ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ

ΣΧΟΛΗ ΕΦΑΡΜΟΣΜΕΝΩΝ ΜΑΘΗΜΑΤΙΚΩΝ ΚΑΙ ΦΥΣΙΚΩΝ ΕΠΙΣΤΗΜΩΝ

ΤΟΜΕΑΣ ΑΝΘΡΩΠΙΣΤΙΚΩΝ, ΚΟΙΝΩΝΙΚΩΝ ΕΠΙΣΤΗΜΩΝ & ΔΙΚΑΙΟΥ

ΕΡΓΑΣΤΗΡΙΟ ΘΕΩΡΗΤΙΚΗΣ & ΕΦΑΡΜΟΣΜΕΝΗΣ ΟΙΚΟΝΟΜΙΚΗΣ & ΔΙΚΑΙΟΥ

ΔΙΔΑΚΤΟΡΙΚΗ ΔΙΑΤΡΙΒΗ

ΚΥΚΛΙΚΕΣ ΔΙΑΚΥΜΑΝΣΕΙΣ ΣΤΗ ΔΙΕΘΝΗ ΟΙΚΟΝΟΜΙΑ: ΜΙΑ ΠΟΣΟΤΙΚΗ ΚΑΙ ΟΙΚΟΝΟΜΕΤΡΙΚΗ ΑΝΑΛΥΣΗ

ΚΩΝΣΤΑΝΤΙΝΟΣ Ν. ΚΩΝΣΤΑΝΤΑΚΗΣ

ΕΠΙΒΛΕΠΩΝ:

ΠΑΝΑΓΙΩΤΗΣ Γ. ΜΙΧΑΗΛΙΔΗΣ

ΕΠ. ΚΑΘΗΓΗΤΗΣ ΕΜΠ

ΑΘΗΝΑ, ΟΚΤΩΒΡΙΟΣ 2016

Οὐ δεῖ λυμαίνεσθαι τὰ παρόντα τῶν ἀπόντων ἐπιθυμία ἀλλ᾽ ἐπιλογίζεσθαι ὅτι καὶ ταὐτὰ τῶν εὐκταίων ἧν

ή

Δεν πρέπει να καταστρέφουμε όσα έχουμε επιθυμώντας όσα δεν έχουμε, αλλά να θυμόμαστε πώς ό,τι έχουμε είναι αυτά που κάποτε ευχόμασταν.

Επίκουρος 341-270 π.Χ

ΕΥΧΑΡΙΣΤΙΕΣ

Θα ήθελα να ευχαριστήσω θερμά τον κ. Παναγιώτη Μιχαηλίδη, Επίκουρο Καθηγητή ΕΜΠ, για τις γνώσεις που μου μετέδωσε και την καθοδήγησή του μέσω της προσωπικής του ενασχόλησης, καθ' όλη την πορεία μου ως Υποψήφιος Διδάκτορας του Τομέα Ανθρωπιστικών, Κοινωνικών Επιστημών και Δικαίου (ΑΚΕΔ) του ΕΜΠ. Επίσης, οφείλω να ευχαριστήσω τον Καθηγητή ΕΜΠ, κ. Ιωάννη Μηλιό, για τη συνεργασία και τον Αναπληρωτή Καθηγητή του Πανεπιστημίου Πατρών, κ. Γεώργιο Οικονομάκη, για τη συμμετοχή του στην ολοκλήρωση της Διδακτορικής Διατριβής. Δεν θα μπορούσα να παραλείψω τις ευχαριστίες μου στον Καθηγητή του Παντείου Πανεπιστημίου, κ. Θεόδωρο Μαριόλη, για τη συνεργασία μας. Ένα μεγάλο ευχαριστώ οφείλω, επίσης, στους γονείς μου και στη γυναίκα μου για την αμέριστη ψυχολογική συμπαράσταση που μου προσέφεραν στην πορεία μου έως τώρα. Τέλος, επισημαίνεται ότι η παρούσα Διδακτορική Διατριβή εκπονήθηκε με χρηματοδότηση από τον Ειδικό Λογαριασμό Έρευνας του ΕΜΠ.

Κατά την πορεία εκπόνησης της παρούσας Διδακτορικής Διατριβής, προέκυψαν (33) δημοσιεύσεις, εκ των οποίων δεκαπέντε (15) σε διεθνή επιστημονικά περιοδικά κατόπιν κρίσης, από τις οποίες δύο (2) "κατ' αρχήν αποδεκτές", δεκαέξι (16) άρθρα σε διεθνή επιστημονικά συνέδρια κατόπιν κρίσης, και δύο (2) άρθρα σε συλλογικούς τόμους.

ΠΕΡΙΛΗΨΗ

Η παρούσα Διδακτορική Διατριβή (Δ.Δ.) μελετά τις κυκλικές διακυμάνσεις, τόσο σε διεθνές, όσο και εθνικό επίπεδο και χωρίζεται σε τρία μέρη. Στο πρώτο μέρος εξετάζεται η διάδοση της κρίσης χρέους μεταξύ των οικονομιών των Ηνωμένων Πολιτειών της Αμερικής (ΗΠΑ) και της Ευρωπαϊκής Ένωσης (ΕΕ), ενώ παράλληλα εξετάζονται οι δυναμικές αλληλεξαρτήσεις μεταξύ των βασικών οικονομιών που απαρτίζουν τη διεθνή οικονομία. Στη συνέχεια, η εργασία εξετάζει τον συγχρονισμό των ασκούμενων δημοσιονομικών πολιτικών από τα διάφορα κράτη της ΕΕ. Στο δεύτερο μέρος, η Δ.Δ. εστιάζει στη μελέτη της οικονομίας των ΗΠΑ. Πιο συγκεκριμένα, διερευνάται η σχέση αιτιότητας μεταξύ των διακυμάνσεων στην ποσότητα χρήματος και στην οικονομική δραστηριότητα. Στη συνέχεια, η Δ.Δ. εισάγει στη βιβλιογραφία έναν νέο οικονομετρικό έλεγχο για την ύπαρξη Χρηματοοικονομικής Φούσκας (Financial Bubble) όπως και έναν νέο αλγόριθμο για την περιοδολόγησή της. Επιπλέον, εξετάζει σε επίπεδο κλάδων οικονομικής δραστηριότητας, εάν το μέγεθος των κλάδων επηρρεάζει την προώθηση της καινοτομικότητας και τεχνολογικής αλλαγής στην οικονομία των ΗΠΑ. Στο τρίτο και τελευταίο μέρος, η διατριβή εστιάζεται στην Ελληνική οικονομία και στις επιπτώσεις της πρόσφατης κρίσης. Αναλυτικότερα, διερευνώνται οι παράγοντες που επηρεάζουν τις διακυμάνσεις της Ελληνικής οικονομίας. Τέλος, εισάγεται στη βιβλιογραφία ένας νέος έλεγχος βραχυχρόνιας αιτιότητας, ικανός να ενσωματώσει τόσο ποιοτικές όσο και ποσοτικές μεταβλητές, και στη συνέχεια αυτός χρησιμοποιείται για τη διερεύνηση των μακροοικονομικών αιτιακών παραγόντων των πωλήσεων των αυτοκινήτων στην περιοχή της Αθήνας. Η εφαρμογή των ως άνωθεν αναπτυχθέντων μεθοδολογικών εργαλείων υπήρξε, γενικά, ιδιαίτερη ικανοποιητική.

ABSTRACT

The present Doctoral Thesis attempts to shed light on basic aspects of the recent crisis and its consequences both at the national and international levels, respectively. The Thesis consists of three main parts. In the first part, the Thesis focuses on the transmission of the debt crisis between the major economic regions of US and EU; it also examines the dynamic interdependencies among the major economic entities in the global economy. Additionally, it investigates the business cycles synchronization of fiscal policies between the EU economies. In the second part, the Thesis focuses on the US economy. In this context, it examines the relationship between the fluctuations in the quantity of money and the fluctuations in economic activity. Additionally, it attempts to detect and date non-linear bubble episodes in the US S&P 500 index, by means of a new econometric test, based on Artifical Neural Networks. At the sectoral level, it investigates whether sector size matters for sectoral technological change and stability in the US economy. In the third part, the Thesis turns to the Greek economy, a prominent victim of the crisis. More precisely, it investigates the determinants of the Greek Business Cycle. Lastly, it introduces a novel econometric test for short-run causality that is capable of handling both qualitative and quantitive variables in order to examine the short-run macroeconomic determinants of the total car sales in the region of Athens.

ΠΡΟΛΟΓΟΣ

Η εκπόνηση της παρούσας Διδακτορικής Διατριβής (Δ.Δ.) έλαβε χώρα σε μία περίοδο που η παγκόσμια οικονομία, στο σύνολό της αλλά και οι επιμέρους οικονομικές μονάδες προσπαθούν να ανταπεξέλθουν στις συνέπειες της παγκόσμιας οικονομικής κρίσης, αλλά και των επιμέρους κρίσεων που ακολούθησαν. Με βασικό ερέθισμα το παγκόσμιο οικονομικό περιβάλλον, η παρούσα Δ.Δ. επιδιώκει να διερευνήσει και να ερμηνεύσει κύριες πτυχές, αναφορικά με τη δημιουργία, αλλά και τις συνέπειες της κρίσης, τόσο σε διεθνές, όσο και σε εθνικό επίπεδο. Σε αυτό το πλαίσιο, κυρίαρχο ρόλο στην παρούσα εργασία έχει η έννοια του οικονομικού κύκλου, που είναι από τις πιο θεμελιακές της οικονομικής επιστήμης και η οποία είναι άρρηκτα συνδεδεμένη με μια σειρά άλλων οικονομικών εννοιών. Στην κατεύθυνση αυτή, αναλύεται η έννοια του οικονομικού κύκλου και των εκφάνσεων αυτού, όπως οι οικονομικές διακυμάνσεις και οι οικονομικές διαταραχές με τρόπο συστηματικό, τόσο σε αναλυτικό όσο και σε εμπειρικό επίπεδο.

Οι οικονομικές διαταραχές συνιστούν το βασικό μέσο διάδοσης των οικονομικών διακυμάνσεων μεταξύ διαφορετικών οικονομικών μονάδων. Το σύνολο των παραπάνω θεωρήσεων οικοδομεί τον αναλυτικό πυρήνα πάνω στον οποίο δομείται η παρούσα Δ.Δ. Με βάση αυτόν τον αναλυτικό πυρήνα, η εργασία παρουσιάζει ένα κατάλληλο αναλυτικό πλαίσιο, το οποίο χρησιμοποιείται για τη διερεύνηση της διάδοσης των οικονομικών διαταραχών. Έτσι, με χρήση των κατάλληλων ποσοτικών και οικονομετρικών τεχνικών, σε πρώτη φάση, ταυτοποιούνται οι κυρίαρχες οικονομικές μονάδες σε διεθνές επίπεδο, ενώ στη συνέχεια εξετάζονται οι δυναμικές αλληλεξαρτήσεις, τόσο μεταξύ τους όσο και μεταξύ των υπολοίπων οικονομιών. Επίσης, διερευνώνται οι επιπτώσεις της κρίσης, ως μελέτες περίπτωσης, τόσο στην ισχυρότερη διεθνή οικονομία (ΗΠΑ), όσο και στον πιο αδύναμο «κρίκο» (Ελληνική οικονομία), σε συνολικό και κλαδικό επίπεδο.

Εν κατακλείδι, η εν λόγω Δ.Δ. ανέπτυξε το αναλυτικό και οικονομετρικό πλαίσιο, μέσω του οποίου δόθηκαν απαντήσεις σε μία σειρά ερωτημάτων, με τέτοιο τρόπο που οι απαντήσεις δύνανται να αποτελούν μία συγκροτημένη μελέτη αναφορικά με τη διάδοση των οικονομικών διακυμάνσεων και διαταραχών, τόσο σε διεθνές όσο και σε εθνικό επίπεδο. Στη μακρά αυτή πορεία, ανακύπτουν σημαντικά ερωτήματα των οποίων η απάντηση προσφέρει αφορμές για περαιτέρω επιστημονική έρευνα.

ΕΙΣΑΓΩΓΗ

Η παγκόσμια οικονομική κρίση και οι επαγόμενες εθνικές κρίσεις, ώθησαν τη διεθνή επιστημονική κοινότητα στην αναθεώρηση των οικονομικών πολιτικών αναφορικά με θέματα που σχετίζονται με τη δημιουργία και διάδοση των κρίσεων. Σε αυτό το πλαίσιο, πρωταρχικό ρόλο διαδραματίζει η έννοια του οικονομικού κύκλου και των θεωριών που τον συνοδεύουν.

Η έννοια του οικονομικού κύκλου είναι συνδεδεμένη, τόσο με την έννοια της κρίσης, όσο και με θεμελιώδεις οικονομικές έννοιες όπως «εισόδημα», «ύφεση» και «άνθιση», «φτώχεια» και «πλούτος» και έχει, συνεπώς, ιδιαίτερη σημασία για την οικονομική θεωρία αλλά και την οικονομική πολιτική. Πολλές φορές, η ύπαρξη οικονομικών κύκλων αυτή κάθ' αυτή αποτελεί και την πρωταρχική γενεσιουργό αιτία των οικονομικών κρίσεων. Αυτό, συμβαίνει εξαιτίας της ταύτισης της οικονομική κρίσης με τη φάση καθόδου (ή ύφεσης) ενός οικονομικού κύκλου. Συνεπώς, όπως γίνεται αντιληπτό, ένα από τα σημαντικότερα ερωτήματα που γεννάται από μία τέτοια θεώρηση είναι η εύρεση του μηχανισμού μέσω του οποίου η κρίση διαδίδεται μεταξύ των διαφορετικών οικονομικών μονάδων.

Η κρίση, γενικά, φέρει την ιδιότητα της αλλοίωσης και στρέβλωσης, τόσο των αιτιακών σχέσεων μεταξύ βασικών οικονομικών μεγεθών, όσο και των αλληλεπιδράσεων μεταξύ αυτών. Για το λόγο αυτό, παρατηρείται μία ραγδαία αύξηση, τόσο της θεωρητικής, όσο και εμπειρικής βιβλιογραφίας των υποδειγμάτων που χρησιμοποιούνται για τη διερεύνηση των επιπτώσεων των οικονομικών διακυμάνσεων μεταξύ διαφορετικών οικονομικών μονάδων. Σε αυτό το πλαίσιο, μεταξύ άλλων προσεγγίσεων, κυρίαρχο ρόλο κατέχουν τα Διανυσματικά Αυτοπαλίνδρομα Υποδείγματα (VAR models), αλλά και μεταγενέστερες προεκτάσεις αυτών, όπως τα Παγκόσμια Διανυσματικά Αυτοπαλίνδρομα Υποδείγματα (GVAR models), τα οποία δύνανται να προσφέρουν απαντήσεις σε ερευνητικά ερωτήματα αναφορικά με τις δυναμικές αλληλεξαρτήσεις εξαιτίας της ύπαρξης και διάδοσης των οικονομικών διακυμάνσεων μεταξύ ανομοιογενών οικονομικών μονάδων. Η ραγδαία ανάπτυξη των παραπάνω υποδειγμάτων οφείλεται στο γεγονός ότι δύνανται να περιγράψουν ικανοποιητικά τις στρεβλώσεις μεταξύ βασικών οικονομικών μεγεθών, τόσο σε επίπεδο κλάδου και οικονομίας, όσο και σε διεθνές επίπεδο.

Όπως προαναφέρθηκε, η παρούσα Δ.Δ. καταπιάνεται με μία σειρά ζητημάτων που αφορούν, τόσο τις οικονομικές διακυμάνσεις και διαταραχές, όσο και τη διάδοση των κρίσεων. Κατά πρώτον, η εργασία εξετάζει τη δυναμική αλληλεξάρτηση των κυρίαρχων μονάδων στη διεθνή οικονομία, δηλαδή των οικονομιών της Ευρωπαϊκής Ένωσης (ΕΕ) και των Ηνωμένων Πολιτειών της Αμερικής (ΗΠΑ). Σκοπός αυτής της ανάλυσης είναι να εντοπίσει και να αναδείξει: (α) τις διαφοροποιήσεις που υφίστανται μεταξύ των μονάδων αυτών καθώς και (β) την κατεύθυνση του βέλους αιτιότητας αναφορικά με τη διάδοση της κρίσης. Για την παραπάνω ανάλυση γίνεται χρήση ενός κατάλληλου υποδείγματος, σε συνδυασμό με τους βασικούς ελέγχους αιτιότητας.

Δεύτερο ζήτημα με το οποίο καταπιάνεται η Δ.Δ. αποτελεί η διερεύνηση των δυναμικών αλληλεξαρτήσεων, σε διεθνές επίπεδο, των σημαντικότερων οικονομιών που συγκροτούν τη διεθνή οικονομία. Σε αυτό το πλαίσιο, διερευνάται η επιρροή των οικονομιών αυτών στις υπόλοιπες οικονομίες. Βασικός στόχος της παραπάνω διερεύνησης είναι η αναλυτική και οικονομετρική ανάπτυξη ενός μηχανισμού διάδοσης της κρίσης, μέσω των οικονομικών διακυμάνσεων και διαταραχών που τη διέπουν. Για το σκοπό αυτό χρησιμοποιούνται: (α) ένα σύστημα Παγκόσμιων Αυτοπαλίνδρομων Υποδειγμάτων ικανό να περιγράψει τις δυναμικές αλληλεξαρτήσεις σε διεθνές επίπεδο, καθώς και (β) τεχνικές Ανάλυσης Δικτύων που βασίζονται, εν μέρει, στο υπόδειγμα Εισροών-Εκροών με στόχο την ταυτοποίηση των κυρίαρχων οικονομικών μονάδων του συστήματος.

Τρίτο ζήτημα αποτελεί η διερεύνηση της θεμελιώδους διαφοροποίησης μεταξύ των κυρίαρχων οικονομικών μονάδων της ΕΕ και των ΗΠΑ, αναφορικά με τους προσδιοριστικούς παράγοντες των οικονομικών διακυμάνσεων. Η ανάλυση εστιάζεται στις ανεξάρτητες δημοσιονομικές πολιτικές που εφαρμόζονται σε επίπεδο κρατών-μελών στην ΕΕ. Η μελέτη των δημοσιονομικών πολιτικών λαμβάνει χώρα με στόχο τη διερεύνηση, τόσο των παραγόντων που επιδρούν στη δημιουργία των οικονομικών κύκλων, όσο και στο συγχρονισμό των οικονομικών κύκλων μεταξύ των διαφόρων κρατών μελών. Για το λόγο αυτό, γίνεται χρήση ενός αναλυτικού πλαισίου προσδιορισμού των διαφόρων οικονομικών κύκλων, ενώ παράλληλα χρησιμοποιούνται και οι κατάλληλες οικονομετρικές τεχνικές και έλεγχοι που απαιτούνται για τη διερεύνηση.

Στο τέταρτο ζήτημα που εστιάζει η Δ.Δ. στρεφόμαστε στη μελέτη της Αμερικανικής οικονομίας. Πιο συγκεκριμένα, βασικό ζήτημα αποτελεί η διερεύνηση των εφαρμοζόμενων νομισματικών πολιτικών, όπως αυτές εκφράζονται από τις διακυμάνσεις στην ποσότητα του χρήματος και τις διακυμάνσεις της οικονομικής δραστηριότητας. Για το σκοπό αυτό, συγκροτείται ένα κατάλληλο αναλυτικό πλαίσιο που δύναται να μοντελοποιήσει επαρκώς τις εν λόγω αιτιακές σχέσεις.

Βασικό μέσο διάδοσης των διαταραχών, μεταξύ των διαφορετικών οικονομικών μονάδων, είναι η λειτουργία του χρηματοοικονομικού συστήματος. Μία από τις διαχρονικές παθογένειες του εν λόγω συστήματος είναι η εμφάνιση και ανάπτυξη Χρηματοοικονομικής Φούσκας (Financial Bubble). Πέμπτο ζήτημα λοιπόν, αποτελεί η δημιουργία ενός μεθοδολογικού πλαισίου ικανού να διερευνήσει τη δημιουργία Χρηματοοικονομικής Φούσκας. Βασικός στόχος είναι η δημιουργία ενός οικονομετρικού ελέγχου ικανού να διασφαλίσει την έγκαιρη πρόληψη δημιουργίας Χρηματοοικονομικής Φούσκας. Για το λόγο αυτό, γίνεται χρήση ενός κατάλληλου Νευρωνικού Δικτύου (Ν.Δ.) ικανού να προσομοιάσει τη μη γραμμική φύση ανάπτυξης τέτοιων φαινομένων, ενώ παράλληλα, αναπτύσσεται ένα αναλυτικό πλαίσιο περιοδολόγησής τους. Ο εν λόγω έλεγχος, εφαρμόζεται επιτυχώς στον βασικό χρηματοοικονομικό δείκτη των ΗΠΑ (S&P 500).

Έκτο ζήτημα που απασχολεί τη Δ.Δ. είναι κατά πόσο οι μεγάλοι κλάδοι της οικονομίας των ΗΠΑ προωθούν την τεχνολογική αλλαγή και καινοτομικότητα. Επίσης, διερευνάται κατά πόσο οι επαγόμενοι οικονομικοί κύκλοι, κατά κλάδο οικονομικής δραστηριότητας, οφείλονται στους κύκλους της τεχνολογίας, όπως αυτή εκφράζεται μέσω των αντίστοιχων μεταβλητών. Για τη διερεύνηση των παραπάνω ερωτημάτων, οικοδομείται ένα πλήρες αναλυτικό πλαίσιο που βασίζεται σε μία σειρά υποδειγμάτων.

Η εργασία, ακολούθως, στρέφεται στον πιο αδύναμο «κρίκο» της παγκόσμιας κρίσης δηλαδή στη μελέτη της Ελληνικής οικονομίας. Πιο συγκεκριμένα, έβδομο ζήτημα αποτελεί η διερεύνηση των παραγόντων που συντελούν στη δημιουργία των κύκλων στην Ελληνική οικονομία. Για το λόγο αυτό μελετάται σε βάθος η πορεία του κύκλου της Ελληνικής οικονομίας και των παραγόντων που τον επηρεάζουν κατά την περίοδο 1996-2014.

Το τελευταίο ζήτημα ενασχόλησης της Δ.Δ. είναι η διερεύνηση της βραχυχρόνιας αιτιότητας (step-by step ή multistep causality) μεταξύ των μεταβλητών που επηρεάζουν τον κύκλο στον κλάδο πωλήσεων των ιδιωτικών αυτοκινήτων στην περιοχή της Αθήνας. Για το σκοπό αυτό δημιουργείται ένα νέο κατάλληλο μεθοδολογικό πλαίσιο ικανό να ενσωματώνει, τόσο ποιοτικές, όσο και ποσοτικές μεταβλητές.

Η συμβολή της παρούσας Δ.Δ. κινείται σε δύο αλληλοσυμπληρούμενα μεταξύ τους επίπεδα. Σε μεθοδολογικό επίπεδο, οι βασικές συμβολές της εργασίας είναι: (α) η ανάπτυξη ενός συστήματος ταυτόχρονων εξισώσεων Παγκόσμιων Αυτοπαλίνδρομων Υποδειγμάτων ικανού να αποτυπώσει τη διάδοση των οικονομικών διακυμάνσεων και διαταραχών σε παγκόσμιο αλλά και εθνικό επίπεδο, (β) η δημιουργία μέσω του υποδείγματος Εισροών-

Εκροών και της Ανάλυσης Δικτύων, κατάλληλης μεθοδολογίας για την εξεύρεση και ταυτοποίηση των κυρίαρχων οικονομικών μονάδων του συστήματος, (γ) η ανάπτυξη ενός εμπειρικού ελέγχου για την ύπαρξη Χρηματοοικονομικής Φούσκας αλλά και για την περιοδολόγησή της μέσω κατάλληλου αλγορίθμου, καθώς και (δ) η δημιουργία ενός μονόπλευρου έλεγχου βραχυχρόνιας αιτιότητας που δύναται να ενσωματώνει, τόσο ποσοτικές, όσο και ποιοτικές μεταβλητές, σε επίπεδο αυτοπαλίνδρομου συστήματος.

Σε εμπειρικό επίπεδο, οι βασικές συνεισφορές της διατριβής είναι οι ακόλουθες: (α) η διερεύνηση των επιπτώσεων της κρίσης χρέους μεταξύ των δύο γεωγραφικών περιοχών της ΕΕ και των ΗΠΑ μέσω της εφαρμογής Παγκόσμιων Αυτοπαλίνδρομων υποδειγμάτων, (β) η διερεύνηση των δημοσιονομικών πολιτικών που εφαρμόζονται από τα κράτη μέλη της ΕΕ, όπως και ο συγχρονισμός των οικονομικών τους κύκλων, (γ) η διερεύνηση της κατεύθυνσης που έχει το βέλος αιτιότητας μεταξύ της ποσότητας χρήματος και των κυκλικών διακυμάνσεων στις ΗΠΑ, (δ) η μελέτη της σχέσης αιτιότητας μεταξύ της τεχνολογικής προόδου και των οικονομικών διακυμάνσεων στις ΗΠΑ, και (ε) η ανάλυση των παραγόντων που διέπουν την εξέλιξη των κυκλικών διακυμάνσεων στην Ελληνική οικονομία.

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Part A

Chapter 1: Transmission of the Debt Crisis: From EU15 to USA or *vice versa* ?[1]

In this chapter we focus on the transmission of the Debt crisis between the two major economies, namely USA and EU. In this context, we will estimate a GVAR model in order to study the transmission of shocks between EU15 and USA, respectively, on a quarterly basis, in the 2000 (Q1) – 2011 (Q4) time span. Our work is based on the global variables of trade and credit, which act as transmission channels, whereas EU15 is being treated as a single economy

1.1 INTRODUCTION

Over the last period, the so-called debt crisis is a hot topic that has been in the research agenda of several economists around the world such as Greenlaw et *al.* (2013) who argue that countries with high debt loads are vulnerable to an adverse feedback loop. In fact, over the years, heavy indebtedness is a crucial policy issue since debt fluctuations constitute a significant component of total macroeconomic volatility, while changes in the fiscal balance are closely monitored in policy circles.

In the meantime, there is no doubt that several developments over the past two decades have drawn attention to global business cycle linkages among major economic regions. As Schneider and Fenz (2011, p. 2) have argued: "research interest focuses on the co-movement of fluctuations in the Euro area and the US." In this work, we focus on the transmission of debt shocks from the US to the EU15 economy and *vice versa*. As we know, the so-called European debt crisis has made it practically impossible for some countries in the Euro area to repay their debts. So, could the EU15 debt crisis threaten the US economy, or *vice versa*? Such questions have received renewed interest lately, and one important research question would be to study the conditions of the unwinding of such conditions.

[1] Another version of this chapter has been published as follows: Konstantakis, N. Konstantinos and Panayotis G. Michaelides (2014), Transmission of the Debt crisis: From EU15 to US or *vice versa*?, *Journal of Economics and Business,* 76(C): 115-132.

The VAR approach[2], and especially the Global VAR (GVAR) model, provide nowadays a useful framework for assessing the transmission of shocks.[3] The GVAR framework was introduced by Pesaran et *al.* (2004) and developed through several high quality theoretical contributions such as Pesaran and Smith (2006), Dées et *al.* (2007b) Chudik and Pesaran (2011a), (2011b) as well as empirical ones such as Dées et *al.* (2005), (2007a), Pesaran et *al.* (2006), Pesaran et *al.* (2007), Bussière et *al.* (2012).

The GVAR model is suitable for assessing relationships between economic entities while its methodology provides a general, yet practical, global modeling framework for the quantitative analysis of the relative importance of different shocks and channels of transmission mechanisms as opposed to the traditional VAR approach. In fact, it comprises a compact econometric model of the world economy which is specifically designed to explicitly model the economic and financial interdependencies at both the national and international level.

More specifically, the GVAR combines individual country/regional vector error-correction models, where the domestic variables are related to corresponding foreign variables that are constructed exclusively to match the international trade, financial or other, desired patterns of the economic entities under consideration. Then the individual country models are linked through a consistent econometric approach so that the GVAR model is solved for the world as a whole in contrast to traditional VAR methodology which is solved for a specific economic entity. Therefore, it can then be used to investigate the degree of interdependencies via impulse response analysis.

The GVAR framework is structured upon observables, which typically include macroeconomic aggregates and financial variables, with the country-specific foreign variables serving as a proxy for common unobserved factors. It is, thus, capable of providing estimates of the impact of a US Debt shock not only on US output, but also on output growth in EU15[4]. It is exactly this characteristic that constitutes an important input in the so-called "decoupling" of these two regions of the world.

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[2] See, for instance, the recent work of Valcarcel and Wohar (2013) who examined the changes in oil price inflation for the US economy using a Time Varying Structural VAR model in a Bayesian set up.

[3] The so-called factor augmented vector autoregressions (FAVAR) are often viewed as an alternative approach to GVAR (see e.g. Bernanke et *al.* 2005; Korobilis 2013a). However, the number of estimated factors used in FAVAR is different for different countries and it is not clear how they relate to each other globally (Dees et *al.* 2007a). In fact, Kapetanios and Pesaran (2011) argue that GVAR estimators perform better than the corresponding ones based on principal components. Also, for a Dynamic Structural VAR approach in the US economy see Valcarcel (2012).

[4] The GVAR model presented in this chapter is estimated with the EU15 being treated as a single economy, a choice which, according to Dees et *al.* (2005, p. 5) is "econometrically justified and allows us to consider the impact of external shocks on the euro area as a whole without the danger of being subject to

In this work, we build the empirical application of our approach on the USA and EU15 economies that produced together a little less than 50% of the world's economic output in 2012 (CIA, 2013). Also, our work estimates the link between output and debt fluctuations in the USA and the EU15, based on the global variables of trade and, especially, credit which act as the transmission channels. In fact, the related literature suggests that there are numerous channels through which the transmissions of shocks could take place, such as common observed global shocks, global unobserved factors, or even specific national/sectoral shocks. In this context see, *inter alia*, Stock and Watson (2002), while for a comprehensive analysis of the transmission of shocks among countries see, for example, Artis et *al.* (1997), Canova and Marrinan (1998), Clark and Shin (2000), Kose et *al.* (2003), Nobili and Neri (2006).

1.2 BACKGROUND LITERATURE

The investigation of the dynamics of debt as a crucial macroeconomic variable, both theoretically and empirically, has always been a key topic for many researchers around the globe. In fact, debt as a key macroeconomic variable as well as its linkages with other macroeconomic indicators was first presented in a seminal paper by Fisher (1933). Over the years a vast literature has emerged. See, for instance, Blinder and Solow (1975), Dixit (1976) and Feldstein (1976). Barro (1979) in a seminal contribution developed a debt theory that incorporated the Ricardian invariance theorem.

In the same time period, another strand of the literature made its appearance where debt repudiation is an option from the borrower and the limits to debt levels are determined by the optimum lending strategies. See, for instance, Eton and Gersovitz (1981), Cohen and Sachs (1986). Along this line, Krugman (1979) developed a model that incorporated the Balance of Payments in order to assess different fiscal policy scenarios and their consequences. In addition, Barro (1983), Aschauer (1985) and Hamilton (1985) using data for the US economy, tested the hypothesis that the present value budget must be balanced, along with a number of assumptions such as: (a) efficient market hypothesis and (b) optimality of both taxation and deficit policies in a historic perspective, in order for debt to be sustainable. In a another seminal paper, Krugman (1988) was among the

possible inconsistencies that could arise if the different economies in the euro area were modeled separately".

first to investigate the tradeoff of a country whose debt is large enough that cannot attract voluntary new lending. Giavazzi and Paggano (1990), having studied the case of Ireland and Denmark in the 80's, argued that large fiscal adjustments are more likely to lead to output expansion.

Bohn (1998) examined the long term conditions under which government debt is sustainable. Their model was estimated using US data and the results suggested that the US fiscal policy tended towards the satisfaction of the so-called inter-temporal budget constraint. A model that incorporated both fiscal and debt policy was introduced by Lockwood et *al.* (1996). Their model was tested for both US and UK economies, with the results being consistent with the theoretical predictions of the model. Giavazzi and Pagano (1996) investigated the effects of fiscal policies implemented in both consumption and taxation, for nineteen (19) OECD countries with the results suggesting that non-Keynesian effects make their appearance.

Optimal fiscal and monetary policy in an economy without capital was developed by Lucas et *al.* (1997) providing new insights on the dynamics between debt and other crucial macroeconomic variables. An empirical survey on fiscal adjustments, regarding OECD countries was undertaken in Alesina and Ardagna (1998). Aiyagari et *al.* (1998) investigated the welfare gains of an economy that has the optimum amount of debt. Their infinite horizon model was tested in the US economy shedding light on the outstanding debt of the US. Kaminsky and Reinhart (1999) provided evidence that debt overhanging is a by-product of the crisis that emerged primarily from the financial sector.

