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Section Empirical contributions

A revisited gravity equation in trade flow analysis: an application to the case of Tunisian olive oil exports

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ABSTRACT: This study revisits the utility of gravity models in the analysis of the principal determinants of exports. Traditional cross-sectional models are improved by considering the effect of omitted variables and/or the dynamic of trade flows through the use of spatial econometric techniques and panel data specification. This proposal is applied to the Tunisian olive oil exports during the period 2001-2009. The results provide evidence of the inertia found in export volumes, with trade relations anchored in the past likely to continue in the future. Also, we obtain evidence on the existence of a clear similarity in flows between neighbouring importing countries. On the other hand, the results show a positive, significant relationship between the importing country's income level and imported olive oil volume. The effect of importers' human development index is positive. The distance between countries has a negative impact on trade flow. On the contrary, sharing a common language increases olive oil trade flows. Finally, trade figures and results reflect a strong dependence of Tunisian olive oil production on precipitations.

JEL Classification: F10, R15, C23.

Keywords: Gravity model, spatial econometrics, panel data, tunisian olive oil exports.

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Una ecuación de gravedad revisada en el análisis de flujos de comercio: una aplicación al caso de las exportaciones de aceite de oliva tunecino

RESUMEN: Este trabajo revisa la utilidad del modelo de gravedad para el análisis de los principales determinantes de la exportación. Se mejoran los modelos tradicionales de corte transversal mediante la consideración de los efectos de las variables omitidas y/o la dinámica de los flujos de comercio, a través del uso de las técnicas de econometría espacial y de especificaciones para datos de panel. Esta propuesta se aplica a las exportaciones de aceite de oliva tunecino durante el periodo 2001-2009. Los resultados muestran evidencia acerca de la inercia encontrada en los volúmenes de exportación, dado que es probable que las relaciones de comercio afianzadas en el pasado continúen en el futuro. También se obtiene evidencia acerca de la existencia de claras similitudes entre los flujos de los países importadores vecinos. Por otra parte, los resultados muestran una relación positiva y significativa entre el nivel de renta del país importador y el volumen de aceite de oliva importado. El efecto del índice de desarrollo humano de los países importadores es positivo. La distancia entre países tiene un efecto negativo sobre el volumen de comercio. Por el contrario, compartir el mismo idioma aumenta el flujo de comercio de aceite de oliva. Finalmente, las cifras de comercio y los resultados reflejan una fuerte dependencia de la producción de aceite de oliva tunecino de las precipitaciones.

Clasificación JEL: F10, R15, C23.

Palabras claves: Modelo de gravedad, econometría espacial, datos de panel, exportaciones de aceite de oliva tunecinas.

1. Introduction

The gravity model has often been used to explain Origin-Destination (OD) flows such as international or regional trade, transportation flows, population migration, commodity flows, information flows along a network, patients' flows to hospitals, etc. Reasons for the prosperity of this model are the simplicity of its mathematical form and the intuitive nature of its underlying assumptions, as Sen and Smith (1995) noted in their monograph.

In relation to international trade, there exists a large literature on theoretical foundations for these models (Anderson, 1979; Anderson and Wincoop 2004). In the regional science literature the gravity model has been labelled a spatial interaction model (Sen and Smith, 1995), because the regional interaction is directly proportional to regional size measures. The model relies on a function of the distance between origin and destination as well as explanatory variables pertaining to characteristics of both, origin and destination countries. The principal explanatory variables used to explain trade flows are as follows. The variables with a positive effect include size of importing economy, per capita income differential of the two countries involved, their degree of openness, the existence of general trade agreements, the existence of a common official language and/or currency, a shared colonial past or the existence of a favourable exchange rate. The factors with a negative impact on trade volumes include cost of transport, which usually depends on the distance between the countries involved.

Most previous empirical studies analyse cross-sectional data using mean flow data and the respective explanatory variables for several years as the model's variables. However, literature has been developed towards an appropriate treatment of two important issues: i) the consideration of the effect of possible omitted variables that could be correlated with the included ones; and ii) the introduction of dynamics. The solution to these problems can be found within two disciplines. On one hand, within the regional science literature, some solution comes with the use of spatial econometric models; on the other hand, the use of panel data econometrics can also overcome those problems. In this paper, we will compare both possible solutions.

