A time-frequency analysis of globalization and environmental degradation in France

(draft version, IRMBAM-2017)

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Abstract
The paper explores the causality between globalization and environmental degradation in France, over the period 1960-2013, by using the wavelet tool. The investigation offers detailed information about this interaction, for different sub-periods of time and frequencies. It also reveals the lead-lag nexus between variables under cyclical and anti-cyclical shocks.
The findings show that, during the oil crisis and disinflation process, the French exports derived from pollutant capacities at low costs of production. In the same time, the inexistence of strong environmental rules for 'inputs' stimulated also 'contagious unclean' import flows. Separately, the trade openness generates CO_2 emissions through the indirect influence of economic growth expansion as scale effect. Fortunately, the effect has a short persistence period, being counted by environmental decentralized policies and international protocols which France became part.

Key words: Globalization, Environmental degradation, Influence, France, Wavelet

JEL classification: F60, F64, C14

1. Introduction

The acceleration of globalization process and environmental degradation represent two of main hot topics widely explored over the last decades. Starting with 1990’s, many researchers in the field focused their attention on the pair ‘globalization-environmental degradation’, by investigating the impact of globalization on environmental degradation and vice-versa. The globalization represents ’a process (or set of processes) that embody a transformation in the spatial organization of social and transactions, generating transcontinental or interregional flows or networks activity, interaction, and power’, as Held et al. (1994: 483) note. More concretely, O’Rourke (2011) states globalization is declining barriers of trade, migration, capital flows, foreign direct investments and technological transfers.

On the one hand, all these economic, social, political and cultural dimensions of globalization have deep and controversial implications on the environmental degradation. Grossman and Krueger (1993) identify three types of openness impacts on environmental degradation: scale, technique and composition effects. The scale effect appears when the openness generates environmental damages due to unchanged nature of economic activity. Conversely, the technique seems to be a good incentive for the level of income and invokes cleaner production processes, attenuating the pollution. Finally, composition effect connects the trade with pollution through the modifications in the structure of economic output.

On the other hand, environmental degradation influences the degree of globalization. Copeland and Taylor (2004) identify two hypotheses. The first one is called the ‘pollution haven effect’ and it is explained by the pollution regulations. The control of pollution generates effects on the plant location decisions and trade flows, influencing the level of openness. The ‘pollution haven’ is the second hypothesis. Herein, any asymmetry between countries regarding the trade or technological transfer barriers orientates the pollution-intensive capacities from the economy with strict regulation to the economy with no stringent one. Further, as protection, receiving country can impose restrictions in the environmental area regarding the level of pollution. Jaffe et al. (1995) stress that such argument is not clear, because the restrictive environmental regulations register low or no effect on trade and investments flows.

There are many published papers, both theoretical and empirical. The last group of contributions considers various countries and periods of time, and different empirical tools and time frequencies, respectively. Although France has not been intensively targeted, this country deserves a special interest for the ‘globalization-environmental degradation’ perspective. France seems to be one of the most reticent countries regarding the globalization, even if the European integration in term of market liberalism and trade liberalization is a current reality. Meunier (2001: 29) emphasizes that the ‘central problem of France’s position to date has been an extremely defensive attitude towards globalization’. Over the last decades, France has also been deeply implicated to promote policies for environmental protection. This set of policies debuted in ’80 during the decentralization process and culminated with the suite of international conventions and protocols addressed to control of atmospheric pollution and climate change. In 1992, 'Directions Regionales de l'Environnement' (DIREN) are the organisms founded at regional levels with prerogatives in the environmental policies. Further, France adhered in March 1997 to the United Nations Framework Convention on Climate Change, extended in 1997 through the Kyoto Protocol. The stabilization of CO_2 emissions between 1990 and 2008-2012 is the main objective of the agreement. France is also part of Climate and Renewable Energy

Package, which came into force on June 2009, under the aegis of European Commission. The package is focused on the attenuation of greenhouse gas and CO2 emissions for new passenger cars. This document was followed by the Transboundary Air Pollution document, known as the Geneva Convention, on November 1979. Coming into force in January 1998, the Geneva Convention was amended by three main protocols: the Gothenburg Protocol (July 2003) and the two Aarhus Protocols (i.e. July 2002 and July 2003, respectively). The environmental preoccupations of France were officially related to the other several firmed agreements, such as: the Helsinki Protocol on sulfur dioxide (SO_2) reduction (March 1986), the Sofia Protocol on nitrogen oxides (NO) reduction (July 1989), the Geneva Protocol on non-methane volatile organic compounds reduction (June 1997), and the Oslo Protocol also on SO2 gradual attenuation (August 1998).

Figures 1 and 2 illustrate the evolution of exports and imports (billions US dollars), as proxy for globalization, and carbon dioxide (CO_2) emissions (metric tons per capita), as proxy for environmental degradation, respectively, in France, for the period 1960-2013.

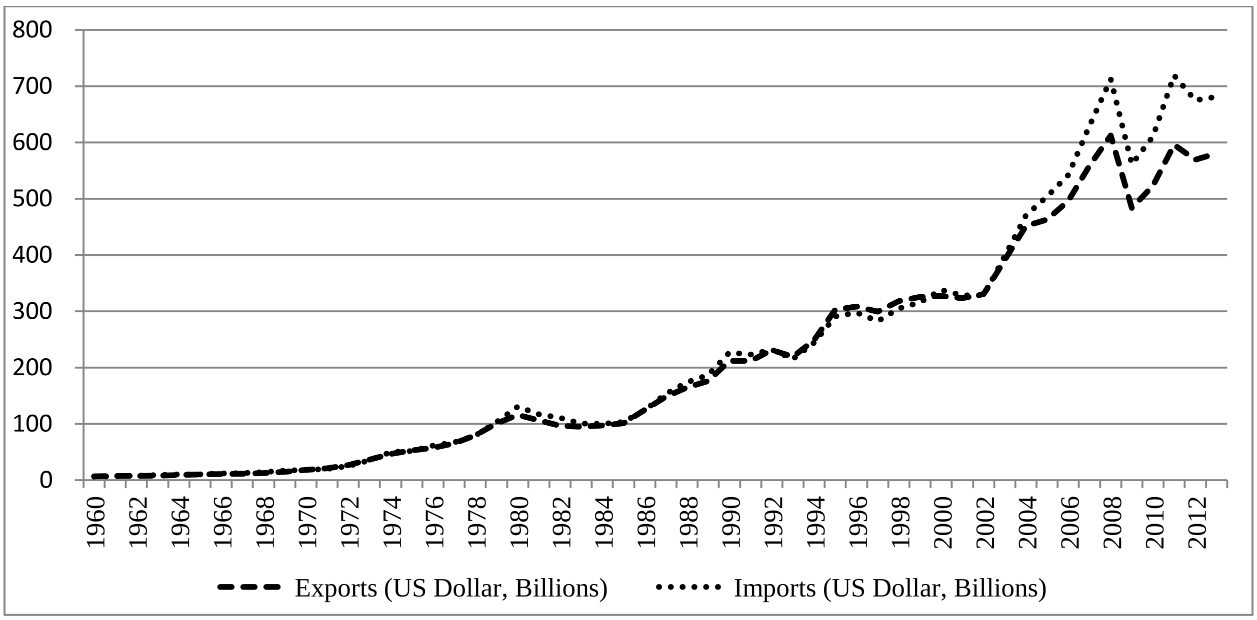

Figure 1 - Exports and imports of France, in billions US dollars, for the period 1960-2013