More recently, Feve et *al.* (2000) assessed the question of debt sustainability among G-7 countries. Their results showed that all debts in G-7 countries are sustainable. Giavazzi et *al.* (2000), using data on OECD countries, examined the existence of non linear effects in economies where some fiscal policy measures towards debt reduction have been taken. The results suggested that these non-linearities were present only when large structural fiscal policy plans were implemented. Aiyagari et *al.* (2002) showed that contingent-debt is an important feature for optimal policy under the "complete markets" assumption. Bravo and Silvestre (2002) examined the sustainability of debt according to the inter-temporal budget constraint hypothesis, in eleven (11) EU countries for the time period 1960-2000, with the results suggesting that Ireland, Portugal, Italy, Finland and Belgium are not in sustainable budget paths. Alfonso (2005) investigated the sustainability of debt in EU15 for the period 1970-2003. The results were alarming since the fiscal policies adopted in most countries were found to be sub-optimal leading to debt that is not sustainable.

Leight and Wrein-Lewis (2006) analyzed fiscal sustainability under a new Keynesian framework. An interesting finding was that in a steady state debt follows a random walk process. Afonso (2007) investigated the sustainability of fiscal policy in EU-15 countries and their results showed that certain countries could face potential sustainability problems. Greiner et *al.* (2007) investigated the debt sustainability of selected EU countries that had either large debt to GDP ratios or had violated the Maastricht treaty allowing for more that 3% deficit. Their results suggested that all deficits were sustainable. Arellano (2008) developed a model in a small open economy framework that could predict the relationships between output interest rates and debt that arises in economies that face recession. Reinhart and Rogoff (2010) investigated the link between inflation and both government and external debt showing that inflation is not connected to debt in developed countries. For a critique see Herndon et *al.* (2014). A comprehensive survey of the recent literature on fiscal and monetary policy as well as the dynamics of debt in an economy can be found in Eslava et *al.* (2010). Recently, Blundell (2013) investigated the EMU debt crisis[5] as well as the proposed policies in order to exit from the crisis and argued that EMU suffers from two distinct crises: debt and financial.

[5] A number of studies have investigated the European debt crisis. See, among others Attinasi et *al.* (2010); Ejsing et *al.* (2011)) and Antonini et *al.* (2013).

1.3 METHODOLOGY

a. GVAR Model

In this work, the Global VAR model consists of two (2) major economic entities, namely USA and EU15 that produced together a little less than 50% of the world's economic output in 2012 (CIA, 2013). Each country *i*, $i = 1, 2$ follows a VAR model, augmented by the exogenous variables of global trade (T) and finance (F), expressing the respective transmission channels. The endogenous variables x_{it} denote a 2×1 vector of macroeconomic variables belonging to each country *i*, consisting of Gross Domestic Product (GDP) and Debt (D). The foreign variables ${x^*}_{i,t}$ represent a weighted average of the other country's variables that are regarded to be weakly exogenous in each country's model, whose weights are pre-determined. Following common practice, the weights are equal to the trade shares (as % of total trade) of each country to the other. Mathematically, the VAR model for each country is:

$$\Phi_i(L, p_i)x_{it} = a_{i0} + \Lambda_i(L, q_i)x*_{it} + a_{i1}G_t + u_{it} \quad \textbf{(1.1)}$$

For $i = 1, 2 \; and \; t = 1 \dots T$ where x_{it} is the set of country domestic variables and $\Phi_i(L, p_i)$ is the matrix of lag polynomial of the associated coefficients; a_{i0} is a vector of fixed intercept; G_t is a set of the Global Variables and a_{i1} is a vector of their respective coefficients $x*_{it} = Wx_{it}$ is the set of weighted foreign variables and $\Lambda_i(L, q_i)$ is the matrix of lag polynomial of the associated coefficients. In this work, matrix W_i is a 2×2 dimensional matrix of weights that defines k_i=2 country-specific cross section averages of foreign variables. Finally, u_{it} is a vector of idiosyncratic, serially uncorrelated country-specific shocks with mean zero and the variance-covariance matrix Σi, $u_{it} \sim i.i.d(0, \sigma^2)$.

The implementation of the GVAR methodology has two steps. Firstly, each country's VARX model is constructed treating the Global Variables as exogenous. After the construction of each VARX model, we relate their corresponding estimates through link matrices by stacking them together to obtain our GVAR model. In particular, we consider the following model for country i:

$$x_{it} = a_{i0} + \Phi_{ip}x_{it-p} + \Lambda_{i0}x *_{it} + \Lambda_{iq}x *_{it-q} + a_{i1}G_t + u_{it} \quad \textbf{(1.2)}$$

To begin with, we group all foreign and domestic variables together as:

$$z_{it} = \begin{pmatrix} x_{it} \\ x *_{it} \end{pmatrix}$$

Therefore, for each country i the respective model becomes:

$$A_i z_{it} = a_{i0} + B_{i.\max\{p.q\}} z_{it} + +a_{i1}G_t + u_{it} \quad \textbf{(1.3)}$$

where: $A_i = (I, -\Lambda_{i0})$ and $B_{i,\max\{p,q\}} = (\Phi_{ip}, \Lambda_{iq})$.

By gathering all the domestic endogenous variables together, we define the following global vector $x_t = \begin{pmatrix} x_{1t} \\ x_{2t} \end{pmatrix}$ and we obtain the identity: $z_{it} = Wx_t \ \forall i = 1, 2,$ where W is the trade matrix. Thus, by using the former identity in the i-th country specific model, we get:

$$A_i W_i z_{it} = a_{i0} + B_{i,\max\{p,q\}} W_i z_{it-\max\{q,p\}} + a_{i1}G_t + u_{it} \quad \textbf{(1.4)}$$

By combining each country model with the later equation we obtain the GVAR:

$$Mx_t = a_{i0} + H_{i,\max\{p,q\}} x_{t-\max\{t,q\}} + +a_{i1}G_t + u_{it} \quad \textbf{(1.5)}$$

where $M = (A_i W_i)$ and $H_i = (B_{i,\max\{p,q\}} W_i)$.

If the M matrix is non-singular, then we obtain the reduced form of the GVAR model:

$$x_t = b_0 + F_{\max\{p,q\}} x_{t-\max\{p,q\}} + b_1 G_t + v_t \quad \textbf{(1.6)}$$

where: $b_i = M^{-1}a_i$. $F_i = M^{-1}H_i$ and $v_t = M^{-1}u_t$

Next, in order to provide a thorough analysis of the transmission mechanisms and, more precisely, of the predictive ability of the available financial variables expressing the transmission channels on GDP we test exactly this: whether the global financial variables of : (i) Credit and (ii) Stocks have predictive ability for each country's GDP. To this end, we conduct bi-variate pairwise Granger causality tests between: (i) Credit and (ii) Stocks and the GDP of the EU and the US economies, respectively.

In general, **t**he empirical investigation of (Granger) causality is based on the following general autoregressive model (Engle and Granger, 1987):

$$\Delta Y_t = a_0 + \sum_{i=1}^{m} a_{1i}\Delta Y_{t-i} + \sum_{i=0}^{n} a_{2i}\Delta X_{t-i} + \lambda\mu_{t-1} + \varepsilon_t \quad \textbf{(1.7)}$$

Where Δ is the first difference operator, ΔY and ΔX are stationary time series; ε_t is the white noise error term with zero mean and constant variance; μ_{t-1} is the lagged value of the error term of the co-integration regression:

$$Y_t = c_1 + c_2 X_t + \mu_t \quad \textbf{(1.8)}$$

through which causality could emerge. This model is appropriate only when co-integration is detected. If the variables are co-integrated, then the null hypothesis that X does not Granger-cause Y implies that all the coefficients a_{2i} and λ are equal to zero.

We examine the dynamic characteristic of our GVAR model through the so-called Generalized Impulse Response Functions (GIRFs) following Koop et *al.* (1996) and Pesaran and Shin (1998). Analytically, a positive standard error unit shock is examined on every variable in the universe of our model aiming at determining the extent to which each economic region, responds to a shock. Also, we study the extent to which these shocks have persistent effects.

The (Generalized) Impulse Response Function (GIRF) is as follows:

$$I_{j\,(n)} = \sigma_{jj}{}^{-1/2} + B_n \Sigma e_j \forall n = 1, 2, \ldots \quad \textbf{(1.9)}$$

where $I_{j\,(n)}$ is the Impulse Response Function *n* periods after a positive standard error unit shock; σ_{jj} is the *j*th row and *j*th column element of the variance–covariance matrix Σ of the lower Cholesky decomposition matrix of the error term which is assumed to be normally distributed; B is the coefficients' matrix when inversely expressing the VAR model as an equivalent MA process and e_j is the column vector of a unity matrix. See further Koop et *al.* (1996) and Pesaran and Shin (1998).

Of course, in order to ensure the soundness of our analysis a number of relevant tests need to be carried out.

b. Outliers

We start by testing for the existence of outliers using the Hadi (1992, 1994) test, which is based on the optimal formation of two distinct sample subsets using a four step algorithm according to the distance:

$$D_i(C_R, S_R) = \sqrt{(x_i - C_R)^T {S_R}^{-1}(x_i - C_R)} \quad \textbf{(1.10)}$$

where: $i = 1, \dots, n$ is the number of observations, x_i denotes the observations, C_R denotes the robust location estimator and S_R denotes the robust Covariance matrix estimator.

c. Stationarity

Next, we test for stationarity. In case the time series employed are not stationary, we induce stationarity following, among others, Koop (2013).

As we know, there are several ways to test for the existence of a unit root. In this chapter, we use the popular Augmented Dickey-Fuller (ADF) methodology (Dickey and Fuller, 1979) following Pesaran et *al.* (2004). The ADF test is based on the following regression:

$$\Delta Y_t = \alpha + bt + \rho Y_{t-1} + \sum_{i=1}^{m} \gamma_i \Delta Y_{t-1} + \varepsilon_\tau \quad \textbf{(1.11)}$$

where Δ is the first difference operator. t the time and ε the error term:

(a) if b≠0 and -1<ϱ<0 implies a trend stationary model;

(b) if b=0 and -1<ϱ<0 implies an ARMA Box/Jenkins class of models;

(c) if b=0 and ϱ=0 implies a difference stationary model where Y variable is integrated of degree one I(1).

d. Optimum Lag Length

We make use of the BIC (Schwartz, 1978) and the optimum lag length is given by the following objective function:

$$\hat{\xi} = argmin_{\xi \le n}\{-2\frac{\ln(LL(\xi))}{n} + \xi\frac{\ln(n)}{n}\} \quad \textbf{(1.12)}$$

where LL(ξ) is the log-likelihood function of a VAR(ξ) model, n is the number of observations and ξ is the number of lags and $\hat{\xi}$ is the optimum lag length selected.

e. Cointegration

We have to check for cointegration, since if cointegration is present then the Error Correction Terms have to be employed in the estimation of the GVAR model. We employ the popular Johansen (1988) methodology that allows for more than one cointegrating relationship, in contrast to other tests. The methodology is based on the following equation:

$$\Delta y_t = m + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + e_p \quad \textbf{(1.13)}$$

$$\text{where: } \Pi = \sum_{\iota=1}^{p} A_i - I \; and \Gamma_i = -\sum_{j=i+1}^{p} A_p$$

The existence of cointegration depends upon the rank of the coefficient matrix Π which is tested through the likelihood ratio, namely the trace test described by the following formulas:

$$J_{trace} = -T \sum_{i=r+1}^{k} \log(1-\lambda_i) \quad \textbf{(1.14)}$$

where: T is the sample size and λ_i is the largest canonical correlation.

The trace test tests the null hypothesis of $r<n$ cointegrating vectors and the critical values are found in Johansen and Juselius (1990). Also, having stationary variables in the system is not an issue according to Johansen (1995) as long as all the time series are integrated of the same order.

f. Weak Exogeneity Test

A main assumption of GVAR is the so-called weak exogeneity of the foreign variables x_{it}^*. Following Dees et *al.* (2007a) the following test can used.

$$\Delta x_{it}^* = \mu_i + \sum_{j=1}^{r_i} \gamma_{ij} ECM_{i,t-1}^j + \sum_{k=1}^{s_i} \varphi_{ik} \Delta x_{i,t-k} + \sum_{m=1}^{n_i} \theta_{im} \Delta \tilde{x}_{i,t-m}^* + e_{it} \quad \textbf{(1.15)}$$

where: $ECM_{i,t-1}^j, j = 1, .. r_i$ are the Estimated Error Correction terms corresponding to the r_i cointegrating relations of the i-th country in the model and $\Delta \tilde{x}_{i,t-m}^*$ are the global variables which are included in both models. The test of weak exogeneity is an F test of the joint hypothesis that $\gamma_{ij} = 0, j = 1, .. r_i$, where the lag orders s_i, n_i need not be the same with the lag orders of our two VARX models.

g. Asymptotic Properties

For the purpose of estimation and inference in stationary models, Chudik and Pesaran (2011a) showed that the relevant asymptotics are:

$$\frac{T}{N} \rightarrow k < \infty \quad \textbf{(1.16)}$$

h. Stability Conditions

Also, to determine whether the model is stable, we check the stability of the country-by-country models, separately. However, following Pesaran et *al.* (2002) and Mutl (2009) it is not sufficient to examine the country-by-country stability, ignoring the endogeneity of the other variables $x^{*}{}_{i,t}$. Hence, it does not suffice to require that $\varrho(\Phi_i) < 1$ for stability, where $\rho(\Phi_i)$ is the spectral radius of the matrix $\Phi_i, i = \{US, EU15\}$. Instead, Mutl (2009, p. 9) derived a sufficient condition for the model to be stable, namely that the maximum absolute row sums of W are less or equal to k_w, that is:

$$\|W\|_1 \leq k_w \quad \textbf{(1.17)}$$

where k_w is the uniform bound of absolute row and column sums of the weight matrix W:

$$\sum_{j=1}^{1} \sum_{m=1}^{k} \left| w_{ij,qm} \right|_1 \leq k_w < \infty \quad \textbf{(1.18)}$$

where k_w does not depend on T or N and the choice of indexes *i* and *q*, but can potentially depend on other parameters of the model; and $w_{ij,qm}$ denotes the (q,m)-th element of W_{ij}.

Finally, note that if r is the maximum number of eigenvalues of Φ, then according to the fundamental algebraic theorem, r$\leq rank(\Phi)$.

1.4 EMPIRICAL ANALYSIS

a. Data and Variables

The data are quarterly, and cover the time period 2000 (Q1)–2011 (Q4), fully capturing the recent global recession. The model incorporates two (2) country-specific variables: GDP and Debt ratio that were obtained from the Federal Reserve Bank of St. Louis and Eurostat, respectively, for the two economic regions, USA and EU15. Regarding the global variables, we use the aggregate values of (i) *Worldwide Total Trade* and also (ii-a) *Worldwide Total Credit,*(ii-b) *Worldwide Total Stocks,* both in millions of dollars, which were obtained in constant prices from the World Data Bank[6]. The trade weights (see Table A2, Appendix) are computed using data gathered from the United States Census Bureau (2001-2011). In this context, Table 1.1 summarizes the data used as well as the techniques implemented.

Table 1.1: Summary of Data and Techniques

ECONOMETRIC TECHNIQUE	VARIABLES	PERIOD	DATA LENGTH/ SOURCE
Hadi Outliers test	GDP, DEBT (EU15 USA)	2000-11	QUARTERLY/EUROSTAT
	CREDIT, STOCKS, TRADE (WORLD)	2000-11	QUARTERLY/WORLD DATA BANK
UnitrootTest-ADF	GDP, DEBT (EU15, USA)	2000-11	QUARTERLY/FEDERAL RESERVE BANK, EUROSTAT
	CREDIT, STOCKS, TRADE (WORLD)	2000-11	QUARTERLY/WORLD DATA BANK
Detrending	GDP, DEBT (EU15, USA)	2000-11	QUARTERLY/FEDERAL RESERVE BANK, EUROSTAT
	CREDIT, STOCKS, TRADE (WORLD)	2000-11	QUARTERLY/WORLD DATA BANK
Cointegration-Johansen	GDP, DEBT (EU15, USA)	2000-11	QUARTERLY/FEDERAL RESERVE BANK, EUROSTAT
VAR	GDP, DEBT (EU15 USA)	2000-11	QUARTERLY/EUROSTAT
	CREDIT, STOCKS, TRADE (WORLD)	2000-11	QUARTERLY/WORLD DATA BANK
Weak Exogeneity	GDP, DEBT (EU15, USA)	2000-11	QUARTERLY/FEDERAL RESERVE BANK, EUROSTAT
GVAR	GDP, DEBT (EU15, USA)	2000-11	QUARTERLY/FEDERAL RESERVE BANK, EUROSTAT
	CREDIT, STOCKS, TRADE (WORLD)	2000-11	QUARTERLY/WORLD DATA BANK
Causality-Granger	GDP, DEBT (EU15, USA)	2000-11	QUARTERLY/FEDERAL RESERVE BANK, EUROSTAT
	CREDIT, STOCKS, TRADE (WORLD)	2000-11	QUARTERLY/WORLD DATA BANK

[6] Whenever quarterly data were missing, the series were interpolated from the annual series following Dees et *al.* (2005).

b. Results

As we have seen, a number of tests need to be carried out. We start by testing for outliers in our sample using the Hadi (1992, 1994) test. See Table 1.2.

Table 1.2: Hadi (1992, 1994) Outliers Test

Variables	GDP US	DEBT US	GDP EU	DEBT EU
Number of Obs	47	47	47	47
Initialy Accepted	2	2	2	2
Expand to (n+k+1)/2	24	24	24	24
Expand p-value=0.01	45	47	41	47
Outliers	2	0	6	0
Excluded observations	**2008 (Q4), 2009 (Q1)**		**2008 (Q2), 2008 (Q3) 2008 (Q4), 2009 (Q1) 2009 (Q4), 2011 (Q4) 2011 (Q2)**	

The results suggest that six (6) observations should be removed from our sample. We then proceed to stationarity testing based on the ADF methodology following Pesaran et *al.* (2004). The original time series were found to be non-stationary, see Table 1.3.

Table 1.3: ADF test results (original variables)

Variable	Country	p-value	Stationarity
GDP	**USA**	0.44	No
GDP	**EU-15**	0.24	No
DEBT	**USA**	0.99	No
DEBT	**EU-15**	0.99	No
TRADE	**WORLD**	0.92	No
CREDIT	**WORLD**	0.93	No
GDP*	**USA**	0.28	No
DEBT*	**USA**	0.99	No
GDP*	**EU-15**	0.32	No
DEBT*	**EU-15**	0.99	No

Table 1.4: ADF test results (First differences)

Variable	Country	p-value	Stationarity
GDP	**USA**	0.00	Yes
GDP	**EU-15**	0.00	Yes
DEBT	**USA**	0.00	Yes
DEBT	**EU-15**	0.00	Yes
TRADE	**WORLD**	0.00	Yes
CREDIT	**WORLD**	0.00	Yes
GDP*	**USA**	0.00	Yes
DEBT*	**USA**	0.00	Yes
GDP*	**EU-15**	0.00	Yes
DEBT*	**EU-15**	0.00	Yes

In fact, all the variables were found to be I(1). Thus, stationarity was induced by means of first differencing. The ADF results of the detrended data suggest that all variables are stationary. See Table 1.4. Furthermore, given that the system is stationary, our model complies with the asymptotics derived in Chudik and Pesaran (2011) since $T/N < \infty$.

In order to determine which variable, namely: (a) Worldwide Total Credit (b) Worldwide Total Stocks should be used as the expression of the global financial transmission channel we employed causality tests for the specification of our GVAR model, so as to assess each variable's predictive ability for the explanation of our endogenous variables, namely GDP and Debt. Given that these two variables (Credit and Stocks) are highly correlated, they offer redundant information and their simultaneous use could cause serious estimation problems, such as multicollinearity. As a result, only one of them should be used as an expression of the transmission channel of global finance. In this context, bi-variate pair-wise Granger causality tests between the endogenous and the exogenous global variables of: (a) Credit and (b) Stocks were conducted, respectively, as follows:

$$\Delta GDP_{i,t} = a_0 + \sum_{j=1}^{m} a_{1,j} \Delta GDP_{i,t-j} + \sum_{k=0}^{n} a_{2,k} \Delta F_{t-k} + \varepsilon_t \quad \textbf{(1.19)}$$

$$\Delta DEBT_{i,t} = a_0 + \sum_{j=1}^{m} a_{1,j} \Delta DEBT_{i,t-j} + \sum_{k=0}^{n} a_{2,k} \Delta F_{t-k} + \varepsilon_t \quad \textbf{(1.20)}$$

where $F = \{Stocks,\ Credit\}$.

For lag selection purposes, we make use of SBIC, whose values have been calculated for lengths up to twelve (12) lags. The results are presented in Table 1.5 and suggest that the explanatory power of Global Domestic Credit is higher than that of Value of Stocks Traded Globally, since the later is causal only for Debt US while Global Credit is causal for both Debt US and EU-15. This is a clear indication that Global Credit is more appropriate for use in our GVAR model, representing the financial transmission channel between the two economies.

Table 1.5: Pairwise Granger Causality

Hypothesis	Lags	Obs	F-statistic	p-value
Credit *does not Granger cause* GDP US	5	40	0.72	0.61
Credit *does not Granger cause* DEBT US	1	44	7.03	0.01*
Credit *does not Granger cause* GDP EU-15	5	40	0.33	0.89
Credit *does not Granger cause* DEBT EU-15	5	40	2.55	0.05*
Stocks *does not Granger cause* GDP US	2	43	0.92	0.4
Stocks *does not Granger cause* DEBT US	2	43	4.82	0.01*
Stocks *does not Granger cause* GDP EU-15	3	42	0.69	0.56
Stocks *does not Granger cause* DEBT EU-15	2	43	0.3	0.74
Trade *does not Granger cause* GDP US	2	43	0.88	0.42
Trade *does not Granger cause* DEBT US	6	39	2.89	0.02*
Trade *does not Granger cause* GDP EU-15	4	41	1.14	0.35
Trade *does not Granger cause* DEBT EU-15	4	41	2.95	0.03*

* statistically significantat at the 5% level or higher

The fact that Global Domestic Credit has predictive ability for the evolution of the Debt variables, in the two economies, is consistent with the work of Bayoumi and Mellander (2008) and Dedola et *al.* (2010). In fact, according to Catao et *al.* (2008), the causal relationship between Credit and Debt could be attributed to the fact that as credit risk rises, debt deteriorates.

Next, since the different variables of EU and USA were found to be I(1) we tested for the existence of cointegration rank up to one vector using the methodology presented in the previous section.Table 1.6 summarizes the results of the Johansen test.

Table 1.6: Johansen Test for Cointegration (rank k)

US variables					
Maximum Rank	**Log-Likelihood**	**Eigenvalue**	**Trace statistic**	**5% critical value**	**Cointegration**
0	-1181.09		12.57	15.41	No
1	-1175.96	0.19	2.31	3.76	No
2	-1174.8	0.05			
EU15 variables					
Maximum Rank	**Log-Likelihood**	**Eigenvalue**	**Trace statistic**	**5% critical value**	**Cointegration**
0	-1167.02		6.91	15.41	No
1	-1163.58	0.14	0.05	3.76	No
2	-1163.54	0.01			

The results suggest that no cointegration is present in either of the economies, which is consistent with the findings of Kim (2013), leading us to apply the GVAR methodology using a VARX model for each economy with stationary variables, i.e. the first differences of the original variables enter the VARX model of each economy. The optimum lag length for each country model was chosen using the SBIC (Table A1, Appendix). The results for both the US and EU15 economy suggest that one (1) lag should be included in their VARX model. Therefore, the VARX model for each economy is as follows:

$$\begin{pmatrix} \Delta GDP_{i.t} \\ \Delta DEBT_{i,t} \end{pmatrix} = a_{i,0} + \Phi_i \begin{pmatrix} \Delta GDP_{i.t-1} \\ \Delta DEBT_{i,t-1} \end{pmatrix} + \Lambda_{i0} \begin{pmatrix} \Delta GDP_{i.t}{}^{*} \\ \Delta DEBT_{i,t}{}^{*} \end{pmatrix} + \Lambda_{i1} \begin{pmatrix} \Delta GDP_{i.t-1}{}^{*} \\ \Delta DEBT_{i,t-1}{}^{*} \end{pmatrix} + A_i \begin{pmatrix} \Delta TRADE_t \\ \Delta CREDIT_t \end{pmatrix} + u_i \quad \textbf{(1.22)}$$

where: Δ is the first difference operator; $i = \{US, EU15\}$; a_{i0} is a vector of fixed intercept; Φ_i is the matrix of lag polynomial of the associated coefficients of endogenous variables; Λ_{i0} is a matrix of coefficients for the foreign variables; Λ_{i1} is a matrix of lag polynomial coefficients for the foreign variables; A_i is a matrix of coefficients for the Global Variables, while u_i are the idiosyncratic shocks which are assumed to be serially uncorrelated country-specific shocks with mean zero and the variance-covariance matrix Σi, $u_{it} \sim i.i.d(0, \sigma^2)$.

Next, we implement the GVAR methodology set out earlier using the following vectors:

$$x_{i,t} = (\Delta GDP_{i,t}, \Delta DEBT_{i,t})$$

$$x_{i.t}^{*} = (\Delta GDP_{i.t-p}{}^{*}, \Delta DEBT_{i,t-p}{}^{*})$$

$$G = (\Delta TRADE_t, \Delta CREDIT_t)$$

where: Δ is the first difference operator; $i = \{EU15, US\}$ are the economies that are included in the GVAR model and $p = 1$ is the lag length of the foreign variables.

The effect of the foreign variables in their country specific counterpart is presented in Table 1.7.

Table 1.7: Effect of foreign variables on their country specific counterparts

	GDPEU	DEBTEU
US	0.10	-2.63
t-stat	0.14	-2.64*
	GDPUS	**DEBT US**
EU	0.73	1.33
t-stat	1.94**	3.25*
* statistically significant at the 5% level or higher ** statistical significant at the 10% level or higher		

We can see that the EU15 GDP does not affect significantly the US GDP. Nevertheless, the EU15 debt affects statistically significantly the US Debt, whereas both US Debt and GDP affect positively their European counterparts, which implies that the evolution of the EU15 GDP is strongly related to its US counterpart, suggesting that a shock in US GDP (e.g. the recent US credit crunch) will affect the EU15 economy. See also Kalemli-Ozcan et *al.* (2011), Aizenman et *al.* (2010) and Dooley (2009).

In other words, the EU15 variables seem more vulnerable to changes in their US counterparts. This, in turn, is consistent with a vast part of the literature suggesting the transmission of the US crisis to EU15. Also, the fact that US Debt and EU15 Debt have a statistically significant relationship suggests that a shock in US Debt is transmitted to EU15 through the international financial channels of finance via the mechanics of Credit (Chudic et *al.,* 2011, de Haas and Klonbloch 2011). Our findings imply that a shock in EU15 debt will affect negatively the evolution of US Debt. These findings could be attributed to the high degree of openness of the two economies as well as to the financial integration of their banking sectors.

We will base our detailed analysis of Generalized Impulse Response Function (GIRFs) and, more precisely, on the robust confidence bands (bootstrapped, 10.000 iterations) rather than the point estimates in order to avoid any possible structural instability. Also, we ensure the robustness of our GIRFs results to the trade weights.[7] Each GIRF shows the dynamic response of the variable of each region to unit shocks to: (i) EU15 Debt and (ii) US Debt, of up to 16 periods, i.e. 4 years.

[7] To this end, according to Dees et *al.* (2007a), the three-year rolling moving averages of the annual trade weights were calculated and the measure between these two expressions in terms of correlation was very high, a fact which is a clear indication of the robustness of our results to the choice of the weights. After all, as denoted in Dees et *al.* (2005), a structural break analysis within the GVAR framework would be impossible.

In the exposition of the results, the reader can focus on the first two years following the shock, which is a reasonable time horizon over which the model presents credible results (Dees et *al.,* 2007a). However, according to the same authors, in what follows we provide an analysis of the results over a period of four years, since visual inspection of the results help us with the analysis of the proposed model's convergence properties. Figures 1.1-1.2 shows the estimates of the GIRFs and their associated 95% confidence intervals.

Figure 1.1: US GIRFs

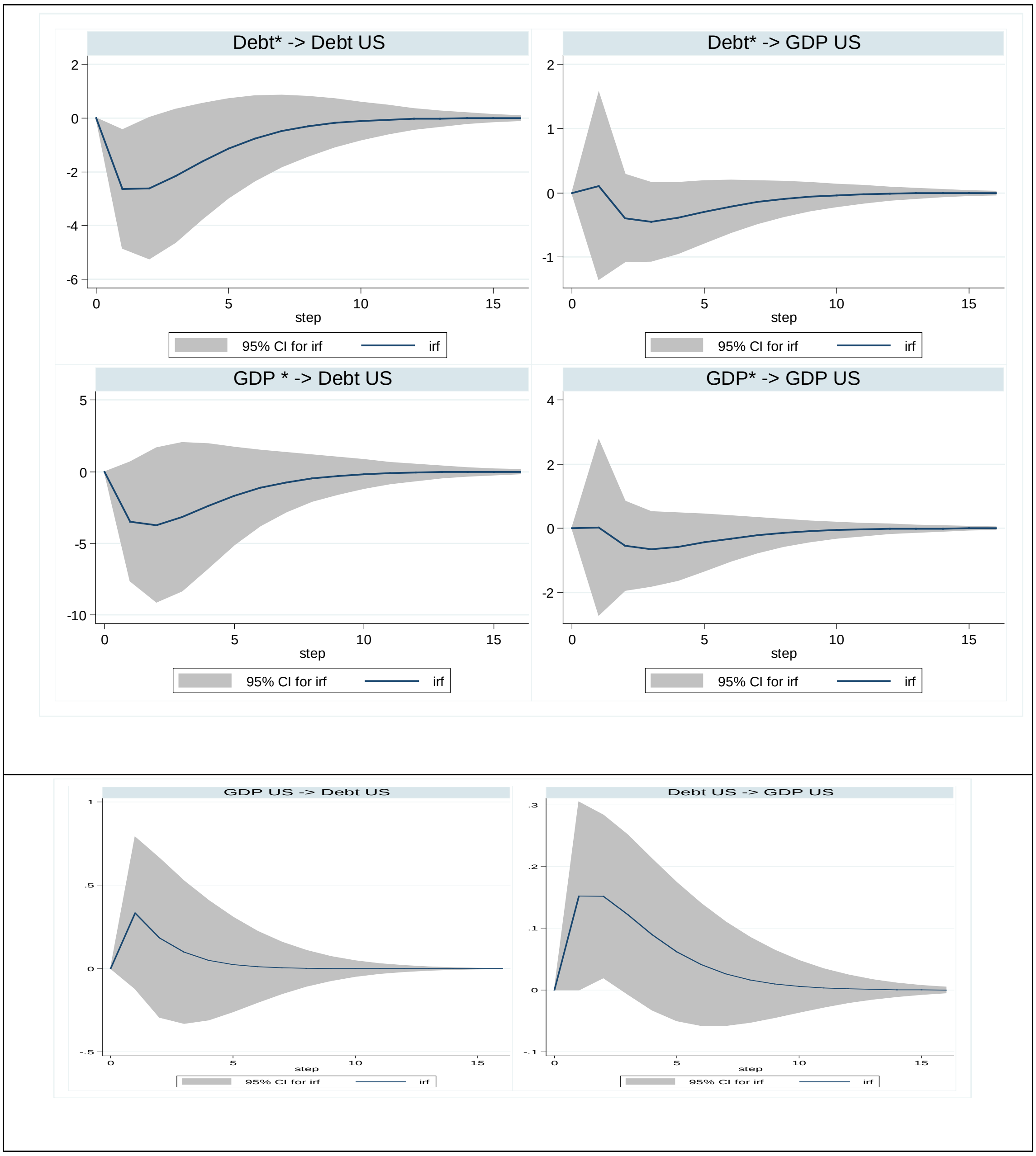
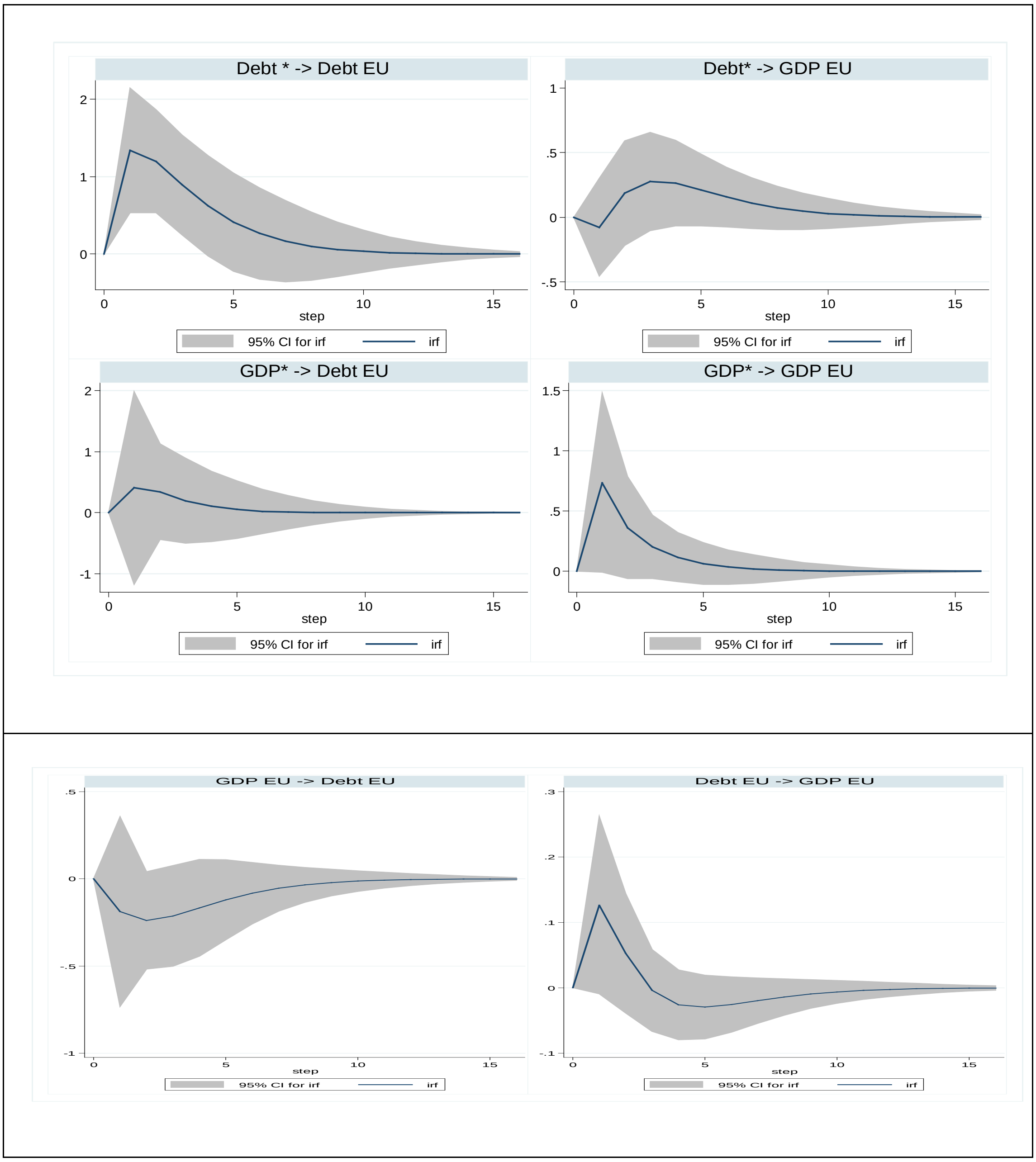


Figure 1.2: EU15 GIRFs



Regarding the GIRFs' figures, we can see that they settle down relatively quickly, a fact which implies that the model is stable and is supported by the eigenvalues of the GVAR model whose modulus is less that unity. See Tables 1.8 and 1.9. Also, we controlled for the sufficient condition of the model as stated earlier which was satisfied.