Regarding spatial econometric techniques, the main issue deals with the concept of spatial dependence among the sample of OD flows, since as noted by Griffith and Jones (1980): i) flows from and origin are «enhanced or diminished in accordance with the propensity of emissiveness of its neighboring origin locations» and flows to a destination are «enhanced or diminished in accordance with the propensity of attractiveness of its neighboring destination locations». The usefulness of distance functions as the way of capturing spatial dependence has been deeply analysed in literature (see Griffith, 2007). However, many empirical works still rely on the assumption of independence among OD flows (LeSage and Pace, 2008). Recently, Porojan (2001), for the case of international trade flows, and Lee and Pace (2005), for retail sales, pointed out that residuals from conventional models were founded to exhibit spatial dependence. Within this argument, LeSage and Pace (2008) overcome the problem by using spatial models which, in fact, are solving a possible problem of omitted variables or a lack of capturing dynamics.

The main advantage of panel data econometric is that it prevents the so-called heterogeneity bias in the estimations, which is generated when a relevant variable is missing from the model. Panel models prevent such bias by considering the individual effects related to cross-sectional, generally the countries involved in trade, and/or time units (Matyas, 1997, 1998). Within this line, many studies have been conducted. For example, Wall (2000) applied the technique to trade figures between Canadian provinces and individual US states; Rose (2002) estimated the effect of multilateral trade agreements —World Trade Organisation (WTO), the General Agreement on Tariffs and Trade (GATT) and the Generalised System of Preferences (GSP)— on international trade, using figures from 175 countries for more than 50 years; Rahman (2004) analysed the trade flows of Bangladesh; finally, Abu Hatab *et al.* (2010) analysed Egyptian agricultural exports to its principal trade partners in the 1994-2008 period.

In this context, we proposed to compare the performance of both methodological alternatives. As an application, we offer results for the determinants of Tunisian olive oil exports which is one of the most important agricultural products exported from

Tunisia. The second section of the paper analyses the importance of the country's olive oil sector, analysing the main exporting countries in detail. We then present the estimated econometric model based on a gravity model using spatial and panel econometric framework. The fourth section describes the data and their sources and the fifth analyses the results obtained. The last section contains our conclusions and describes some future lines of research.

2. Tunisian olive oil sector and exports

Olive orchards in Tunisia occupy 1.7 million ha, the equivalent of 30% of the total arable land, and represent about 19% of the world olive orchards (second largest olive land after Spain which counts 3 million ha). Sixty-six million olive trees are widespread all-over the country: North, Centre and South. The olive oil sector employs directly or indirectly over one million persons and 269,000 farmers are dedicated to this growing.

Olive oil production in Tunisia is highly dependent on precipitations. For the last three years olive oil production was stabilized around 170,000 tons/year. Tunisian government is encouraging the use of irrigation (intensive or hyper-intensive growing) to increase the proportion of irrigated olive orchards (2% actually) in order to decrease production fluctuation mainly due to climatic change.

The Tunisian olive oil manufacturing system is composed by three triturating systems that coexist actually: the traditional one called «classic», the Super-Press, and the modern one. The red accounts for 1,734 olive oil mills (MAHR, 2010) decomposed as follows: 628 classic units, 388 Super-Press, 718 continuous chains. Some olive oil mills have more than one type of processing units. They are called mixed units. In addition to this processing structure, the sector counts with 40 industrial units for olive oil packaging, or for pomace olive oil extraction. Actually the overall trend is to increase the number of modern olive oil mills (continuous chains).

Olive oil consumption in Tunisia ranges between 35,000 to 50,000 tons per year (25% to 30% of total production). Trend consumption is showing a decreasing pattern during the last decade essentially due to price increment, but also to culinary and habit changes in the Tunisian population. Compared to other traditional producing countries, olive oil per capita consumption in Tunisia is very low (around 4 kg/capita/year). Olive oil consumption is mainly in bulk. Tunisian consumers are used to purchase olive oil directly from the manufacture. Bottled olive oil purchase still very limited (3% of total consumption) and concentrated in large cities like Tunis Capital.

