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Time–frequency dependency of financial risk and economic risk: evidence from Greece

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Abstract

This study aims to shed some light on the one of the most popular phenomena in the economics and finance literature—nexus between economic growth and financial development—for the case of Greece over 1990Q1 to 2018Q4 within the framework of risk. In other words, this study investigates the causal link between financial risk and economic risk in Greece using wavelet coherence tests while answering the following questions: (i) does financial risk lead to economic risk in Greece and/or does economic risk lead to financial risk in Greece, and (ii) if so, why? The wavelet coherence approach allows the study to capture the long-run and short-run causal linkages among the time series variables since the approach combines time and frequency domain causalities. The findings from wavelet coherence supports the Schumpeter hypothesis since the findings proves that there is unidirectional causality from financial risk to economic risk in Greece (i) between 1995 and 1998; (ii) between 2003 and 2013; (iii) between 2013 and 2017 at different frequency levels. The findings clearly reveal how financial risk is important predictor for economic risk in Greece over the period of 1990–2018.

Keywords: Financial risk, Economic risk, Greece, Wavelet coherence, Causality

1 Introduction

Since the innovative theoretical study of Schumpeter (1911), considerable attention has been drawn to the nexus between financial development and economic growth. Globally, this nexus has remained one of the most important research topics in the last ten decades. To open new debate in the literature within the risk framework, co-movement between economic risk and financial risk in Greece is explored using wavelet coherence approach. The approach allows the present study to capture the short term and long term relationship among the time series variables since the decomposition of one-dimensional time data into the bi-dimensional time–frequency sphere is allowed with the wavelet coherence approach.

To best of my knowledge, the present study is the first to investigate in detail the short term and long term linkages between economic risk and financial risk for the case of Greece. It is important for policymakers to know whether there is any causal linkage between financial risk and economic risk in either developed or developing countries. Even, it is more important for Greece where the country is hit by the 2007–2008 global crisis and faced by the domestic debt crisis between 2009 and 2012. As widely accepted, Greece' debt crisis triggered the political instability and social exclusion in Greece, even

thousands of well-educated Greeks have left the country due to dramatically rising unemployment rate, especially for young generation. The Greek government announced a series of austerity measures within the framework of bailout programmes—First, Second and Third Economic Adjustment Programme between 2010, May and 2018, August. Therefore, the causal linkage between financial risk and economic risk is vital for policy-makers in Greece because it has expressly different implications for development policy.

In the literature, scholars have tested three different hypotheses: (1) supply-leading hypothesis—(is called "finance-led growth"), (2) demand-leading hypothesis (is called "growth-led finance"), and (3) feedback linkage between economic growth and financial development. While the supply-leading hypothesis of Schumpeter (1911) is well-documented by Goldsmith (1969), King and Levine (1993), Neusser and Kugler (1998), Rajan and Zingales (2003), Levine et al. (2000), and Beck et al. (2000), demand-leading hypothesis is theoretical or empirical supported by Robinson (1952), Gurley and Shaw (1967), Goldsmith (1969), and Jung (1986). Moreover, since the initial attempt of the Patrick (1966), the feedback relationship between economic growth and financial development has been shed light by the studies of Demetriades and Hussein (1996), Greenwood and Smith (1997), Aretsis and Demetriades (1997), Arestis et al. (2001), Al-Yousif (2002), Wolde-Rufael (2009), Hassan et al. (2011), Rousseau and Wachtel (2011), Yu et al. (2012), and Cecchetti and Kharroubi (2012).

Cournède and Denk (2015) aimed to investigate the effect of financial development on long-run economic development. They found supportive empirical evidence for the supply-leading hypothesis in the OECD and G20 countries. They argued that financial development played a significant role in accelerating economic growth by increasing the availability of loanable funds, improving resource allocation, increasing efficiency in capital allocation, and reducing adjustment cost due to higher demand in the market. Moreover, Madsen and Any (2016) also support the finance-led growth hypothesis while underlining the financial development causes economic growth through four channels, including production, savings, fixed investment, and schooling in 21 OECD countries. A more recent study of Asteriou and Spanos (2019) explored the nexus between financial development and economic growth in the EU over the period of 1990–2016. They conclude that although at the pre period of the global crisis, economic growth was triggered by financial developed, the effect turned into negative during the global crisis period. In addition, "during the recent sub-prime crises the capital adequacy of banks promoted the stability the financial system" (Asteriou and Spanos 2019). On the other hand, the studies of Rousseau and Wachtel (2002) and Demetriades and Law (2006) underline that "expanding financial instruments and developing financial systems do not play a significant role in fostering economic growth" (Kirikkaleli 2016).