Table 1.8: Stability Test VARX US

	Root	Modulus
1	0.59+0.09i	0.59
2	0.59-0.09i	0.59
3	0.11	0.11
4	0.01	0.01

Table 1.9: Stability Test VARX EU15

	Root	Modulus
1	0.60+0.10i	0.60
2	0.60-0.10i	0.60
3	0.12	0.12
4	0.03	0.03

The general picture of the GIRFs results is that the response of most variables to various shocks die out in the medium run, namely in less than 12 quarters, i.e. 3 years, becoming statistically non-significant after several months or years.

1.5 DISCUSSION

In detail, the results of the GIRFs suggest that a shock in EU15 GDP affects negatively the EU15 debt in the short run since the effect dies out in less than 8 quarters. On the other hand, a shock in EU15 debt affects positively in the short run EU15 GDP, while its effect also dies in approximately 8 quarters. Nevertheless, these effects do not seem to have a statistical significant impact.

A shock in US Debt affects positively both the EU15 GDP and EU debt since both variables diverge from their equilibrium position. This effect is significant in the medium run since in less than 10 quarters both variables return back to their equilibrium position. In addition, according to the robust confidence interval, US Debt affects significantly EU15 Debt in the short run implying that EU15 debt is directly affected by the US debt a fact highlights the vulnerability of EU15 Debtin changes on its US counterparts.

EU15 Debt and GDP are positively affected by a shock in the US GDP. The effect on both variables dies out in less than 5 quarters. Our findings are in line with the work of Osborn et *al.* (2005) who argued that the US growth rates have positive impacts on several European economies, while Perez et *al.* (2003) found that the US economy leads the German economy, which is the locomotive of EU15. Therefore, it is natural to expect that the EU15 GDP would be affected by its US counterpart. This impact of the USA on EU15 variables implies that a transmission mechanism is in place between the two economies (Brutti, 2011).

A shock in the US GDP has a positive effect on US Debt in the short run since in less than 5 quarters. In addition, a shock in US debt has a positive impact on the evolution of US GDP in the medium run, since the effect dies out in approximately 10 quarters. Additionally, according to the robust confidence bands the effect of US Debt seems to be statistically significant while there is only weak evidence in favor of the effect of US GDP on the evolution of US Debt.

Furthermore, EU15 GDP affects negatively both US Debt and GDP in the short run since both variables return to their long run equilibrium position in less than 5 quarters. Again, there is only weak statistical evidence in favor of these effects.

Lastly, EU15 Debt affects positively the US GDP and negatively the US Debt in the short run since both effects die out in less than 5 quarters. Nevertheless, these effects do not seem to have a statistically significant effect according to the confidence intervals, suggesting that EU15 variables are unable to significantly affect any of the US variables.

In general, in both countries we do not detect any factor that could create a long lasting effect. Nevertheless, the economy of EU15 seems to be connected with that of US since a shock to US Debt is transmitted to EU15 Debt and not *vice-versa*. This fact is consistent, among others, with the work by Michaelides and Papageorgiou (2012) and Michaelides et *al.* (2013) and can be attributed to the role of US economy over the last decades to dictate global demand. This, obviously, suggests that the transmission of a debt crisis from US to EU15 takes place, since EU15 is more vulnerable to shocks in the US economy probably due to the fact that it lacks the federal structure and, thus, the adaptive ability of the US economy to external shocks.

1.6 CONCLUSION

In this chapter, we checked for the direction of the transmission of the so-called debt crisis between the USA and the EU-15 economies, using the GVAR approach. Our work identified and estimated the link between output and debt fluctuations in the USA and the EU15 based on the global variables of Trade and Credit, which act as the transmission channels that have been documented in the literature as being the most important.

In general, in both countries we do not witness any factor that could create a long lasting effect in their key macroeconomic variables. The results suggest that EU-15 is more vulnerable to incoming shocks from US, since the reaction of its macroeconomic variables examined is less smooth and more lasting compared to those of the US. The difference in the smoothness of the response between the two economies can be attributed to the fact that in the USA the Federal Reserve Bank reacts more effectively to the incoming shocks by implementing both monetary and fiscal adjustments. In contrast, the EU15 fiscal policy is implemented at a country-to-country level, while monetary policy is implemented by ECB at an aggregate level, thus, coordination problems could arise.

Now, regarding the differences in the time horizon of the effect of the shocks between the two economies, a possible explanation could be that monetary policy in EU15 is more time consuming than in the USA, due to its aggregate character. Nevertheless, the economy of EU15 seems to be connected with that of US since a shock to US Debt is transmitted to EU15 Debt and not *vice-versa*. Evidently, this result shows that the sovereign EU15 debt crisis cannot be transmitted to the USA, unlike the financial crisis of 2007 that was transmitted to EU15.

Our findings are in line with the work of Osborn et *al.* (2005) who argued that the US growth rates have positive and significant impacts on several EU economies, while Perez et *al.* (2003) found that the US economy leads the German economy, which is the locomotive of EU-15 GDP. In general, vulnerability of EU15 Debt to US Debt implies that a one way transmission mechanism is in place between the two economic regions which is partly consistent with the findings of Brutti (2011). Moreover, regarding the effects of Global variables of the model that represent the transmission channels of the crisis, Global Domestic Credit seems to dictate the evolution of both Debt variables in the two economies. This result is consistent with the work of Bayoumi et *al.* (2008) and Dedola et *al.* (2010), while according to Catao et *al.* (2008) the relationship between Credit and Debt could be attributed to the fact that as credit risk rises debt deteriorates. In a similar manner, Global trade also seems to dictate the evolution of both Debt of US and EU-15 leaving their GDP components unaffected, which is in line with the works of Broda et *al.* (2003) and Min (1988).

Chapter 2: Crisis Transmission in the World Economy[8]

So far, we have seen that the EU economy is more vulnerable to shocks, compared to the US economy. In this context, we examine the dynamic interdependencies among all the major economic entities in the global economy. Due the fact that the dynamics of the traditional economic structures have changed dramatically in the US and globally after 2006, the need for modeling complex macroeconomic interactions, has led us to develop an upgraded compact global (macro)econometric model, which is capable of incorporating both the complex interdependencies that exist between the various economic entities and the fact that in the global economy more than one of these entities could have a predominant role, without of course neglecting the channels of trade and finance. We demonstrate the dynamics of our model by focusing on the impact of a potential slowdown in the BRICs on the US and EU17 economies.

2.1 INTRODUCTION

Over the last years, we are in the middle of a devastating global crisis that has significantly affected the economic conditions of the two major economic regions of the world, USA and EU17. According to the World Economic Outlook (2013), the IMF cut its global GDP forecast to 3.1% from 3.3%, since growth in advanced economies was trimmed from 1.3% to 1.2%, due to both the EU17 and the US weakness, while emerging markets growth was cut by 0.3 % to 5%. In this context, the so-called BRICS account for about 20% of world GDP and 55% of the output of emerging and developing economies (World Economic Outlook, 2013). Nevertheless, the impact of a potential slowdown of BRICs on other major economies (e.g. US, EU) has attracted limited attention in the literature, so far.

[8] Another version of this chapter has been published as follows: (i) Konstantinos N. Konstantakis, Panayotis G. Michaelides, Efthymios G. Tsionas and Chrysanthi Minou (2015), System estimation of GVAR with two dominants and network theory: Evidence for BRICs, *Economic Modelling*, 51: 604-616; and (ii) Efthymios G. Tsionas, Konstantinos N. Konstantakis and Panayotis G. Michaelides (2016), Bayesian GVAR with k- Endogenous Dominants & Input-Output Weights: Financial and Trade Channels in Crisis Transmission for BRICs, *Journal of International Financial Markets Institutions and Money,* 42(C): 1-26.

In this chapter, we attempt to shed light on the impact of BRICs[9] on the two major economic regions of EU17 and US. Of course, when attempting to model the complex interdependencies between the emerging economies of BRICs and the major economies of US and EU one should not neglect neither the predominant role of US and EU in the global economy, nor the fundamental channels of trade and finance that are hailed to be the most important channels of transmission (e.g. Cetorelli and Goldberg 2011).

In this context, the GVAR approach, introduced by Pesaran et *al.* (2004), would be a relevant tool for the analysis of such complex dynamics. In the GVAR framework, it is widely accepted that the US could be considered as being a dominant economy in the model (Chudik and Pesaran, 2013). Nevertheless, the use of the US economy as the only dominant unit in the GVAR model is an *ad-hoc* approach that is, thus far, justified solely based on economic intuition, as opposed to formal quantitative and econometric methods. To this end, there are two predominant research questions on the topic of dominant units in a GVAR framework: (a) is the USA indeed dominant according to formal methods? (b) Is there any other dominant economy in the model, and to what extent the introduction of a second dominant unit in a GVAR framework will affect the implied results of the model?

To this end, in this chapter we construct an upgraded compact (macro)econometric model that incorporates both the complex interdependencies that exist between the various economic entities and the fact that in the global economy more than one of these entities could have a predominant role. In this context, we modify the GVAR model featuring one dominant economy, introduced by Chudik and Pesaran (2013) so as to be able to accommodate more than one dominant entities. Additionally, based on the trade weight matrix that lies in the core of the GVAR framework, we provide both an analytical procedure and an *ex-post* criterion for the selection of the dominant entities.

The present chapter contributes to the literature as follows: (a) it proposes system estimation for the GVAR with K dominants; (b) it formally estimates a GVAR with two (2) dominant economies; (c) it sets out a formal method for identifying the number of

[9] For a thorough discussion on the BRIC economies and their complex dynamic interdependencies see *inter alia* Cakir and Kabundi (2013), Allegret and Sallenave (2014), and Dreger and Zhang (2014).

dominant entities in a GVAR framework; (d) it sets out a novel method based on network theory for selecting the dominant entities; (e) it compares the estimation results of GVAR using one dominant and two dominant economies, respectively; (e) it estimates how a slowdown in the BRICS will affect EU17 and USA.

The remainder of the chapter is structured as follows: Section 2 sets out the proposed methodology; Section 3 presents the empirical results; Section 4 provides a brief discussion of the main results; Section 5 concludes.

2.2 METHODOLOGY

The Global VAR approach (GVAR) provides a flexible technique for assessing relationships between economic variables and constitutes a useful tool for analyzing the transmission of shocks between economic regions. While factor augmented vector autoregressions (FAVAR) could be viewed as an alternative approach to GVAR (see e.g. Bernanke et *al.,* 2005; Laganá and Mountford, 2005), the number of estimated factors used in FAVAR would be different for the different countries and it is not clear how they relate to each other globally, according to Dees et *al.* (2007a).[10]

The present work builds on the work introduced by Pesaran et *al.* (2004) and developed through several contributions. For instance, Pesaran and Smith (2006) showed that the VARX* models could be derived as solutions to a DSGE model. Dées et *al.* (2007b) presented tests for controlling for the long-run restrictions. Furthermore, Chudik and Pesaran (2011) derived the conditions under which the GVAR approach is applicable in a large system of endogenously determined variables. Also, the GVAR model was applied to a variety of research questions, such as the international linkages of the euro area (Dées et *al.,* 2005, 2007a), a credit risk analysis (Pesaran et *al.,* 2006), the construction of measures of steady-state of the global economy (Dées et *al.,* 2009), an analysis of the UK's and Sweden's decision not to join EMU (Pesaran et *al.,* 2007), the application of the GVAR approach to the issue of international trade and global

[10] In this spirit, see Kapetanios and Pesaran (2007) who argue that GVAR estimators perform better than the corresponding ones based on principal components. Also, Korobilis (2013a) proposed a FAVAR model with time-varying coefficients and stochastic volatility whose coefficients and error covariances change gradually over time or are subject to abrupt breaks. His model showed that both endogenous and exogenous shocks to the US economy resulted in high inflation volatility during the 1970s and '80s.

imbalances in Greenwood-Nimmo et *al.* (2010), Bussière et *al.* (2012), Konstantakis and Michaelides (2014).

Furthermore, until recently, each country was treated in a "small economy" framework (Schmitt-Grohe and Uribe, 2003). There the idea was that all foreign economies are typically approximated by one representative economy constructed as a weighted average of foreign economies, while the rest of the countries' aggregate variables are generally treated as exogenous to the home economy. However, Chudik and Straub (2011) demonstrated recently that such an approach is justified only if no country is dominant. In a similar vein, recently Chudik and Smith (2013), following Chudik and Pesaran (2013), derived a GVAR approach as an approximation to an Infinite-Dimensional VAR (IVAR) model corresponding to the world featuring one dominant economy, i.e. the USA.

a. The System GVAR Model

Consider a GVAR with $i = 1, \dots, N$ small open economies and $k = 1, .., K$ large economies. The VARX model of each small open economyas we have seen is:

$$y'_{i,t} = a_{i0} + \Phi(L_1)y'_{j,t} + \Phi(L_2){y'_{i,t}}^{*} + \Phi(L_3)g'_{i,t} + u_{i,t}, j\epsilon\{1, .., N, N+1, \dots N+k\} \quad \textbf{(2.1)}$$

where a_{i0} denotes a $(1xm)$ vector of m intercepts, $y'_{i,t} = [y_{i_1,t}, \dots, y_{i_m,t}]$ denotes the transpose of a $(1xm)$ vector $y_{i,t}$ of m variables for each economy $i = 1, .., N$ expressing the country specific variables; $y'_{j,t} = [y_{i_1,t}, \dots, y_{i_m,t}, y_{i_{k_1},t}, \dots, y_{i_{k_m},t}, \dots, y_{i_{k_K},t}, \dots, y_{i_{k_K},t}]$ denotes the transpose of a $((m + Km)x1)$ endogenous variables. The m endogenous variables are augmented by the km variables of the dominant entities, and $\Phi(L_1)$is the $((m + Km)xL_1)$ matrix of the associated lag polynomial; ${y'_{i,t}}^{*} = [{y_{i_1,t}}^{*}, \dots, {y_{i_m,t}}^{*}]$ denotes the transpose of a $(mx1)$ vector ${y^{*}}_{i,t}$, of m foreign-specific variables for each economy $i = 1, \dots, N-1$ and $\Phi(L_2)$ is an (mxL_2) matrix of the associated lag polynomial; $g'_{i,t} = [g_{i_1}, \dots, g_{i_p}]$ denotes the transpose of a $(px1)$ vector of p global variables for each economy $i = 1, .., N$ while $\Phi(L_3)$ is an (pxL_3) matrix of the associated lag polynomial. In general, m and p may be allowed to vary between economies.

Traditionally, each country VAR is estimated and then the endogenous variables are stacked together and solved. However, this is not always expected to approximate reality very satisfactorily, since the models interact simultaneously through the dominant variables incorporated in all models as well as through the possible existence of global variables. Hence, it is reasonable to assume that: $Cov(u_{i,t}, u_{c,t}) \neq 0 \ \forall i \neq c$, i,c=1,...,N since the variables of the dominant entities and of the global variables clearly act as common regressors. By grouping together the $y_{i,t}$ for the $i = 1, \ldots, N$ small open economies, except for the variables that correspond to the dominant entities, we get:

$$B_i y_{i,t} = \Gamma z_{\xi,t} + u_i \ \textbf{(2.2)}$$

where: $B_i = (I; -\Phi(L_1))$, is a $(1xmL_1)$ vector of coefficients of the country's $i = 1, \ldots, N$ specific variables; $z_{\xi,t} = \left[y_{i_1,t}{}^*, \ldots, y_{i_m,t}{}^*; y_{i_{k_1},t}, \ldots, y_{i_{k_m},t}, y_{i_{K_1},t}, \ldots, y_{i_{K_m},t}; g_{i_1}, \ldots, g_{i_p}\right]$ is the transpose of a $(1xM)$ vector of variables, $M = L_2 mk + L_3 p + 2$; while Γ_i is a (Mxm) matrix of coefficients and $u_i' = [u_{1,t}, \ldots, u_{N,t}]$ is a $(1xN)$ vector of idiosyncratic shocks such that $u_i \sim N(0, \Sigma_{ii})$ where the covariance of the error term is:

$$\begin{pmatrix} u_{1,t}{}' \\ \vdots \\ u_{N,t}{}' \end{pmatrix} \sim N(0, \Omega = \begin{pmatrix} \Sigma_{11}\Sigma_{12} \ \ldots \Sigma_{1N} \\ \Sigma_{21}\Sigma_{22} \ \ldots \Sigma_{2N} \\ \ldots \\ \Sigma_{N1}\Sigma_{N2} \ \ldots \Sigma_{NN} \end{pmatrix})$$

and each Σ_{il}, represents a covariance matrix between the error terms of countries i and l, $i, l = 1, \ldots, N$.

For the foreign-specific variables:

$$y_{i,t}{}^{*\prime} = \sum_{c=1}^{N} w_{i,c} y_{c,t}{}' = w_i Y_t \ \textbf{(2.3)}$$

w_i represents the vector of trade weights of country i with countries $c \neq i, i = 1, .., N-1, w_{ii} = 0$. If B_i is non-singular, the GVAR model of the small open economies is:

$$y_{i,t} = \Delta_i z_{\xi,t} + v_i{}', i = 1, \ldots, N \ \textbf{(2.4)}$$

where: $\Delta_i = \Gamma_i B_i^{-1}$ and $v_i = B_i^{-1} u_i'$.

According to Pesaran et *al.* (2004), the GVAR model represented by the system of equations in (2.4), is estimated using equation-by-equation Ordinary Least Squares (O.L.S.). Nevertheless, since in equation (2.4) the variables $z_{\xi,t}$ are not the same across the $i = 1, \ldots, N$ economic entities, it is obvious that: $Cov(v_i, v_j) \neq 0, i, j \in \{1, \ldots, N\}$, and thus the GVAR estimators obtained via O.L.S. would not belong to the class of best linear unbiased estimators (BLUE).

However, since we are interested in *incorporating the dominant units* in the system of equations represented in (2.4), we proceed using standard notation and following the same procedure. Hence, the GVAR for the $k = 1,..,K$ dominant economies is:

$$y_{k,t} = \Delta_{\kappa} z_{\zeta,t} + v_{\kappa}', k = 1, \dots, K \quad \textbf{(2.5)}$$

where: $\Delta_k = B_k^{-1}\Gamma_k$ and $v_k' = B_k^{-1}u_k'$,.

According to Pesaran et *al.* (2004) and Chudik and Pesaran (2013), the system of equations in (2.5) should be estimated separately from the GVAR system presented in (2.4). Nevertheless, since the two systems share common regressors, it is possible to stack the two GVAR models together and solve them *simultaneously*. To this end, the system of (2.4) and (2.5) is:

$$\begin{Bmatrix} y_{i,t} = \Delta_i z_{\xi,t} + v_i', i = 1, \dots, N \\ y_{k,t} = \Delta_{\kappa} z_{\zeta,t} + v_{\kappa}', k = 1, \dots, K \end{Bmatrix} \Rightarrow$$

$$\begin{Bmatrix} y_{i,t}' = \widetilde{\widetilde{\Gamma}_i z_{J,t}} + \Lambda_i z_{i,t}{}^{*} + \omega_{i,t}',\ i = 1, \dots, N \\ , y_{k,t}' = \widetilde{\Gamma}_k \widetilde{z_{k,t}} + \Lambda_k z_{k,t}{}^{*} + \omega_{k,t}', k = 1, \dots, K \end{Bmatrix} \quad \textbf{(2.6)}$$

where: $\widetilde{z_{J,t}} = [y_{i,t-1}, \dots, y_{i,t-L_1}; y_{k,t-1}, \dots, y_{k,t-L_2}; y_{p,t-1}, \dots, y_{p,t-L_3}]$ represents the own lags of the country-specific variables, the dominant entities and the global variables and $\widetilde{\Gamma_i}$ the respective coefficients; $z_{i,t}{}^{*\prime} = [y_{i,t-1}{}^{*\prime}, \dots, y_{i,t-L_2}{}^{*\prime}]$ are the foreign specific variables and Λ_i the respective coefficients; $\widetilde{z_{k,t}} = [y_{k,t-1}, \dots, y_{k,t-L_4}; y_{p,t-1}, \dots, y_{p,t-L_6}]$ represents the own lags of the dominant entities and the global variables and $\widetilde{\Gamma_i}$ the respective coefficients; $z_{k,t}{}^{*\prime} = [y_{k,t-1}{}^{*\prime}, \dots, y_{k,t-L_5}{}^{*\prime}]$ are the foreign specific variables and Λ_k the respective coefficients. Finally, $\omega_{i,t}'$ and $\omega_{k,t}{}'$ represent the error terms where $\omega_k \sim N(0, \Sigma_{kk})$ and $\omega_i \sim N(0, \Sigma_{ii})$ with:

$$Cov(\omega_c, \omega_d) \cdot Cov(\omega_f, \omega_g) \cdot Cov(\omega_q, \omega_r) \neq 0, c, d = 1,..,N, f, g = 1,..,K, q, r = 1,..,N + K \quad \textbf{(2.7)}$$

since the $\widetilde{z_{J,t}}$ has common regressors, the $\widetilde{z_{k,t}}$ has common regressors and $\widetilde{z_{J,t}}$ and $\widetilde{z_{k,t}}$ have common regressors.

In this context, equations (2.6) are estimated using 3SLS (Zellner and Theil, 1962) and we call this *System GVAR* (*SGVAR)*. We assess the results of the proposed SGVAR estimation using the so-called Generalized Impulse Response Functions (GIRFs). The GIRF are expressed as follows (Koop et *al.,* 1996, Pesaran and Shin 1998):

$$I_{j\,(n)} = {\sigma_{jj}}^{-1/2} + B_n \Sigma e_j \forall\, n = 1, 2, \dots \quad \textbf{(2.8)}$$

where: $I_{j\,(n)}$ is the Impulse Response Function *n* periods after a positive standard error unit shock; σ_{jj} is the *j*th row and *j*th column element of the variance–covariance matrix of the lower Cholesky decomposition matrix of the error term which is assumed to be normally distributed; B is the coefficients' matrix when inversely expressing the VAR model as an equivalent MA process and e_j is the column vector of a unity matrix.

Finally, in order to assess the time profiles of the effects of the variables-specific shocks on the potential cointegrating relations in the SGVAR model presented earlier, we will make use of the respective Persistent Profiles (PP). In this context, the PP of the j-th cointegrating relation, namely $b'_{ji}\, z_{it}$, in the i-th country $(j = 1, \dots r_i)$, at an horizon $n \in \mathbb{N}$ with respect to a variable specific shock to the l-th element of y_t, is given by the following expression:

$$PP\big(b'_{ji}\, z_{it};\ \varepsilon_{lt}, n\big) = \frac{b'_{ji} W_i B_n \Sigma_\varepsilon e_l}{\sqrt{\sigma_{ll}}}, n = 1, \dots N \quad \textbf{(2.9)}$$

where: σ_{ll} is the l-th diagonal element of Σ_ε; e_l is a selection vector with its elements corresponding to the l-th variable in y_t is unity and zero elsewhere and B_n is the coefficients' matrix, when inversely expressing the VAR model as an equivalent MA process for the n-th period.

b. Calculating the Number of Dominant Economies

In order to select the number of dominant entities in the dataset we investigate the eigenvalue distribution of a matrix (*Q*) that accounts for the exchangeable quantities between the various economies:

$$Q \equiv \begin{pmatrix} q_{11} & \cdots & q_{1(N+K)} \\ \vdots & \ddots & \vdots \\ q_{(N+K)1} & \cdots & q_{(N+k)(N+K)} \end{pmatrix} \equiv Wx_t = \begin{pmatrix} 0 \; w_{1,2} \dots w_{1,N+K} \\ w_{2,1} \; 0 \; \dots w_{2,N+K} \\ \vdots \ddots \; \dots \; \vdots \\ w_{N+k,1} \cdots \quad 0 \end{pmatrix} \begin{pmatrix} x_{1,t} \\ x_{2,t} \\ \vdots \\ x_{N+K,t} \end{pmatrix} \quad \textbf{(2.10)}$$

where: x_t is a (N+K)x1 vector of outputs and W is the (N+K)x(N+K) trade weight matrix, and the q_{ij} element of matrix Q expresses the quantity of output that flows from economy i to economy j. The row elements express the quantities supplied by one economy to all others. Column elements express quantities obtained by an economy from all others. Hence: $q_{ii} = 0$.

In a seemingly unrelated publication, Bródy (1997) showed that the behavior of systems describing economic interconnections depends on the ratio of the modulus of the subdominant eigenvalues to the dominant one, such that a ratio close to zero implies negligible power of this economy. Let λ(pf) = λ(1) denote the dominant eigenvalue of *Q* and the normalized eigenvalues: ϱ(i) ≡ $|\lambda(i)/\lambda(pf)|$, i=2,... N+K are the *non*-dominant normalized eigenvalues. The number of dominant economies is i^*, such that $\varrho(i^*)>0.40$, since values <0.40 are practically negligible (Mariolis and Tsoulfidis, 2014). The fact that every normalized eigenvalue that is below the threshold of 0.40 could, without loss of generality, be considered negligible lies on the diminished impact of these eigenvalues in the overall stability of the system, which implies insignificant loss of information in its description.

c. Network / Node Theory for selecting the Dominant Economies

In a novel approach, we will make use of network theory to virtually select the dominant economies using the concept of centrality (Freeman 1979), which is widely used to identify the most important nodes of a graph.

Any selected panel of world economies can be represented by a finite graph, $G(V, E)$, where V accounts for the vertex set i.e. the set of nodes in the graph and E accounts for the edge set, i.e. the number of edges in the graph. Therefore, without loss of generality, economies could be depicted as nodes, while the exchangeable quantities between the economies could be depicted by the edges of a graph. In this context, the vertex set would contain all the economies incorporated in the model i.e. $V = \{1,2, \dots, N+K\}$, while the edge set, would contain the row elements of matrix Q, so the edge set would be of the form $E = \{x_{11}, \dots, x_{1N+K}; \dots; x_{N+K,1}, \dots, x_{N+K,N+K}\}$. To this end, the edge $x_{ij}, i, j \in \{1, \dots, N+K\}$ represents the product of economy i that flows to economy j.

In order to examine which nodes are dominant, we use the three main vertex theory measures, namely: (i) degree centrality, (ii) alter-based centrality, and (iii) beta centrality.

(i) The degree centrality of a node shows how connected a node is to the other nodes in the graph. See, among others, Ying et *al.* (2014) and Bates et *al.* (2014). In our case, we normalize the flows $x_{ij}, i, j \in \{1, \dots, N+K\}$ with the total amount of flows to $i, i \in \{1, \dots, N+K\}$ economies incorporated in the model using the formula:

$$z_{ij} = \frac{x_{ij}}{\sum_{i=1}^{N+K} \sum_{j=1}^{N+K} x_{ij}} \quad \textbf{(2.11)}$$

so as to produce weights instead of flow quantities. Therefore, we create a new weighted graph, $G'(V, E')$ where the vertex set remains unaffected i.e. $V = \{1,2, \dots, N+K\}$ economies, while the edge set since every edge is transformed to $E' = \{z_{11}, \dots, z_{1N+K}; \dots; z_{N+K,1}, \dots, z_{N+K,N+K}\}$. The centrality, c_i, of each node is given by the following formula:

$$c_i = d(i) \sum_{j=1}^{N+K} z_{ij} \quad \textbf{(2.12)}$$

where $d(i)$ is the degree of each node i.e. the number of ties with the rest of the nodes (Fagiolo et *al.,* 2008). In this context, the dominant economies are those, which exhibit the largest centrality. Hence, the largest c_i corresponds to the dominant economy, the second largest c_i to the second-dominant economy, and so on.

However, degree centrality does not take into consideration how the neighbors of each node interact with the rest of the nodes of the vertex. In this context, we take into account two additional measures of node centrality, namely alter-based power and beta power, that take into consideration both the nearby and the distant neighbors of a node (Bonacich and Lloyd, 2001).

(ii) Altered based power of a node i, identifies the most central nodes of a vertex by taking into consideration both the degree centrality of the neighboring nodes, and their respective weights. Alter-based centrality is given by the following formula:

$$AC_i = \sum_{i=1}^{N+K}(z_{ij} * c(i)^{-1}) \quad \textbf{(2.13)}$$

where: $z_{ij}, i, j \in \{1, \ldots, N+K\}$ are the weights between each node, i, with the rest of the j nodes and $c(i)^{-1}$ is the inverse degree centrality of each node in the network. In this sense, a node is central if it is connected to nearby non-central other nodes (Neil, 2011). The larger value of alter based power of a node corresponds to the first dominant economy, the second largest to the second dominant and so on.

(iii) **Beta based power** of a node, i, was developed by Bonacich (1987) as an extension of the eigenvector centrality (Bonacich, 1972), and can identify the centrality power of a node according to either their distant neighbors or their nearby neighbors of the specific node. It is given by the following formula:

$$BC_i = (I - \beta R)^{-1}R \quad \textbf{(2.14)}$$

where: I is the indentity matrix, β is a discount parameter and $R = [z_{ij}], i, j \in \{1, \ldots, N+K\}$ is the adjacency matrix. Different values of the discount parameter β provide us with different centrality powers for the node i. In particular, according to the value of β we have the following cases: (a) if $\beta \gg 0$ or $\beta \ll 0$ then the power centrality of a node, i, is based on the distant neighbors of the specific node and approaches the eigenvector centrality; and (b) if $\beta > 0$ or $\beta < 0$ then the power centrality of a node, i, is based on the nearby neighbors of the specific node and it approaches the alter-based power of a node; Apparently, the dominant economies are those with the greater values of beta based centrality power.

d. Information Criterion for selecting the Dominant Economies

In this sub-section, we will make use of the so-called Schwartz-Bayes Information criterion (SBIC) or, simply, BIC introduced by Schwartz (1978) in order to econometrically confirm the selected dominant entities. Let $L_T(o)$ be the maximum likelihood of the SGVAR system, described by the following equations:

$$\left\{\begin{array}{l} y'_{i,t} = \widetilde{\Gamma}_i \widetilde{z_{j,t}} + \Lambda_i z_{i,t}{}^* + \omega'_{i,t},\ i = 1, \ldots, N \\ , y'_{k,t} = \widetilde{\Gamma}_k \widetilde{z_{k,t}} + \Lambda_k z_{k,t}{}^* + \omega'_{k,t}, k = 1, \ldots, K \end{array}\right\} \quad \textbf{(2.15)}$$

where: $t = 1, \dots, T$ is the time dimension which corresponds to the number of observations and $o = \max\{H, M\}\, xm$ denotes the number of unkown parameters of the system of equations.