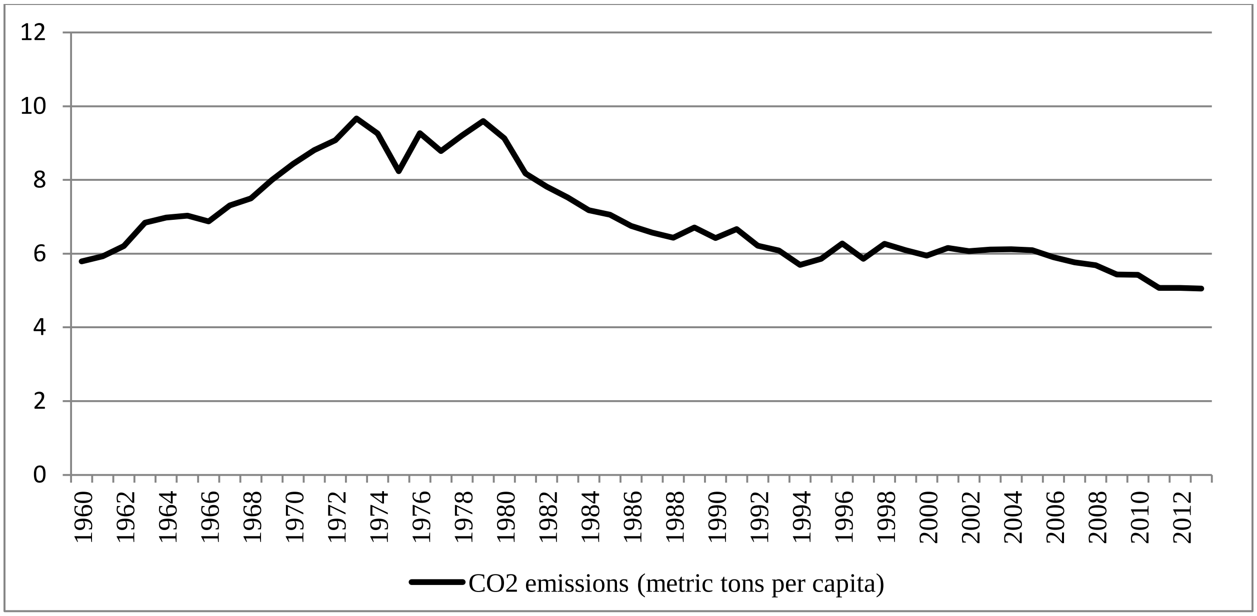

Figure 2 - CO_2 emissions in France, in metric tons per capita, for the period 1960-2013

In Figure 1, the exports and imports capture the trade openness in France, as these indicators are widely used as proxy for globalization. It is clear that there is a smooth increasing trend of openness until 1980 and accelerated one after this year. Several shocks are registered during the economic crisis, between 2008 and 2010, which are persistent at the end of considered period. CO_2 emissions plot allows us to identify two specific sub-periods of time, as Figure 1 illustrates. First sub-period is registered until 1973, with an accelerated increasing trend of CO_2 emissions, and the second one, after 1979, with smooth descending evolution. Between 1973 and 1979 several environmental shocks are registered. By comparing the plots, it is evident that the French trade openness coexists with both increasing and descending CO_2 emissions trends, raising interest for exploration of this country.

On this ground, the paper analyses the connection between openness and CO_2 emissions in the case of France, by following the wavelet approach, for the period 1960-2013. The contribution of this research to the literature in the field in fiftyfold. First, the paper is a pioneering work in time-frequency domain which focused on the globalization-environmental degradation nexus. Second, to the best of our knowledge, it represents the first study which uses the wavelet tool to investigate the issue of globalization and environmental degradation in the case of France. Third, the paper offers detailed information regarding the globalization-environmental degradation pair, by showing the direction and sign of causality. Fourth, as novelty, it generates short-, medium- and long-run frameworks. Fifth, the overcome allows us to detect how the series interact at different frequencies and how they evolve over time, from cyclical and anti-cyclical point of view.

The rest of the paper it is as follows: Section 2 reviews the literature in the field, Section 3 describes the data and methodology, while Section 4 presents the empirical results. Section 5 concludes.

2. Literature review

The literature dedicated to the relationship between globalization and environmental degradation is generous, with many both theoretical and empirical papers. By considering theoretical models or empirical tools, those papers focus on different countries and various periods of time. Whatever, the connection ‘globalization-environmental degradation’ remains a challenging and controversial topic. In this light, the literature in the field can be systematized by identifying four main assumptions: (i) globalization-environmental degradation hypothesis, (ii) environmental degradation-globalization hypothesis, (iii) synchronization hypothesis, and (iv) neutral hypothesis.

(i) The globalization-environmental degradation hypothesis reveals there is a one-way causality direction between globalization and environmental degradation. This runs from globalization to environmental degradation (i.e. globalization leads environmental degradation).

Having as starting point the contribution of Grossman and Krueger (1993), many empirical studies claim this hypothesis. Machado (2000) investigates Brazil, for the years 1985, 1990 and 1995, by using a commodity-by-industry IO model in hybrid units. He finds the foreign trade has a positive impact on CO2 emissions in Brazil. Antweiler et al. (2001) extend their study on 43 countries, for the period 1971-1996 and use SO_2 as a proxy for environmental degradation. They follow the Grossman and Krueger’s (1993) scale, composition and technique effects. Regarding the scale effect, the trade openness increases emissions through the indirect influence of economic growth expansion. More precisely, when the trade rises, the Gross Domestic Product (GDP) raises also, the industrial sector generating gas emissions. Small and negative influence of trade on environmental degradation has been identified, by taking into account the composition effect. Finally, in the light of technique effect, the trade seems to exercise a positive influence on environment as result of higher demand for cleaner production techniques. In the same way, similar conclusion via the technique effect finds Liddle (2001). Frankel and Rose (2002) address to the endogeneity issue of income and especially trade. Country size and physical distance between the pair of countries are the main trade instruments. As conclusion, they validate the positive effect of trade on several measures of environmental quality (i.e. SO_2, organic water pollution and to some extent nitrogen dioxide (NO_2)). Dean (2002) emphasises trade openness generates damages in the environmental quality, but only as first step. Finally, the income expansion will attenuate the environment degradation. 63 developed and developing countries, over 1960-1999, are the main target of Managi (2004). He uses a comprehensive panel dataset and reveals the elasticity of emissions in respect to the trade liberalization is of 0.579, with negative impact. Dinda and Coondoo (2006) find different overcomes. He works in panel with developed Organisation for Economic Co-operation and Development (OECD) and developing (Non-OECD) country groups. The results show the influence of globalization on the environment quality depends on the country characteristics and her dominating comparative advantage. The author suggests that globalization stimulates CO_2 emissions. Naughton (2006) follows a research strategy focused on nineteen European countries, with 21-year panel of data. The environmental quality is captured through SO_2 and, as novelty, NO emissions. The conclusion states that the countries which are less open have higher level of emissions. For McCarney and Adamowicz (2006), only the governmental policies have the capacity to manage the impact of trade openness on environmental quality. The environmental degradation is captured in Bangladeshi economy by Al-Amin et al. (2008) via three variables: CO_2, SO_2 and

NO. They argue that ‘to achieve sustainability emphasis must be given utilization of clean technology with environmental rules and regulations and environmental taxation policy so that negative impact on the environment could be reduced’ (p. 381). By investigating China over 1981-2008, through a vector autoregressive (VAR) model, Chang (2012) formulates nuanced overcome. On the one hand, he finds that on short run the China’s exports expansion generates more SO_2 emissions. On the other hand, the imports and foreign direct investments (FDI) seem to stimulate the solid waste generation. Shahbaz et al. (2015) introduce in the ‘globalization-environmental degradation’ equation several other variables, such as: energy consumption, financial development and economic growth. Having India as target, during the period 1970-2012, their ADRL model shows that the acceleration of economic, social and political globalization process stimulates energy consumption, which will further generates CO_2 emissions. Contributions regarding the validation of globalization-environmental degradation hypothesis also offer McAusland (2008) and Frankel (2009).