However, Ndlovu (2013) demonstrated the relationship between financial sector development and economic growth, finding unidirectional causality from economic growth to financial development in Zimbabwe. In addition, Pan and Mishra (2018) explore the relationship between stock market and economic growth in China using the ARDL and Toda Yamamoto causality tests. They find that changes in economic growth significantly cause financial development, especially the Shenzhen B stock market. The study of Bist (2018) focuses on 16 selected low-income countries in Africa for the period of 1995 to 2014 and also supports the growth-led finance hypothesis, empirically.

However, existing empirical and theoretical studies in the economics and finance literatures reveal that there is no exact answer for the direction of this relationship. The direction of causality among the variables, if they exist, have changed from one study to another due to focusing on a different country or countries, focusing on different time periods, or even using different techniques. Even, there are quite limited numbers of studies specifically have focused on the case of Greece. Dritsakis and Adamopoulos (2004) examined the nexus in Greece using the VAR model over the period of 1960 to 2000 on a quarterly basis. They concluded that the feedback causal linkage between the economic growth and financial development exist since they observed the presence of common trend among these variables. Hondroyiannis et al. (2005) examines empirically the causal relationship between economic growths, the development of the banking system and the stock market in Greece and they underline the importance of bank and stock market financing on the economic performance of Greece in the long-run. Dritsaki and Dritsaki-Bargiota (2005) explore the triangle between financial development, credit market and economic growth in Greece. They underscore that while there is long-run relationship among the variables, there is unidirectional causal linkage from economic growth to stock market development and there is two-way causal relationship between banking sector development and economic growth.

2 Data and methodology

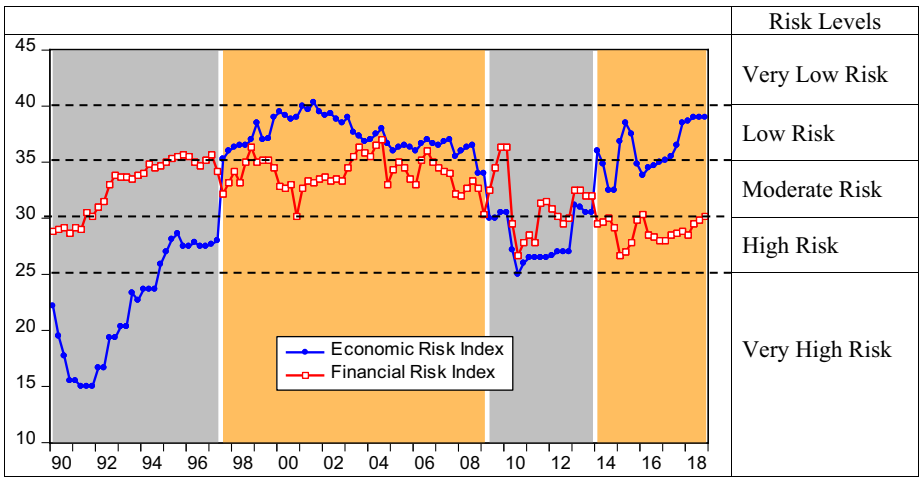
Since the main purpose as well as novelty of this paper is to explore the time–frequency dependency of financial risk and economic risk in Greece, unique dataset is used—financial risk index and economic risk index—from the Political Risk Services, covering the period of 1990Q1 to 2018Q4. While the financial risk index is constructed by 5 components, namely Foreign Debt as a Percentage of GDP, Foreign Debt Service as a Percentage of Exports of Goods and Services, Current Account as a Percentage of Exports of Goods and Services, Net International Liquidity as Months of Import Cover, and Exchange Rate Stability, The PRS Group used GDP per Head, Real GDP Growth, Annual Inflation Rate, Budget Balance as a Percentage of GDP, and Current Account as a Percentage of GDP to construct economic risk index. The score of the economic risk index and financial risk index ranges from 0 to 50, where 0 indicates a very high risk environment, and a score of 50 points indicates a very low risk environment. The descriptive statistics of the financial risk and economic risk variables and their codes are presented in Table 1.