Following the methodology described in the previous section there exist k^* dominant economies in the system. In order to test which of the $i = 1, .., N + K$ economies are dominant we need to calculate the BIC criterion for the different combinations of k^* dominant economies regarding the system (2.15).

Let $\widehat{\Sigma_{k^*_i}}$, be the estimated variance of the above system of equations (2.15). Then the BIC criterion for each $k^*_i, i = 1, .., N + K$ combination of dominant economies will be given by the following formula:

$$c_T{}^{3-SLS}(k^*_i) = \ln(\det(\widehat{\Sigma_{k^*_i}}) + o\frac{ln(T)}{T} \quad \textbf{(2.16)}$$

The dominant combination of $\overline{k^*_i}$ economies is the combination that optimizes the BIC, i.e. in mathematical terms: $\overline{k^*_i} = argmin\ \{c_T{}^{3-SLS}(i)\}$. [11]

Of course, the aforementioned selection strategy could easily be followed using some other relevant information criterion, e.g. AIC, etc. However, we have used BIC over other criteria, following Breiman and Freedman (1983) and Speed and Yu (1992), who have shown that BIC is an optimal selection criterion when used in finite samples.

Finally, a number of fairly standard tests need to be carried out, such as stationarity, cointegration, optimum lag length, stability and asymptotic properties.
A number of relevant tests need to be carried out.

***e.* Stationarity**

We start by testing for stationarity. In case the time series employed are not stationary, we induce stationarity following, among others, Koop (2013).

There are several formal tests of stationarity, among which quite popular is the Phillips-Perron (PP) test. Phillips and Perron's test statistics can be viewed as a Dickey–

[11] Please note that the same criterion could be used, *ex-post*, to assess the *number* of dominant economies that should be selected in a GVAR model, since the number of variables does not depend on the number of dominant economies but on the total number of economic entities that are included in the GVAR i.e. $i = 1, \dots, K + N$.

Fuller statistics that have been made robust to serial correlation by using the Newey–West (1987) heteroskedasticity -and autocorrelation- consistent covariance matrix estimator. The main advantage of the PP tests over the ADF tests is that the PP tests are robust to general forms of heteroskedasticity in the error term u_t. Another important advantage is that no *a-priori* specification of the lag length for the test regression is required.

The Phillips–Perron(1988) test involves fitting the model:

$$Y_t = a + \rho Y_{t-1} + \varepsilon_t \quad \textbf{(2.17)}$$

where we may exclude the constant or include a trend term. There are two statistics, Z_ρ and Z_τ, calculated as follows:

$$Z_\rho = T(\widehat{\rho_T} - 1) - \frac{1}{2}\frac{n^2\widehat{\sigma^2}}{s_T^2}(\widehat{\lambda_T^2} - \widehat{\gamma_{0,T}}) \quad \textbf{(2.18)}$$

$$Z_\tau = \sqrt{\frac{\widehat{\gamma_{0,T}}}{\widehat{\lambda_T^2}}}\frac{\widehat{\rho_T}-1}{\hat{\sigma}} - \frac{1}{2}(\widehat{\lambda_T^2} - \widehat{\gamma_{0,T}})\frac{1}{\widehat{\lambda_T^2}}\frac{T\hat{\sigma}}{s_T} \quad \textbf{(2.19)}$$

where $\gamma_{j,T} = \frac{1}{T}\sum_{t=j+1}^{T}\widehat{u_t}\widehat{u_{t-j}}$, $\widehat{\lambda_T^2} = \widehat{\gamma_{0,T}} + 2\sum_{j=1}^{q}(1 - \frac{j}{q+1})\gamma_{j,T}$ and $s_T^2 = \frac{1}{T-k}\sum_{t=1}^{T}\widehat{u_t}^2$

where u_t is the OLS residual, k is the number of covariates in the regression, q is the number of Newey–West lags to use in calculating λ_T^2, and $\hat{\sigma}$ is the OLS s.e. error of $\hat{\rho}$.

Under the null hypothesis that $\rho = 0$, the PP statistics, Z_ρ and Z_τ, have the same asymptotic distributions as the Augmented Dickey–Fuller (ADF) t-statistic and normalized bias statistics. If the series are not stationary, we induce stationarity by means of first differencing.

f. Optimum Lag Length

In this work, we make use of the so-called Schwartz-Bayes Information criterion (SBIC) introduced by Schwartz (1978), as we have seen in Chapter 1.

g. Cointegration

Also, we have to check for cointegration between the different variables that enter the model, since if cointegrating relationships are present then the Error Correction

Terms have to be employed in the estimation of the GVAR model. We employ the popular Johansen (1988) methodology that allows for more than one cointegrating relationship, in contrast to other tests. See Chapter 1.

h. Asymptotic Properties

For the purpose of estimation and inference in stationary models, we follow Chudik and Pesaran (2011a). See Chapter 1.

i. Stability Conditions

Following Pesaran et *al.* (2002) and Mutl (2009), it is not sufficient to examine the country-by-country stability. In this work, to determine whether the model is stable, we check the stability of the whole system. Hence, we require that: $\rho_{system\,(i)} < 1$ for stability, where $\rho_{system\,(i)}$ is the spectral radius of the system's matrix.

2.3 EMPIRICAL RESULTS

a. Data and Variables

The data are quarterly and cover the period 1992 (Q1)-2014 (Q4), fully capturing the ongoing recession. For all the economies that enter the SGVAR model i.e. USA, EU17, Brazil, Russia, India, China, Japan, Australia and Canada we used data[12] regarding their exchange rates to the dollar, GDP deflator, GDP in current prices and interest rates[13]. The EU17 economy is considered as a single economy and includes the economies of: Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal, Slovak Republic, Slovenia and Spain.

All the data come from OECD's main economic indicators database, while the data on the EU17 GDP come from the official Eurostat, National Accounts section. The implicit assumption is that the variables of global finance and global trade act as

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[12] When data were missing, following Pesaran et *al.* (2004) we intra/extra-polated the missing values.

[13] Note that in this work the interest rates used represent the discount rates of each economy. In other words, the interest rate used in determining the present value of a future payment for each economy, and come from the IMF site, International Financial Statistics section.

transmission channels of the crisis. See *inter alia* Xu, (2012), Cesa-Bianchi (2013), Eickmeier and Ng (2015).

Hence, regarding the global variables, we use the aggregate values of: (i) Worldwide Total Credit and (ii) Worldwide Total Trade, both in millions of dollars, which were obtained in constant 2005 prices from the World Data Bank. Additionally, in each VARX model we include (exogenous) dummy variables that account for the global financial crisis of 2007-2009 as well as for the local/regional crises that some countries experienced during the period under investigation, like the Russian crisis of 1998, the lost decade of the Japanese economy, the currency crisis in Brazil, etc.

Following Pesaran et *al.* (2004), in this work the weights are assumed to be constant over the whole sample and are equal to the average trade weights which are calculated using ECB's database, which is freely accessible. Also, using each economy's GDP deflator, i=1,..,9, GDP_i we calculated the GDP in constant 2005 prices using the formula:

$$GDP_{2005_i} = \frac{GDP_i\, current\ prices}{GDP_i\, deflator} \quad \textbf{(2.20)}$$

Then, we made use of the exchange rate of each economy's, i=1,..,9, so as transform, GDP_{2005_i}, into dollars, using the formula:

$$GDP_{i,2005\ in\ \$} = GDP_{2005_i} * exchange\ rate_i \quad \textbf{(2.21)}$$

b. Dominant Economies

According to Brody's (1997) established methodology described earlier, the results undoubtedly indicate the existence of two dominant economies for which: $\varrho(i^*)>0.4$ ($\rho_1 = 1, \rho_2 = 0.72$).

Table 2.1: Centrality measures of economies

Economy (i)	Degree Centrality, $c(i)$	Alter power, AC_i	Beta power, BC_i
US	1.321	1.724	0.445
EU17	1.831	1.757	2.498
JAP	0.754	1.014	0.370
RUS	0.806	0.595	0.172
C□N	0.170	0.171	0.059
CHI	0.139	0.093	-0.021
BRA	0.658	0.576	-0.203
AUS	0.894	0.906	0.097
IND	1.184	0.607	-1.530

Next, we select the two dominant entities using the various centrality measures based on network theory, as described earlier. The: (i) degree of centrality, (ii) alter based power centrality and (ii) beta based power centrality of each node are presented in Table 2.1.

The results obtained by all the centrality measures employed for each economy, show that the economies of US and EU17 are the most central ones[14] and, thus, may be considered as being dominant in the model. Notice that together the two economies account for more than 30% of global output and are usually considered as being two of the most powerful economies in the globe (CIA, 2013).

In order to confirm the selection of the dominant economies in our model and its relevant measures of centrality, we calculate the Bayes Information Criterion for the system as described earlier. In this context, we present the results in Table 2.2.

[14] The increased centrality that the economies of Australia and India exhibit could be attributed to the fact that the sample of countries utilized in this paper covers sufficiently the main trading partners of these economies.

Table 2.2: Bayes Information criterion

Dominant Pairs	*BIC*
US and EU17	-745.28
US and China	-635.64
EU17 and China	-668.75
US and Japan	-521.28
EU and Japan	-333.59
Japan and China	-342.75

According to the results in Table 2.2 the pair of US - EU17 presents the lowest BIC value, compared to the rest of the pairs, which are the most likely alternative pairs for dominant economies in the model.

c. Relevant Tests

In what follows, we present the results of the various tests. To avoid any spurious effect, we continue our analysis by testing for the existence of unit roots in the various time series. We investigate the existence of unit roots in our time series data using the Phillips and Perron (1988) test.

Table 2.3: Phillips Perron test (original variables)

Region	Variables	Lags	P-value	Stationarity
AUS	GDP	3	0.42	No
	Interest Rate	3	0.13	No
BRA	GDP	3	0	Yes
	Interest Rate	3	0.30	Yes
CAN	GDP	3	0.35	No
	Interest Rate	3	0.13	No
CHN	GDP	3	0.99	No
	Interest Rate	3	0.86	No
EU17	GDP	3	0.57	No
	Interest Rate	3	0.48	Yes
IND	GDP	3	0.98	No
	Interest Rate	3	0.88	No
JPN	GDP	3	0.62	No
	Interest Rate	3	0	Yes
RUS	GDP	3	0	Yes
	Interest Rate	3	0.67	No
USA	GDP	3	0.95	No
	Interest Rate	3	0.52	No
WORLD	Trade	3	0.52	No
	Credit	3	0.93	No

Table 2.4: Phillips Perron test (first differences)

Region	Variables	Lags	P-value	Stationarity
AUS	GDP	3	0	Yes
	Interest Rate	3	0	Yes
BRA	GDP		-	-
	Interest Rate	3	0	Yes
CAN	GDP	3	0	Yes
	Interest Rate	3	0	Yes
CHN	GDP	3	0	Yes
	Interest Rate	3	0	Yes
EU17	GDP	3	0	Yes
	Interest Rate	3	0	Yes
IND	GDP	3	0	Yes
	Interest Rate	3	0	Yes
JPN	GDP	3	0	Yes
	Interest Rate		-	-
RUS	GDP		-	-
	Interest Rate	3	0	Yes
USA	GDP	3	0	Yes
	Interest Rate	3	0.05	Yes
WORLD	Trade	3	0.04	Yes
	Credit	3	0.04	Yes

Most GDP variables were found to be stationary in their first differences (Table 2.4) except for the GDPs of Brazil and Russia that are stationary in levels (Table 2.3).

The interest rates were also found to be stationary in first differences, except for that of Japan, which is stationary in levels.

Next, in the presence of I(1) variables in the VARX's models of each economy, following standard econometric practice, we investigated the existence of possible long run relationships using the Johansen and Juselius (1990) methodology. See Appendix. The results in Table 2.5 suggest that cointegration is present in all the models.

Table 2.5: Johansen Cointegration test

Economies	Cointegration Rank	Eigenvalue	Log Likelihood	Trace statistics	5% Critical value	Cointegration
US	1	0.51	-243.91	21.34	29.68	Yes
EU17	1	0.36	-172.40	28.84	29.68	
BRA	3	0.18	-56.20	14.53	15.41	
RUS	1	0.54	-121.32	42.17	47.21	
IND	1	0.57	-164.21	54.22	68.52	
CHN	1	0.58	-180.52	66.54	68.52	
JPN	2	0.31	-136.86	19.23	29.68	
CAN	1	0.59	-158.21	59.09	68.52	
AUS	3	0.28	-97.23	26.65	29.68	

Next, having determined the number of cointegrating vectors that each VECX model has to incorporate, we proceed by selecting the optimum numbers of lags for each VECX model. The optimum lag length of each VECX is determined using the BIC (1978) criterion (Table 2.6).

Table 2.6: **Lag Length Selection Criterion**

Region	Optimal Lags	SBIC
US	2	11.24
EU17	2	10.52
BRA	3	3.21
RUS	3	5.22
IND	2	4.32
CHN	3	9.56
JPN	5	4.35
CAN	2	4.29
AUS	3	3.78

Having determined the VECX (p, q) specification for each economy in the GVAR model, we proceed by estimating the whole system of VECX models simultaneously using 3-SLS estimation. Following the notation presented earlier, the SGVAR estimation has the following basic components:

$i = 1, ..7$ small open economies, where: $i = \{BRA, IND, RUS, CHN, JPN, AUS, CAN\}$

$k = 1,2$ dominant economies where $k = \{US, EU17\}$

$y_{j,t} = (GDP_{j,t}, Interest\ Rate_{j,t}\}$, where $j = 1, \dots N + K$

$g_{j,t} = \{Credit_t, Trade_t, Global\ Crisis_t, Regional\ Crisis_{j,t}\}$

where: $j = 1, \dots N + K$

Having estimated the GVAR system, we compute the persistent profiles of the country specific shocks, following, Pesaran and Shin (1998) and Pesaran et *al.* (2007). Each persistent profile shows the time profiles of the effects of the variables-specific shocks on the potential cointegrating relations in the SGVAR model.

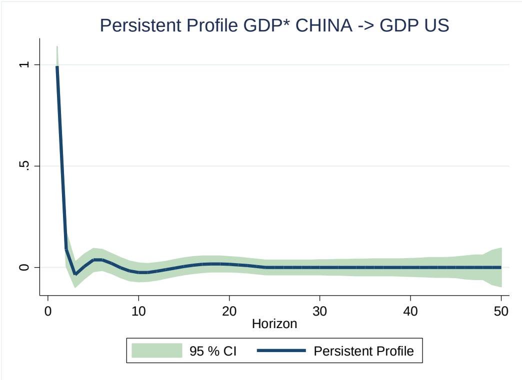
d. Persistent Profiles

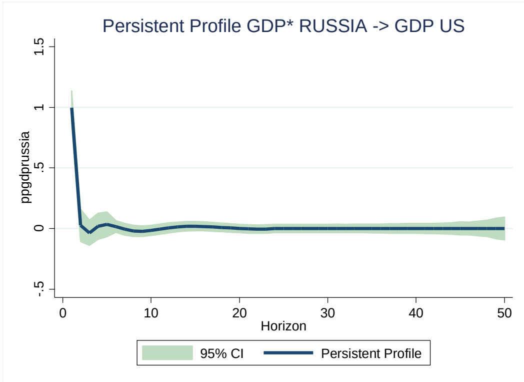
Figure 2.1, presents the persistent profiles of the EU17 GDP to shocks in the GDP of the BRICs. The results clearly indicate that the EU17 GDP is only affected in the short-run, i.e. less than five (5) quarters, by the various shocks in the GDP of the BRICs economies since all the persistent profiles die out after approximately five (5) quarters.

Figure 2.1: Persistent Profiles of EU17 GDP to shocks in the BRIC's GDP

Next, Figure 2.2 presents the persistent profile of the US GDP to the various shocks in the GDP of the BRICs. According to these results, no persistent effect is evident since in less than approximately four (4) quarters all effects seem to die out. Hence, the US GDP is only affected in the short run by the shocks in the various GDPs.

Figure 2.2: Persistent Profiles of US GDP to shocks in the BRIC's GDP





e. Generalized Impulse Response Functions

Next, having explored the persistent profiles of the various shocks in the BRICs on the GDP of the dominant economies (US, EU17), we will proceed with the presentation of the GIRFs. Each GIRF shows the dynamic response of the GDP of each economy to unit shocks in the rest of the economies' GDP, for up to 4 years.

We will base our analysis of Generalized Impulse Response Function (GIRFs) on the robust confidence bands (bootstrapped, 10.000 iterations) rather than the point estimates in order to avoid any possible structural instability. Since we are mainly interested in the impact of a sudden change in the economic activity of the BRICs (e.g. potential slowdown) and its impact on EU and US economic activity, we focus on the impact of a unit shock in the BRICs GDP on the GDP of the EU17 (Figure 2.3) and US (Figure 2.4).

Figure 2.3: Response of GDP EU17 to BRICs GDP

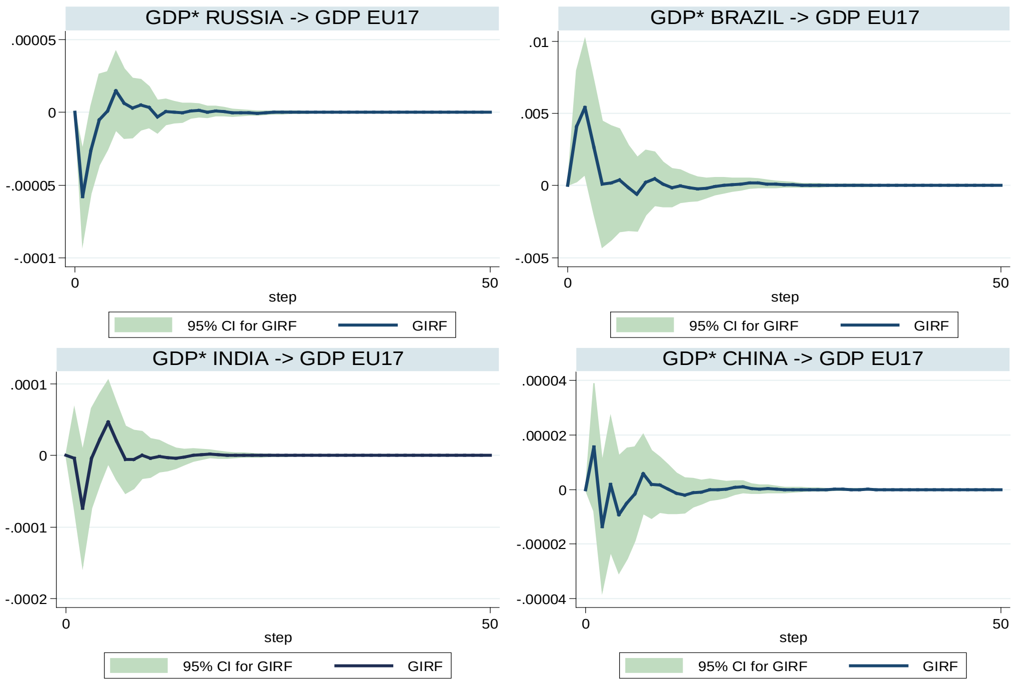
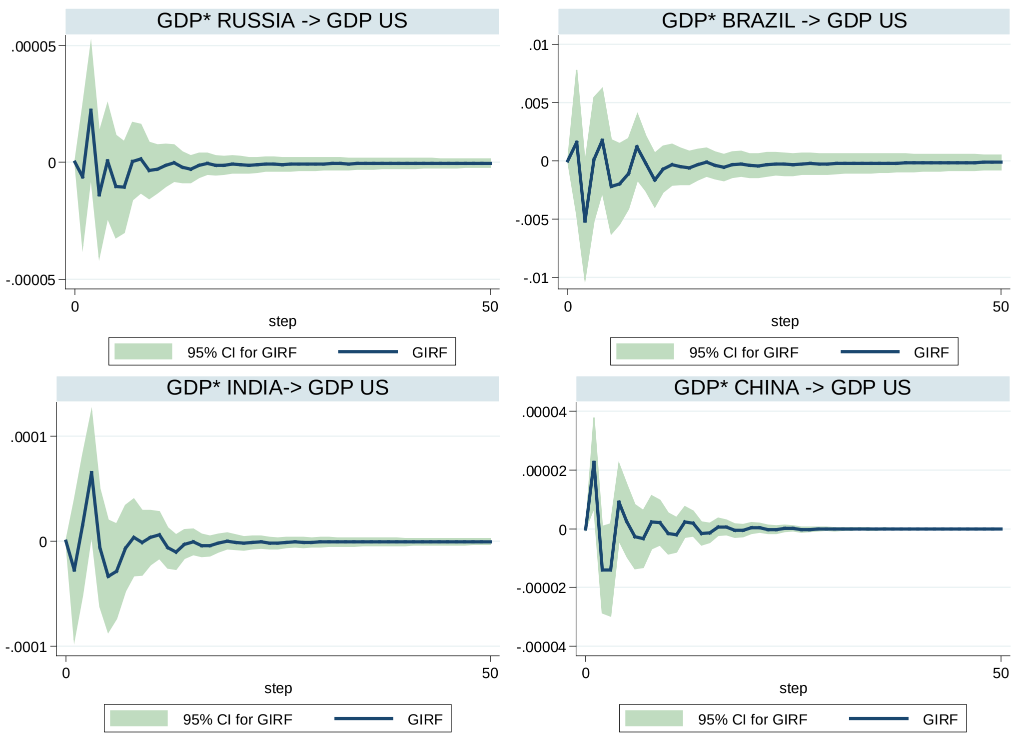
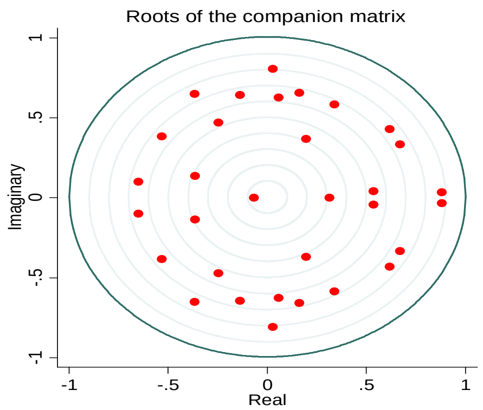


Figure 2.4: Response of GDP US to BRICs GDP



The robustness of the results is confirmed by the stability of the system (Figure 2.5).

Figure 2.5: Stability of the SGVAR



f. Comparison of results: one (1) VS two (2) dominant economies

In what follows, we will provide a thorough comparison between a system GVAR (SGVAR) featuring one (1) and (2) two dominant economies, respectively, visually and formally.

i. Visual Comparison

Due to the increasing significance of the Chinese economy in the global economy, we focus on the economy of China and how it is affected by a unit shock in either the interest rate or the GDP in the economies of US, EU. In this context, Figure 2.6 presents the response of the Chinese GDP on a unit shock on either US or EU17 GDP, when both economies are treated as dominant in the GVAR system, while Figure 2.7 presents the response of the Chinese GDP to a unit shock on either US or EU17 GDP, when only the US economy is treated as dominant.

Figure 2.6: Response of Chinese GDP to shocks in US GDP and EU17 GDP (2 dominants)

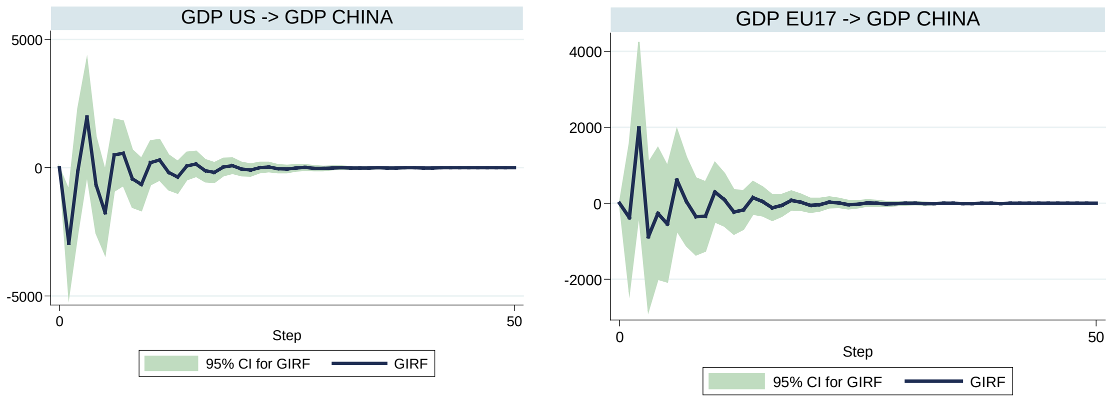
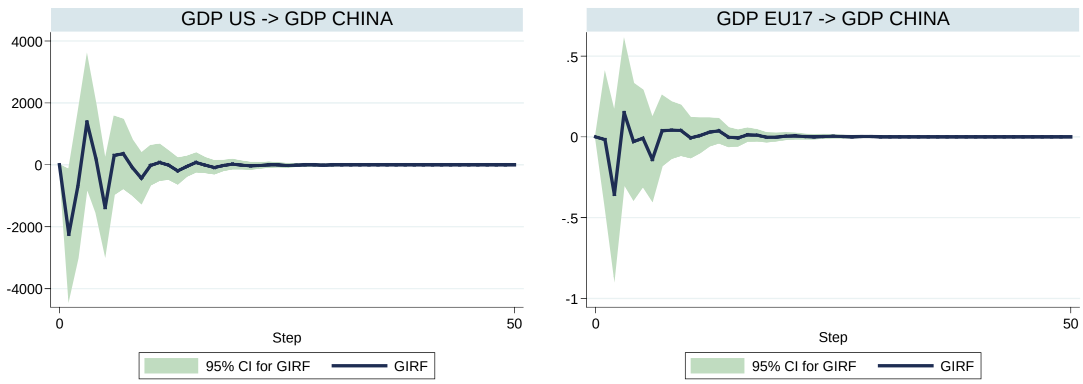


Figure 2.7: Response of Chinese GDP to shocks in US GDP and EU17 GDP (1 dominant)



The results indicate that in the case of two (2) dominant economies, the US GDP seems to statistically significantly affect - in the short-run - the Chinese GDP, while if we rely on the one (1) dominant unit case, this does not seem to be true. Also, the Chinese GDP reacts differently to a shock in the EU17 GDP when the EU17 economy is dominant.

Next, Figure 2.8 shows the response of the Chinese GDP in a unit shock in the Interest Rate of either US or EU17, when both economies are treated as dominant in the GVAR system. Figure 2.9 shows the response of the Chinese GDP in a unit shock in the Interest Rate of EU17 and US, when only the US economy is treated as dominant.

Figure 2.8: Response of Chinese GDP to shocks in US Int. Rate and EU17 Int. Rate (2 dominants)

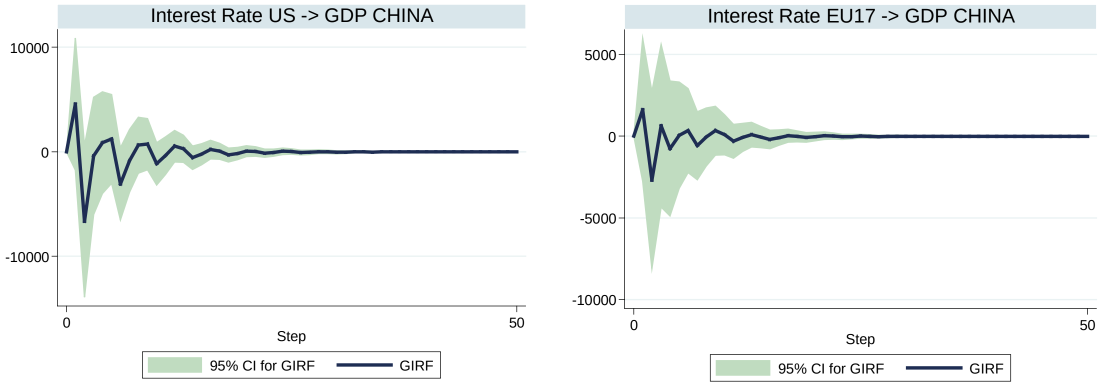
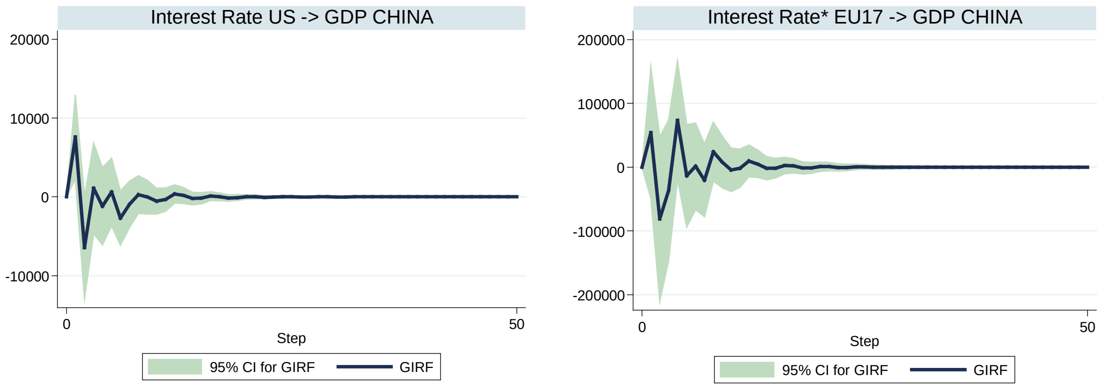


Figure 2.9: Response of Chinese GDP to shocks in US Int. Rate and EU17 Int. Rate (1 dominants)



The results indicate that no significant differences are present in the GIRFs of the Chinese GDP regarding the unit shocks in the Interest Rates of US and EU17 in neither the case when both EU17 and US are treated as dominant, nor in the case when only the US economy is treated as dominant. Also, we can see that the in the two dominants case, the various GIRFs present a slightly faster of convergence to equilibrium.

As a result, the comparison of the GIRF's of the two GVAR models i.e. the classical GVAR model described above featuring one (1) dominant entity and the SGVAR system proposed in this chapter with two (2) dominants shows, as expected, that most of the responses (GIRF figures) are quite similar in pattern but different in measures and timing. Hence, a thorough comparison of the two cases is relevant, based on formal methods.

g. Formal Comparison

In what follows, we will provide a comparison between a system GVAR featuring one (1) and (2) two dominant economies, respectively, using various formal criteria and methods.

a) Brody's (1997) criterion

According to Brody's (1997) methodology set out earlier, the normalized eigenvalues are presented below (Table 2.7). Since, there are (2) two normalized eigenvalues with $\rho(i^{*})>0.4$, namely $\rho_1 = 1, \rho_2 = 0.72$, Brody's criterion is in favour of the existence of two (2) dominant economies in the model, instead of one (1).

Table 2.7: Normalized Eigenvalues of matrix *Q*

Eigenvalue	ρ_ι
1	1.000
2	0.720
3	0.330
4	0.180
5	0.080
6	0.040
7	0.020
8	0.002
9	0.003

b) Information Criteria

In order to provide a thorough comparison of the system GVAR featuring one (1) or (2) two dominant economies, respectively, we re-estimated the proposed GVAR system using, this time, only one dominant, i.e. the US economy. In this context, Table 2.8 presents the various information criteria for both cases.

Table 2.8: Information Criteria of the system GVAR with one and two dominant units, respectively.

Dominant Economies	FPE	AIC	HQIC	BIC
US and EU17	-430.25	-530.89	-616.84	-745.28
US	-65.09	-438.67	-507.74	-610.17

The results presented in Table 2.8, show that the model incorporating two (2) dominant units is superior, according to the various information criteria, to the one that employs only one (1) dominant unit, since all information criteria present their optimal values when two (2) dominant economies are employed.

c) Fitting Criteria

Furthermore, Table 2.9 below shows the overall fitting statistics for the two GVAR systems.

