 2.25 to 5.01, that is deviations from the equilibrium are corrected in 5 weeks at most. Transaction costs are mild and decreasing over time. The only exception is found for Sint Katelijine Waiver: the "band" is prohibitive (larger than 100!) which is a clear evidence of lack of market integration between this market and La Roja.

As far as price transmission between London (United Kingdom) and the other markets is concerned we do observe an evident asymmetry[12], and, similarly to the above mentioned case (La Roja), the adjustments are weaker in the first regime than in the third ($\rho_I < \rho_{III}$). The only exception we found is related to transmission between London and Sint Katelijine Waiver prices were no observations pertain to the third regime, that is the coefficient ρ_{III} cannot be estimated. A large share of observations fall in the first regime: the percentage are, respectively, 36%, 46% and 67% for Den Bosch, Dublin and Sint Katelijine Waiver. In all the three cases the observations in the third regime occur with the much lower frequency (ranging from less than 1% to 5.9%). The average time required for deviations to return into the "inactivity band" is lower than one week for deviations in the third regime (price falls) and from 1.8 to 6.48 for deviations in the first regime (price spikes). The "inactivity band" is wide and increasing over time, suggesting a loosening integration of London with the other European markets.

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[12] The p-values of LR tests conducted on prices series of Dublin and Sint Katelijine Waiver are, respectively, 0.001 and 0.051. As regard Den Bosch, the $\chi^2(1)$ value is 2.02 (p-value:0.15) but the largely uneven distribution of observations between the regimes I and III suggest an asymmetric adjustment process.

Table 4 Price transmission in cauliflower markets

	Den - Lar	Dub - Lar	Lon - Lar	SKW - Lar	Den - Lon	Dub - Lon	SKW - Lon
β	-.109 * (.064)	-.107 ** (.053)	-.013 (.046)	-.046 (.046)	-.186 *** (.063)	-.094 ** (.052)	-.027 (.046)
ρ_I	-.137 *** (.034)	-.201 *** (.027)	-.264 *** (.033)	-.129 *** (.021)	-.146 *** (.036)	-.319 *** (.046)	-.101 *** (.020)
ρ_{III}	-2.833 $^{a\ ***}$ (1.231)	-	-.611 *** (.244)	-	-.784 $^{a\ ***}$ (.418)	-.803 *** (.145)	-4.356 $^{a\ ***}$ (1.364)
% obs. regime I	47.78	32.45	41.88	21.58	36.05	46.61	67.31
% obs. regime III	< 1	-	2.78	-	< 1	5.90	< 1
Half-life regime I (weeks)	4.71	3.07	2.25	5.01	4.36	1.81	6.48
Half-life regime III (weeks)	1.14 ^{a}	-	.73	-	0.45 ^{a}	.42	0.57 ^{a}
θ^T (% w.r.t $\overline{PA}$)	9.75 (14.9%)	15.25 (32.4%)	7.5 (18.4%)	109.4 (109.5%)	35.84 (54.9%)	15.17 (32.2%)	37.41 (37.4%)
Δθ: $\frac{(\theta^0 - \theta^T)}{\theta^0}$	-78.2 %	-36.9 %	-55.3 %	-5.13 %	94.7 %	116.7 %	124.4 %
N. obs.	231	337	467	467	231	337	467

[a] The results rely on very few observations.

As far as price transmission between London (United Kingdom) and the other markets is concerned we do observe an evident asymmetry[13], and, similarly to the above mentioned case (La Roja), the adjustments are weaker in the first regime than in the third ($\rho_I < \rho_{III}$). The only exception we found is related to transmission between London and Sint Katelijine Waiver prices were no observations pertain to the third regime, that is the coefficient ρ_{III} cannot be estimated. A large share of observations fall in the first regime: the percentage are, respectively, 36%, 46% and 67% for Den Bosch, Dublin and Sint Katelijine Waiver. In all the three cases the observations in the third regime occur with the much lower frequency (ranging from less than 1% to 5.9%). The average time required for deviations to return into the "inactivity band" is lower than one week for deviations in the third regime (price falls) and from 1.8 to 6.48 for deviations in the first regime (price spikes). The "inactivity band" is wide and increasing over time, suggesting a loosening integration of London with the other European markets.

V. FINAL REMARKS

Our paper aimed to provide evidence on spatial price dynamics of selected EU F&V Regions. In particular, the analysis has been carried out on prices of tomatoes and cauliflowers collected on several EU markets in production and consumption areas in order to evaluate prices transmission. The time-varying threshold autoregressive specification adopted in the analysis allowed to evaluate the different speed of adjustments for price rises and price falls as well as the trends of the "inactivity band".

The analysis showed that horizontal price transmissions among net producer and net consumer markets is asymmetric but such characteristic is less evident for markets closer to production or main export areas (e.g. Almeria and Chateau Renard for tomatoes, La Roja and London for cauliflowers). In particular, the asymmetry is mainly due to the

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[13] The p-values of LR tests conducted on prices series of Dublin and Sint Katelijine Waiver are, respectively, 0.001 and 0.051. As regard Den Bosch, the $\chi^2(1)$ value is 2.02 (p-value:0.15) but the largely uneven distribution of observations between the regimes I and III suggest an asymmetric adjustment process.

different likelihood of occurrence of deviations in the upper or lower regime: the likelihood of the former is substantially grater than the latter, especially among the main production centers (e.g. Spanish markets) and the net consumer locations (e.g. Den Bosch and Dublin).