(ii) The environmental degradation-globalization hypothesis denotes a one-way causality direction between globalization-environmental degradation, driving from environmental degradation to globalization (i.e. environmental degradation leads globalization). Important contributions regarding this assumption bring Bommer (1999) and Cole (2003, 2004). The authors claim the Copeland and Taylor’s (2004) ‘pollution haven hypothesis’, demonstrating that the advantages in the countries with low pollution monitoring stimulate the relocation of multinational companies in areas with weak environmental protection (i.e. developing countries).

For example, Anderson and McKibbin (2000) find that eliminating of subsidies for fossil fuel use represents a good incentive to animate the international energy markets. Esty (2001) sees the environmental degradation as a complex factor against the market. He considers that environmental degradation via uninternalized externalities threats ‘market failures that will diminish the efficiency of international economic exchanges, reduce gains from trade, and lower social welfare’ (p. 116). By considering the KOF index of globalization proposed by Dreher (2006), Shahbaz et al. (2017) analyse the environmental Kuznets curve (EKC) hypothesis for China in the presence of globalization, for the period 1970-2012. They empirical tools are the Bayer and Hanck combined cointegration test and the auto-regressive distributed lag (ARDL) estimator. The authors evidence a one-way Granger causality between CO_2 emissions and globalization, which runs from CO_2 emissions to globalization. The direction of causality is validated for all dimensions of KOF index (i.e. social, economic and political).

Not only researchers claim the evidence of environmental degradation-globalization hypothesis, but also international organisms. For example, OECD (2005) considers the environmental regulations can have severe impact on international trade.

(iii) The synchronization hypothesis assumes there is a two-way causality direction between globalization and environmental degradation. In this case, the globalization generates environmental degradation and, further, environmental degradation influences globalization (i.e. globalization leads environmental degradation and vice-versa). The related literature is very poor. Seems that only Frankel and Rose (2005) offer support in this way. The 21-years panel of data, focused on nineteen European countries, is the main empirical core of their analysis. The authors deal with the endogeneity issues by instrumenting the income, income squared and openness to trade. The findings show the trade attenuates the level of air pollution and, further, the pollution level via regulations influence the openness, reinforcing the idea that countries with weak environmental regulations export dirty goods.

(iv) The neutral hypothesis considers there is not any connection between globalization and environmental degradation. Globalization does not influence environmental degradation, while changes in the environmental degradation do not have impact on globalization. One of the first papers which offer some evidence in this way belongs to Birdsall and Wheeler (1993). They explore the interaction between trade policy and industrial pollution in Latin America. The authors do not find any association of foreign investments with pollution-intensive industrial development. Ederington et al. (2004) conduct a study focused on the case of US, for the period 1972-1994. The authors analyze the trade-environment quality transmission channel by taking into account the composition of industries. They conclude emphasizing that the domestic production of pollution-intensive goods does not have any impact on the imports from overseas. Rafiq et al. (2015) introduce the agriculture in the 'trade-emissions' equation, by analyzing high, medium- and low-income countries, for the period 1980-2010. Both linear and nonlinear approaches are considered. The authors highlight there is not any significant linear effect of trade openness on carbon emission. In the same time, a significant nonlinear impact of the trade liberalization on emissions reduction is found.

Only two paper are devoted to the case of France, to the best of our knowledge: Wiers (2008) and Kheder (2010). The first author, in reality, analyses theoretically the position of France regarding the CO_2 tax on imports from countries not respecting a post-Kyoto regime. Wiers (2008) opines that in 'the debate on climate change and trade, the more general French ideas that Europe should no longer be naïve and demand reciprocity from its trading partners coincide with competitiveness worries' (pag. 31). Kheder (2010) conclusions have as ground an empirical study. The author considers French FDI flows at a disaggregate sector-level, in a mix of developing, transition, emerging and developed countries, for the period 1999-2003, by following simultaneous equations. The results show the environmental regulation has a negative impact on FDI location. The models take into account the endogeneity status of environmental regulation.

Overall, the globalization-environmental degradation literature offers many contributions, with heterogeneous findings via different tools and periods used. Generally, the globalization is captured through the trade (i.e. imports and/or exports) and FDI, while other authors follow the KOF index proposed by Dreher (2006). On the other hand, CO_2, SO_2 and NO have been widely used as proxy for the environmental degradation.

On this context, the paper investigates the 'co-movement' between globalization and environmental degradation in France, for the period 1960-2013, through the wavelet approach.

3. Data and methodology

The study is based on a spam which covers France for the period 1960-2013, with annual frequency. The source of dataset is the OECD.Stat online 2017 database, belonging to OECD. The globalization *(x)* is quantified through the cumulated volume of imports and exports, in billions US dollars. We follow the trade openness as proxy for globalization as the other variables used by the literature are not available for such a long period of time (e.g. foreign direct investments, migration, KOF index). The cumulated volume of imports and exports is not related to the GDP in order to remove the cyclical effect of GDP. The environmental degradation *(y)* is captured via the volume of CO_2 emissions, expressed in metric tons per capita. Unfortunately,

the other proxies generally exploited in the literature to measure the environmental degradation are not available for whole targeted period of time. Both series are finally treated in log form.
The stationarity is not a required property in frequency-domain approach. As Aguiar-Conraria et al. (2008, p. 2877) note, the wavelet transformation is used 'to quantify the degree of linear relation between two non-stationary time series in the time-frequency domain'. The same point of view is reinforcing by Crowley and Mayes (2008), Hallett and Richter (2008) or Boashash (2015). A battery of tests is used to check the stationarity status of the series: Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. Expecting the existence of structural breaks, Zivot-Andrew (ZA) test for unit root with structural break is also performed. As the white noise can induce strong disturbances in the time-frequency analyses, we deal with any potenital trend components by transforming the series in their first difference.
Dar et al. (2014, p.3) state that the 'true economic relationship among variables can be expected to hold at disaggregated (scale) level rather than at the usual aggregation level'. Hence, our time-frequency domain approach allows us to see not only the dynamic between globalization-environmental over time, but also how this interaction varies across different frequencies. These aspects are crucial for economic and environmental policies, because such view offers important strategical details about the policy adjustments to be followed during a given economic context.
The wavelet is one of the best tools in the time-frequency domain which can respond to the aforementioned aspects. Several advantages are offered by wavelet comparative with the classical techniques: (1) offers short-, medium- and long-run frameworks; (2) details the interaction between variables across different frequencies over time; and (3) shows the lead-lag and cyclical vs. counter-cyclical status of the nexus.
The starting point in the wavelet analysis is the selection of the wavelet function, which has zero mean and finite energy. There are many wavelet types: Morlet, Paul, Mexican hat, Haar, Daubechies etc. We consider the Morlet wavelet as 'it provides a good balance between time and frequency localization' (Grinstead et al., 2004, p. 563). Morlet represents a complex type of wavelet which offers both amplitude and phase information, being very useful for investigation of the business cycle synchronism between different time series.
We assume the time-series $\{x_n\}$, where $n=0...N-1$, with δt time spacing, and a Morlet wavelet function $\psi_0(\eta)$, depending by the nondimensional 'time' parameter η.
The simplified version of Morlet function is as follows:

$$\psi_0(\eta) = \pi^{-\frac{1}{4}} e^{i\omega_0\eta} e^{-\frac{1}{2}\eta^2}, \tag{1}$$

where ω_0 denotes the nondimensional frequency (6 in our case, in order to satisfy the admissibility condition, according to Farge (1992) and i is $\sqrt{-1}$.
The time-series conversion in time-frequency domain is called the wavelet transformation. The discrete wavelet transformation (DWT) and continuous wavelet transformation (CWT) are two types of such adjustments. DWT is typical for noise reduction and data compression, while CWT offers good results in terms of feature-extraction purposes (Tiwari et al., 2013). As we investigate the interaction between two variables, the CWT is more appropriate. In this case, the series is 'multiplied' through the Morlet wavelet function, by repetitive translations.
The CWT of a discrete time series $\{x_n\}$ of N observations, with $\{x_n, n=0, ..., N-1\}$, scale s and time step δt is written as follows:

$$w_n^x(s) = \frac{\delta t}{\sqrt{s}} \sum_{n'=0}^{N-1} x_{n'} \psi^* \left((n' - m)\frac{\delta t}{s}\right), \text{ with } m=0, 1, ..., N\text{-}1. \quad (2)$$

Our wavelet approach follows a battery of five tools: the wavelet power spectrum, the cross-wavelet power, the wavelet coherency, the phase difference and the wavelet cohesion. The first four tools are proposed by Torrence and Campo (1998), based on Grinstead et al.'s (2004) work and corrections of Ng and Chan (2012), while the last one belongs to Rua (2010). Additionally, for sensitivity, classical Granger causality in time domain of Granger (1969) and short- and long-run causality test in frequency domain of Breitung and Candelon (2006) are also adopted.

3.1. Wavelet power spectrum

$|W_n^x|^2$ is the wavelet power spectrum, revealing the local variance. A cone of influence is considered to illustrate the edge effects of the observations. Herein, the observations are influenced by the edge effects below cone. The statistical significance of wavelet power is tested by null hypothesis, which claims that the data generating process is the result of a stationary process with a certain background power spectrum P_f. White and red noise wavelet power spectra are presented by Torrence and Compo (1998).
The distribution for the local wavelet power spectrum, under the null hypothesis, is as follows:

$$D\left(\frac{|W_n^x(s)|^2}{\sigma_x^2} < p\right) = \frac{1}{2} P_f \chi_v^2 \ , \quad (3)$$

where, P_f denotes the mean spectrum at the Fourier frequency f for the wavelet scale s (i.e. $s \approx 1/f$). σ is the variance and χ^2 shows the product of two distributions. The probability attached to a process P_f is greater than p, when v takes value 1 for real wavelet and 2 for complex one. The general processes have as ground the Monte-Carlo simulations.

3.2. Cross-wavelet power

The cross-wavelet power (XWT) is the seminal work of Hudgins et al. (1993) and connects two time series, $x=\{x_n\}$ and $y=\{y_n\}$. XWT has this form:

$$W_n^{xy} = W_n^x W_n^{y*}, \quad (4)$$

where, W_n^x and W_n^y are the wavelet transforms of x and y, respectively, whereas $|W_n^{xy}|$ is the cross-wavelet power. Relied on the Fourier power spectra P_f^x and P_f^y, the XWT illustrates the confined covariance between of two series, for each scale.
According to Torrence and Campo (1998), the theoretical distribution is:

$$D\left(\frac{|W_n^x W_n^{y*}|}{\sigma_x \sigma_y} < p\right) = \frac{Z_v(p)}{v}\sqrt{P_f^x P_f^y}, \tag{5}$$

where, *Zv(p)* is the confidence level of the probability *p* for a *pdf* representing the square root of the product of two χ^2 distributions.

3.3. Wavelet coherency

The wavelet coherency (WTC) is "the ratio of the cross-spectrum to the product of the spectrum of each series, and can be thought of as the local correlation, both in time and frequency, between two time series" (p. 2872), as Aguiar-Conraria et al. (2008) note.
WTC is as follows:

$$R_n(s) = \frac{|S(s^{-1}W_n^{xy}(s))|}{S(s^{-1}|W_n^x|)^{\frac{1}{2}}\,S(s^{-1}|W_n^y|)^{\frac{1}{2}}} \tag{6}$$

where, *S* illustrates the smoothing operator in both time and scale.

3.4. Phase difference

The phase ϕ_x of time series $x=\{x_n\}$ denotes the position in the pseudo-cycle of the series, based on Aguiar-Conraria et al. (2008). By extending this status over $x=\{x_n\}$ and $y=\{y_n\}$ series, the phase difference $\phi_{x,y}$ is given by the mean and confidence interval of phase difference, with this form:

$$\phi_{x,y} = tan^{-1}\left(\frac{I\{W_n^{xy}\}}{R\{W_n^{xy}\}}\right) \text{ and } \phi_{x,y} \in [-\pi, \pi]. \tag{7}$$

In this case, when the phase difference is zero, the time series move together at the specified frequency. We say the series are in phase and x leads y when $\phi_{x,y} \in \left[0, \frac{\pi}{2}\right]$, and y leads x for $\phi_{x,y} \in \left[-\frac{\pi}{2}, 0\right]$, respectively. By contrast, when the phase difference is π or $-\pi$, the series are in anti-phase. Therefore, x leads y for $\phi_{x,y} \in \left[-\pi, -\frac{\pi}{2}\right]$, and y leads x when $\phi_{x,y} \in \left[\frac{\pi}{2}, \pi\right]$, respectively.

3.5. Wavelet cohesion

Wavelet cohesion (WC) is proposed by Rua (2010), having as starting point the work of Croux et al. (2001). When the WTC is based on very noisy time series, it cannot be able to offer relevant information about the phase of the two time series. On this ground, Rua (2010) constructs a comovement measure $\rho_{x_n y_n}$, as real number on [-1, 1]. Relied on WTC, the nominator uses only the real part of wavelet cross-spectra. As novelty, the WC captures also the negative correlations and has this form:

$$\rho_{x_n y_n} = \frac{\Re(W_n^x W_n^y)}{\sqrt{|W_n^x|^2 |W_n^y|^2}}, \tag{7}$$

where, $\Re$ denotes the real part of the cross-wavelet spectrum of *x={x_n}* and *y={y_n}* series, being calculated as the squared root of two power spectra for the given time series in denominator.