Figure 1 shows the economic risk and financial risk indexes for the case of Greece over the period of 1990 to 2018 on a quarterly basis. As clearly seen, the performance of Greece was vulnerable in terms of economics and finance environments.

The period of 1990 and 1998, the economic environment of Greece was worse relative to financial one and in this time period, Greece found position itself from very high risky environment to high risk environment in terms of economic performance. As demonstrated in Fig. 1, between 1999 and the beginning of the global crisis, due to mainly rising the debt of GDP ratio kept Greece in a moderate risk in terms of finance while economic risk was relatively better. Erupting the global crisis, political vulnerabilities, cutting Greece' credit rating by the credit agencies in the world apart from leading domestic crisis in Greece, also increased the both economic risk and financial risk levels. Although economic risk in Greece was in downward trend between 2013 and 2018,

Table 1 Data and descriptive statistics

Code	ER	FR
Variable	Economic risk index	Financial risk index
Source	Political risk services group	Political risk services group
Time	1990Q1 to 2018Q4	
Mean	31.744	32.352
Median	34.916	33.000
Maximum	40.333	37.000
Minimum	15.002	26.666
Std. Dev.	7.067	2.690
Skewness	− 0.848	− 0.340
Kurtosis	2.640	1.928
Jarque–Bera	14.554	7.783
Probability	0.000	0.020



Source: Political Risk Service Group

Fig. 1 Economic risk index and financial risk index in Greece

financial risk level remained in the high risk environment, as seen in Fig. 1 in the orange shaded area. This clearly shows that finance system in Greece still risky and the report of the European Union Statistics Office confirms this since the office announce that government debt ratio in Greece reached 181.1% of the nation's GDP which broke the records in an all-time high.

The present study examines the co-movement between financial risk and economic risk in Greece using the wavelet approach initially developed by Goupillaud et al. (1984). The main innovation of wavelet techniques appears where the decomposition of one-dimensional time data into the bi-dimensional time–frequency sphere is allowed. This allows the present study to capture the long-run and short-run causal linkages between the variables. A multi-scale decomposition method brings out a natural framework to show frequency-dependent behaviour for investigating the linkage between economic risk and financial risk in Greece.

In this study, a wavelet (ψ) is based model that is part of the Morlet wavelet family. The equation is as follows:

$$\psi(t) = \pi^{-\frac{1}{4}} e^{-i\omega_0 t} e^{-\frac{1}{2}t^2},\ p(t), \quad t = 1, 2, 3 \ldots,\ \mathrm{T}.$$

"Frequency, represented by (f), and time or location, represented by (k), are the main parameters of the wavelet. While a wavelet's particular location in time is the fundamental character of the k parameter, the frequency parameter controls the distended wavelet for localizing various frequencies. By transforming the wavelet equation, $\psi_{k,f}$ can first be constructed" (Kirikkaleli and Gokmenoglu 2019). The equation of this transformation is shown below:

$$\psi_{k,f}(t) = \frac{1}{\sqrt{h}}\psi\left(\frac{t-k}{f}\right), \quad k,f \in \mathbb{R}, \quad f \neq 0 \tag{1}$$

The continuous wavelet can be generated from ψ as a function of k and f given time series data $p(t)$ as follows:

$$W_p(k,f) = \int_{-\infty}^{\infty} p(t)\frac{1}{\sqrt{f}}\psi\left(\overline{\frac{t-k}{f}}\right)\mathrm{d}t, \tag{2}$$

The regenerated initial times series $p(t)$ with the ψ coefficient is shown in the following equation:

$$p(t) = \frac{1}{C_\psi}\int_0^{\infty}\left[\int_{-\infty}^{\infty}\left|W_p(a,b)\right|^2 da\right]\frac{db}{b^2}. \tag{3}$$

To capture vulnerability and to get deeper information of the time series variables, the wavelet power spectrum (WPS) is employed.