Olive oil exports account for 120,000 tons per year representing 70% of total production. They also represent 10% of total exports in values and about 45% of agro-food exports (first ranked product). Tunisia occupies the fourth position as olive oil exporter preceded by Spain, Italy and Greece. These exports are mainly directed to the European Union (Italy, Spain, France), USA, Morocco and Switzerland

(Figure 1). These countries receive from 88% (2002) to 98% (2005 or 2006) of total Tunisian olive oil exports (Table 1). In general, this ranking has remained unaltered over time. These figures show that exports are highly concentrated, which could be seen as a weakness and a threat for future Tunisian olive oil sales abroad.

Figure 1. Value of Tunisian olive oil exports to leading importers (thousands of dollars)

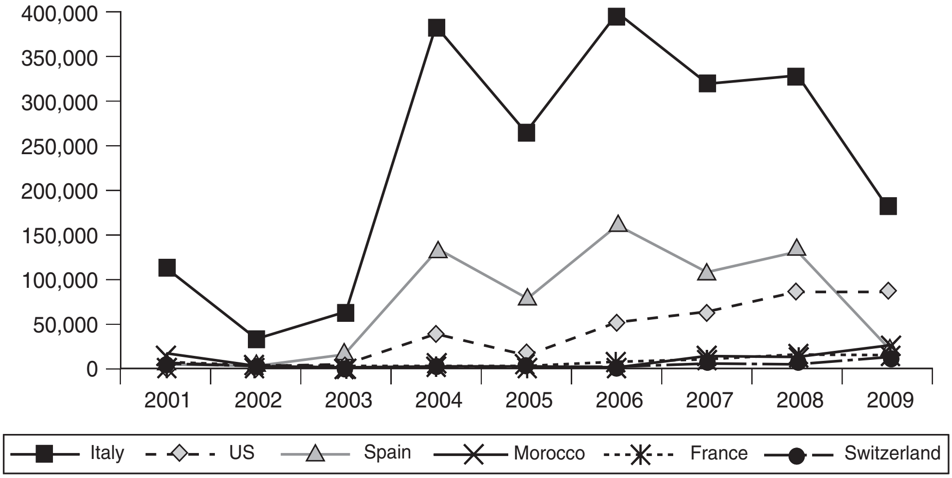

Table 1. Evolution of the market share of leading Tunisian olive oil importers (2001-2009) (%)

	2001	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
Italy	80.4	81.0	69.8	66.6	71.5	62.7	58.9	52.9	46.2
US	5.5	6.4	4.1	6.8	4.5	8.3	11.4	14.1	21.7
Spain	5.8	0.0	20.5	23.6	22.0	25.7	20.1	21.3	6.5
Morocco	0.9	0.2	0.0	0.4	0.0	0.2	1.9	2.3	6.1
France	0.7	0.5	0.3	0.2	0.2	1.3	1.8	3.2	3.7
Switzerland	1.3	0.1	0.9	0.5	0.0	0.0	1.5	0.6	3.3
Total	**94.5**	**88.1**	**95.7**	**98.1**	**98.2**	**98.2**	**95.5**	**94.5**	**87.7**

During the last decade (2000 to 2009), around 190 olive oil companies have exported Tunisian olive oil with no continuous frequency. Only 9 companies exported olive oil continuously each year. They regrouped on average 65% of total Tunisian olive oil exports value.

3. Methodology

The traditional econometric formulation of the gravity model applied to the trade between two countries, *i* and *j,* is given by the following expression:

$$\ln\left(F_{ij}\right)=\beta_0+\beta_1\ln\left(Xo_i\right)+\beta_2\ln\left(Xd_j\right)+\beta_3\ln\left(D_{ij}\right)+u_{ij} \quad (1)$$

where F_{ij} is the volume of trade between country *i* and country *j*; Xo_i represents the emission capacity of the country of origin (exporter); Xd_j represents the power of attraction of the country of destination (importer); D_{ij} denotes the distance between them; and u_{ij} is the error term under ideal condition.