Table 2.9: Overall fitting statistics of the GVAR system with one and two dominant units, respectively

Dominant Economies	Log likelihood	R-squared adjusted	RMSE
US and EU17	-1403.58	0.67	6172.5
US	-1171.65	0.58	665.35

Again, the overall statistics of the GVAR system with two (2) dominants clearly outperforms the GVAR with one (1) dominant entity.

d) Speed of Convergence

Finally, we compare the two models, with two (2) and one (1) dominant units, respectively, by means of each model's speed of convergence to equilibrium. As is well known, a system's speed of convergence is governed by the spectral radius $\rho(T)$ of the coefficient companion matrix. As a results, the largest eigenvalue (in modulus) should be as small as possible since this will lead to the smallest spectral radius and, hence, to faster convergence rate (e.g. Hughes Hallet and McAdam, 1999).

In this context, Table 2.10, presents the spectral radius of the two GVAR systems, featuring one (1) and two (2) dominant economies, respectively.

Table 2.10: Spectral radius of the GVAR system with one and two dominant units, respectively.

Dominant Economies	**Spectral Radius**
EU17 and US	0.88
US	0.92

According to Table 2.10, the spectral radius of the system with two (2) dominant units was calculated to be equal to $\rho(2)=0.88$ while in the case of one (1) dominant unit it was calculated to be equal to $\rho(1)=0.91$. Therefore, from the results of the two models presented above, again the two (2) dominants scheme outperforms the one (1) dominant scheme.

After all, the goal of researchers in quantitative sciences and applied data analysis is to construct systems whose coefficient matrix has as small a spectral radius as possible in order to accelerate convergence. Hence, the two (2) dominants case is clearly found to be superior to the one (1) dominant case according to the various formal criteria employed.

2.4 ANALYSIS AND DISCUSSION

We will begin our analysis by the persistent profiles of the country specific shocks. Each persistent profile shows the time profiles of the effects of the variables-specific shocks on the potential cointegrating relations in the SGVAR model. In general, in all persistent profiles presented in Figures 2.1-2.4, as the time horizon grows the value of each persistent profile tends to zero. In fact, all persistent profiles die out in less than ten (10) quarters, i.e. 2.5 years, when all the cointegrating relationships tend to zero. In this context, taking into consideration the overall picture of the persistent profiles we can infer that the EU17 GDP seems to be more vulnerable that the US GDP to shocks in either the GDPs or the Interest rates of the BRIC economies, since it needs more time to overcome the potential shocks.

Now, we base our analysis on the results obtained by the Generalized Impulse Response Functions (GIRFs) along with the 95% confidence bands that were generated using 10,000 iterations. In this context, significant divergence in a GIRF is represented by a confidence interval that does not include zero. In general, most of the GIRFs suggest a 95% confidence interval that includes zero, since we did not witness persistent deviations from that equilibrium point. This finding is, more or less, expected and should - by no means - be considered as being surprising and has to do with the rationale of the methodology and the nature of the disturbances (unanticipated sudden shocks). After all, it is largely consistent with the pioneering works of Dées et *al.* (2005, 2007a), Pesaran et *al.* (2006) and numerous empirical GVAR studies in the literature thereafter. See, for instance, Dees et *al.* (2009), Castren et *al.* (2010), Chudik and Fratzscher (2011), Chudik and Pesaran (2011), Chudik and Pesaran (2013), Dees et *al.* (2014).

More specifically, we have seen that a shock in the GDP of Russia and China does not create a statistically significant divergence to EU17 GDP from its equilibrium position. Nevertheless, a unit shock in the GDP of Brazil seems to have a statistically significant positive short-run impact on the EU17 GDP that lasts for almost two-three (2-3) quarters and dies out after four (4) quarters, when it returns back to its initial equilibrium position.

This statistically significant effect of the Brazilian GDP on the EU17 GDP could be attributed, to a large extent, to the overall trade relationship between the two regions, since the EU is Brazil's first trading partner, accounting for 21.2 % of its total trade (2013). On the other hand, a shock in the GDP of India seems to have a statistically significant negative short run impact on the GDP of EU17, which in turn dies out after a year i.e. four (4) quarters, when the European GDP returns back to its initial equilibrium position. This statistically significant impact of India's GDP on EU 17 GDP could be attributed both to the increasing trade relations between the two regions as well as to the Agreement on Scientific and Technological cooperation of 2002 that made India one of the largest exporters of Information and Technology services to the EU.

Hence, EU17 seems to be, at least partly, vulnerable to the shocks of BRICS, a fact that could be attributed to the rising FDI flows from the BRICs to EU17. Therefore, it is evident that a potential slowdown of the BRICs economies will affect the EU17 economy as well.

Next, a shock in the GDP of either Russia, India or Brazil does not seem to have any statistically significant effect on the GDP of US. In contrast, a shock in the Chinese GDP seems to have a statistically significant positive effect, on the short run i.e. two-three (2-3) quarters in the GDP of US. Nevertheless, this effect dies out in less than one year when the US GDP returns back to its initial equilibrium position. The statistically significant impact of the Chinese GDP could be attributed to the fact that China's central bank withholds large reserves of US dollars. In general, by taking into consideration all the aforementioned facts, it could be argued that a slowdown in the BRICs economies will have little - if at all - impact on the US economy. The empirical results are consistent with the literature arguing that EU17 is more vulnerable to shocks than the US (e.g. Aizenman et *al.,* 2011).

Finally, China is only statistically significantly affected, in the short run, i.e. three (3) quarters, by a shock in the US GDP, which in turn dies out after one year, when the Chinese GDP returns back to its initial equilibrium position.

Of course, this impact could be attributed to the fact that the Yuan was pegged to the dollar for more than a decade, making the Chinese economy more vulnerable to US shocks but, at the same time, immune to shocks from all other regions, a fact which is also consistent with our findings (World Economic Outlook, 2013).

2.5 CONCLUSION

The point of departure of our investigation for constructing this model has been the need for an upgraded compact (macro)econometrictool that could incorporate both the complex interdependencies that exist between the various economic entities and the fact that in the global economy more than one of these entities could have a predominant role. In this context, we have extended the GVAR model of Chudik and Pesaran (2013), featuring one dominant economy, in order to incorporate more than one dominant entity. Additionally, based on the trade weight matrix that lies in the core of the GVAR framework, we have provided both an analytical procedure and an *ex-post* econometric criterion for the selection of dominant entities. We illustrated the dynamics of the proposed SGVAR model by assessing, among other things, the impact of a shock in the economic activity of the BRICs on the US and EU17 economies, respectively.

In brief, the present chapter contributed to the research conducted on GVAR in the following ways: (a) it proposed system estimation for the GVAR with *K* dominants; (b) it formally estimated a GVAR with two (2) dominant economies; (c) it set out a formal method for indentifying the number of dominant entities in a GVAR framework; (d) it set out a novel method based on network theory for selecting the dominant entities; (e) it compared the estimation results of GVAR using one dominant and two dominant economies, respectively; (e) it estimated impact of a shock in the economic activity of the BRICs on the US and EU17 economies, respectively.

According to our findings, the dominant economies are those of the USA and EU17, with the results suggesting that EU17 is more vulnerable than the USA to GDP shocks from the BRICs, implying that a potential slowdown in the BRICs would primarily affect the EU17 economy.

Additionally, the comparison between the SGVAR featuring one (1) and two (2) dominant entities, respectively, showed that the two (2) dominant model's performance was superior based on the results of several formal criteria.

Of course, there are several ways in which the present study could be extended. From a macroeconomic point of view, it could be further investigated whether the US and international financial crisis played a distinct role in each country's financial system, whereas other crucial variables could be investigated.

From a technical point of view, for example, a Bayesian GVAR could be adopted, whose main advantage is the possibility of mixing different pieces of information (sample information, prior information, etc) in order to construct a model that accounts for the stochastic character of the variables that could lead to a better approximation of reality.

In addition, the so-called World Input Output Table (WIOT) could serve as the tool to construct the GVAR weight matrix. With respect to the traditional GVAR approach, such a weight matrix - derived based on Leontief's Input Output matrix -, would be capable of accurately expressing the total, i.e. direct and *indirect* (*e.g. intermediate flows)* linkages between the various economies. Hence, the modeling of the world economy would be complete since there would be no missing relationships and/or interconnection channels due to the fact that all economies would be explicitly and accurately included in the GVAR model. Undoubtedly, further research on the topic seems of great interest.

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Chapter 3: Business Cycles Determinants and Fiscal Policy in Europe[15]

So far, we have seen that the EU economy is more vulnerable to unexpected shocks than the US economy. In this context, a question of great interest is the investigation of the determining factors of the vulnerability of the European economy. Hence, we will attempt to shed light on business cycles determinants, in the time period 1996-2013, using quarterly data fully capturing the on-going recession. In this framework, we acknowledge the significant role: of fiscal policy, the quality of institutions and the elections in a Political Business cycles framework. Additionally, based on the business cycle characteristics of the EU-12 economies, we will explore the potential formation of clusters in the European economy. To this end, a number of relevant econometric techniques will be employed.

3.1 INTRODUCTION

The European Monetary Union (EMU) is, thus far, the only Union that allows its members to conduct their own fiscal policy, which has to be consistent with the Maastricht treaty. Given that a number of EMU members such as the so-called PIIGS or GIPSI (*alphabetically*: Greece, Italy, Ireland, Portugal and Spain) are hailed to be among the most prominent victims of the recent recession, it is evident that the role of the individual economies' fiscal policy in a European context, still remains elusive.

The relevant literature suggests that business cycles volatility is an important determinant of a wide range of economic phenomena (Giovanni and Levchenko, 2008), while a number of studies examine the impact of business cycles volatility on a set of key macroeconomic variables (Ramey and Ramey, 1995; Gavin and Hausmann, 1998; Pallage and Robe, 2003; Barlevy, 2004; and Laursen and Mahajan, 2005). However, relatively limited research has been done regarding the impact of fiscal policy variables on business cycles fluctuations (e.g. Lane, 2003; Galli and Perotti, 2003; Alesina et *al.,* 2008).

[15]Another version of this chapter has been published as follows: Konstantinos N. Konstantakis, Theofanis Papageorgiou, Panayotis G. Michaelides and Efthymios G. Tsionas (2015), Business Cycles Determinants in Europe: A Political Business Cycles Approach using Panel Data and Clustering (1996-2013), *Open Economies Review,* 26: 971-998.

Despite the fact that Elections and the Quality of Institutions are often (in-) directly related to fiscal policy in the so-called *Political Business Cycles* literature (e.g. Nordhaus, 1975; Rogoff and Sibert, 1988; Rogoff, 1990; Persson and Tabellini, 1990; Aidt and Veiga, 2011; Alegre, 2012; Potrafke, 2012; Abott and Jones, 2013; Mechte and Potrafke, 2013; De Haan et *al.,* 2013), the impact of *Political Business Cycles* (PBC) on key fiscal determinants has been inadequately acknowledged in the empirical literature. In this framework, we investigate whether these variables could be used to manipulate business cycle volatility and synchronization in the EMU.

More precisely, in this chapter we will attempt to shed light on the fiscal determinants of business cycles in the EU-12 economies by acknowledging the key role of PBC. In this context, we regard business cycles as deviation from trend. See, among others, Lucas (1977), Kydland, and Prescott (1990), Alesina et *al.* (2008), Battaglini and Coate (2008), Ales et *al.* (2014)). We extract the business cycles component for each economy utilizing the Hodrick-Prescott filter. We then examine the characteristics of the business cycles extracted for each economy so as to ensure that the business cycle components are not random walks and follow some distinctive pattern that exhibits periodicity via white noise testing and Fourier analysis. Next, utilizing two panel data models we explore the fiscal determinants of business cycles in the EU-12 economies taking into consideration the significant role of PBC. In addition, we conduct sensitivity analysis via panel Rolling windows so as to examine the time consistency of our findings, while using Causality testing we explore the causality of the fiscal determinants identified by our two models towards the business cycles. Lastly, by augmenting our dataset with the European countries that belong to EMU but do not utilize the Euro currency, we explore the formation of potential clusters between the EU-15 economies based on their business cycles characteristics.

The chapter contributes to the literature in the following ways: (a) It the first, to the best of our knowledge, that directly relates Political Business Cycles (PBC) with the key fiscal determinants of business cycles in the EMU; (b) It investigates the role of key fiscal determinants of business cycles in the EMU by decomposing the key fiscal variable of government spending into capital expenditures, social transfers and social benefits, taking into account that the effects of the various components of government spending on the business cycle may differ. In this context, government revenues are also further divided into direct and indirect taxes; (c) It identifies the potential formation of clusters in the EU-15 economy based on the business cycle that each economy exhibits; (d) It uses a wide dataset in quarterly format which includes the core EMU countries i.e. Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Holland, Portugal and Spain, as well as the economies of UK, Sweden and Denmark that belong to EMU and do not use the Euro as their domestic currency, in the time period 1996-2013, fully capturing the recent recession; and (d) It provides a robust econometric framework based on advanced techniques in order to tackle the research questions, such as Dynamic Panel Data Analysis, Panel SUR, Toda-Yamamoto Causality and k-means Clustering.

The remainder of this chapter is structured as follows: section 2 provides a review of the literature; section 3 sets out the methodological framework; section 4 presents the empirical results, while section 5 analyses them; finally, section 6 concludes.

3.2 BACKGROUND LITERATURE

a. On business cycles determinants

In an early study, Razin and Rose (1994) linked business cycle volatility to barriers on international mobility of capital and goods. Their empirical results showed that there exists a strong and significant relation between the volatility of consumption, output and investment with the degree of capital mobility and the degree of goods mobility. The reason suggested is the common nature and persistence of shocks worldwide.

After EMU formation, real time data availability substantially boosted the empirical research conducted on business cycles. To this end, Easterly et *al.* (2001) in an attempt to investigate business cycles determinants reported that wage flexibility is not related, in a statistically significant way with volatility. In a prominent paper, Acemoglu et *al.* (2003) found that weak institutions cause volatility through a number of microeconomic as well as macroeconomic channels. Kose et *al.* (2003) reported that financial integration is associated with an increase in the ratio of consumption.

Gali and Perotti (2003) suggested that the Stability Growth Pact (S.G.P.) does not influence the ability of E.U. governments to conduct effective discretionary countercyclical fiscal policy. According to their work, discretionary fiscal policy in the EMU has become more countercyclical over time, following what appears to be a trend that affects other industrialized countries as well. Fatás and Mihov (2003) aimed at studying the effects of discretionary fiscal policy on output volatility and economic growth. Their findings give credit to the view that governments using fiscal policy as an instrument induce macroeconomic instability. Bergman (2004) studied the business cycles of various European economies for the last fourty (40) years. According to the paper's findings, EMU formation increased the intensity of the cycle.

In a broader context, using data from selected economies across the world, Malik and Temple (2006) examined the structural determinants of output volatility in developing countries and especially the role of geography and institutions. They found that countries with weak institutions are more volatile. Furceri and Karras (2007) suggested a strong, statistically significant and negative relationship between country size and business cycle volatility implying that smaller countries are subject to more volatile business cycles than larger ones.

Furthermore, Montoya and de Haan (2008) showed that there is increasing volatility in most EU countries, in the period 1975-2005, attributing their finding to the Maastricht treaty. Magud (2008) argued that the effectiveness of fiscal policy depends on on the fiscal fragility of the government. Also, Hakura (2009) testified that output volatility has declined across groups of non-transition countries studied over the past three decades, but has remained considerably higher in developing countries. Evidence from cross-section investigation suggests that among the key determinants of output volatility was the discretionary fiscal spending.

Canova and Pappa (2010) found that business cycles in several E.U. countries have not changed significantly after EMU formation, and thus these small changes should be attributed to the inherent characteristics of each economy. This view was also consistent with the findings by Giannone et *al.* (2008) who found that the characteristics of business cycles in Europe have not changed significantly. Castro (2011) showed that the institutional changes that occurred in the E.U. after 1992 were not harmful to growth. Again, recently, Kose et *al.* (2012) argued that world factors cannot explain satisfactorily business cycle, contrarily to domestic factors.

b. On business cycles clustering

Our research also deals with business cycle clustering in EU-15. The rationale behind clustering goes back to the theory of the so-called Optimal Currency Area (O.C.A.) (e.g. Bayoumi and Eichengreen, 1997a; Frankel and Rose, 1998; Kenen, 1969; McKinnon, 1963; Mundell, 1961; Tavlas, 1993) according to which, the lack of an independent monetary policy could lead to a breakdown of the monetary union, if the union members exhibit non-symmetric output fluctuations.

In this framework, on the one hand Krugman (1991) argues that increasing integration would lead to regional concentration of industrial activities which, in turn, would lead to region-specific shocks, that would increase the likelihood of asymmetric shocks and diverging business cycles. See also Kalemli-Ozcan, Sorensen, and Yosha (2001). On the other hand, there is the view that a removal of the trade barriers would lead to more trade such that demand shocks would be more easily transmitted. See Frankel and Rose (1998), and Coe and Helpman (1995). See also Trichet (2001), Furceri and Zdzienicka (2011). In fact, a question of great interest directly related to the aforementioned *problematique* is the possible existence of a core–periphery type distinction among European countries' business cycles (e.g. Dickerson et *al.,* 1998), or a possible grouping of EU-15 countries in clusters (Camacho et *al.,* 2006).

Furthermore, Bayoumi and Eichengreen (1997) were among the first that developed a framework to test for the existence of an optimum currency area within EMU. Their findings suggested the existence of four (4) groups of countries that broadly coincide with a geographical grouping, namely a central European group of countries, a northern European group, a Southern group of countries and a group of countries that chose not to participate in the Euro-area.

Artis and Zhang (1998b) showed that the most distant economies from the core of EMU are Ireland and Finland. Likewise, Spain, Italy and Portugal are set aside because of their distinctive behaviour. Crowley and Christi (2003) showed that in the time period 1983–1992, E.U. consisted of four (4) groups and a core was identified; in the 1993–2001 time span European countries formed either two (2) or four (4) clusters. Bergman (2004) found that the economic and monetary integration during the last ten (10) years has affected business cycle behaviour. Again, Crowley and Lee (2005) found that Euro-area countries fall into three clusters: high and dynamic correlations at all frequency cycles, low static and dynamic correlations with little sign of convergence and those with low static correlation but convergent dynamic correlations. Concaria and Soares (2009) identified two groups of countries in the Euro area: the core countries consisting of Germany, France, Spain, Austria; the Benelux countries; and the periphery consisting of the rest of the countries.

3.3 METHODOLOGICAL FRAMEWORK

a. Business Cycles Analysis

In this work, we regard business cycles as fluctuations around a trend in the spirit of the seminal contributions by Lucas (1977), Kydland, and Prescott (1990), Alesina et *al.* (2008), Battaglini and Coate (2008), Ales et *al.* (2014). Hence, every time series can be decomposed into a cyclical component and a trend component as follows:

$$c_t = y_t - g_t \quad \textbf{(3.1)}$$

where: c_t is the cyclical component of time series, y_t is the actual time series and g_t is the respective trend that the time series exhibits[16].

b. Filtering

In order to extract the cyclical component, we use the Hodrick - Prescott (HP) filter, due to its widespread acceptance in the literature. The robustness of the HP de-trending method is confirmed, among others, by Artis and Zhang (1997) and Dickerson et *al.* (1998). The parameter used for quarterly data is equal to λ=1600 (Ravn and Uhlig, 2001). The trend is obtained by minimizing the fluctuations of the actual data around it, i.e. by minimizing the following function:

$$\sum_{t=1}^{T}(y_t - y_t^*)^2 - \lambda \sum_{t=2}^{T-1}[(y_{t+1}^* - y_t^*) - (y_t^* - y_{t-1}^*)] \quad \textbf{(3.2)}$$

where y* is the long-term trend of the variable y, and the coefficient λ>0 determines the smoothness of the long-term trend.

c. White Noise

In order to test whether the cycles extracted are not mere random walk processes we test for white noise using the Ljung and Box (1978) test (Q-Stat) which tests the null hypothesis of white noise for a maximum lag length k:

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[16] Other relevant approaches for assessing the role of fiscal policy on business cycle stabilization would be to estimate the response of fiscal variables to the cycle or to assess the impact of fiscal policy on output volatility.

$$Q = n(n+2)\sum_{j=1}^{k}\frac{\widehat{p_j}^2}{n-1} \quad \textbf{(3.3)}$$

where n is the sample size, $\widehat{p_j}^2$ the sample AC at lag j, and h the number of lags being tested; for significance level a, the critical region for rejection of the hypothesis of randomness is $Q > x^2{}_{1-a,h}$ is the a-quantile of the chi-squared distribution with h degrees of freedom.

d. Fourier Analysis

Next, we investigate the average length of the cycle based on the Fourier-transformed function of the cycle. A periodogram is a graph of the spectral density function of a time series in the natural frequency domain. The function has the following form:

$$f(\omega) = \begin{cases} f(1-\omega),\ if\ \omega \in [0.5,1] \\ \frac{1}{n}\left|\sum_{t=1}^{n} x_t \exp\{2\pi i(t-1)\omega\right|, if \omega \in [0,0.5) \end{cases} \quad \textbf{(3.4)}$$

where $\omega = \frac{2\pi}{n}$ is the natural frequency and x_t is the time series.

Peaks in the periodogram represent the dominant frequencies (cycles) in the dataset.

e. Stationarity

Finally, before turning to our model, we have to investigate the stationarity characteristics of the panel data series that will enter our investigation so as to avoid *potential spurious regression effects* between the variables. We use the panel unit root test of LLC (Levin, Lin and Chu, 2002) which is relevant for this type of investigation.

The LLC procedure has the following steps:

1st Step: Run the ADF test for each cross section on the equation:

$$\varDelta y_{i,t} = \rho_i y_{i,t-1} + \sum_{L=1}^{p_i}\theta_{i.L}\varDelta y_{i,t-L} + a_{m.i}d_{m,t} + \varepsilon_{i,t} \quad \textbf{(3.5)}$$

2nd Step: Run the auxiliary regressions for each cross-section i:

$$\varDelta y_{i,t} = \sum_{L=1}^{p_i}\theta_{i.L}\varDelta y_{i,t-L} + a_{m.i}d_{m,t} + \varepsilon_{i,t} \quad \textbf{(3.6)}$$

$$y_{i,t-1} = \sum_{L=1}^{p_i}\theta_{i.L}\varDelta y_{i,t-L} + a_{m.i}d_{m,t} + v_{i,t} \quad \textbf{(3.7)}$$

and obtain the residuals $\widehat{\varepsilon_{\iota,t}}$ *and* $\widehat{v_{\iota,t}}$ *respectively.*

3rd Step: Standardize the residuals obtained as follows:

$$\overline{\varepsilon_{\iota,t}} = \frac{\widehat{\varepsilon_{\iota,t}}}{\widehat{\sigma_{\varepsilon_\iota}}}, \overline{v_{\iota,t}} = \frac{\widehat{v_{\iota,t}}}{\widehat{\sigma_{\varepsilon_\iota}}} \quad \textbf{(3.8)}$$

where σ_{ε_i} is the standard error of each cross-section ADF.

4th Step: Run the OLS pooled regression:

$$\overline{\varepsilon_{\iota,t}} = \rho \overline{v_{\iota,t}} + u_{i,t} \qquad \textbf{(3.9)}$$

f. Panel Data

In order to examine the determinants of business cycles volatility, we use Dynamic Panel Models. However, before proceeding we perform a Hausman test in order to determine the specification to be used, i.e. Fixed effects or Random effects.

g. Hausman Test

The test is based on the difference between two estimates $b_1$and b_2. Under Ho, b_1 is assumed to be consistent and efficient estimate with asymptotic covariance matrix V_1. The alternative estimator b_2, with asymptotic covariance matrix V_2, is consistent - but usually inefficient - both under Ho and the alternative hypothesis Ha. A large difference b_1-b_2 between the estimates is seen as evidence against Ho, this is measured by the Mahalanobis distance, thus: Ho:

$$Var(b_1 - b_2) = V_1 - V_2 \qquad \textbf{(3.10)}$$

and the Hausman statistic is:

$$H = (b_1 - b_2)^T (V_1 - V_2)^{-1}((b_1 - b_2) \ \textbf{(3.11)}$$

which is asymptotically chi-square distributed with $k = rank(V_1 - V_2)$ degrees of freedom under Ho (Hausman and McFadden 1984; Amemiya 1985).

h. Models

As Arrellano and Bond (1991) suggested, the Dynamic Panel OLS estimators do not belong to the class of efficient estimators. To this end, Arellano and Bond (1991) derived an efficient[17] generalized method moments (GMM) estimator for the parameters of this model. Therefore, we make use of both fixed effects Dynamic OLS and Arelano-Bond (1991) Dynamic GMM, using as instruments the lagged values of the dependent variable.

[17] Alternatively, IV or biased correct LSVD estimators have been used but the results did not change significantly.

We exclude from our analysis monetary variables since all the countries under investigation are members of the EMU and, thus, share in common monetary circulation dictated by the European Central Bank (ECB). The estimated models, where $i = 1,..,12$ denotes the panel dimension and $t,$ denotes the time dimension, are the following:

Model 1

$$Ycycle_{i,t} = c_t + a_1 ST_{i,t} + a_2 SB_{i,t} + a_3 CE_{i,t} + a_4 DT_{i,t} + a_5 IT_{i,t} + a_6 U_{i,t} + a_7 GD_{i,t} + a_8 EMUGDPcycle_t + a_9 Ycycle_{i,t-1} + m_i \quad \textbf{(3.12)}$$

Model 2

$$(Ycycle_{i,t}/Y_{i,t}) = c_t + a_1(ST_{i,t}/Y_{i,t}) + a_2(SB_{i,t}/Y_{i,t}) + a_3(CE_{i,t}/Y_{i,t}) + a_4(DT_{i,t}/Y_{i,t}) + a_5(IT_{i,t}/Y_{i,t}) + a_6(U_{i,t}/Y_{i,t}) + a_7(GD_{i,t}/Y_{i,t}) + a_8(EMUGDPcycle_t/Y_{i,t}) + a_9(Ycycle_{i,t-1}/Y_{i,t}) + m_i \quad \textbf{(3.13)}$$

For a detailed description of the variables, see Table 1 (Section on *Data and Variables*). The variable c_t denotes the intercept of the panel regression which may vary over time, while m_i denotes the individual-specific effects for each economy (Wooldridge 2010).

Model 2 is normalized by dividing with the GDP. This is done in order to control, in an econometric sense, for the magnitude of the variables that enter the panel, meaning to homogenize our panel in a sense that both large and small economies in our panel analysis to have the same predictive ability over our dependent variable.

i. Political Business Cycle

In general fiscal policy variables are supposed to be manipulated before and after the elections in the context of political business cycles (PBC). If political business cycles are opportunistic, manipulation of fiscal policy variables can be used irrespectively of the political affiliation of the party governing. Controlling for such variables is very important and has not been used in the literature before.

In this context, the interaction between two key Political Variables[18], such as Elections (*ele*) and Quality of Institutions (*IQ*), with fiscal variables is of particular

[18] Also, several other important factors, such as Private Investment, Corruption, Openness, Political orientation of the Government, Trade relations and Labour forms, have been considered as determinants

interest. In order to account for the influence of Political business cycles on the key fiscal variables of our model we make use of a Random Effects Panel Seemingly Unrelated Regression Equations (SURE) model. To this end, the following system of equations is estimated:

$$SB_{i,t} = C_1 + a_{11} ele_{i,t} + a_{12} IQ_{i,t} + m_i \quad \textbf{(3.13)}$$

$$ST_{i,t} = C_2 + a_{21} ele_{i,t} + a_{22} IQ_{i,t} + k_i \quad \textbf{(3.14)}$$

$$DT_{i,t} = C_3 + a_{31} ele_{i,t} + a_{32} IQ_{i.t} + l_i \quad \textbf{(3.15)}$$

where $i = 1,..12$ is the panel dimension, $t = 1, ... T$ is the time dimension and m_i, k_i and l_i are the individual specific effects for each economy. This system allows for a full examination of whether Elections and Institutional Quality manipulate the fundamental policy variables. The model can be used to examine carefully the politically induced business cycle, and provide useful insights into the nature of opportunistic politico – economic behavior.

j. Rolling Window

Next, we use the rolling window methodology in a panel set up in order to investigate whether the respective coefficients of our proposed models are stable over time. A common technique to assess the constancy of a model's parameters is to compute parameter estimates over a rolling window of a fixed size through the sample. If the parameters change at some point during the sample, then the rolling estimates capture this instability. Using economic intuition, since the year 2000 is the land mark of EMU formation, it is natural to assume that any break in the time constancy of coefficients is more likely to occur in that year. To this end, we employ panel rolling window using a fixed length of 10-15 years by shifting the starting period from 1996 to 2001.

The rolling window is a methodology that repeats estimations using subsamples of the total data by shifting the start (and/) or end-points with a fixed window (Zivot and Wang 2006). Consider a panel estimation with time series data using the rolling window as follows:

$$Y_{t,i} = a_i + b_i x_{t,i} + \varepsilon_i \text{ , } i = 1,..n \text{ and } n < T \quad \textbf{(3.16)}$$

---

of the key fiscal variables. Nevertheless, none of them had statistically significant effects and were, thus, dropped from all three equations.

Where n denotes the length of the sub-sample or window, T is the total number of observations of our panel time series, $Y_{t,i}$ denotes the dependent panel variable for each sample period, $x_{t,i}$ denotes the independent panel variable for each sample period and ε_i denotes the error term of each sample period which is typically assumed to be *i.i.d.* Therefore, for each i, the rolling windows approach estimates the above model using the T-n+1 sample length.

k. Causality Testing

Lastly, we conduct the Toda-Yamamoto (1995) causality test to examine the causal relationship between the variables examined and the cyclical part of GDP. This technique is applicable irrespectively of the integration and co-integration properties of the system. The augmented VAR procedure proposed by Toda-Yamamoto (1995) allows for causal inference based on an augmented VAR [*VAR* $(s + d_{max})$] with integrated and co-integrated processes, where d_{max} is the maximal order of integration in the model. The dynamic causal relationships among the cyclical component of GDP and the aforementioned variables follow the scheme:

$$Y_t = \mu + \sum_{i=1}^{p-1} \Gamma_i Y_{t-k} + \zeta_t \quad \textbf{(3.17)}$$

where Y_t is a $(n * l)$ column vector of p variables, μ is a $(n * l)$ vector of constant terms, Γ_i represents the coefficient matrices, k denotes the lag length and ζ_t is *i.i.d.* and p-dimensional Gaussian error with mean zero and variance matrix Λ.

The method involves testing the significance of the parameters of a VAR(s) model, where s is the lag length in the system. The traditional F tests and its Wald test counterpart are not valid for non-stationary processes, as the test statistics do not have a standard distribution (Toda and Phillips 1993). The lag length of the variables in the causality models are selected in accordance to the Schwartz Bayesian Information Criterion (SBIC). Since lagged dependent variables appear in each equation, their presence is expected to purge serial correlation among the error terms.

l. Clustering

We proceed by investigating the formation of clusters in EU-15, so as to identify the groups of countries that share similar characteristics, regarding their business cycle. Various strategies for the determination of the number of clusters have been proposed (e.g. Bozdogan, 1993). The most common relocation method is *k*-means clustering

(Hartigan and Wong, 1978) because the distance between any two objects is not affected by the addition of new objects in the analysis (Timm, 2002).

There is no standard procedure for determining the number of clusters. Among the most popular criteria to derive the optimal number of clusters in *k*-means clustering is the Calinski–Harabasz (1976) F-stopping-rule index that is based on the within cluster sum of squares of the *k* formed clusters and the between clusters sum of squares. The formula used for Calinski–Harabasz statistic, for *k* clusters and *n* observations is:

$$F_{\text{Calinski–Harabasz}} = \frac{Trace(T)/(k-1)}{Trace(SSE_k)/(n-k)} \quad \textbf{(3.18)}$$

where: T is the total sum of square between clusters and is given by the expression:

$$T = \sum_{i=1}^{n} \|y_i - \bar{y}\|^2 \quad \textbf{(3.19)}$$

and SSE_k is the within cluster sum of squares for cluster k (Ck) given by the expression:

$$SEE_k = \sum_{i=1}^{k} \|y_i - \bar{y}_k\|^2 \quad \textbf{(3.20)}$$

Thus, the Calinski-Harabasz F-statistic is a measure of (dis-)similarity between clusters. In other words, it measures the degree of homogeneity between groups. The larger the values of Calinski-Harabasz index, the more significant the differences among groups.

3.4 DATA AND VARIABLES

We use quarterly data covering the period 1996 (Q1)-2013 (Q4), regarding the core EMU economies of: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Holland, Portugal and Spain.[19] Table 3.1, summarizes the data and variables used in the analysis, where the panel is balanced.

[19] Given that some of the data were not available, following Pesaran et *al.* (2004), we intra-polated the missing observations.