4. Data analysis and findings

The descriptive statistics globalization *(x)* and environmental degradation *(y)* time-series, in France, for the period 1960-2013, are presented in Table A1, in Appendix. Table 1 below reports the ADF, PP, KPSS and ZA test overcomes. The non-stationary property is checked in the level, with intercept, and also with trend and intercept, respectively.

Table 1: The unit root tests of ln(x) and ln(y)

Variable	Test							
	ADF (H_0 = the series has unit root)		PP (H_0 = the series has unit root)		KPSS (H_0 = the series is stationary)		Zivot-Andrew (H_0 = the series has unit root with structural break)	
	Intercept	Trend and intercept	Intercept	Trend and intercept	Intercept	Trend and intercept	Intercept	Trend and intercept
ln(x)	-2.472	-1.265	-2.472	-0.642	0.842***	0.230***	-3.864 (k=4)	-4.117 (k=4)
ln(y)	-0.524	-2.730	-0.803	-2.737	0.587**	0.155**	-3.331 (k=4)	-3.881 (k=4)
Breakpoint in ln(x)							1974	1973
Breakpoint in ln(y)							1981	1981

Note:
(a) ***, **, and * denote significance at 1, 5 and 10% level of significance, respectively;
(b) k is the optimal lag according to Schwarz Info Criterion.

The ADF and PP tests clearly support that the null hypothesis is not rejected for both variables, with intercept, and trend and intercept, respectively. The same conclusion is reinforced by KPSS tests, which reject the null hypothesis of stationarity, with intercept, and trend and intercept, respectively. The unit root with structural breaks is sustained by the ZA tests for both variables, which do not reject the null of unit root with structural break for all level of significances, also with intercept, and trend and intercept, respectively. Moreover, there are found two structural breaks: in 1973-1974 (during the oil crisis), in the case of globalization, and in 1981 (over the decentralization and disinflation processes), in the case of environmental degradation. Concluding, both series are non-stationary in their level, have trend components and present structural breaks. Therefore, the series are finally considered in their first difference in order to remove the trend component.
The CWT power spectra[1] of the *ln(x)* and *ln(y)*, in the case of France, are presented in the Figures 3 and 4 below.

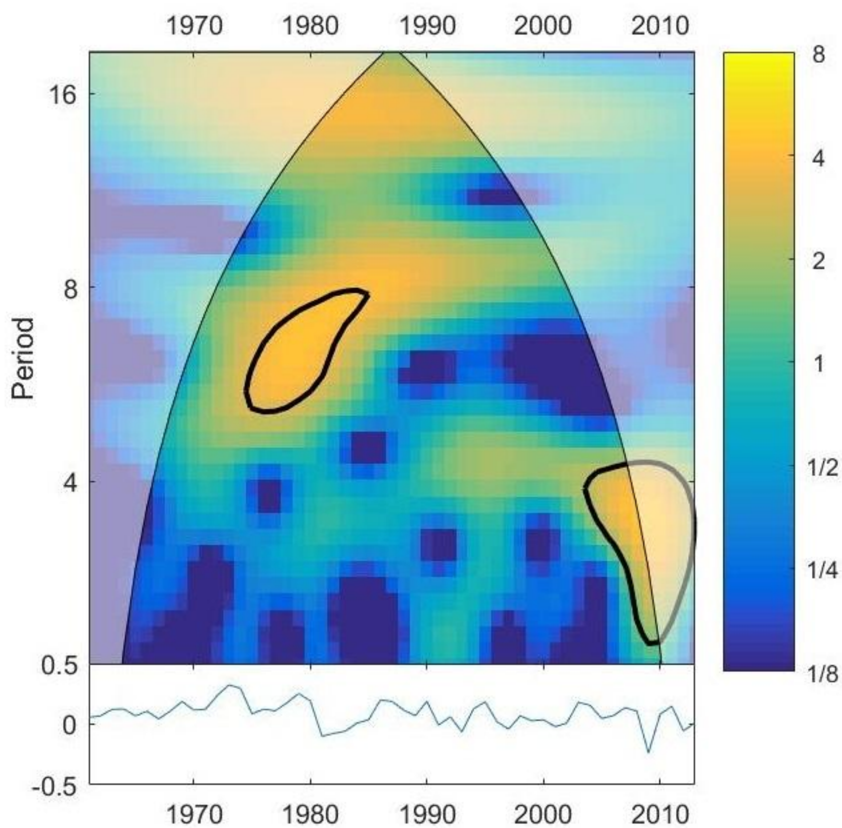

Figure 3: CWT power spectrum of *d(ln(x))* - globalization (cumulative volume of imports and exports)

Note:
(1) The thick black contour depicts the 5% significance level against red noise, while the cone of influence (COI) where the edge effects might distort the picture is designed as a lighted shadow;
(2) The colour code for power ranges goes from blue (low power) to yellow (high power);

[1] For wavelet estimations, we used Matlab codes proposed by Grinstead et al.'s (2004), with corrections of Ng and Chan (2012), and Rua (2010), adjusted by Tiwari and Olayeni (2013).

(3) The X-axis denotes the studied time period, whereas the Y-axis illustrates the frequency.

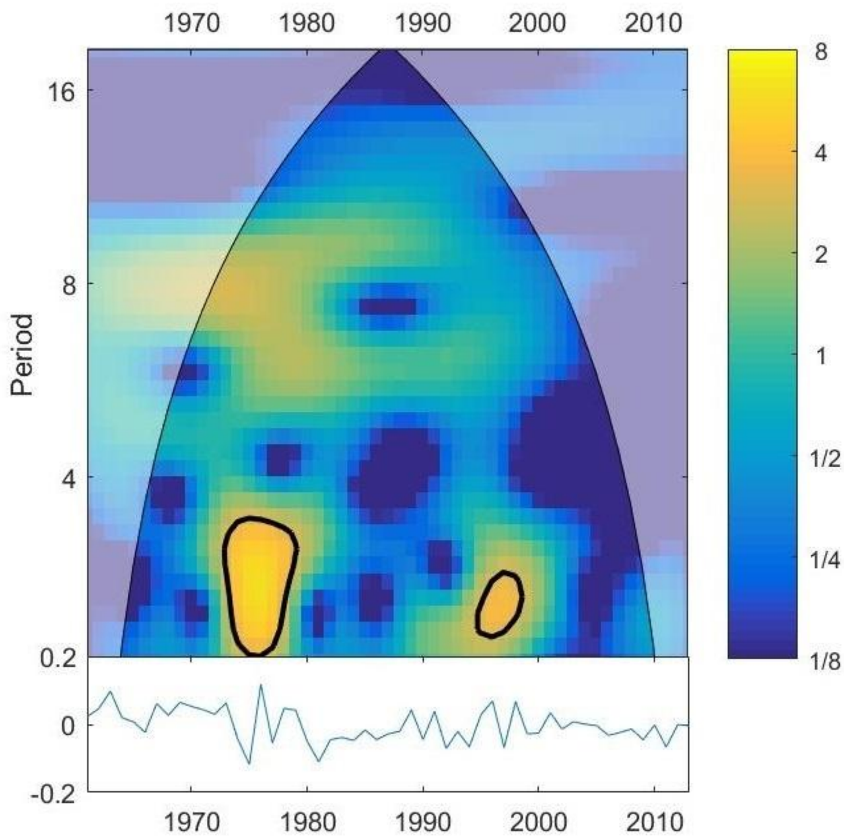

Figure 4: CWT power spectrum of *d(ln(y))* - environmental degradation (CO_2 emissions)

Note:
(1) The thick black contour depicts the 5% significance level against red noise, while the cone of influence (COI) where the edge effects might distort the picture is designed as a lighted shadow;
(2) The colour code for power ranges goes from blue (low power) to yellow (high power);
(3) The X-axis denotes the studied time period, whereas the Y-axis illustrates the frequency.