Traditionally, equation (1) has been applied to cross-sectional data using mean flow data and the respective explanatory variables for several years as the model's variables. However, if a panel data set is available, the corresponding pool gravity model can be expressed as:

$$\ln\left(F_{ijt}\right)=\beta_0+\beta_1\ln\left(Xo_{it}\right)+\beta_2\ln\left(Xd_{jt}\right)+\beta_3\ln\left(D_{ijt}\right)+u_{ijt} \qquad t=1,\ldots T \quad (2)$$

As explained in the introduction section, several authors pointed out that previous specification should be improved in order to consider the effect of possible omitted relevant variables and/or to consider the dynamics of trade. Next, we show how spatial econometrics and panel data econometrics overcome those problems.

3.1. Spatial econometric literature

3.1.1. Treatment of omitted variables

As shown in LeSage and Pace (2008), the use of traditional least-squares regression to estimate gravity models ignores possible spatial dependence in the sample data of flows. As a consequence, the estimated parameter could be biased and inconsistent (LeSage and Pace, 2004). In our case, the origin country (*i*) is Tunisia, while we have *N* the destination countries (j = 1..., *N*). Therefore, we analyse what it is called in literature a Local Origin-Destination flow model. For each year, our model involves *N* observations, providing a situation similar to traditional spatial econometric applications. In these circumstances, the spatial weight matrix labelled *W*, represents as a *N* by *N* nonnegative, sparse matrix, would contain positive elements for neighbors to each of the regions treated as destinations. Besides continuities, various measures of proximity such as cardinal distances (e. g. kilometres), and ordinal distance (e. g., the *s* closest neighbors) can be used.

LeSage and Pace (2008) motivate the presence of spatial lags in flows on an omitted variables argument. For instance, we assume that a single omitted variable *z*, for instance, the political situation in countries involved in trade, is an important determinant of trade, but we don't have data on that. Beside, such omitted variable could exhibit spatial dependence, which we represent using a spatial autoregressive process consisting of a scalar spatial dependence parameter ρ and the spatial weight matrix W, as follows:

$$\begin{aligned} \ln\left(F_{ijt}\right) &= \beta_0 + \beta_1 \ln\left(Xo_{it}\right) + \beta_2 \ln\left(Xd_{jt}\right) + \beta_3 \ln\left(D_{ijt}\right) + z_{ijt} \\ z_{ijt} &= \rho W z_{ijt} + \varepsilon_{ijt} \\ \varepsilon_{ijt} &= \gamma_0 + \gamma_1 \ln\left(Xo_{it}\right) + \gamma_2 \ln\left(Xd_{jt}\right) + \gamma_3 \ln\left(D_{ijt}\right) + u_{ijt} \end{aligned} \tag{3}$$

Expression (3) indicates that the omitted and included variables are correlated with the scalar parameter $\gamma \neq 0$, which is the typical assumption made in the omitted variable literature.

From equation (3), we can arrive at the so-called Spatial Durbin Model (SDM) as protection against bias arising from possible omitted variables, with independent, identically distributed (*iid*) disturbances, which in matrix notation can be expressed as:

$$\begin{aligned} &\ln\left(F\right) = \rho W \ln\left(F\right) + X\left(\beta + \gamma\right) + WX(-\rho\beta) + u \\ &\text{with } \beta' = \left[\beta_0\, \beta_1\, \beta_2\, \beta_3\right];\ \gamma' = \left[\gamma_0\, \gamma_1\, \gamma_2\, \gamma_3\right];\ X = \left[\iota \ln\left(Xo_{it}\right) \ln\left(Xd_{jt}\right) \ln\left(D_{ijt}\right)\right] \end{aligned} \tag{4}$$

with ι, we denote a vector of ones. Including the notation $\theta = \beta + \gamma$ and $\phi = -\rho\beta$, previous model can be expressed as:

$$\ln\left(F\right) = \rho W \ln\left(F\right) + X\theta + WX\phi + u \tag{5}$$

From estimated parameter in (5), we can recover estimates for the individual parameters in model (3).

If the parameter $\gamma = 0$, it means that the included and excluded variables are not correlated, and the restriction $\phi = -\rho\theta$ holds. In this case, a Spatial Error Model (SEM) emerges:

$$\left(\ln\left(F\right) - \rho W \ln\left(F\right)\right) = \left(X - \rho WX\right)\beta + u \quad \text{or} \quad \begin{cases} \ln\left(F\right) = X\beta + z \\ z = \rho W z + u \end{cases} \tag{6}$$

Note that, both, SDM and SEM models rely on a model that includes spatial lags of the dependent and explanatory variables.