Table 3.1: Data and Variables

Variable	Description	Source	Time period
GDP	**Gross Domestic Product** out of which the cyclical component is extracted;	OECD, constant 2005 prices in € billions.	1996(Q1)-2013(Q4)
CE	**Capital expenditures**		
SB	**Social benefits** other than transfers in kind, a variable which includes on the one hand social benefits paid in cash to households by social security funds which are provided under social security schemes e.g. pensions and unemployment benefits and, on the other hand, social assistance benefits in cash payable to households by government units outside a social insurance scheme incorporating social contributions e.g. as living allowances paid by municipalities, child maintenance, etc		
ST	**Social transfers** in kind, a variable which consists of individual goods and services provided as transfers in kind to individual households by government units and non-profit institutions serving households (NPISHs), whether purchased on the market or produced as non-market output by government units or NPISHs		
DT	**Direct Taxes** refer to revenues for the general government collected by individuals and enterprises		
IT	**Indirect Taxes** refer to revenues for the general government, e.g. consumption tax		
U	**Unemployment** is expressed as percentage (%) of labour force and is used to capture the phase of the cycle		
GDPcycle	**Cyclical component of GDP**, de-trended by means of the HP filter		
EMUGDP cycle	**Cyclical component of the aggregate EMU GDP**, extracted by means of the HP filter from aggregate EMU GDP		
IQ index	**Institutional Quality index** refers to the key variables that dictate per capita economic growth to OECD countries.	CESIFO, index as percentage %	
Elections	**Elections** refers to a dummy variable that account for elections in each EMU country, taking the value of 1 in a year that elections took place and 0 elsewhere	World Data Bank	

In addition we use OECD quarterly data regarding the GDP of UK, Sweden and Denmark, in 2005 prices in billions of dollars.

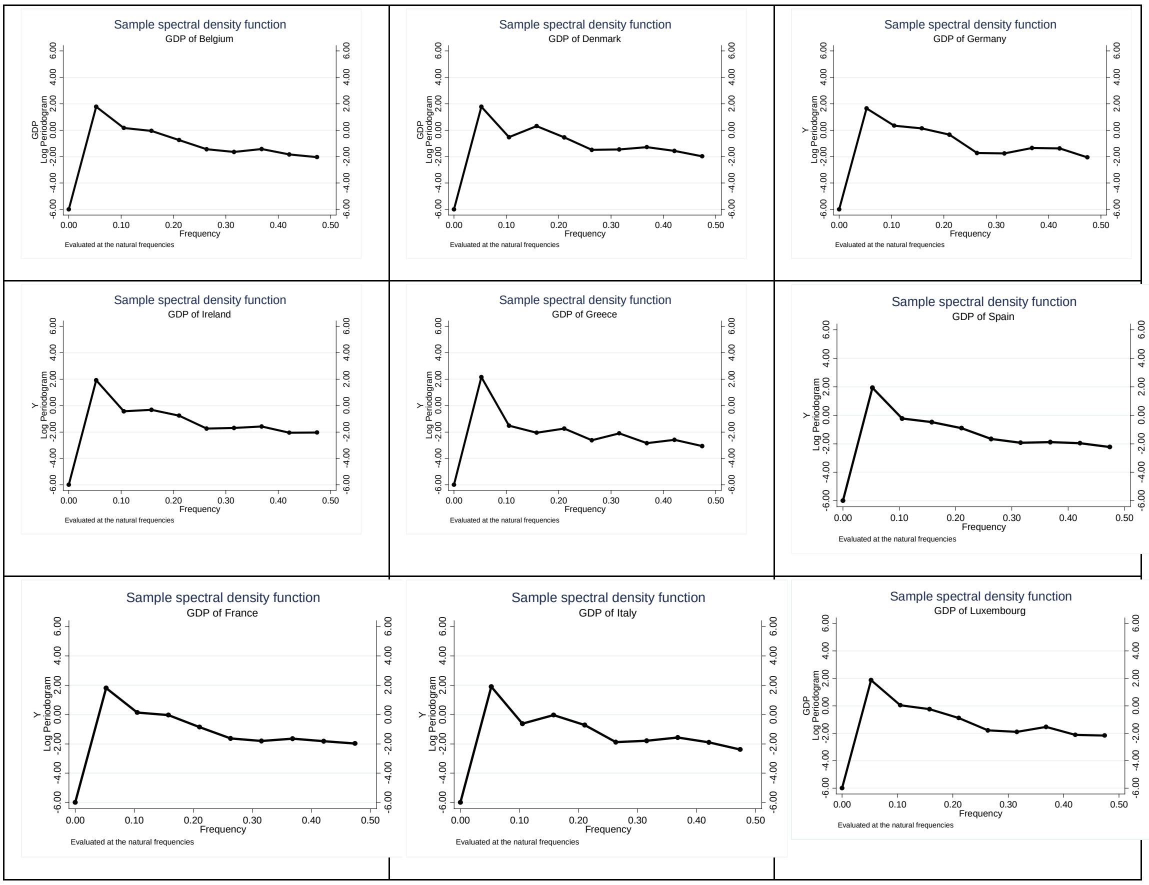
3.5 RESULTS

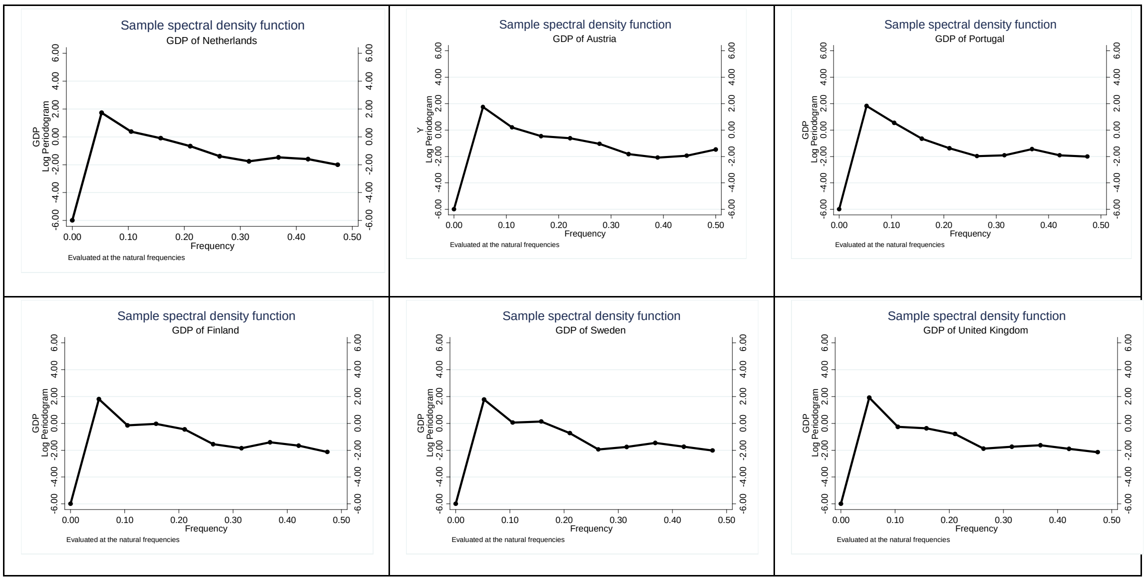
To begin with, the stationarity properties of the various macroeconomic variables were checked. The LLC test was applied both on the original variables and on their first differences, where relevant. All variables are found stationary except for the variables of Social Transfers (ST) and Social Benefits (SB); however they are found stationary in their first differences (Table B.1, Appendix B).

In order to extract the cyclical components of each country's GDP and the Aggregate EMU GDP, we used the HP filter to decompose it into a trend and cyclical component. Next, the results of the Ljung and Box test on the cyclical components of GDP and Aggregate EMU GDP indicate a rejection of the null hypothesis of white noise for both variables under investigation

Hence, the existence of cyclical regularities is a valid hypothesis, from an econometric perspective. Furthermore, the results of the Fourier analysis for EU-15 economies are illustrated in Figure 3.1.

Figure 3.1: Periodograms of GDP





In brief, a short term cycle of approximately two (2) years is evident in most EMU economies. Also, a second mid-term cycle with a frequency of 6-8 years is present.

Next, we provide cross-correlation results between the cyclical variable of GDP and the rest of the variables that enter the model (Figures 3.2-3.7). The results suggest that the dynamics of the German economy differ, compared to the rest of the EMU countries.

Now, in order to decide about the specification, we conducted the Hausman specification test (Table 3.2). The results show that, as expected, the fixed effects model is appropriate for our investigation.

Table 3.2: Hausman Specification Test

	Coefficients		
Independent Variables	**Fixed effects (b)**	**Random effects (B)**	**Difference (b-B)**
Capital expenditure	-0.05	-0.14	0.09
Direct Taxes	0.55	0.03	0.52
Gross Debt	-0.04	0.00	-0.04
Indirect Taxes	-0.08	0.01	-0.09
Social benefits	-1.06	-1.06	0.00
Social transfers in kind	1.01	-1.05	2.06
Unemployement	-0.15	0.12	-0.27
EMU GDPcycle	0.03	0.05	-0.02
lagged GDP	0.15	0.36	-0.21
Ho: No difference in coefficient		p-value=0.00	

Next, we used fixed effects analysis as described above to estimate the relationship between the fiscal variables and the cyclical component of GDP (Table 3.3).

Table 3.3: Dynamic Panel Data Analysis

	Model 1		Model 2	
	Dynamic OLS	GMM	Dynamic OLS	GMM
Independent Variables	Coefficients			
Capital expenditure	-0.05	-0.02	-0.05	-0.02
t-stat	-0.49	-0.24	-0.72	-0.35
Direct Taxes	0.54	0.62	0.35	0.54
t-stat	7.36*	8.54*	4.22*	6.27*
Gross Debt	-0.04	-0.05	-0.03	-0.03
t-stat	-6.29*	-7.81*	-2.86*	-5.13*
Indirect Taxes	-0.08	-0.08	-0.07	-0.14
t-stat	-0.96	-0.96	-0.82	-1.77**
Social benefits	-1.05	-1.02	-0.86	-0.81
t-stat	-5.58*	-6.00*	-4.82*	-5.32*
Social transfers in kind	1.01	0.92	1.01	0.88
t-stat	4.42*	4.28*	4.23*	4.20*
Unemployement	-0.15	-0.20	-0.31	-0.34
t-stat	-0.51	-0.68	-4.24*	-5.03*
EMU GDPcycle	0.03	0.03	0.01	0.01
t-stat	7.83*	8.85*	9.39*	10.76*
lagged GDP	0.15	0.10	0.39	0.35
t-stat	3.17*	2.42*	9.24*	10.47*
Constant	-20.71	-23.37	-0.02	-0.03
t-stat	-5.16*	-6.07*	-2.26*	-3.46*
$R^2 - adj$	**0.71**	$Wald\ \chi^2 = 863.40$	**0.69**	$Wald\ \chi^2 = 921.72$
F-stat	**7.89**		**4.12**	

* denotes statistical significance at the 5% level or higher.

** denotes statistical significance at the 10 % level or higher.

Next, using the rolling window approach set out earlier (Figure 3.2a-3.2b) we examined the sensitivity of the estimated parameters. From visual inspection, it is clear that in both models the estimated coefficients remain practically unchanged over time.

Figure 3.2a: Rolling window (model 1)

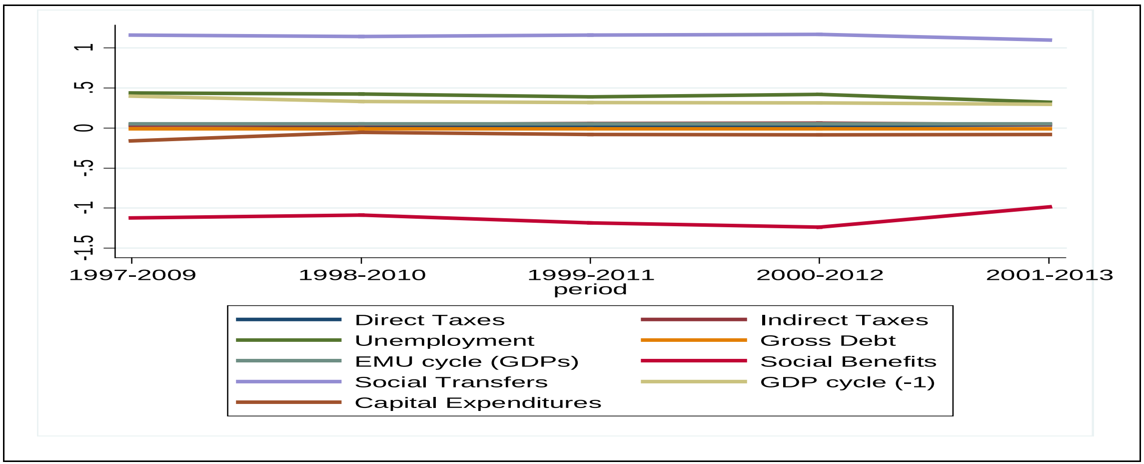
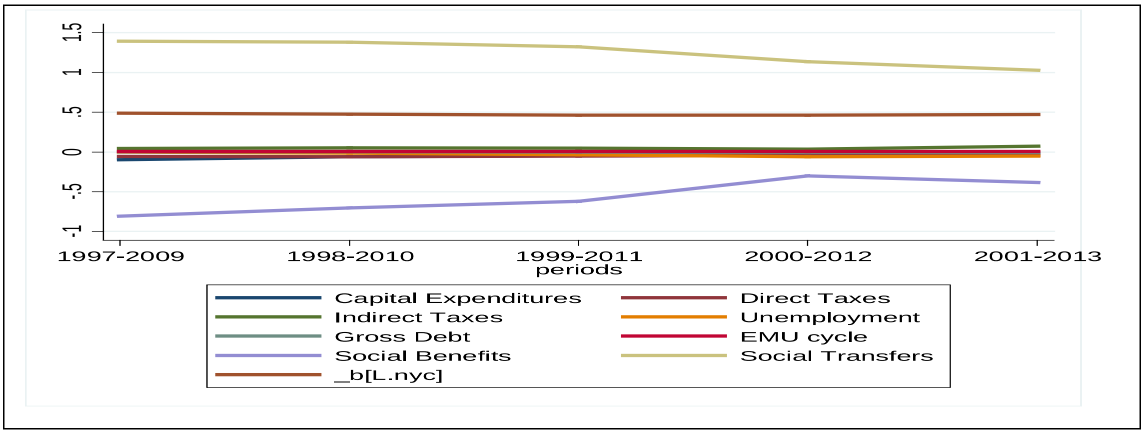


Figure 3.2b: Rolling window (model 2)



Next, in order to account for the significant role of PBC, the results concerning the impact of Elections and Institutional Quality on the key fiscal variables dictated by our previous panel data analysis are presented (Table 3.4).

Table 3.4: Random Effects Panel SURE estimates of Political Business Cycles (PBC)

Variables	**Equation 1 (SB)**	**Equation 2 (ST)**	**Equation 3 (DT)**
IQ index	20.4	14.25	79.15
t-stat	2.48	1.93	1.64
Elections	0.01	0.02	-0.01
t-stat	1.67	2.01	-0.83
Intercept	0.01	0.01	0.13
t-stat	13.38	10.91	47.18
Summary statistics			
RMSE	0.01	0	0.03
χ^2	7.8	7.93	4.28

The results suggest that Election as well as Institutional Quality significantly affect the key fiscal variables of our model. In fact, we found no qualitative differences between OLS, and random effects panel SURE. This is an expected result because each equation contained exactly the same set of regressors. In addition, there were no significant cross-equation correlations between the error terms of each equation as can be seen in Table 3.5.

Table 3.5: Cross-Equation Correlations between the Error Terms of each Equation

	SB	**ST**	**DT**
SB	1.00		
ST	0.40	1.00	
DT	-0.05	0.18	1.00

Finally, the Toda-Yamamoto causality test is implemented, in order to determine which variables have predictive power for business cycles volatility (Table 3.6).

Table 3.6: Toda-Yamamoto test for Granger causality

Hypothesis tested	χ^2	**d.f**	**p-value**
SB ***does not cause*** **GDP cycle**	2.24	2	0.33
ST ***does not cause*** **GDP cycle**	5.79	2	0.05
U ***does not cause*** **GDP cycle**	0.65	2	0.72
CE ***does not cause*** **GDP cycle**	5.88	2	0.05
GD ***does not cause*** **GDP cycle**	8.77	2	0.01
EMUGDPcycle ***does not cause*** **GDP cycle**	0.31	2	0.85
DT ***does not cause*** **GDP cycle**	5.62	2	0.06
IT ***does not cause*** **GDP cycle**	1.96	2	0.37

The results suggest that Social transfers, Gross Debt, Government Capital expenditures and Direct Taxation are the variables that dictate business cycles volatility in EMU.

Finally, *k*-means clustering is implemented using a vector of all the available macroeconomic variables of our dataset for each EMU-15 economy. In order to determine the optimum number of clusters, we use of the Calinski -Harabasz F-statistic (Figure 3.3). The results suggest the existence of four (4) clusters (Table 3.7).

Figure 3.3: Optimum number of clusters (Calinski-Harabasz criterion)

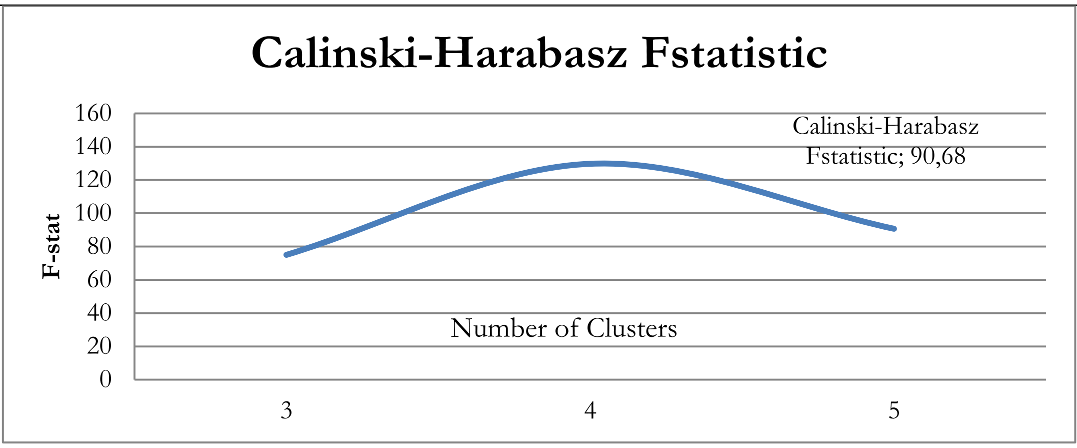


Table 3.7: Clusters of EU15 economies

	Clusters			
Economies	**1**	**2**	**3**	**4**
Austria				v
Belgium				v
Finland				v
France			v	
Denmark				v
Germany		v		
Greece				v
Ireland				v
Italy		v		
Luxemburg				v
Netherlands				v
Portugal				v
Spain				v
Sweden				v
United Kingdom	v			

The four clusters are: (a) United Kingdom; (b) Germany and Italy; (c) France and (d) Belgium, Finland, Netherlands, Spain, Denmark, Greece, Ireland, Luxembourg, Portugal and Sweden.

3.6 DISCUSSION

In Figures B.1-B.6 (Appendix B), the cross correlations of the variables examined with the cyclical GDP at various lags/leads are presented. Interestingly, in Germany social benefits are negatively correlated with the GDP cycle, while the opposite is the case in France, Portugal, Greece, Italy and Spain. This, in turn, suggests that social benefits are counter-cyclical for the German economy, so social benefits act as a stabilizing mechanism for Germany, while they have a pro-cyclical character for the economies of France, Portugal, Greece, Italy and Spain. The destabilization effect of social benefits could be attributed to the fact that when they are used as a fiscal policy instrument, they increase the overall government expenditures and as a result deteriorate the Current Account Balance, a result which is consistent, among others, with the work of Abbot and Jones (2013). In addition, in Germany, social benefits have an immediate effect (not lagged) on the cycle of the economy, while in the economies of France, Finland, Portugal, Greece, Luxembourg, Italy and Spain a minor lead is observed, implying that spending for social benefits in these economies is an active fiscal policy instrument that leads to their destabilization.

The same picture is in line regarding social transfers in kind and GDP cycle, with the German economy to exhibit a negative correlation and thus a counter-cyclical character, while in France, Finland, Portugal, Italy, Luxembourg, Netherlands and Spain, a pro-cyclical scheme is in place. Nevertheless, for the economies of Austria, Belgium, Italy, and Luxembourg social transfers in kind exhibit a minor lag, as opposed the rest of the EMU economies suggesting that in these economies spending on social transfers in kind follow their cycle with a lag.

The cross correlation between domestic and EMU cyclical output can be interpreted as the degree of synchronization of the various EMU economies with the EMU aggregate cycle. The results suggest that all countries are synchronized with the EMU cycle except for the economies of Germany and Greece. In fact, the economy of Germany exhibits a negative correlation with EMU cycle with a lead of three (3) years, suggesting that the German cycle is countercyclical to the EMU cycle and vice versa, giving credit to the view of Artis and Zhang (1997, 1999) that Germany could act as a dominant economy within the EMU. On the other hand, Greece exhibits a positive correlation with EMU aggregate, suggesting that it was hit by the EMU cycle with a lag of approximately one (1) year.

Capital government expenditures in the economies of Netherlands and Finland are positively correlated with their GDP cycle as opposed to the rest of the economies. This suggests that for these two economies, capital government expenditures are destabilizing the aggregate economic activity. Moreover, in the economies of the Netherlands, Luxembourg, Greece, Finland and Austria, government capital expenditures follow their GDP cycle with a minor lag, while the opposite holds for the rest of the economies with the exception of Germany, where both variables are synchronized.

Direct taxes are countercyclical to GDP cycle for the economies of Germany and Portugal, suggesting that they have a stabilizing effect, while the opposite holds for the rest of the EU-15 economies. This, in turn could be attributed to an inherent characteristic of the two economies which is depicted by the efficiency of their taxation system and the taxation policies that have been implemented throughout the last decades. Additionally, direct taxes in the economies of Portugal, Ireland, Finland and Austria exhibit a minor lag compared to their GDP cycle suggesting that their overall taxation system is dependent on the phase of their economy, in contrast to the rest of the EMU countries.

Again, an interesting result is that Germany is the only economy where indirect taxes have a stabilizing effect, while in the rest of the EMU economies indirect taxes tend to destabilize them. This interesting finding could be attributed to the fact that Germany is the larger exporter within EMU and, thus, its economic gains from indirect taxes lead to an increase of the economy's overall current account balance and thus to a stabilization effect. On the other hand, indirect taxes in the economies of Austria, Belgium, Ireland, Luxembourg and Spain follow the cyclical movement of their economy, as opposed to the rest of the countries, suggesting that for these economies indirect taxes are considered to be an active tool for fiscal policy implementation.

Next, the GDP periodograms of the various EU-15 economies are presented in Figure 3.1. The results suggest the existence of one dominant frequency, i.e. a short term cycle of approximately 2 years, but also a medium-term cycle of 6-8 years, in the period

1996-2013. An interesting result is that the same cycle is present even in the economies of Denmark, UK, and Sweden that do not participate in the common currency.

We continue our investigation with the estimation of different models using Dynamic Panel Analysis (Table 3.6). We can see that in Model 1, using dynamic panel G.M.M., most of the variables are significant, while the model is able to capture a large part of the variance of the GDP cycle. The Social Benefits and Gross Debt are countercyclical and highly significant. Meanwhile, direct taxation, social transfers in kind and EMU GDP cycle are found to be highly pro-cyclical and significant. The fact that Gross Debt was found to be significant and counter cyclical to GDP's cycle, could be attributed to the fact that Debt accumulation leads to credit barriers and thus to a direct influence on each economy's GDP, which is partly in line with the work of Aloui (2013), and to the fact that debt accumulation is supposed to stabilize the economy in the presence of financial integration (see, *inter alia,* Furceri and Zdzienicka, 2011).

On the other hand, aggregate EMU cycle was found to be significant and pro-cyclical to the GDP cycles, a finding which could be attributed to the financial integration and trade relationship between the various EMU economies. Lastly, the significant effect of lagged GDP, that is pro-cyclical to the GDP cycle, could be attributed to the fact that the fiscal policies within EMU are implemented with respect to the overall past performance of each economy, in an attempt to be in line with the Maastricht treaty. These results are fully consistent with the ones based on dynamic panel O.L.S., since both the statistical significance of the variables as well as their respective signs and magnitudes remain, practically, unaffected.

The results of Model 2, using dynamic panel GMM, suggest that both Direct and Indirect taxation, as well as EMU cycle and Social Transfers in kind, are the main statistically significant pro-cyclical variables, while Social Benefits and Unemployment and Gross Debt were found to have a counter-cyclical character. The fact that Gross Debt and Social Benefits were not found to be statistically significant for GDP cycle can be attributed to the normalization of our model, meaning that the ratio of Debt over GDP is unable to explain the volatility of GDP, which is largely consistent with the findings of Aizenmann et *al.* (2013).

Meanwhile, the pro-cyclical character of Social Transfers could be attributed, at least partly, to a direct effect on consumption of the groups taking part to the transfers. Now, regarding the variable of unemployment that has become statistically significant and counter-cyclical to the GDP cycle, suggests that unemployment could serve as a stabilizing mechanism for GDP cycles, mainly due to its inverse relationship with the profiteering functioning of the economy. In another formulation, the unemployment rate is countercyclical in the sense that it is lower when the economies' health is good and higher when the economies' health is bad. These findings are fully consistent with the ones based on dynamic panel O.L.S., with the exception of Indirect Taxation which is, now, found insignificant. In addition, the stability of our estimates regarding both the Dynamic Panel OLS and the Arellano-Bond GMM estimations are confirmed via the rolling window analysis for both models (Figure 2a, 2b) since all coefficients appear to be constant over time.

Next, turning to political business cycles (Table 3.7) and the impact of elections and institutional quality on the key fiscal variables of our analysis (i.e. social benefits, social transfers and direct taxes), we found that the quality of institutions has a positive effect on all the variables which implies that a better quality of institutions leads, in the short-run, to better economic conditions and to the fact that more effective spending leads to an increase of spending towards a more fair society. Also by considering the fact that Direct Taxes and Social Transfers are pro-cyclical we can infer that the Quality of Institutions has an indirect pro-cyclical character.

On the other hand, elections have a statistically significant impact on the key fiscal variables of our analysis. In particular, elections have a positive impact upon social benefits in an attempt of the governing party to enhance its chances of being re-elected. Nevertheless, elections have a negative effect on both social transfers and direct taxation. The positive relationship between elections and social transfers could be attributed to the reasons already mentioned with regard to social benefits. Thus, an increase of social benefits should be accompanied by an increase of social transfers, given that the total amount of government expenditures is growing before the elections, which is consistent with the same sign of elections between the variables of social benefits and social transfers in kind. Our finding is fully consistent, with the results of Potrafke (2012). Finally, as far as the effect of elections to direct taxation is concerned, the negative relationship could be attributed to the pro-electoral cycle that dictates a slight decrease of taxation as a means of enhancing the probabilities of re-election for the government party, irrespective of their political identity (e.g. Katsimi and Sarantides, 2011; Efthyvoulou, 2011; Efthyvoulou, 2012;). Now, by taking into consideration the procyclical character of Dirtect taxes and Social Transfers as well as their negative relationship with election we can infer that election have an indirect counter cyclical character.

In brief, our results regarding Elections and the Quality of Institutions, which are indirectly related to fiscal policy in the political business cycles' literature, are in line with the works - among others - by Nordhaus (1975), Rogoff and Sibert (1988), Rogoff (1990), Persson and Tabellini (1990) and Rosenberg (1992) Potrafke (2012), Abott and Jones (2013), Mechte and Potrafke (2013), De Haan et *al.* (2013). Thus, these variables could be used in a policy framework in order to manipulate business cycles volatility and synchronization in the EMU.

Turning to the causality results of Toda-Yamamoto (Table 3.8) we observe that Gross Debt, Social Transfers, Direct Taxation and Government Capital Expenditures are the variables which are, in principal, able to dictate the evolution of GDP cycles. Now, due to the fact that all the aforementioned variables are related to the Current Account Balance of each economy, and thus to the Maastricht stability treaty, we conclude that the treaty is able to capture the essence of business cycles by influencing the main factors that affect business cycles volatility, and thus the overall stability of each economy.

Combining the causality results with our Panel analysis results it is evident that Gross Debt is the main counter-cyclical fiscal variable which has to be used as an active fiscal policy instrument for the overall economy stabilization, while Social Transfers is the fiscal variable whose usage as a fiscal policy tool could result in the economy's destabilization.

Next, an interesting empirical finding is the distinction in core and periphery counties in EU-15, a finding which is reported in the majority of studies in the relevant literature. Among others, the existence of a core of countries with similar characteristics has been documented by Bayoumi and Eichengreen (1993), Dickerson et *al.* (1998), Artis and Zhang (1998a, 1998b), Crowley and Christi (2003), Massmann and Mitchell (2004), Camacho et *al.* (2006) and Concaria and Soares (2009). See also Canzoneri et *al.* (1996), Bayoumi and Eichengreen (1997a, 1997b) and Taylor (1995).

More precisely, according to the results of the cluster analysis performed, there exist four (4) clusters (Figure 3.2, Table 3.9). The first cluster consists of the economy of United Kingdom. This result could be attributed to the fact that UK is one of the largest and strongest economies in E.U., which does not belong to the common currency area. Our finding is partly consistent with the work of Kishor (2012) who studied the response of monetary policy of selected EMU countries and found that only England's Central Bank was the least responsive to external shocks.

The second cluster consists of the economy of France, which is among the largest economies in EMU. Once again the fact that France stands alone could be attributed to its dominant position within EMU, but also to its opposing policies implemented by the other two E.U. dominant economies, namely Germany and the UK.

In the third cluster lie together the economies of Italy and Germany. This finding should be attributed to the fact that the cycles of the two countries are synchronized through their bilateral trade activity, since Italy has the largest debt in EMU, while Germany is the largest exporter in EMU. Our analysis seems to suggest that the two economies have closely related cycles, since Italy acts as the principal (15%) importer of German products (E.C.B., 2012), which is largely consistent with the findings of Dees and Zorell (2012).

The rest of the countries lie in the fourth cluster, that of the so-called "periphery", probably due to their size that is relatively small compared to the rest of the economies (Gouveia and Correia 2008), or due to the fact that the fiscal policies implemented in these economies are unable to counter-effect the monetary policies implemented by the E.C.B., at an aggregate level.

The results show that there is a core – periphery distinction in the EMU, although the core consists of three main clusters, i.e. (i) France, (ii) UK and (iii) Italy-Germany. The periphery countries tend to group together, probably as a result of the recent European crisis. This pattern does not conform to a conventional division and shows that the definition of the so-called core-periphery is more involved. In the light of recent developments after the sub-prime crisis it seems, however, that this view has indeed considerable merit. The recent economic crisis hit the various economies in different ways. First, it brought to the foreground the differing Anglo-Franco-German views on the future of the Eurozone. Second, it emphasized the different patterns of reaction to debt-related problems in Greece, Spain, Portugal and Italy. We could say that the clustering results reflect the different business cycles dynamics that each EU15 economy exhibits based on its size. In other words, our results conform more to a separation of "big and small" rather than that of a "core and a periphery", in the traditional sense of the term. Therefore, the clustering approach reflects various factors which operate simultaneously and are largely consistent with what we know after the sub-prime crisis.

Summing up, the large and dominant economies of Germany, France and United Kingdom constitute the main clusters of the core of EMU. Meanwhile, most of the periphery countries lie in one cluster suggesting that the ongoing crisis has led a number of smaller economies to cluster together.

3.7 CONCLUSION

The purpose of this chapter was threefold. First, it tried to answer some fundamental economic questions regarding the fiscal determinants of business cycles in the EU-12 (1996-2013) using Dynamic panel data analysis. Second, it tried acknowledge the significant role of Political Business Cycles investigating their indirect role on the business cycle of the EU-12 economies to the overall business cycles. Third, it made an attempt to shed light on the dynamics of the recent crisis by using cluster analysis.

The results suggest that all EU-15 economies share similar short-term and mid-term cycles of approximately 2 and 6-8 years, respectively. Cross-correlation results between the cyclical variable of GDP and the rest of the fiscal variables suggest that the dynamics of the German economy differ significantly, compared to the rest of the EMU countries. Furthermore, Social benefits, Social Transfers and Gross Debt were found to be the most significant counter-cyclical fiscal variables, while taxation - both direct and indirect - is the major pro-cyclical variables. This result is also consistent with the use of the Toda-Yamamoto causality test. In addition, elections and institutions seem to directly affect the key fiscal variables of our model, suggesting that manipulation of fiscal determinants is possible through political variables. In fact, both Quality of institutions and Elections seem to have an indirect pro-cyclical effect on the EU-12 business cycles. Lastly, the results of cluster analysis suggest the existence of three major core clusters including three major EU economies, while the recent crisis has led a number of smaller economies to cluster together.