Figure 3 shows that the globalization *ln(x)* has high and significant power between 1972 and 1982, at 5-8 years of scale (medium frequency), and 2005-2010, at 1-4 years of scale (high frequency). The first period confirms the oil crisis and disinflation process in the beginning of '80, while the second one claims for the last economic crisis's turbulences. On the other side, Figure 4 reveals the environmental degradation *ln(y)* has strong and significant power over 1973-1979 and 1994-1998, for 1-4 years of scale and 1-2 years of scale, respectively (both at high frequency). The first period seems to be related to the oil crisis. The second one is connected to the development of 'Directions Regionales de l'Environnement' for regional environmental policies, founded in 1992.

CWT power spectra do not reveal any common features between the series. Whatever, such potential common features might be the result of a simple coincidence. Therefore, the XWT is called to connect the variables, by offering additional information about their related covariance. The XWT of the pair *ln(x)-ln(y)* is shown in Figure 5.

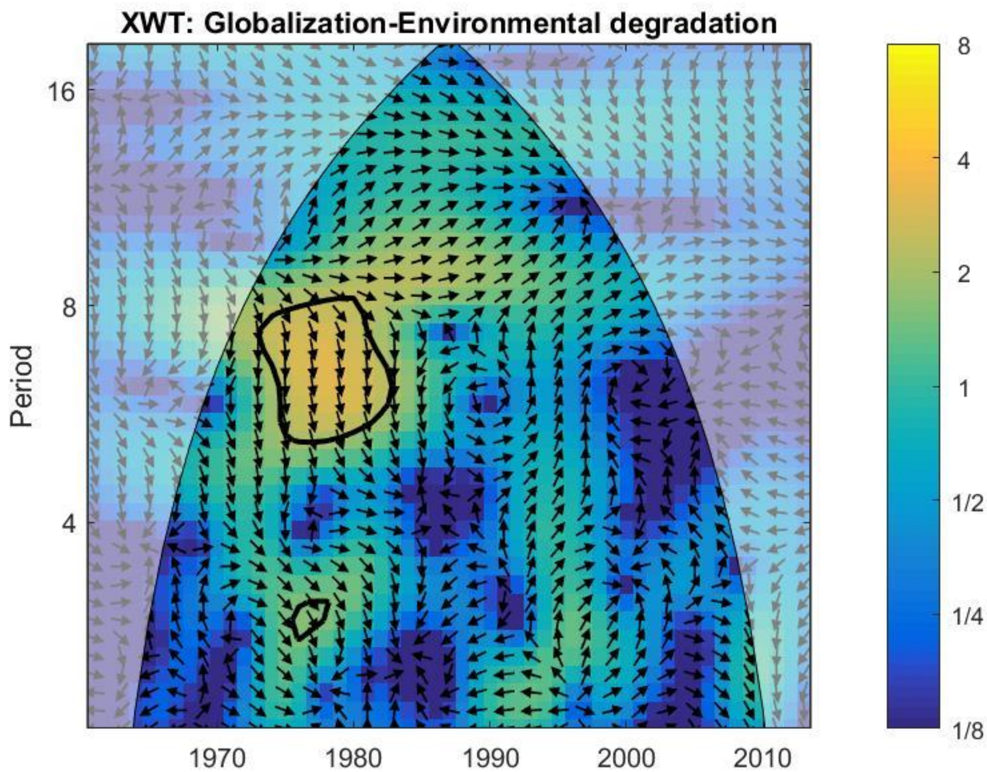

Figure 5: XWT of the pair *d(ln(x))-d(ln(y))*

Note:
(1) The thick black contour depicts the 5% significance level estimated from Monte Carlo simulations by following phase randomized surrogate series, while the cone of influence (COI) where the edge effects might distort the picture is designed as a lighted shadow;
(2) The colour code for power ranges goes from blue (low power) to yellow colour (high power);
(3) The arrows denote the phase difference between the two series. The variables are in phase when the arrows are pointed to the right (positively related). The globalization is leading when the arrows are oriented to the right and up. Otherwise, environmental degradation is leading when the arrows are pointed to the right and down.
(4) The variables are out of phase when the arrows are pointed to the left (negatively related). The environmental degradation is leading when the arrows are oriented to the left and up, while the globalization is leading when the arrows are oriented to the left and down.
(5) The variables have each other cyclical effect in the phase and anti-cyclical effect in the anti-phase or out of phase.
(6) The X-axis denotes the studied time-period, whereas the Y-axis illustrates the frequency.

XWT of the pair *ln(x)-ln(y)* in Figure 5 illustrates that only for 1975-1984 there is a strong and significant link between variables, at 5-8 years of scale (medium frequency). As the arrows are pointed to the right and down, the variables are in phase (i.e. cyclical effects). The environmental degradation influences the globalization with the same sign.

Unfortunately, the XWT does not use a normalized wavelet power spectrum. In other words, the XWT can generate misleading overcomes when one spectrum is locally and another one presents peaks. All such peaks generate spurious correlation between variables which actually are not correlated. Given these criticisms of XWT, the WTC seems to be more appropriate to fix its fails.
The WTC plot of the pairs *ln(x)-ln(y)* is presented in the Figure 6.