$$\mathrm{WPS}_p(k,f) = \left|W_p(k,f)\right|^2. \tag{4}$$

The main innovation of wavelet coherence approach is that the approach allows the present study to picture any correlation between economic risk and financial risk in combined time–frequency based causalities. The cross wavelet transform (CWT) of the time series is as shown below:

$$W_{pq}(k,f) = W_p(k,f)\overline{W_q(k,f)}, \tag{5}$$

where $W_p(k,f)$ and $W_q(k,f)$ denotes the CWT of two time series economic risk and financial risk, correspondingly (Torrence and Compo 1998). As constructed by Torrence and Compo (1998), the equation of the squared wavelet coherence can be represented as in the Eq. 6

$$R^2(k,f) = \frac{\left|C\left(f^{-1}W_{pq}(k,f)\right)\right|^2}{C\left(f^{-1}\left|W_p(k,f)\right|^2\right)C\left(f^{-1}\left|W_q(k,f)\right|^2\right)} \tag{6}$$

where $R^2(k,f)$ ranges between 0 and 1. Whenever $R^2(k,f)$ gets close to 1 it indicates that the time series variables are correlated at a particular scale, surrounded by a black line and depicted by a red color. On the other hand, when the value of $R^2(k,f)$ approaches 0 it indicates that there is no correlation between the time series variables and is pictured by a blue color.

However, obtaining the value of $R^2(k,f)$ does not provide any way to distinguish positive correlation from negative; thus "Torrence and Compo (1998) postulated a means by which to detect the wavelet coherence differences through indications of deferrals in the wavering of two time series" (Pal and Mitra 2017). The equation of the wavelet coherence difference phase is constructed as follows:

$$\phi_{pq}(k,f) = \tan^{-1}\left(\frac{L\{C(f^{-1}W_{pq}(k,f))\}}{O\{C(f^{-1}W_{pq}(k,f))\}}\right), \tag{7}$$

where L and O denote an imaginary operator and a real part operator, respectively.

3 Empirical finding

As an initial test, the wavelet power spectral test is employed to identify the vulnerability and behaviour of the economic risk and financial risk indexes in Greece. Figures 2 and 3 shows the wavelet power spectral for financial risk and economic risk in Greece, respectively. In the Figures, the white cone-shaped curve represents the cone of influence demonstrating an edge below where the wavelet power is affected because of discontinuity, while the thick black shape indicates a 5% significant level determined by Monte Carlo simulations. The main difference among the figures is the colour defences in the white cone-shaped curve, indicating that the vulnerability of the financial risk in Greece over the period of 1990 to 2018 is more than economic one. As clearly seen in Fig. 2, financial risk is significantly vulnerable between 2005 and 2013 at 4 to 12 quarter scales. Since the financial risk demonstrates the country's