Future work on business cycles determinants, using both fiscal and monetary variables in an attempt to explain business cycles volatility, would be of great importance. In addition, controlling for EMU formation, as well as for openness and corruption in a political business framework, would also be an interesting path for future investigation.

Part B

Chapter 4: Quantity-of-Money Fluctuations and Economic Instability in the USA[20]

Despite the vulnerability of the EU economy when compared to the US economy, the global recession was primarily triggered by the crisis in the USA. In this context, we will attempt to shed light on the relationship between the quantity of money and economic activity, in the US economy. More precisely, the next chapter will examine the relation between the fluctuations in the quantity of money and the fluctuations in economic activity, i.e., the cyclical components of each variable. The principal question posed is: *how do the fluctuations in the quantity of money affect or are affected by the fluctuations of output and profitability in the US economy* (*1958-2006)*? Our investigation will stop in 2006 since the dynamics of the traditional economic structures changed dramatically in the US and globally after 2006.

4.1 INTRODUCTION

The so-called *Quantity Theory of Money*, probably one of the oldest theories in economics, has triggered interesting discussions, among others, in the works of Hume and J.S. Mill, but primarily in the research programme of the Austrian School of Economics and that of the Monetarists. Of course, it is also present in the Marxian, (Post-) Keynesian and Schumpeterian doctrines. In fact, according to some authors the quantity theory of money dates back to sixteenth-century Europe, where gold and silver inflows from the New World into Europe were used in the coinage of money and therefore increased prices[21].

However, the present chapter does not focus on the *Quantity Theory of Money, per se*. In fact, it deals with the relation between the *fluctuations* in the quantity of money and the *fluctuations* in economic activity, i.e., the cyclical components of each variable. Analytically, the question posed is *how do the fluctuations in the quantity of money affect or are affected by the fluctuations of output and profitability in the US economy* (*1958-2006)*? Our

[20] Another version of this chapter has been published as follows: Panayotis G. Michaelides, John G. Milios, Panayiotis Tarnaras and Konstantinos N. Konstantakis (2015), Quantity-of-Money Fluctuations and Economic Instability: Empirical Evidence for the USA (1958-2006), *European Journal of Economics and Economic Policies: Intervention*, 12 (3): 277-299.

[21] See further Arestis and Howells (2001/2) and the references cited therein.

investigation stops in 2006 since the dynamics of the traditional economic structures changed dramatically in the US and globally after 2006.

The chapter is structured as follows: section 2 sets out the theoretical framework, section 3 presents a brief review of the literature; section 4 describes the methodology; section 5 presents the empirical results; finally, section 6 concludes.

4.2 THEORETICAL FRAMEWORK

a. Endogeneity VS Exogeneity: A Brief Overview

The issue of endogeneity or exogeneity of money shapes a strong debate and most economists seem to have views on either side (Desai, 1989). The *exogeneity* of money dominates mainly the research work of the Monetarists and Neoclassical economists, whereas the *endogeneity* of money is mainly supported by the Post-Keynesians and Marxists and other relevant theoretical traditions.

b. Monetarism and Neo-Classicism

Monetarists, led by Friedman (1912-2006), famously claimed that money matters (Friedman, 1956) and is responsible for almost every nominal economic phenomenon. In other words, movements in the stock of money determine the market price of a bunch of macroeconomic variables, i.e., output, price levels, etc. Friedman also believed that many phases of economic instability noticed in U.S. economic history (from the Great Depression of 1930s to the inflation of 1970s) could be explained by the fluctuations in the money supply (Tsoulfidis, 2007). Actually, Friedman and Schwartz (1963) attempted to demonstrate the *exogeneity* of money empirically, meaning – roughly speaking – that money supply fluctuations cause nominal output fluctuations. They thus tried to link preceding monetary policy decisions that led to changes in the money supply with economic fluctuations in the U.S. economy.

Monetarist theory illustrates the causal role of money meaning that changes in money supply are the most significant determinants of nominal output and inflation.[22] Of

[22]Friedman famously defended exactly this idea of money being brought to the economy by helicopters: "Let us suppose now that one day a helicopter flies over this community and drops an additional $1000 in bills from the sky […] Let us suppose further that everyone is convinced that this is a unique event which will never be repeated," (Friedman, 1969: 4-5).

course, monetarism has not gained universal acceptance among economists and was doubted, so far, by several famous economists (e.g., Tobin, 1965, 1970; Temin. 1976; Kaldor, 1970, etc).

Neoclassical economic theory regards money as a neutral device that facilitates economic transactions and whose quantity, *ceteris paribus*, may only influence the level of prices. Moreover, the money supply is considered to be *exogenous*, meaning that the public authorities, and more precisely the Central Bank, fully control the quantity of money supplied to the economy, according to the policy objectives that they aim for. For instance, the issue of *exogeneity* appears in the writings of Irving Fisher (1867-1947) (Tsoulfidis, 2007).

Following the neutrality principle, neoclassical theorists suggested a 'dichotomous' conception of two economies: one economy of real magnitudes and another economy of monetary magnitudes. Neoclassical economists believe that rational economic agents are not interested in monetary but in real magnitudes (e.g., quantities, relative prices). This affirmation is in accordance with the microeconomic foundations of mainstream economics. Loans and deposits are simply the monetary outcome of rational decisions (or expectations), which aim at spending or saving real magnitudes, i.e., certain quantities of goods and services.

c. Post-Keynesianism

The non-neutrality of money and its significance, not merely as a means of exchange that facilitates transactions but mainly as a store of value which may be held for future transactions and in response to economic uncertainty and future expectations, has been stressed by both Marx and Keynes[23] (e.g., Moore, 1988: 207ff; Milios et *al*., 2002).

Further to this, Post-Keynesian theorists, following Kaldor's tradition, formulated the conception that in contemporary developed economies based on credit, money is created *endogenously* (see for a compendious presentation of these approaches Moore, 1988; Rousseas, 1992: 65-122; Itoh and Lapavitsas 1999: 207-245; Lapavitsas and Saad-Fihlo, 2000; Mollo, 1999).

[23]Keynes responded to the question of money endogeneity in an ambiguous way and seemed to give an affirmative response to it only at certain points of his *Treatise on Money* and in other works preceding the writing of the *General Theory*. For a detailed presentation of Keynes's views on this issue, see Moore (1988:, 171-204).

The money-causality direction adopted by the monetarists is inversed, as post-Keynesians state that the major part of the money stock arises for endogenous reasons (Lavoie, 1984).[24] According to the Post-Keynesian approach, the origin of money is economic activity itself: In response mainly to investment spending, money is created in the form of credit, which determines the creation of reserves (and in most cases the issuing of fiat money) by the Central Bank. In a different formulation, the money supply is determined by the demand for (credit) money.

These approaches focus on money through its properties. As with the development of the capitalist economy, credit money becomes the main money form, reducing the significance of fiat money. The creation of overdrafts and other forms of credit deposits issued by commercial banks finally determine the Bank's creation of reserves. The Post-Keynesian view is summarised by Wray (2002: 9-10):

"[M]ost mainstream theoretical approaches presume that money is under control of the "monetary authorities" -in theory, if not in practice. […] In contrast, most heterodox economists, including institutionalists, adopt an "endogenous" money approach […]. Privately issued money (mostly bank deposits today) is issued only on demand, that is, only because someone has deposited cash or is willing to take out a loan. The latter activity has been concisely described by Post Keynesians as "loans make deposits" because when a bank accepts a borrower's IOU it simultaneously creates a bank deposit. (…) The second important point made by Post Keynesians is that "deposits make reserves", reversing the interpretation of the deposit multiplier".

However, more recently, a New Consensus has arisen among the so-called New Keynesians and New Classical economists, in an attempt to reconcile the views of both schools of thought into one unified framework.

[24] According to Mason (1980-81, 239), empiricism seems to have led monetarists to confuse temporal ordering for logical causality.

d. New Neoclassical Synthesis

The term New Neoclassical Synthesis has been used to define the New Consensus model which tries to draw a parallel to the original neoclassical synthesis that has dominated textbooks in the discipline over decades (Fontana and Passarella, 2013). In fact, the New Consensus model claims to be a new synthesis incorporating important elements of each of the apparently irreconcilable traditions of macroeconomic thought (Woodford, 2009: 3). Arguably, this is the reason why some authors, such as Goodfriend and King (1997), Dixon (2008), and McCombie and Pike (2013), call it the New Neoclassical Synthesis. Just as the old consensus tried to include both neoclassical and Keynesian elements in its analysis, the New Consensus tried to pull together the microfoundation and dynamic tools of (New Classical) real-business-cycle (RBC) models and the work of New Keynesians on the role of labour and product market frictions and on staggered price- and wage-setting (Blanchard, 2008).

According to the New Consensus model, long-term inflation is the result of excess aggregate demand. Supply shocks are random, and their average tends to zero, so that they will have a non-lasting impact on inflation. In the short run, there is a trade-off relationship between inflation and unemployment, which however disappears in the long run. Supporters of the New Consensus, believe that monetary policy could influence the real economy in the short run, as reflected in the IS curve. According to this, investment and production capacity are inversely related with changes in the real interest rate (Lavoie and Kriesler, 2005). McCallum (2001) states that economists belonging to the New Consensus have the following five arguments: (a) money is neutral in the long run; (b) aggregate demand changes cause an expansionary or recessionary output gap; (c) the economic growth process is influenced by potential GDP; (d) the inflation rate is influenced largely by inflation expectations; and (e) the interest rate is exogenous in relation to the money supply, but endogenous in relation to other variables, such as the inflation rate or the output gap (monetary policy rule[25]).

In this context, in the New Consensus model, money is not the main variable that the central bank is targeting, but the one that is being manipulated to make interest rates behave in the way it desires (Romer, 2000). In this sense, the Post-Keynesian argument that money supply is endogenous and demand-led, has been accepted by the

[25] For a detailed analysis of this topic, see Major (2012) and Fontana and Passarella (2013).

New Keynesian economists who argue that the central banks have the power to determine real interest rates (Lavoie, 2006). In this vein, from the standpoint of the New Consensus, money is endogenously created, in the sense that the stock of money is a "residual" based on the demand for money (Arestis and Sawyer, 2006a, 2006b). According to Woodford (2009), monetary policy needs not be theoretically identified with the control of the money supply, mainly because where central banks have an explicit commitment to an inflation target, monetary aggregates play little if any role in policy deliberations. The same position has been anticipated by Romer (2000).

In a broader sense, it could be argued that in the New Consensus model the credibility of the monetary authorities play a crucial role, as Rogoff (1985) argued. Accordingly, the behaviour of the monetary authorities must be expressed in the form of a policy rule, i.e., a predictable reaction function depending on few economic variables (Fontana and Passarella, 2013). The rationale is to anchor the inflation expectations of agents in the medium to long run (see Allsopp and Vines, 2000). If the central bank credibly signals its intent to maintain inflation low in the future, it is usually argued that it can also reduce current inflation with less cost in terms of output reduction than might otherwise be required (Clarida et *al.* 1999). A noteworthy corollary is that it is desirable to shift monetary policy decisions from national governments to politically-insulated bodies. In particular, point 3 entails the rejection of the exogenous supply of money, and the replacement of a money growth rule by a real rate of interest targeting rule (Lavoie, 2006).

However, the consensus obviously was not as broad or stable as Blanchard (2008) and others had thought. With the eruption of the US subprime crisis and its transformation into a global economics crisis comparable to the Great Depression, the convergence towards this approach has come under fire from economists inside and outside academia. Buiter (2009, p. 1) emphatically characterises it as "a costly waste of time", whereas Krugman (2009) describes it as "spectacularly useless at best, and positively harmful at worst".

4.3 BACKGROUND LITERATURE

The dilemma between the endogenous and the exogenous character of money, described in the previous section, is also present in the empirical literature, since the results of many works seem to shape views on either side. In what follows, we provide a selected review of the empirical literature on the causal relationship between money and real economic variables.

Over the last decades, the investigation of the dynamics between money and other crucial macroeconomic variables has always been a key topic for many researchers around the globe. In fact, since the seminal work of Mundell (1963) and Tobin (1965) - according to which an increase in the exogenous growth rate of money increases the nominal interest rate and velocity of money, but decreases the real interest rate - a vast empirical literature emerged trying to assess the interdependencies between money and key macroeconomic variables that dictate real economic activity. Nearly fifty years ago, Karenken and Solow (1963) emphasized the identification and estimation problems associated with drawing causal inferences between money and output. In this vein, they pointed out to the fact that one might conclude that monetary policy has no effects at all on economic activity, which would be precisely the opposite of the truth. Probably one of the first sound empirical attempts to investigate the exogeneity of money in the money income relationship was made by Sims (1972). The results, based on Postwar US data, suggested that a statistically significant causal relationship from money to income is evident but the opposite is not true. This causal relationship was further confirmed by the prominent work of Sims (1980) who considered interwar US data, as well.

In a Real Business Cycles framework, King and Plosser (1984) examined the causal relationship between money and business cycles fluctuations under the hypotheses of market clearing and rational expectations, using data on the US economy (1953-1978). According to their findings, increased correlation was evident between money and business cycles in real economic activity. Their results were further confirmed by Bernake (1986) who found evidence of correlation by using an alternative formulation.

In a seminal paper, Bernake and Blinder (1992) extended the work of Bernake and Blinder (1988) who provided an IS-LM model that accounted for monetary policy transmission, by empirically testing their model using data on the US economy in the period 1959-1989. According to their findings, money as expressed through the interest rate of Federal Reserve Bank, is informative towards real macroeconomic variables. The same year, Friedman and Kuttner (1992), presented empirical evidence based on the US economy that did not indicate a close relationship between money and nonfinancial economic activity. More precisely, using data from the 1980's sharply weakened the postwar time-series evidence which indicated significant relationships between money and nominal income or between money and real income and prices separately. In fact, when focusing on data from 1970 onward, the authors found no evidence altogether.

In a different framework, Friedman and Kuttner (1996) investigated money's predictive power on real economic activity using data on US economy for the time period 1965-1994. Their empirical findings gave credit to the monetary policy implemented by the Federal Reserve Bank of US when compared to other countries. In this context, Caporale et *al.* (1998), using US data on monetary aggregates, output and interest rates, found statistical evidence that monetary aggregates cause output - in a Granger sense - while the opposite did not hold. Nevertheless, their view is contradicting the results of Estrella and Mishkin (1997) according to which the empirical relationships between monetary aggregates, nominal income and inflation are not sufficiently strong and stable in the US economy to support an important role in policy making. On this matter, Friedman (1998) argued that - with some notable exceptions - money growth targets have been a visible influence on policy actions when some form of evidence on these relationships seemed to justify it. However, he was of the opinion that a more advanced econometric model incorporating error correction mechanisms might be able to provide stronger evidence of a relationship between money and either output or prices.

More recently, Stock and Watson (2001), utilizing a monthly dataset on a selected panel of world economies in the time period 1979-1993, examined the relationship between monetary aggregates, output, short term interest rates and long term interest rates. According to their findings, monetary variables were causal to output in a bivariate set up, while in a trivariate set up the opposite causal relationship seemed to be in place.

To sum up, the empirical literature on the relationship between money and output is inconclusive, often supporting a non-monetarist explanation of economic phenomena, where money is endogenous. See Lavoie (2000). Such an explanation is consistent with a passive role for money, casting doubts on the monetary theories of output, which argue that money should have a causal role in the economic system.[26]

4.4 METHODOLOGY

a. Structural Breaks

Following common econometric practise we test for the existence of structural breaks in our time series using the popular Zivot and Andrews (1992) test. The Zivot and Andrews (1992) model endogenises one structural break (T_b) in a time series series Y_t as follows:

$$Y_t = \mu + \theta DU_t(T_b) + \beta t + \gamma DT_t(T_b) + aY_{t\text{-}1} + \sum_{j=1}^{k} c_j \Delta Y_{t\text{-}j} + e_t \quad \textbf{(4.1)}$$

where: DU_t is a sustained dummy variable capturing a shift in the intercept, and DT_t is another dummy variable representing a break in the trend occurring at time T_b where $DU_t = 1$ if $t > T_b$, and zero otherwise and is equal to $(t - T_b)$ if $(t > T_b)$ and zero otherwise. The null hypothesis is rejected if the coefficient is statistically significant.

The above equation which is referred to as model C by Zivot and Andrews (1992), accommodates the possibility of a change in the intercept as well as a trend break. Model C, in that work, is the least restrictive compared to the other two models; we thus base our empirical investigation on this model. The Zivot and Andrews test asserts that T_b is endogenously estimated by running the above equation sequentially in order to allow for T_b to be in any particular observation with the exception of the first and last observations. The optimal lag length is determined on the basis of the Schwartz Information Criterion (SIC), AIC or t-test (the use of the most significant t ratio in the literature is referred to as the general to specific approach).

[26] As we know, Friedman used to argue that money is responsible for almost all economic phenomena: "[c]hanges in the behaviour of the money stock have been closely associated with changes in economic activity" (Friedman and Schwartz, 1963, 676).

b. Stationarity

Now, in order to avoid spurious correlation, we examine the stationarity characteristics of each time series. We use the popular Augmented Dickey – Fuller methodology (ADF) (Dickey and Fuller, 1979). If the results suggest that a time series is non-stationary in levels then de-trending and filtering the data to induce stationarity is recommended and the estimated residuals are the de-trended data series (McDonald and Kearney, 1987).

c. De-trending and Filtering

Next, in order to create the cyclical part of the time series under investigation we use both, the popular Hodrick-Prescott (HP) and Baxter-King (BK) filters, respectively (see Appendix C.1). Analytically, the HP-filter is a widely used method by which the long-term trend of a series is obtained using actual data. The trend is obtained by minimizing the fluctuations of the actual data around it. This method decomposes a series into a trend and a cyclical component. The parameter used for annual data is equal to $\lambda=100$ (Hodrick and Prescott, 1997; Kydland and Prescott, 1990; Canova 1998).

Another popular method for extracting the business cycle component of macroeconomic time series is the BK-filter (Baxter and King 1999), which is based on the idea of extracting a frequency range dictated by economic theory, corresponding to the minimum and maximum frequency of the business cycle. There is widespread agreement that a business cycle lasts between 8 and 32 quarters and the length of the (moving) average is 12 quarters (Baxter and King, 1999). Consequently, these are the values (2 to 8 years) that we use.

d. White Noise

In order to econometrically test whether the cyclical components of the time series under investigation are indeed a cycle and not white noise we test for autocorrelation by using the Ljung and Box (1978) test (Q-stat) which practically tests the null hypothesis of white noise for a maximum lag length k (see Appendix C.2). The alternative hypothesis is that at least one of these autocorrelations is non-zero, so that the series is not white noise. In case the null hypothesis is rejected, then the underlying time series is clearly not white noise and, in this sense, it could be considered to follow a fluctuation pattern. In case of trending time series, then we test its deviations from trend, i.e., the residuals from which sample autocorrelations can be computed. As we know, white noise does not permit any temporal dependence and so its autocovariance function is trivially equal to zero for the various lags. The sample autocorrelation function measures how a time series is correlated with its own past history. Its graphical illustration is the correlogram.

e. Periodograms

Here, we investigate the periodicities of business cycles assuming that the actual fluctuations of the data are chiefly of a periodic character. We are supposing that the presence of periodic elements in the given fluctuations is possible. The length of the period in an economic series may, in general, be variable. Therefore, we understand by the term "period" the average length of the cycles and the periodogram can assist in finding these average lengths. The period is measured by testing for the maximum values of R in the time frequency (Rudin, 1976).

f. Correlation

Next, the co-movements between the cyclical components of the quantity of money and output/profitability are assessed, using correlation analysis. Furthermore, the cyclical components of output/profitability and the quantity of money are examined to see if they move in the same direction and if there is a significant correlation between them for various leads and lags, i.e., indicating the timing pattern (Appendix C.3).

g. Co-integration and Causality

Next, we investigate whether the fluctuations in the quantity of money have predictive power for the fluctuations in profitability/output, and vice versa. The concept of causality (Granger, 1969) has been widely used. In general, we say that a variable X causes another variable Y if past changes in X help to explain current change in Y with past changes in Y. The general autoregressive model is appropriate for testing Granger causality only if the variables are *not* cointegrated. Granger (1986) and Engle and Granger (1987) suggested a test based on cointegration and error-correction models. If cointegration is not detected, the autoregressive model is estimated, otherwise the error – correction model needs to be estimated. In order to identify the optimal lag length, we use the FPE criterion. See, among others, Thornton and Batten (1985), Gutiérrez et *al.*

(2007), Hsiao (1981) and Ahking and Miller (1985), Khim and Liew (2004) and Hacker and Hatemi (2008). We conduct bi-variate causality tests between:

(a) Quantity of Money (M3) and nominal output(GDP)

(b) Quantity of Money (M3) and Profitability (Profit Rate).

4.5 EMPIRICAL ANALYSIS

a. Data and Variables

We apply the methodological framework set out earlier. The data used are on an annual basis and come from the European Commission's Directorate General for Economic and Financial Affairs (AMECO) database and also the Organisation for Economic Co-operation and Development (OECD) database, and cover the period 1958-2009.

Various economic variables are used. Appendix 1 shows the results of the ADF test regarding the following time series: output (*Y*); stock of fixed capital (*K*), wages (*W*), quantity of money (M3); and profit rate (Π) defined as: $\Pi=(Y-W)/K$ (Duménil and Lévy, 2002; Milios et *al.,* 2002; Mohun, 2006; Wolff, 2003).

Given that official data regarding several time series, such as the stock of fixed capital (and, hence, profitability) are not available in quarterly format, we proceed by using annual data which are readily available to us by the aforementioned sources. Our approach is also supported by the fact that the length of the time series at hand is adequate for reliable econometric estimation. Regarding the quantity of money, there is no single "correct" measure. Instead, there are several measures, the broader of which is M3. It is exactly because of its broad character expressing the totality of the quantity of money, that it is employed in this study.

The term M3 refers to the monetary aggregate. In fact, M3 in technical terms, is equal to the sum of M1, savings deposits (including money market accounts from which no checks can be written), small denomination time deposits, retirement accounts, large time deposits, Eurodollar deposits, dollars held at foreign offices of U.S. banks, and institutional money market funds. Whereas, M1 is defined as the sum of the tender that is held outside banks, travelers' checks, checking accounts (but not demand deposits), minus the amount of money in the Federal Reserve float.

4.6 RESULT ANALYSIS

Following standard econometric practise, we begin by testing for structural breaks in our time series data using the Zivot and Andrews (1992) test. In this context, following economic intuition we test for the existence of a structural break around 2007 when the US subprime crisis made its appearance, see Table 4.1.

Table 4.1: Zivot and Andrews Structural Break test around 2007

	T-statistic		
Period	**Y(Output)**	**Π (Profit rate)**	**M3 (Quantity of Money)**
1960-2006	-0.46	-3.51	0.38
1960-2007	-0.68	-3.61	-0.23
1960-2008	-0.54	-3.59	0.93

The results presented in Table 4.1, clearly indicate the existence of a statistically significant structural break in the profit rate in the year 2007, while all the other time series also present the most negative t-statistic in the same year. By taking into consideration the fact that after 2007 the remaining observations are too few, from an econometric perspective, we have to end our analysis in 2006, i.e., the year before the structural break takes place. After all, during the post-2006 era the dynamics of the traditional economic structures are widely hailed to have changed dramatically in the US and globally. As a result, in what follows we focus on the period 1958-2006.

Next, all macroeconomic variables in levels were non-stationary, Table 4.2, and various de-trending approaches were employed.

Table 4.2: ADF Statistics

Variable	LAGS	T-statistic	Probability	Stationary
Y	1	-0.753585	0.8229	NO
K	2	1.164560	0.9975	NO
W	0	-1.879211	0.3391	NO
Profit rate	1	-0.764595	0.8199	NO
M3	1	2.253547	0.9999	NO

The graphs of the cyclical components are presented in Table C.3 (Appendix C). Also, the results of the analysis based on the correlograms for the various economic variables. The results of the Ljung and Box (1978) test imply a rejection of the white noise hypothesis for all the de-trended variables. So, the existence of fluctuations is a valid hypothesis from a statistical viewpoint.

The periodograms reveal the periodicity of the cycles and are shown in Table 4.3, below.

Table 4.3: Periodograms

Figure 4.1: Periodogram Y

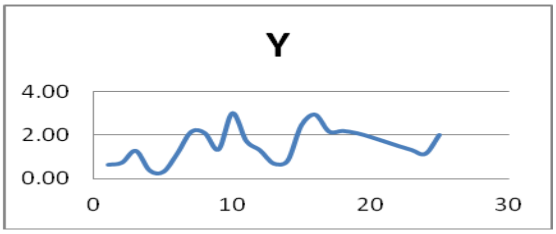


Figure 4.2: Periodogram K

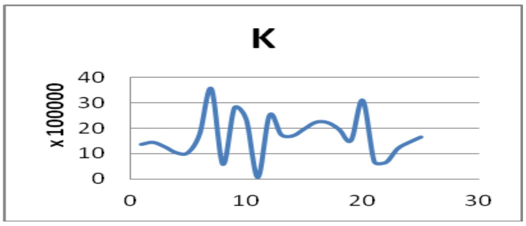


Figure 4.3: Periodogram W

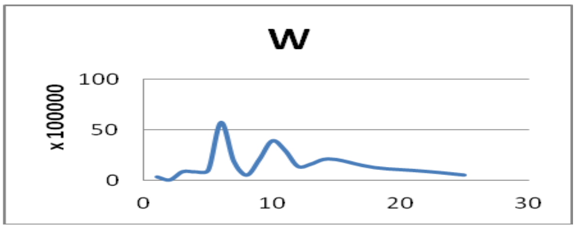


Figure 4.4: Periodogram Π

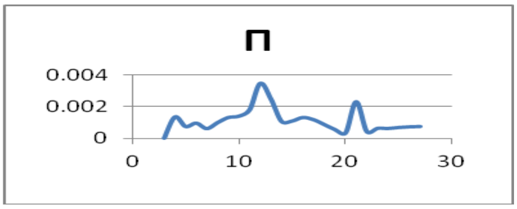
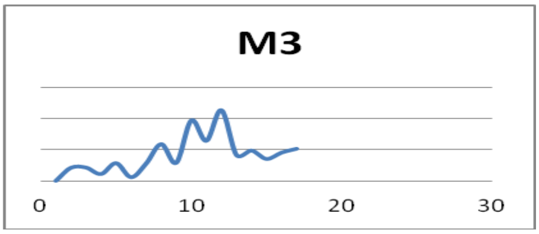


Figure 4.5: Periodogram M3



The de-trended output seems to follow an 11-year period cycle. Similarly, the de-trended profit rate is characterized by practically the same periodicity, i.e., an 11-year period cycle clearly implying that the movements of output and profit rate that characterize the economic conjecture are largely synchronized. Also, the cycles of the money aggregate M3 have an almost identical periodicity, i.e., of 12 years. This clearly implies a high degree of synchronization among these crucial macroeconomic variables that characterize the economic conjecture. Furthermore, since they all follow almost identical cyclical behaviors, one would expect them to be highly correlated with no time lags.

In fact, Table C.1 (Appendix C.1) shows the correlation coefficients among the variables examined. We find evidence of high positive correlation between the variables examined. Thus, it could be argued that the cyclical components of output/profitability go hand in hand with the quantity of money, towards the same direction. Moreover, the timing pattern of the quantity of money indicates that the peak correlations appear at very moderate lags.

Table 4.4: Cointegration and Pairwise Granger Causality Tests

	Lags	**Observations**	**F-Statistic**	**Probability**
Y does not Granger cause **M3**	3	46	13.5857	0.000
M3 does not Granger cause **Y**	3	46	0.75962	0.524
Πdoes not Granger cause **M3**	10	39	5.07544	0.001
M3 does not Granger cause **Π**	10	39	0.53009	0.847

Table 4.4 presents the results of the Granger causality tests. It is evident that the fluctuations in output/profitability *do* cause fluctuations in the quantity of money, but fluctuations in the quantity of money *do not* cause fluctuations in output/profitability. This finding is consistent with a passive role for money, casting doubts on those monetary theories of output which argue that money should have a causal role in the economic system.

4.7 DISCUSSION AND CONCLUSION

To sum up, in this chapter, first we examined the stationarity properties of the various time series and de-trending/filtering was applied. Next, the de-trended/filtered variables were examined to see whether their time pattern could be considered a cycle and spectral analysis was performed. Then, the co-movements between the cyclical components of the quantity of money and output/profitability were assessed. The results indicate a strong cyclical behavior of most variables. Also, another interesting finding is that our variables exhibit, roughly speaking, a similar pattern characterized by periodicities of 11-12 years, approximately. Next, we assessed the co-movements between the cyclical components of each time series and we found that the cyclical components of output/profitability and the quantity of money move in the same direction and also that there is a significant correlation between them. Furthermore, after the relevant co-integration tests, we conducted bivariate (Granger) causality tests between output/profitability and quantity of money (M3).

In a broader context, we note that fluctuations in the U.S. economy are not very sharp but the collapse of output following the first oil crisis is obvious (Fig. C.1, Appendix C). Between 1963 and 1970, there is a smooth and slightly upward movement in output that was stopped by the oil crisis, the effect of which is evident in the de-trended time series. The 1990's began with a recession (Basu et *al.,* 2001), whereas between 1997 and 2000 a sharp increase of output took place, often attributed to the so-called "new economy" period. Regarding the de-trended profit rate (Figs. C.4-C.9, Appendix C), it was apparently related to the negative macroeconomic environment of the 1970's[27] and the oil crisis. Finally, an upward movement occurred in the beginning of the 1990's until 1998, reaching its peak in 1997. This rise coincides with the third period of the U.S. economy characterized by a period when profitability rose, probably as a result of the rapid rise in the productivity of labour.

The main finding of our research is that fluctuations in output/profitability cause fluctuations in the quantity of money, but fluctuations in the quantity of money *do not* cause fluctuations in output/profitability, giving priority to a *macroeconomic* point of view, where economic conjecture in the total economy, expressed through profitability and

[27]It is argued in the paper that oil shocks are to blame for USA's output declines in the 1970s. While this cannot be denied, given the USA's industry dependence on foreign energy, other important events such as the economic (inflationary, etc.) impact of the Viet-Nam war and the demise of Bretton Woods also played a role.

output, shapes the quantity of money, and not vice-versa. In fact, our finding is consistent with the work of several major authors who have found that money fluctuations do not cause cyclical movements in economic activity (see among others, Kareken and Solow (1963), Tobin (1965), King and Plosser (1984), Bernanke and Blinder (1992), Friedman and Kuttner (1992, 1996), Estrella and Mishkin (1997), Friedman (1998), Stock and Watson (2001)). Our empirical findings, thus, imply a revision of the mainstream belief that the quantity of money is the causal factor.

Our empirical results seem to be reversing the Humean, Monetarist and Neo-classical view of the cause and effect linking money and total economic activity. More precisely, in our research, it is the U.S. economy (1958-2006) as a whole, which takes the causal role, and thus determines the main features and the mode of evolution of the quantity of money. It is exactly this theoretical *paradigm* that cannot be traced in the Monetarist and Neo-classical approaches.

We are aware of the fact that, generally speaking, "the issue of exogeneity versus endogeneity is not settled yet and therefore, continues to attract the attention of economists" (Tsoulfidis, 2007: 479). However, our empirical findings stress the theoretical importance of a tradition that should probably be traced back, among others, to Barbon, Wicksell, and Marx, and later to Schumpeter and Keynes (e.g. Arestis and Sawyer, 2006a, 2006b; Itoh and Lapavitsas, 1999; Milios et *al.,* 2002; Moore 1988; Rousseas, 1986; Wray, 2002).

Chapter 5: Prevention of Financial Bubbles in the USA[28]

Based on our analysis, the monetary policies implemented by the Federal Reserve Bank before 2006, were not found to be causal on the total economic activity of the US economy. However, the mortgage bubble of 2006, evolved into a global crisis, which was comparable to the crisis of 1929. In this context, the main question in the next chapter is whether such bubbles could be modeled and identified at an early stage. In this context, significant model misspecification could result from ignoring potential nonlinearities and, hence, it would seem wise to ensure that no terms with explanatory power are neglected. More precisely, the present chapter attempts to detect and date non-linear bubble episodes. To do so, we use Neural Networks to capture the neglected non-linearities. Also, we will provide a recursive dating procedure for bubble episodes.

5.1 INTRODUCTION

In August 2015, the Chinese stock market lost over 30% of its stock value experiencing one of the worst stock market crashes in recent financial history. Despite the efforts made by the Chinese Government and the Chinese Central Bank to prevent the crash by implementing a strict legislatory framework on short selling as well as by providing huge cash injections to brokers so as to stimulate stock demand, the Shanghai Stock Exchange experienced an unprecedented crash. As a result, on the 24th of August, the Shanghai Stock Exchange experienced an overall devaluation of approximately 8% in stock prices, the so-called "Black Monday" of the Chinese Stock Market (The New York Times, 25 August 2015).