Moreover, price raises are transmitted among production centers in two weeks, while the adjustments in consumption markets require from 3 to 5 weeks to take place, that is the integration among production centers exceeds the one we observe between production and destination locations. The main implication of these findings, is that, for F&V price raises due to scarce harvests or a bump in demand, price transmission seems to follow a tree-structure in which shocks are fast transmitted among the nodes (production centers) and slower passed trough the branches to the leaves (final destinations), poorly integrated each others[14].

Differently, deviations in the lower regimes are occasional (with a frequency lower than 3%) among main production and net consumption locations, while they occur more often (up to 25% of the cases) among secondary production centers (Chateau Renard for tomatoes and London for cauliflowers) and EU destination markets. This characteristic is rather marked in the cauliflower sector where the lower regime contains at most 5% of observations. Such findings suggest that when F&V prices in production areas fall (e.g. when markets face an unexpected over-production, a large increase in imports or a sudden fall of local demand) they might tend to remain at a low level since adjustment dynamics are confined to the local areas.

Finally, we found a clear evidence of declining transaction costs between the main production markets and the other markets, implying a tendency for prices spikes to be transmitted more and more during next years. We cannot conclude on a general tendency for EU markets since the results on transaction costs among secondary production centers and final destinations are quite heterogeneous.

Despite the relevance of the implications of our paper, a main limitation is that results rely on a limited number of products and markets. A robust generalization of our findings would be possible if they are confirmed with a larger dataset which should include other relevant products (e.g. fruits such as apple, oranges or fresh grapes; vegetables such as carrots, cabbages, onions or lettuce) as well as markets of important players in the EU F&V sector (mainly Italy, a large producer, and Germany, a relevant net importer). A further development would be to replicate our work with a different data frequency, i.e. by adopting daily prices, since the adoption of weekly data might have biased the estimates of speed of adjustments.

Recent industry trends are such that the share of production traded on the EU's wholesale fruit and vegetable markets tend to be declining, as more and more frequent transactions occur outside of these channels, rather than through contractual relationships between seller and purchaser, in increasingly short supply chains. This has two important implications: on one hand the prices determined on traditional fruit and vegetable markets reflect less and less relationships between demand and aggregate supply, losing the information content of the fundamentals of economy (e.g. regarding changes in consumer preferences), on the other hand the relevance of price transmission along chain is increasing more and more. In this scenario it would be interesting to investigate deeply on the degree and the asymmetry of vertical price transmission, that is along the supply chain, in order to highlight additional features of the spatial dynamics of the EU F&V sector.

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[14] Santeramo [15] shows that inter-countries price transmission for consumption centers is rather limited.

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Corresponding author: Fabio Gaetano Santeramo
Email address: fabiogaetano.santeramo@unina.it

APPENDIX

Table A - Descriptive statistics

	Observations	Mean	Median	Std. dev.	Skewness	Kurtosis
Tomatoes markets						
Almeria	221	58.47	49.66	28.58	1.83	7.04
Chateau Renard	221	84.65	79.51	32.45	0.98	4.36
Den Bosch	221	92.44	84.62	33.15	1.62	6.79
Dublin	221	108.32	99.45	40.04	1.41	5.31
London	221	90.66	77.68	42.94	1.25	4.54
Cauliflower markets						
Den Bosch	233	65.30	54.73	42.01	1.78	7.43
Dublin	339	47.07	44.91	13.57	1.46	5.59
La Roja	469	30.23	28.93	8.86	0.81	4.14
London	469	40.83	36.91	16.59	1.38	5.73
Sint Katelijine Waiver	469	99.97	86.71	56.1	0.85	3.27

Table B – Price correlations

Tomatoes	Almeria	Chateau Renard	Den Bosch	Dublin	London
Almeria	1				
Chateau Renard	.590	1			
Den Bosch	.617	.726	1		
Dublin	.746	.691	.791	1	
London	.669	.712	.690	.834	1

Cauliflower	Den Bosch	Dublin	La Roja	London	Sint Katelijine Waiver
Den Bosch	1				
Dublin	.263	1			
La Roja	.218	.515	1		
London	.364	.728	.451	1	
Sint Katelijine Waiver	.360	.182	.256	.308	1

Table C - Likelihood ratio tests

	Cht - Alm	Dub - Alm	Lon - Alm	SKW - Alm	Dub - Cht	Lon - Cht	SKW - Cht
LR $\chi^2(1)$	4.86	0.01	-	5.82	3.78	0.02	0.72
Prob. > χ^2	0.027	0.927	-	0.015	0.052	0.902	0.396

	Den - Lar	Dub - Lar	Lon - Lar	SKW - Lar	Den - Lon	Dub - Lon	SKW - Lon
LR $\chi^2(1)$	-	-	1.83	-	2.02	10.59	3.79
Prob. > χ^2	-	-	0.175	-	0.155	0.001	0.051