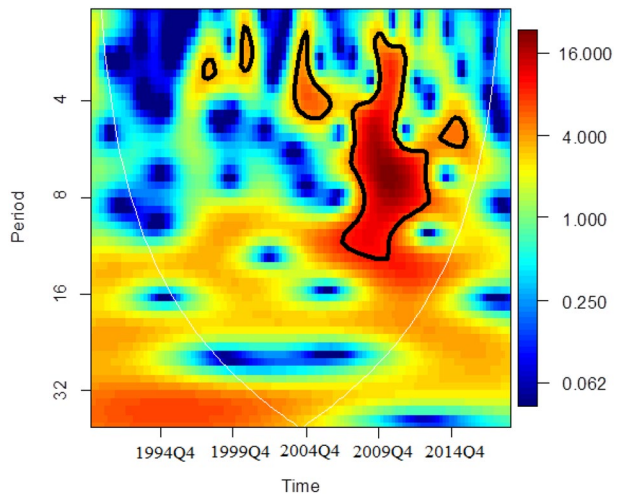


Fig. 2 Wavelet power spectrum for financial risk

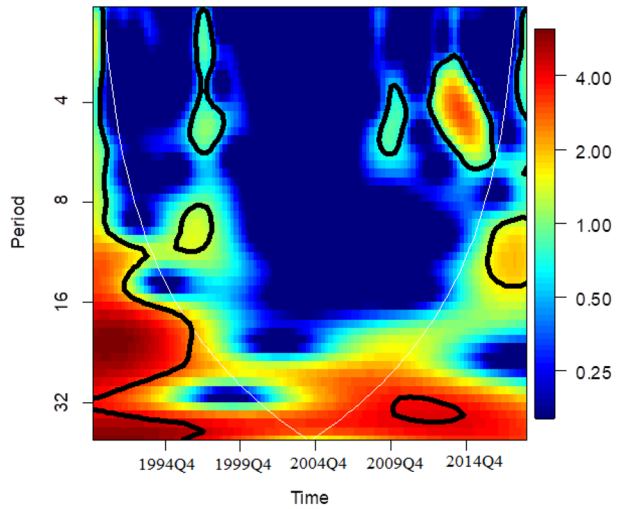


Fig. 3 Wavelet power spectrum for economic risk

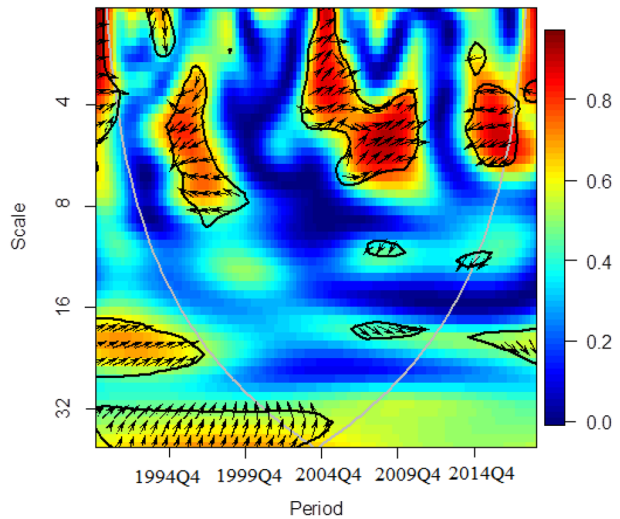


Fig. 4 Wavelet coherence between economic risk and financial risk

ability to pay its debt, the financial risk index in Greece was signalling the approaching the debt crisis. Although the vulnerability is overcome in the financial risk index in Greece, to obtain 181.1% government debt ratio in 2018 is very risky. In case of the global or European crisis in near future, Greece might again face the sovereign debt crisis. During the period of 2013 and 2015, in the short term, economic risk index was significantly vulnerable but as seen in Fig. 1, this was a period that Greece moved from high risky economic environment to low risk economic environment.

In order to explore the co-movement between economic risk and financial risk in Greece and to able to answer the main question of the present study, wavelet coherence approach is employed. While the x-axis represents the time, the y-axis refers to the frequency. The cone-shaped white line indicates the cone of impact in Fig. 4 while

the thick black shape in Fig. 4 indicates a 5% significance level, which is tested against AR(1). In the figure, while cold (blue) represents "no dependency between economic risk and financial risk in Greece", warmer colours areas denote the high dependency among the variables. In the wavelet coherence analysis, the direction of the significant causality is represented by arrows surrounded by the thick black line. While arrows pointing to the left indicate negative correlation among the variables, arrows point to the right represent the positive correlation. In addition, arrows pointing to the up, right-up or left-down show that the financial risk causes economic risk in Greece whereas arrows pointing to the down, right-down or left-up indicate that changes in economic risk in Greece significantly lead to changes financial risk. The outcome of the wavelet coherence test is reported in Fig. 4. Arrows that point right up and left down at the thick black shape area indicates that the null hypothesis that financial risk does not Granger cause economic risk can be rejected at 5% level between 1995 and 2000, between 2005 and 2010 and 2014 and 2016. In other words, the outcome underlines how financial risk is important predictor for economic risk in Greece. Since the financial risk index denotes a countries ability to pay its debt, to observe the causality running from financial risk to economic risk is not surprising result for the case of Greece. The result also supports the innovative theoretical study of Schumpeter (1911)—finance-led growth—within the framework of risk.

4 Conclusion

The present study aims to explore co-movement between economic risk and financial risk over the period of 1990Q1 to 2018Q4 in Greece using wavelet coherence approach. The empirical findings reveal that changes in financial risk significantly lead to changes in economic risk in Greece. Actually, this is rational and in line with the expectation. Therefore, to achieve economic stability in Greece; governors should have a sound financial environment. In other words, foreign debt, liquidity, trade, and exchange rate need to be controlled in Greece to minimize economic instability in the market. Since the present study clearly underlines the importance of financial risk over the economic risk in Greece, increasing debt GDP ratio to over 181% in 2018 might be disturb the macroeconomic dynamics in the market in the near future if there will be any global and regional uncertainties. Therefore, the outcome strongly suggests for the incumbent government in Greece to implement policies for facilitating economic growth and reducing debt as a percentage of GDP. Although the present study makes it possible to identify strong empirical findings, further studies should be conducted for the other Southern European economies.

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Authors' contributions
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Availability of data and materials
The data that support the findings of this study are available from the Political Risk Services Group but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Political Risk Services Group.

Competing interests
The author declares that he has no competing interests.

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