A likelihood-ratio (LR) test based on log-likelihood values from SDM and the SEM models tests the restriction $\phi = -\rho\theta$ for the coefficient on WX and X. Obviously, this restriction can only hold when the parameter $\gamma = 0$, indicating no omitted variables exist that are correlated with those included in the model.

3.1.2. How to introduce dynamic into the model

As shown in LeSage and Pace (2008), the Spatial Autoregressive model (SAR) can be behind a purpose of considering a time-lag relationship describing a diffusion process over space. In other words, they view the spatial dependence as a long-run equilibrium of an underlying spatiotemporal process. That is, starting with a time-lag relationship as the following:

$$\ln\left(F_{ijt}\right) = \rho W \ln\left(F_{ijt-1}\right) + \beta_0 + \beta_1 \ln\left(Xo_i\right) + \beta_2 \ln\left(Xd_j\right) + \beta_3 \ln\left(D_{ij}\right) + u_{ijt} \tag{7}$$

where they omit the time subscript on the explicative variables to reflect a situation where they reflect regional characteristics that describe regional variation flow changes slowly over time, relative to the change in flows. As shown in LeSage and Pace (2008), using the recursive relation: $\ln(F_{ijt-1}) = \rho W \ln(F_{ijt-2}) + \beta_0 + \beta_1 \ln(Xo_i) + \beta_2 \ln(Xd_j) + \beta_3 \ln(D_{ij}) + u_{ijt-1}$, implies in model (7), we can reach as the steady-state equilibrium model the Spatial Autoregressive (SAR) model, commonly used in the context of spatial econometric techniques:

$$\ln\left(F_{ijt}\right) = \rho W \ln\left(F_{ijt}\right) + \beta_0 + \beta_1 \ln\left(Xo_{it}\right) + \beta_2 \ln\left(Xd_{jt}\right) + \beta_3 \ln\left(D_{ijt}\right) + u_{ijt} \tag{8}$$

3.2. Panel data econometric literature

3.2.1. Treatment of omitted variables

The use of the gravity model with panel data has the advantage that it prevents bias from omission of relevant variables by considering what is known as unobservable heterogeneity. If we have panel data, instead of considering the model's estimation for all the data, or the pool model, expressed in (2), we can estimate the following model:

$$\ln\left(F_{ijt}\right) = \beta_0 + \beta_1 \ln\left(Xo_{it}\right) + \beta_2 \ln\left(Xd_{jt}\right) + \beta_3 \ln\left(D_{ij}\right) + \beta_{ij} + u_{ijt} \tag{9}$$

in order to take into account the unobserved heterogeneity thought the term β_{ij}.

3.2.2. How to introduce dynamic into the model

In the context of panel data set, previous model can be dynamised, considering the strong inertia in trade relations between countries. This would lead us to specify the following dynamic model:

$$\ln\left(F_{ijt}\right) = \beta_0 + \beta_1 \ln\left(Xo_{it}\right) + \beta_2 \ln\left(Xd_{jt}\right) + \beta_3 \ln\left(D_{ij}\right) + \beta_{ij} + \sum_{\tau=1}^{n} \rho_\tau \ln\left(F_{ij,t-\tau}\right) + u_{ijt} \qquad (10)$$

The traditional estimation of equation (10) consisted of applying the Generalised Method of Moments, using appropriate tools, to the model's first difference equations (Arellano and Bond, 1991) or the System Generalised Method of Moments («system GMM») proposed by Blundell and Bond (1998), which combines the moments conditions for the first difference model with the moments conditions for the level model.

4. Data analysis

Table 2 describes the data used in this analysis, its measurement unit and the sources used. The model's dependent variable refers to olive oil exports from Tunisia (country *i*) to the leading importers (countries *j* = Italy, US, Spain, Morocco, France and Switzerland). This information comes from the International Trade Centre (ITC). With regards to the explanatory variables, we use the variables commonly used in this type of model, such as importers' GDP [1], distance, together with a variable indicating a language shared by exporter and importers. To this last respect, we consider that France and Morocco are sharing the same language with Tunisia. All information refers to the period 2001 to 2009; therefore, we have a total number of 54 observations for each variable.