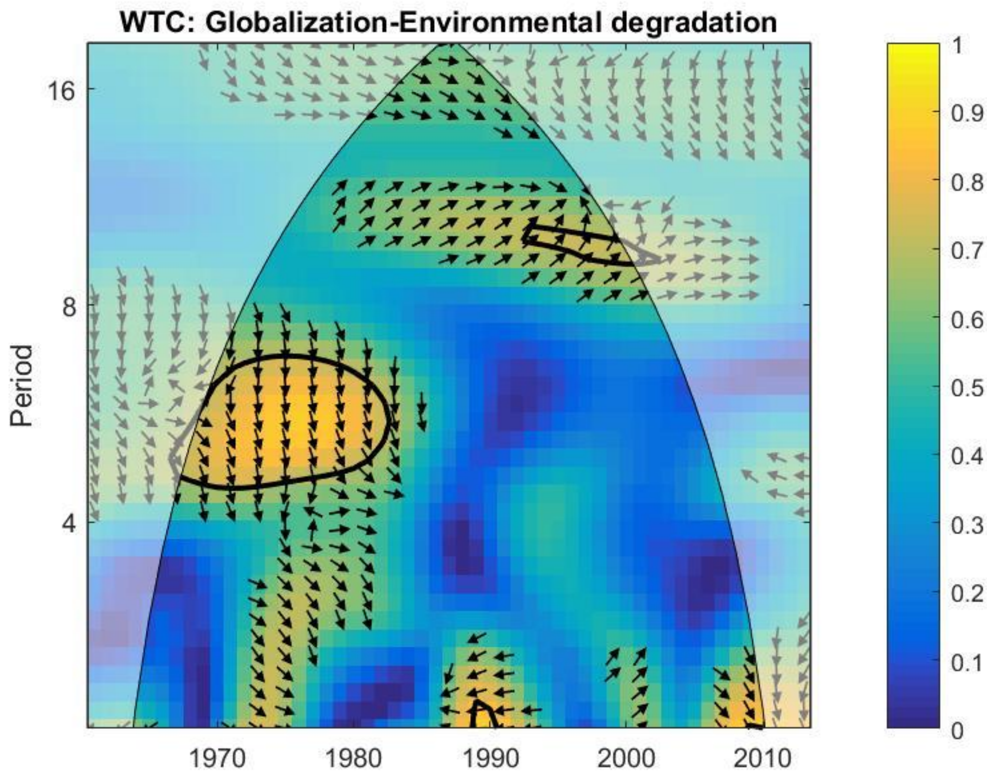

Figure 6: WTC of the pair *d(ln(x))-d(ln(y))*

Note:
(1) The thick black contour depicts the 5% significance level estimated from Monte Carlo simulations by following phase randomized surrogate series, while the cone of influence (COI) where the edge effects might distort the picture is designed as a lighted shadow;
(2) The colour code for power ranges goes from blue (low power) to yellow colour (high power);
(3) The arrows denote the phase difference between the two series. The variables are in phase when the arrows are pointed to the right (positively related). The globalization is leading when the arrows are oriented to the right and up. Otherwise, environmental degradation is leading when the arrows are pointed to the right and down.
(4) The variables are out of phase when the arrows are pointed to the left (negatively related). The environmental degradation is leading when the arrows are oriented to the left and up, while the globalization is leading when the arrows are oriented to the left and down.
(5) The variables have each other cyclical effect in the phase and anti-cyclical effect in the anti-phase or out of phase.
(6) The X-axis denotes the studied time-period, whereas the Y-axis illustrates the frequency.

The WTC offers very interesting things. In contrast with the XWT findings, new significant connections appear for the periods 1975-1985 and 1992-2002, respectively. The variables have cyclical effects for both intervals of times, the arrows being oriented to the right. For the period 1975-1985 and 5-7 years of scale (medium frequency), as the arrows are pointed to the right and down, the environmental degradation causes openness, with positive sign. This overcome validates the environmental degradation-globalization hypothesis.

In the second case, for 1992-2002 and 9-10 years of scale (medium frequency), the arrows are oriented to the right but up. This means globalization positively drives environmental degradation, reinforcing the globalization-environmental hypothesis.

We note the link effects are more persistent in the first identified period, during the crisis, than in the second one. Not at least, a short episode of interaction between globalization and environmental degradation is registered in 1990, at 1 year of scale (high frequency), but its persistence is negligible. Here, there is a anti-cyclical effect between variables, the globalization negatively running the environmental degradation.

The WC in the Figure 7 is performed according to the approach à la Rua (2010). The plot generally confirms the aforementioned overcomes.

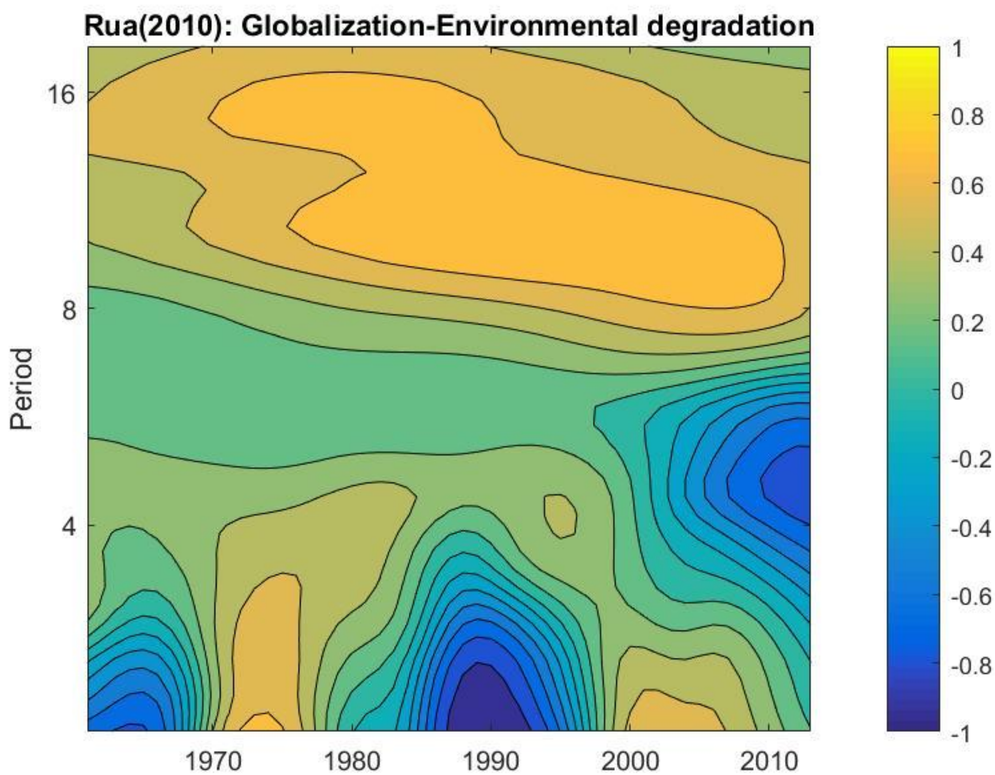

Figure 7: WC of the pair *d(ln(x))-d(ln(y))*

Note:
(1) The colour code shows the intensity of correlations, which goes from blue (positive correlation) to yellow colour (negative correlation);
(2) The X-axis denotes the studied time-period, whereas the Y-axis illustrates the frequency.

It is clear that the variables have intensive positive comovements over 1970-2009, at 8-16 years band of scale (low frequency). Several strong negative comovements are also registered in 1990, under 2 years band of scale (high and medium frequency), confirming the WTC results but they are still negligible.

Corroborating with the WTC findings, the most notable and strong effects remain registered over 1992-2002, when unfortunately the globalization was a good stimulus for environmental degradation. For the rest of sub-periods, no causality between globalization and environmental degradation is found, confirming neutrality hypothesis for those time intervals.

For sensitivity, in Appendix, the classical Granger causality in time domain of Granger (1969), and short- and long-run causality test in frequency domain of Breitung and Candelon (2006) are presented in the Table A2 and Figures A1 & A2, respectively. In Table A2, the null hypothesis of no Granger causality is not reject at all levels of significance. Hence, we conclude there is not any causality between globalization and environmental degradation. The same results offer the short- and long-run causality tests in frequency domain. For both directions of causalities, at all frequencies, the significance level of 6% is not reached. This means no causality between considered variables.

Finally, we claim the findings reinforce quasi-all literature assumptions regarding the link between globalization and environmental degradation, but for different sub-periods of time and frequencies. It is noteworthy that, these new results, performed in the time-frequency domain by using the wavelet tool unravel the time and frequency interactions between globalization and environmental degradation, in the case of France, which could not be detectable through traditional econometric tools. Despite that the time and frequency domain separately approaches do not evidence any causality, the time-frequency domain via wavelet tool clearly shows causalities but for various sub-period of times and frequencies.