Table 2. Description of variables and data sources

Variable	*Description*	*Source*
F_{ij}: Exports from *i* to *j*	Thousands of dollars	International Trade Centre, calculations based on COMTRADE statistics [(a)]
GDP_d_j: *GDP* of importer *j*	GDP, PPP (current international $)	World Bank [(b)]
HDI_d_j: *HDI* of importer *j*	Standard of living in importing country	UN Development Programme [(c)]
D_{ij}: Distance from *i* to *j*	Distances between country capitals (km)	Distances between cities [(d)]
$Lang_{ij}$: Dummy variable related to language of countries.	1 if the importer and exporter have the same official language, 0 otherwise.	

(a) *http://www.trademap.org/Index.aspx.*
(b) *http://data.worldbank.org/country.*
(c) *http://hdr.undp.org/en/.*
(d) *http://www.marinewaypoints.com/learn/greatcircle.shtml.*

1 As we are analysing unidirectional flows from Tunisia (what it is called in literature a Local Origin-Destination flow model), the characteristics of destination countries are the main determinants of flows.

Finally, particularly interesting is the variable related to the standard of living in both the importing and exporting country, known as the Human Development Index (HDI), which was edited by the United Nations Development Programme. This index measures a country's status in relation to three dimensions: health, education and living standards. The health dimension refers to life expectancy at birth, the education dimension to mean years and level of education and the living standards dimension to per capita income. Figure 2 shows this variable for Tunisia, the exporter, and the different importing countries.

Figure 2. Evolution of the Human Development Index (HDI) in Tunisia and importing countries

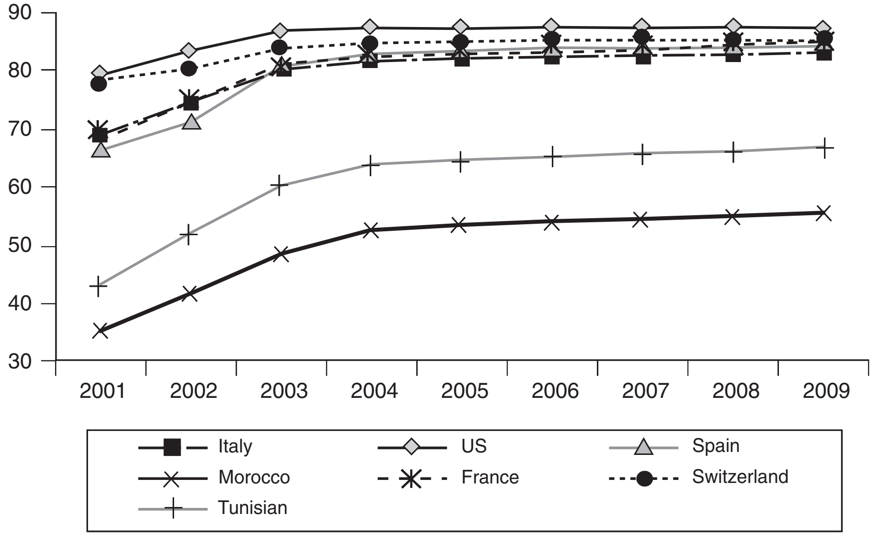

Figure 2 clearly leads us to several conclusions. On the one hand, the index has grown more since 2004, since which it has remain practically constant. On the other, the country with the lowest index is Morocco, followed closely by Tunisia. Finally, the ranking of the other countries is similar and stable over time, in the following order: Spain, Italy, France, Switzerland and the US.

Finally, in order to capture spillover and estimate the models, we must specify a *W* matrix to reflect the network of cross-sectional relationships in the system of importing countries. The weight matrix, *W*, is obtained after row-standardizing the matrix which weights are the inverse of the square distance between any pair of importers:

$$w_{ij} = \frac{1}{D_{ij}^2} \tag{11}$$

This specification captures the fact that distance between countries negatively affects interactions.

5. Results

This section shows the results obtained when the gravity model is estimated with both approaches: spatial and panel data econometric. As said before, the nature of the model, as a Local Origin-Destination flow model, makes that destination countries are the main determinants of flows. Analogously, spatial and panel models considers the effect of possible omitted variables referred to importers' countries. Table 3 shows the results obtained for spatial econometric and panel data techniques.

As regards spatial specifications, we follow the following steps. We start by estimating the traditional pool gravity model, expressed in (2), by Ordinary Least squares (OLS) enlarged by considering one dummy variables associated to the first three years of the sample, 2001-2003, which are characterised by a much smaller export volume. Results are displayed in the first column of the table. Next, we test the null hypothesis of no spatial dependence through the Lagrange Multipliers (LM) tests for panel data (Elhorst, 2009). As shown in the table, the null hypothesis of no spatial autocorrelation is rejected and, attending to the robust version of the statistics, the SAR specification is slightly preferred to the SEM model. Nevertheless, next we estimate both specifications, together with the SDM. Since, both, SAR and SEM are nested on the SDM, a selection among them can be carried out through the corresponding Likelihood Ratio (LR) tests. The LR obtained for testing the null hypothesis of preference of the SAR over the SDM model equals 18.72, while the LR obtained for testing the null of preference of the SEM specification over the SDM equals 20.40. Both LR statistics are higher than a critical value of $\chi^2(4)$ and, therefore, the SDM is the preferred specification.

As regards panel econometric techniques, we analyse the dynamic version of the model (equation 10). The results of estimating this model following Blundell and Bond (1998) are shown in the last column of Table 3. In relation to the need to dynamise the model, we see how the parameter associated to the export volume in the previous period variable is significant.

From previous results, we can draw the following conclusions. Initial gravity equations can be benefit from considering the effect of omitted variables and dynamics, both through the consideration of spatial dependence or panel data techniques. However, in order to compare results for SDM and dynamic panel model, we have to take into account that for SDM we have to calculate what it is known the average direct effect with respect to a variable Xd_j, which represent the average effect of flows to such variable over the sample of observations. It can be calculated as follows:

$$\text{Average Direct Effect}_j = N^{-1}\,\text{Trace}\left[\left(I_N - \rho W\right)^{-1}\left(I_N\theta_j + W\phi_j\right)\right] \tag{12}$$

Table 3. Results obtained for spatial and panel specifications [(a), (b)]

	Ordinary least square	*Spatial models*			*Panel model, dynamic model*
		SEM	SDM	SAR	
Ln (GDP_d)	2.10** (5.69)	1.99** (6.14)	3.68** (3.58)	2.21** (6.22)	1.79** (3.67)
HDI _d	0.01 (0.10)	0.04 (0.44)	0.14 (1.25)	0.01 (0.11)	0.35** (2.64)
Ln (D)	–2.49** (–4.20)	–2.47** (–4.51)	–5.27** (–3.02)	–2.68** (–4.82)	–2.83** (–4.42)
Lang	3.52 (1.12)	3.95 (1.24)	11.49** (2.49)	3.48 (1.21)	14.21** (3.29)
W*Ln (GDP_d)			2.77 (1.49)		
W* HDI _d			–0.26** (–2.04)		
W*Ln (D)			–6.34 (–0.40)		
W* Lang			1.84 (0.26)		
Dyear2001–2003	–2.07** (–2.24)	–1.88* (–1.91)	–1.77* (–1.91)	–1.49* (–1.65)	–0.48 (–0.48)
Constant	–31.67** (–3.03)	–30.89** (–3.07)	–78.04 (–1.20)	–35.24** (–3.55)	–51.99** (–4.35)
ρ		0.17 (1.14)	0.15 (1.00)	0.22 (1.59)	
Ln (export (t-1))					0.24* (1.85)
Log-likelihood	–111.693	–111.14	–100.94	–110.30	
R^2	0.58	0.57	0.72	0.60	
Adjusted R^2	0.53	0.57	0.71	0.59	
σ^2	4.12	3.56	2.40	3.43	
Spatial diagnostics: Testing the null of no spatial dependence on the residuals					
LM test no spatial lag	3.47				
Robust LM test no spatial lag	8.92**				
LM test no spatial error	1.11				
Robust LM test no spatial error	6.56**				
Specification tests for dynamic panel model					
Arellano-Bond test for AR(1) in first difference, z:					–3.00 **
Arellano-Bond test for AR(2) in first difference, z:					–0.64
Sargan test of overidentifying restrictions					43.04

[(a)] In parenthesis are the t-ratios.
[(b)] Two asterisks means that the null hypothesis is rejected at the 5% level of significance; one asterisks means that the null hypothesis is rejected at the 10% level of significance.