5. Conclusions

By following the wavelet tool, the study explores the causality and sign of causality between the globalization and environmental degradation, in the case of France, for the period 1960-2013. Detailed information of this interaction is offered, for different sub-periods and frequencies, revealing the lead-lag nexus between variables under cyclical and anti-cyclical effects.

Important implications are given by economic crises and disinflation process. During 1975-1985, France confronted with the negative effects of the oil crisis, disinflation starting process, maximum level of CO_2 emissions and smooth increase of trade openness. This suggests the exports were alimented by pollutant capacities at low costs of production. Moreover, the inexistence of strong environmental rules for 'inputs' stimulated also 'contagious unclean' import flows. Not at least, as scale effect, the trade openness provokes CO_2 emissions through the indirect influence of economic growth expansion. Fortunately, the effect has a short persistence period, being counted by the environmental decentralized policies and international protocols which France became part.

Regarding the policy implications, it is recommended for the France government to be very careful with the sensitivity of globalization-environmental damages nexus, especially during the economic crisis, inflation control process and sustained economic growth. More precisely, the

government should increase the level of environmental protection in respect to production and import contingents. Otherwise, a strict control of pollutant capacities is also required during the sustained economic growth tendency as the effect of Environmental Kuznets Curve cannot be neglected.
The limit of research is given by two aspects: on the one hand, the unavailability of an extended dataset sample, with different frequencies, and on the other hand, the missing of control variables to isolate the interaction globalization-environmental degradation as the cross-wavelet is a bivariate approach.

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Appendix

Table A1: Summary statistics of variables

	x	y
Mean	430.6939	6.917474
Median	275.2100	6.501293
Maximum	1325.080	9.666681
Minimum	13.23000	5.050483
Std. Dev.	409.1910	1.295485
Skewness	0.832603	0.697168
Kurtosis	2.484373	2.344379
Jarque-Bera	6.837259	5.341525
Probability	0.032757	0.069199
Sum	23257.47	373.5436
Sum Sq. Dev.	8874174.	88.94889
Observations	54	54

Table A2: Classical Granger causality of the pair *d(ln(x)) -d(ln(y))*

H_0 (null hypothesis)	Obs.	F-Statistic	Prob.
d(ln(y)) does not Granger Cause *d(ln(x))*	51	2.11744	0.1319
d(ln(x)) does not Granger Cause *d(ln(y))*		0.16719	0.8466

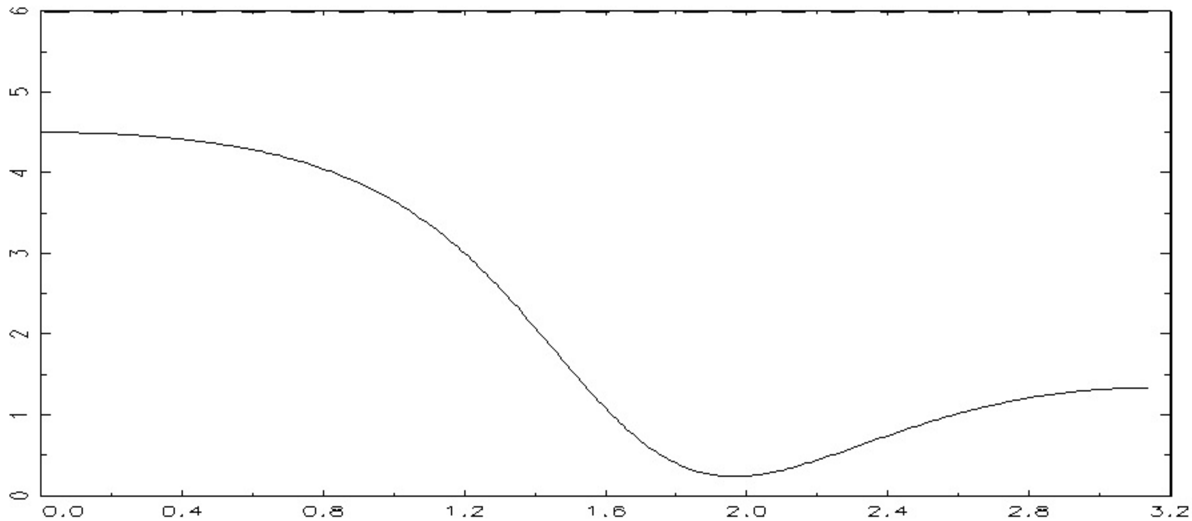

Figure A1: Short- and long-run causality test in frequency domain, from *d(ln(x))* to *d(ln(y))*

Note:
(1) The horizontal axe represents the frequency;
(2) The vertical axe denotes the level of significance, which is set at 6% according to Breitung and Candelon (2006);
(3) The Gauss code used belongs to Breitung and Candelon (2006).

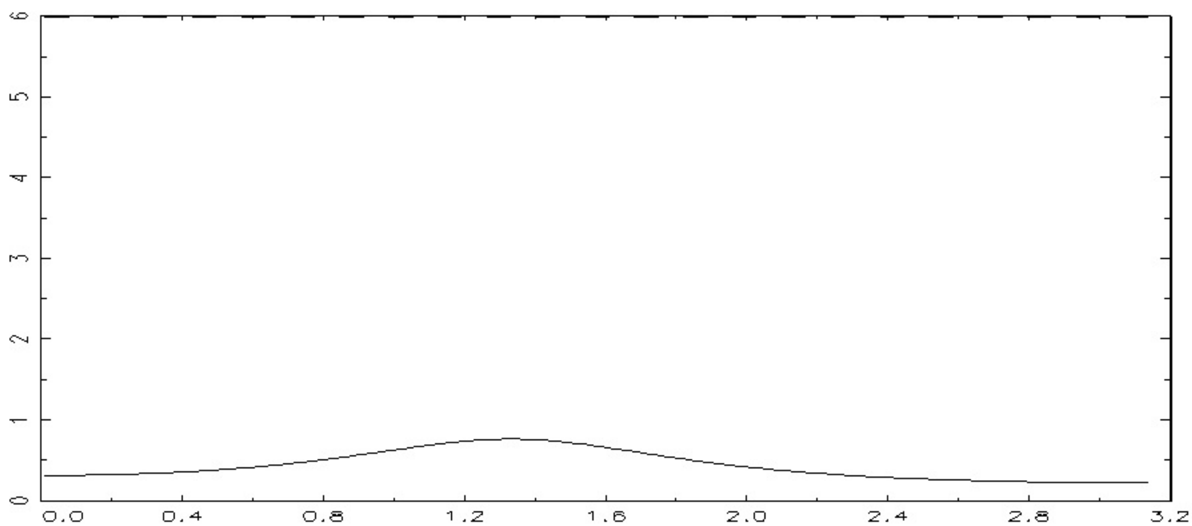

Figure A2: Short- and long-run causality test in frequency domain, from *d(ln(y))* to *d(ln(x))*

Note:
(1) The horizontal axe represents the frequency;
(2) The vertical axe denotes the level of significance, which is set at 6% according to Breitung and Candelon (2006);
(3) The Gauss code used belongs to Breitung and Candelon (2006).