Regarding panel data results, we can derive the short and long-run effects. The obtained results are shown in Table 4.

Table 4. Responses of olive oil flows with respect to continuous explicative variables

	SDM	*Dynamic panel model*	
	Average direct effect	*Short-run*	*Long-run*
Ln (*GDP_d*)	3.85**	1.79**	2.36**
HDI _*d*	0.13	0.35**	0.46**
Ln (*D*)	–5.64**	–2.83**	–3.72**
Lang	11.67**	14.21**	18.69**
D year 2001-2003	–1.79*	-0.48	–0.63

For spatial and panel specification, the empirical evidence obtained shows, as expected, a positive and significant relationship between the importer's income level and imported olive oil volume. According to the SDM model the average direct elasticity is 3.85, while from panel specification the short-run and long-run elasticity are 1.79 and 2.36, respectively. The importers' HDI has a positive effect in both cases, although only significant in the case of the panel specification. This result is also logical, since it is expected that an increase in the standard of living of importers' countries will increase the demand of healthy products, such as the Tunisian olive oil. For both selected models, the distance has a significant, negative effect on trade flows. As for the SDM, flows decrease in 5.64% in response to a one-percent increase of the distance between countries. Elasticities derived from the panel specification are a bit lower: –2.83 and –3.72 for the short-run and long-run, respectively. This result implies that Tunisia could try to develop trade relationship with other closest countries, taking also advantage of their current development. Regarding the common language variable, we can conclude that sharing a common language increases olive oil trade flows. In other words, this means that Morocco and France get benefits from sharing the language with Tunisia. This result implies that in order to enlarge trade flows, Tunisia could try to develop other trade relationships with other Arabic countries or French colonies. As regards the time dummy variable introduced into the model, estimation results show that the exported volume during the period 2001-2003 is lower than in the rest of the years. This result reflects the problem concerning the high production fluctuation due to climatic change. As said before, olive oil production in Tunisia is highly dependent on precipitations, and when the harvest is poor, as from 2001 to 2003, exports to the different countries highly decreases. As a consequence, it should be advisable for Tunisia government to support the use of irrigation.

Finally, specific information obtained from SDM or panel results are the following. On one hand, the estimation for the ρ parameter of the SDM model indicates that flows to a destination are enhanced in accordance with the propensity of attractiveness of its neighboring destination locations. In other words, result points to the existence of a clear similarity in flows between neighbouring importing countries. On the other hand, panel data results let measure the inertia affecting trade flows between countries, with a clear time-dependence effect.

6. Conclusions

This study shows the importance of olive oil as one of the leading agrofood products exported from Tunisia. The sector is vulnerable, however, because its exports are heavily concentrated in six countries. We have therefore attempted to identify the principal determinants in Tunisia's trade with the product.

A revisited gravity equation has been estimated by paying attention to the effect of possible omitted variables and the consideration of trade dynamics. Spatial and panel econometric techniques have been applied to a panel sample referring to the 2001-2009 period. The results obtained show a positive, significant relationship between the importer's income level and imported olive oil volume. The effect of importers' human development index is positive. There is a significant, negative effect of the distance between countries, while sharing a common language, such as Morocco and France, increases the volume of trade. This result implies that Tunisia could try to develop trade relationships with other closest Arabic countries, taking also advantage of their current development. Export figures and results reflect the strong dependence of olive oil production on precipitations. As a consequence, it should be advisable for Tunisia government to support the use of irrigation. Furthermore, results show evidence concerning the inertia related to export volumes, as trade relations anchored in the past will probably continue in the future. Finally, results show the existence of a clear similarity in flows between neighbouring importing countries.

Future research will be aimed at investigating whether the evidence obtained for olive oil is applicable to other agrofood products that are important for the Tunisian economy, such as dates and fishery products.

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