Despite the fact that in the long history of financial bubbles the Chinese case is not the first and certainly not the last one, only limited attention has been paid by the scientific community to creating a rigorous and robust framework for the detection of bubble formation based on a credible Early Warning Mechanism (EWM). In general, EWMs are essential components of time-varying macroprudential policies that can help reduce the high losses associated with both banking and country specific crises. In this

[28] Another version of this chapter has been published as follows: Panayotis G. Michaelides, Konstantinos N. Konstantakis and Efthymios G. Tsionas (2016), Non linearities in Financial Bubbles: Theory and Bayesian Evidence, *Journal of Financial Stability*, 24: 61-70.

context, the EWMs employed should not only have sound statistical forecasting power, but also need to satisfy several additional requirements.

Analytically, the importance of bubble dating lies on the appropriate timing, which is a crucial requirement for EWMs. In this context, macroprudential policies need time before they become effective (Basel Committee, 2010) and, hence, signals should need to arrive at a relatively early stage in order to prevent policy measures from being costly (Caruana, 2010). The stability of the signal is a second, largely overlooked, requirement. More precisely, policy makers tend to base decisions on trends rather than reacting to changes in signaling variables immediately (Bernanke, 2004). Meanwhile, the gradual implementation of policy measures may also allow policy makers to affect market expectations more efficiently and deal with uncertainties in the transmission mechanism (Committee on the Global Financial System (CGFS), 2012). Finally, a last requirement is that EWM signals should be easy to interpret, as any signals that do not "make sense" are likely to be ignored by policy makers (Önkal et *al,* 2002; Lawrence et *al*, 2006). In sum, well designed EWIs, in terms of timing and signal processing, can reduce uncertainty and allow for more decisive policy action.

Thus far, one of the main reasons behind the inability of most models to capture the formation of bubbles, at a relatively early stage, is the fact that bubble formation has inherent non-linear characteristics, which are difficult to capture using standard linear model. This clearly implies that any econometric test that aims at capturing the formation of bubbles, especially at an early stage, should be able to capture their non-linear character.

Additionally, another equally important challenge for the econometric detection of bubbles is their dating, in the sense that an econometric test should be able to accurately date the bubble periods detected in the sample. Of course, early detection and accurate dating of financial bubbles could have important policy implications, especially for central bankers and policy makers since it could assist in the implementation of relevant policy actions that could potentially ease the consequences of bubbles. More specifically, the importance of early identification lies in the timing of specific countermeasures that could potentially prevent: a) the magnitude of a potential collapse through regulatory interventions in the financial markets; b) the potential downturn effects of bubble collapse in the economy through appropriate inflation targeting, and c) the devastating spillover effects in the global economy through interest rate and/or exchange rate setting.

Due to the fact that, according to the recent financial history of bubbles, more than one bubble could occur in the same sample period (Ferguson 2008), any econometric test for bubble detection should be structured upon flexible backward and/or forward recursive estimation techniques. However, relatively limited research has been done in the literature using recursive estimation techniques for dating multiple bubble episodes. See Phillips and Yu (2011), and Phillips et *al.* (2011a, 2011b, 2011c, 2013, 2014, 2015a) and Phillips et *al.* (2015b) [hereafter PSY].

Meanwhile, nonlinear economic models have become quite popular lately, because economic data exhibit significant non-linearities. To this end, in this chapter, we propose a rigorous and robust mathematical and econometric framework for the detection of bubbles, which is structured upon Artificial Neural Networks (ANN), that are perfectly capable of capturing any neglected non-linearity. In fact, this is the first paper in the relevant literature, to the best of our knowledge, which employs ANNs, to capture neglected non-linearities in bubbles.

After all, according to PSY, the use of computationally efficient dating methods "over long historical periods presents a more serious econometric challenge due to the complexity of the *nonlinear* structure and break mechanisms that are inherent in multiple-bubble phenomena within the same sample period". Finally, our approach provides a recursive algorithm for the accurate detection of bubbles, which serves as an EWM that could be used in order to guide a policy decision in an uncertain environment, without the need of taking into consideration the policy maker's preferences (e.g. Pesaran and Skouras, 2002; Granger and Machina, 2006; Baxa et *al.,* 2013).

In brief, the present chapter contributes to the literature in the following ways: (a) It establishes a rigorous framework, based on ANNs, under which bubble detection could be achieved, while emphasizing on the presence of non-linearities; (b) It provides a new algorithm for the accurate and early detection of bubble formation, as well as for the identification of potential explosive behaviors; (c) it illustrates the proposed test by early detecting and capturing accurately the bubble episodes that are present in the S&P 500 index for the time period 1871 (M1)-2014 (M6), and by identifying more episodes compared to a competitive methodology in the literature.

This chapter is structured as follows: in section 5.2, a review of the literature takes place; section 5.3 presents the theoretical model; section 5.4 sets out the proposed non-linear test; section .55 presents the empirical analysis; finally, section 5.6 concludes.

5.2 BACKGROUND LITERATURE

According to Kindleberger (1978) a bubble is defined as "an upward price movement over an extended range that then implodes". Brunnermeier (2009) argued that bubbles "are typically associated with dramatic asset price increases followed by a collapse", whereas Garber (2000) defined a bubble as the part of the price movement that cannot be explained by fundamentals. Also, Barlevy (2007) described a bubble as "a situation where an asset´s price exceeds the fundamental value of the asset". In brief, a bubble occurs when the market value is higher than the fundamental (Diba and Grossman, 1988). Some researchers (e.g. Wu, 1997) define bubbles as the difference between the fundamental value and the market price allowing, thus, for negative bubbles.

Reasons for the occurrence of bubbles include, among other things, greed (Kindleberger, 1978), introduction of breakthrough technologies or financial innovations (e.g. Perez, 2009); existence of rational and irrational traders (Dufwenberg, et *al.,* 2005; Hong et *al.,* 2007); institutional restrictions on short selling (Haruvy and Noussair, 2006); herding (DeMarzo, Kaniel and Kremer 2008), speculating investors (Greenwood and Nagel, 2005; Scheinkman and Xiong, 2002), and "bubble riding" (Abreu and Brunnermeier, 2003, and Temin and Voth, 2003).

Despite the fact that several approaches, even seminal ones (e.g. Fama, 1965), have denied the possibility of bubbles in financial markets, the phenomenon has made its appearance long ago (e.g. Dutch Tulipmania [1634-1637], Mississippi Bubble [1719–1720]) and has often led to generalized and deep economic recessions. As a result, Fama's *Efficient Mark*et *Hypothesis* and other similar theories have not always found so much support. After all, probably the most prominent economist, who considered the existence of bubbles in financial markets, was John Maynard Keynes (1936).

Following the related literature on financial bubble detection, Shiller (1981) and Lerroy and Porter (1981) were probably the first to develop variance bound tests for equity prices. Despite the fact that Shiller's (1981) variance bound test was not initially developed for bubble detection, the works of Blanchard and Watson (1982) and Tirole (1985) suggested that violation of variance bounds could be attributed to the presence of bubbles. Nevertheless, the variance bound tests were heavily criticized by a number of authors like Flavin (1983), Mash and Merton (1983), Mankiw et *al.* (1985), Kleidon (1986) and Flood et *al.* (1994), due to the fact that the variance bound tests could fail not only if bubbles exist but also if any of the assumptions of the present value model is violated.

In a different approach, West (1987) developed a two-step test for the identification of bubbles in equity prices based on Euler's equation of no arbitrage process and the autoregressive process of dividends that governs the market fundamental stock price. Despite the fact that West's (1987) test was more attractive than the variance bound test as it explicitly incorporated the null hypothesis of no bubbles, once again Dezbakhsh and Demirguc-Kunt (1990), as well as Flood et *al.* (1994), criticized the econometric procedure of the test because it exhibited significant size distortions in small samples.

Another popular approach for bubble detection was the one proposed by Diba and Grossman (1987, 1988a, 1988b), who tried to exploit the theoretical properties of bubbles. Their test allowed for unobserved fundamentals in the market fundamental price and a bubble would exist if the dividends and stock prices did not have the same order of integration. However, Evans (1991) criticized the test of Diba and Grossman (1988b) by arguing that it was unable to capture a periodically collapsing bubble.

Following Evans (1991), a vast literature emerged concerning the detection of bubbles, like Hall and Sola (1993), van Norden (1996), van Norden and Vigfusson (1998), Driffil and Sola (1998), and Hall et *al.* (1999) who incorporated regime switching models for bubble detection. In the meantime, in a seemingly unrealted approach, Wu (1997) used Kalman filtering in an attempt to test for bubbles, while Wu and Xiao (2002) tried to establish a test for bubbles based on the residuals of the cointegrating equation between dividends and stock prices.

This signified the formation of the latest strand in the literature of bubble detection where researchers based the existence and detection of bubbles on the unit root behavior of key fundamental financial variables. In a prominent paper, Phillips and Yu (2011) introduced a recursive regression methodology in order to analyze the bubble characteristics of various financial time series during the subprime crisis. Phillips et al. (2011a) extended the work of Phillips and Yu (2011) by introducing a relevant econometric framework where more than one bubbles could exist in the same sample. Phillips et *al.* (2011b) provided the identification conditions regarding the explosive behavior of bubbles, based on the unit root behavior of relevant financial time series.

In the same context, Phillips et al. (2011c) provided a dating algorithm for bubble emergence and collapse. Breitung and Holmes (2012) investigated the power properties of rational bubbles considering a large variety of testing alternatives, while Breitung and Kruse (2013) showed that structural break Chow-type tests have considerable power for the detection of bubbles. Again, Phillips et *al.* (2013) illustrated their proposed bubble specification and dating algorithm using data from S&P500 series, while Phillips et *al.* (2014) provided the asymptotic properties of the related bubble dating and identification conditions. Finally, recently, in two seminal works, Phillips et *al.* (2015a) and PSY provided probably the only framework, thus far, in the existing literature, under which an EWM is established for the detection of multiple bubble episodes.

5.3 THE THEORETICAL MODEL

From a technical point of view, probably the most important feature of bubbles is that they are characterized by explosive growth patterns, despite the fact that speculative movements are often assumed to follow a random walk process (e.g. Blanchard and Watson, 1982; Campbell et *al.*, 1997). And it is exactly this, the most common way to identify a bubble, by applying tests for a structural change from a random walk regime to an explosive one. Such tests have been developed by Phillips, et *al.* (2011a), Phillips and Yu (2011), Homm and Breitung (2012), Phillips et *al.* (2014), and PSY.

a. Time Series Model

From a technical perspective, the identification of bubbles involves the use of key financial time series variables such as dividends, stock prices, equity prices etc.

For any financial time series variable, $x_{t_j}, j \in J$, we will make a number of fairly standard assumptions:

Assumption 1: The time series x_t is assumed to conform to the standard additive component model, i.e. every financial time series variable $x_{t_i}, i \in I$, follows the process:

$$x_{t_i} = s_{t_i} + g_{t_i} + c_{t_i} + \varepsilon_{t_i}, \; i \in I \quad \textbf{(5.1)}$$

where: s_{t_i} is the seasonal component, g_{t_i} is the trend component, c_{t_i} is the cyclical component and $\varepsilon_{t_i} \sim N(0, \sigma^2)$ is the error term.

For the sake of simplicity, and without loss of generality, we also make the following assumption:

Assumption 2: The trend and constant term of the series $x_{t_i}, i \in I$, are both assumed to be equal to 0.

In case, (deterministic) terms are to be considered, the standard procedure is to apply demeaning and detrending procedures before computing the relevant test statistics.

Now, we present (Assumption 3) the general formulation of the unit-root test upon which the econometric testing of bubbles will be based.

Assumption 3: The unit root detection is described by the following model:

$$\Delta x_{t_i} = \rho x_{t_i - 1} \cdot H(x_{t_i - 1}; \gamma) + \varepsilon_{t_i}, \; t_i = 1, \ldots, T, i \in I \quad \textbf{(5.2)}$$

where $\varepsilon_{t_i} \sim NID\ (0, \sigma^2)$ and *G* is a sufficiently smooth function.

With reference to the aforementioned general specification, without deterministic components, the most popular unit root test in the literature, i.e. the traditional Dickey Fuller (D.F.) test, is based on the t-statistic of ρ from the model:

$$\Delta x_{t_i} = \rho x_{t_{i-1}} + \varepsilon_i, \; i \in I \quad \textbf{(5.3)}$$

The null hypothesis, H_0, of a unit root is parameterized by $\rho = 0$.

The vast majority of empirical tests in the literature are based on alternative forms of the D.F. test above (Equation 5.3). However, some other unit root testing attempts are also present in the literature, where researchers have attempted to capture bubbles based on some non-linear unit root specification. More precisely, Kapetanios et *al.* (2003) or KSS extended the standard approach on unit root testing through the introduction of a so-called exponential smooth transition autoregressive (ESTAR) model and decided to consider the following ESTAR process, emphasizing the expected low power of the linear augmented D.F. test, when applied to such a series:

$$\Delta x_{t_i} = \gamma x_{t_i - 1}\{1 - \exp(-\theta x^2{}_{t_i - 1})\} + \varepsilon_{t_i}, \; i \in I \quad \textbf{(5.4)}$$

The analysis of KSS focuses on θ, with $H0: \theta = 0$ and $H1: \theta > 0$. As γ is unidentified under $H0, \theta = 0$ cannot be tested. Hence, they based their work on Luukkonen et *al.*

(1988) and employed a first-order Taylor series approximation to the ESTAR model under the null $H0: \theta = 0$. The relevant equation is:

$$\Delta x_{t_i} = \rho x^3{}_{t_i-1} + \varepsilon_{t_i}, i \in I \quad \textbf{(5.5)}$$

where the nonlinear test relies on the *t*-statistic of *ρ* from the O.L.S. regression on the previous equation.

However, it should be noted that the aforementioned models (i.e. linear, or ESTAR, etc) are not grounded on some formal mathematical or statistical criterion, but rather on the modeling choices of each individual researcher. Therefore, both attempts that are equivalent to the assumption that either $G(x_{t_i-1};\gamma) \equiv 1$ or $G(x_{t_i-1};\gamma) \equiv x^3{}_{t_i-1}, i \in I$, which are implied by the linear and ESTAR models, respectively, need to be reconsidered.

For instance, changing the degree of the implied polynomial assumed in the aforementioned ESTAR process would lead to another exponential power of the relevant test. Hence, misspecification issues arise from ignoring potential nonlinear terms. As a result, it would seem absolutely imperative to test for the presence of nonlinear terms and ensure that no terms with explanatory power are neglected.

In this work, in order to overcome these serious drawbacks which result from the arbitrarily assumptions about the processes to be followed, instead of fitting the *G* function with a pre-specified equation, we will use an Artificial Neural Network (ANN) to let dataset itself serve as evidence to support the model's approximation of the underlying specification.

b. ANNs Formulation

As we have seen, the main idea is to express the arbitrary specification $\Delta x_{t_i} = \rho x_{t_i-1} \cdot G(x_{t_i} - 1;\gamma), i \in I$ not as a pre-specified form based on *a priori* assumptions, but rather let the dataset itself determine the specification of the underlying process. In other words, instead of fitting Δx_{t_i} with a pre-specified functional form, ANNs let the dataset itself serve as evidence to support the model's approximation of the specification. In what follows, we proceed by providing a formal definition of ANNs (Definition 1).

Definition 1: ANNs are collections of functions that relate an output variable Y to certain input variables $\boldsymbol{X}' = [X_1, \dots, X_M]$. The input variables are combined linearly to form *N* intermediate variables $Z_1, \dots, Z_N : \boldsymbol{Z}_N = X'\beta_n(k = 1, \dots, N)$ where $\beta_n \in \mathbb{R}^N$are parameter vectors. The intermediate variables are combined non-linearly to produce Y:

$$Y = \sum_{n=1}^{N} a_n \varphi(Z_n) \quad \textbf{(5.6)}$$

where: φ is an activation function, the α_n 's are parameters and *N* is the number of intermediate nodes (Kuan and White, 1994).

We make use of a single layer ANN to avoid computational and energetic requirements (see Sanger, 1989). Hence, it is worth mentioning that the mechanism behind ANNs is that they combine simple units with intermediate nodes, so they can approximate any smooth nonlinearity (Chan and Genovese, 2001). In fact, ANNs provide very good approximations to a large class of arbitrary functions while keeping the number of parameters to a minimum (Hornik et *al.,* 1989, 1990). Also, they can approximate their derivatives, a fact which justifies their success (Hornik et *al.,* 1990; Brasili and Siltzia, 2003).

To sum up, ANNs are data-driven and self-adaptive, nonlinear methods that do not require specific assumptions about the underlying specification (Zhang and Berardi, 2001). In addition, they are universal approximators of functions. In this chapter, we use a ANN formulation in order to capture and model nonlinearities in bubbles.

c. Mathematical Properties

As we have seen in the previous section, the main idea for capturing a financial bubble episode is to thoroughly investigate the respective unit root behavior of the financial time series variable. To this end, using the general specification of unit root detection, i.e. $\Delta x_{t_i} = \rho x_{t_i} - 1 \cdot G\big(x_{t_i} - 1;\, \gamma\big), j \in J$ we will formally approximate the function G, using an ANN. To do so, we will make use of the formal definitions of open set, open covering, compact set, dense set and closure (e.g. Rudin, 1976) that will help us in formally stating our main Theorems, below. In what follows, we will make use of Hornik's (1991) Theorem, which states the conditions under which an ANN specification can approximate any given function (see Appendix).

In simple words, according to Hornik's (1991) Theorem, (see Theorem 1, Appendix D) ANN's that are based on non-constant, continuous and bounded activation functions are capable of approximating any smooth function as long as the domain of the function is compact. Thus, we begin by formally defining the set of times series, which constitutes the domain of the function, and then we prove that this set could be considered as being compact (see Definition 2, Appendix D)

Theorem 2: If $x_{t_i}, i \in I, I$ is an arbitrary time series, such that $x_{t_i} \in \mathbb{R}^{\mathrm{N}}$ $\forall i \in I$ and $\forall t \in T$ and the set of time series is $\bigcup_{i \in I} x_{t_i} \subset \mathbb{R}^{\mathrm{N}}$, is closed and bounded, then $\bigcup_{i \in I} x_{t_i}$ is a compact subset of $\mathbb{R}^{\mathrm{N}}$.

Proof: See Appendix D.1.

Please note that the implicit assumptions made for the time series set is that it is closed and bounded. The financial time series set could be considered as being closed since it could contain all its boundary points. Additionally, we consider the financial time series set to be bounded since all financial time series could have a finite time dimension.

Next, in order to be able to apply Hornik's (1991) Theorem, we also need to formally prove that the proposed specification, for the unknown function *G* of the general unit root specification, possesses all the mathematical properties that Theorem 1 explicitly states. Below, Theorem 3 formally presents the proposed functional specification and proves the relevant properties.

Theorem 3: If $x_{t_i}, i \in I$ is an arbitrary time series and the set of time series $\bigcup_{i \in I} x_{t_i} \subset \mathbb{R}^{\mathrm{N}}$ is a compact subset of $\mathbb{R}^{\mathrm{N}}$, whereas $\varphi: \mathbb{R}^{\mathrm{N}} \to \mathbb{R}$ is a non-constant, bounded and continuous function, then any function $k: \mathbb{R}^{\mathrm{N}} \to \mathbb{R}$ of the form $k(x_{t_i-1}) \equiv \rho x_{t_i-1} \cdot F(x_{t_i-1}), \rho \in \mathbb{R}, t \in T$, where: $F(x_{t_i-1}) \equiv \sum_{n=1}^{N} a_n \varphi(\beta_n \cdot x_{t_i-1})$, with $a_n, \beta_n \in \mathbb{R}$ $\forall n \in \mathbb{N}$, and $a_n \neq 0$, for some $n \in \mathbb{N}$, where n is the number of nodes of the neural function, is also continuous, bounded and non-constant.

Proof: See Appendix D.1.

Having formally shown that the proposed specification is fully compatible with Hornik's (1991) Theorem, below we state our main result (Theorem 4), which states that the specification can formally approximate arbitrarily well the general non-linear specification.

Theorem 4: If the set $\bigcup_{i\in I} x_{t_i} \subset \mathbb{R}$, $t \in T \subset \mathbb{N}$ is a compact subset of $\mathbb{R}$, then the family of functions $\mathcal{F} = \{k(x_{t_i-1}) \in \mathrm{C}(\bigcup_{j\in J} G_j): k(x_{t_i-1}) \equiv \rho x_{t_i-1} \cdot F(x_{t_i-1}), F(x_{t_i-1}) \equiv \sum_{n=1}^{N} a_n \varphi(\beta_n \cdot x_{t_i-1})$, with a_n, $\beta_n \in \mathbb{R} \forall n \in \mathbb{N}, \rho \in \mathbb{R}\}$ is dense in the set of functions $\mathcal{H} = \bigcup_{j\in J} G_j$

Proof: See Appendix D.1.

In simple words, Theorem 3 implies that the proposed specification $k(x_{t_i-1}) \equiv \rho x_{t_i-1} \cdot F(x_{t_i-1}), F(x_{t_i-1}) \equiv \sum_{n=1}^{N} a_n \varphi(\beta_n \cdot x_{t_i-1})$, with a_n, $\beta_n \in \mathbb{R} \forall n \in \mathbb{N}, \rho \in \mathbb{R}$ is a global approximator to any arbitrary specification $\rho x_{t-1} G(x_{t-1}; \gamma)$ and, hence, the proposed specification could approximate arbitrarily well the general non-linear unit root specification.

5.4 THE TEST

As PSY have emphatically pointed out, the econometric identification of multiple bubbles over time is difficult mainly because of the complex *non-linear* structure involved in the multiple breaks that produce the bubble phenomena. This is the reason why a general *nonlinear* ANN approximation is used in this work as the main mechanism in the proposed econometric test.

a. Formulation

We have, formally shown that the proposed specification $k(x_{t_i-1}) \equiv \rho x_{t_i-1} \cdot F(x_{t_i-1}), F(x_{t_i-1}) \equiv \sum_{n=1}^{N} a_n \varphi(\beta_n \cdot x_{t_i-1})$, with a_n, $\beta_n \in \mathbb{R} \forall n \in \mathbb{N}, \rho \in \mathbb{R}$ is a global approximation to any arbitrary non-linear unit root specification i.e. $\rho x_{t-1} G(x_{t-1}; \gamma)$. Therefore, $\forall i \in I,$ the general unit root test of the form $\Delta x_{t_i} = \rho x_{t_i-1} \cdot G(x_{t_i-1}; \gamma) + \varepsilon_t$ could be approximated arbitrarily well by the test $\Delta x_{t_i} = k(x_{t_i-1}) + \varepsilon_t$, where ε_t

satisfies the usual assumptions.[29] In detail, exploiting the proposed NN specification the relevant testing equation becomes:

$$\Delta x_{t_i} = \sum_{n=1}^{N} \rho a_n x_{t_i-1} \cdot \varphi(x_{t_i-1};\ \beta_n),\ \forall i \in I \quad \textbf{(5.7)}$$

Now, without loss of generality, we can safely make an additional simplifying assumption about the behavior of the employed time series.

Assumption 4: x_{t_i} represents time series of the form: $x_{t_i} = \ln(\frac{P_{t_i}}{P_{t_{i-1}}})$.

For instance, x_{t_i} would naturally represent the logarithmic return of asset prices between two time periods in time *t* and *t-1*, e.g. daily. As a result, the quantity $x_{t_i} = \ln\left(\frac{P_{t_i}}{P_{t_{i-1}}}\right)$ hovers around zero, or $x_{t_i} \in B(0, \varepsilon)$.

This is due to the fact that the quantity (before taking natural logarithms): $\frac{P_{t_i}}{P_{t_{i-1}}} \in B(1, \varepsilon)$ hovers around unity, or $\frac{P_{t_i}}{P_{t_{i-1}}} \in B(1, \varepsilon)$, even for large daily fluctuations in prices P_{t_i}. However, it should be noted that large daily fluctuations in prices P_{t_i} are extremely improbable, even in developing markets. Additionally, we have to make an assumption about the activation function φ of the ANN.

Assumption 5: Without loss of generality, we may assume, that the activation function of the ANN has the following form:

$$\varphi(z_t) = e^{z_t{}^{\beta}} - 1 \quad \textbf{(5.8)}$$

It should be noted that $\varphi(z_t)$ is continuous, non-constant and bounded when $z_{t_i} \in B(0, \varepsilon)$, and $\beta > 0$.

Of course, it should also be pointed out that other alternative activation functions could be used, as long as they comply with the previously stated hypotheses. See Bishop (1995).

[29] It should be noted that lag augmentation, in case of serial dependence, does not affect either the test or its mathematical derivation. On the contrary, lags of the dependent variable may indeed be included to eliminate serial correlation.

However, in general, the empirical results are robust, regardless of the activation function used (Haykin, 1999).

In this work, and given the complexity of the problem, the chosen function is able to transform the model to one which lends itself to empirical estimation, contrarily to other possible activation functions. In this sense, the argument by Kuan and White (1994) is in force: "given the popularity of linear models in econometrics, this form is particularly appealing, as it suggests that ANN models can be viewed as extensions of, rather as alternatives to, the familiar models".

Now, based on equation (5.8), equation (5.7) takes the following form:

$$\Delta x_{t_i} = \sum_{i=1}^{N} \rho a_i x_{t_i-1} \cdot [e^{x_{t_i-1}{}^{\beta_i}} - 1] \quad \textbf{(5.9)}$$

In what follows, we will make use of Taylor's expansion Theorem, to get an equivalent but more convenient form, of the term:

$$e^{x_{t_i-1}{}^{\beta_i}} - 1 \quad \textbf{(5.10)}$$

Thus, by applying the aforementioned Theorem around $x_0 = 0$, we get that:

$$e^{z_t{}^{\beta}} \approx 1+z_t{}^{\beta} \quad \textbf{(5.11)}$$

Hence, taking into consideration equation (5.11), equation (5.9) becomes:

$$\Delta x_{t_i}=\rho a_1 x_{t_i-1} \cdot \left[1 + x_{t_i-1}{}^{\beta_1} - 1\right] + \rho a_2 x_{t_i-1}\left[1 + x_{t_i-1}{}^{\beta_2} - 1\right] + \cdots + \rho a_k x_{t_i-1}\left[1 + x_{t_i-1}{}^{\beta_k} - 1\right] + \cdots + \rho a_N x_{t_i-1} \cdot \left[1 + x_{t_i-1}{}^{\beta_N} - 1\right]$$

$$\Delta x_{t_i} = \rho a_1 x_{t_i-1}{}^{\beta_1+1} + \rho a_2 x_{t_i-1}{}^{\beta_2+1} + \ldots + \rho a_N x_{t_i-1}{}^{\beta_N+1}, \forall i \in I \quad \textbf{(5.12)}$$

Now, without loss of generality, $\forall\, n \in \mathbb{N}$, let: $\rho a_n = \kappa_n$ and $\beta_n + 1 = \delta_n$. Thus, we get:

$$\Delta x_{t_i} = \kappa_1 \cdot x_{t_i-1}{}^{\delta_1} + \kappa_2 \cdot x_{t_i-1}{}^{\delta_2} + \ldots + \kappa_N \cdot x_{t_i-1}{}^{\delta_N}, \forall i \in I \quad \textbf{(5.13)}$$

With the inclusion of the error term, we have the following test:

Proposition 1: The null hypothesis, H_0, of a unit root is parameterized by a test of $\sum_{i=1}^{N} \kappa_i = 0,\ \delta_n \in |B(1,\varepsilon)|, \varepsilon > 0$, n = 1,2,…*N* in:

$$\Delta x_{t_i} = \kappa_1 \cdot x_{t_i-1}{}^{\delta_1} + \kappa_2 \cdot x_{t_i-1}{}^{\delta_2} + \ldots + \kappa_N \cdot x_{t_i-1}{}^{\delta_N} + \varepsilon_{t_i}, \forall i \in I \quad \textbf{(5.14)}$$

Proof: See Appendix D.1.

It is worth noting that equation (5.14) could be seen as a generalization of KSS.

Now, following PSY and the relevant strand in the literature, the previous model specification is complemented with transient dynamics, just as in standard ADF unit root testing. Hence the proposed specification takes the form:

$\Delta x_{t_i} = \kappa_1 \cdot {x_{t_i-1}}^{\delta_1} + \kappa_2 \cdot {x_{t_i-1}}^{\delta_2} + \ldots + \kappa_N \cdot {x_{t_i-1}}^{\delta_N} + \sum_{p=1}^{P} b_p \Delta x_{t_i-p}, \forall i \in I$ **(5.15)**

Of course, in order to allow application of the test with intercept, or intercept *and* trend terms included, these deterministic terms are removed via preliminary regression with the demeaned or detrended version of x_t.

b. Existence of Bubbles

In what follows, we propose a generalized *max* NN Unit Root (NNUR) test for the presence of bubbles, as well as a recursive forward and backward technique, to detect and time-stamp the bubble origination and termination dates, where flexible window widths are used in their implementation.

Instead of fixing the starting point of the recursion on the first observation, the proposed test extends the sample coverage by changing both the starting point and the ending point of the recursion over a feasible range of flexible windows and is, therefore, suited to analyzing long historical data (PSY).

Now, following the literature on the econometric detection of bubbles as set out earlier, we may make the following assumption:

Assumption 6: $\forall i \in I$ the error term, $\varepsilon_{t_i} \sim N(0, \sigma_{t_i}^2)$, where $\sigma_{t_i}^2$ follows a GARCH process of the form: $\sigma_{t_i}^2 = g\left(\sigma_{t_i-1}^2, {\varepsilon_{t_i-1}}^2\right) = a_0 + a_1 \sigma_{t_i-1}^2 + a_2 {\varepsilon_{t_i-1}}^2$ **(5.16)**

where: $a_0 > 0, a_1 > 0, a_2 > 0$.

In what follows, we perform repeated NNUR tests on sub-samples of the data on a recursive, backward and forward manner, changing the starting and ending points. We proceed by providing a simple algorithm for the implementation of the test, regarding the detection of bubbles in a time frame. The following simple algorithm sets out the mechanism behind the proposed approach.

Step 1: Let $i \in I$, and x_{t_i} an arbitrary time series of length $T > 0$ and consider a sample of it, the so-called window W with length $0 < W < T$.

Step 2: Partition the sample W into all the possible sub-samples $r_{w_j} = [r_{1_j}, r_{2_j}] \subseteq W$ where r_{1_j} is the starting date of the j-th sub-sample and r_{2_j} the respective ending date. In this way, we obtain the set of all subsamples $r_w = \bigcup_{j \in J} r_{w\,j}$ in W.

Step 3: Compute the model's significance $Sig - NN_j$, corresponding to F-like tests, to obtain the set of Sig-s which refers to each window Was $Sig - NN^W = \bigcup_{j \in J \subseteq \mathbb{N}} Sig - NN_j$. Note that these models do not necessarily belong to a single sub-sample.

Step 4: For all the subsamples with the same starting point, choose the $Sig - NN_m, m \in M \subseteq J \subseteq \mathbb{N}$ that are (equally or) more significant than their corresponding critical values$Sig - NN_m{}^*$, to obtain the set $Sig = \bigcup_{m \in M \subseteq J \subseteq \mathbb{N}} Sig - NN_m$, which corresponds to the set of sub-samples $r_w{}^m = \bigcup_{m \in M \subseteq J \subseteq \mathbb{N}} r_{w_m}$. Note that this choice reduces the cost of keeping the non-significant values in the set.

Step 5: Compute the $max_{m \in M \subseteq J}\{Sig - NN_m\}$ on the set $\bigcup_{m \in M} Sig - NN_m$.

Step 6: **(a)** If there is only a single maximal point $max_{m \in M \subseteq J}\{Sig - NN_m\}$ for all the models with the same starting point, a unique bubble exists in the sub-samplem^*. **(b)** (i) If multiple maximal points exist in different neighborhoods of the same subsample, then multiple bubbles exist. (ii) If multiple maximal points exist in the same neighborhood of the same subsample, then one bubble exists: The one with the longer duration.

Step 7: Repeat steps (1)-(6) for all the possible sets $Sig - NN_j, j \in J$.

Step 8: Repeat steps (1)-(7) for all the models with the same ending point.

Step 9: Repeat steps (1)-(8) above for all possible (rolling) windows W.

Note that the initial size of the window is equal to the one suggested in PSY, namely: $w_0 = 0.01 + 1.8/\sqrt{T}$. Finally, a parameter to account for data frequency could easily be included in the model. The dating of bubbles is done trivially in the spirit of PSY.

For expository reasons, we provide the following Data Generating Process (DGP), using standard notation. Consider a time series X_t, with length T>0. Let T be partitioned into $j \in J$ sub-samples, r_{w_j}. Let $r_{w_j}{}^*$ be the only sub-sample where the bubble occurs. The DGP has the following representation:

$$X_t = X_{t-1}{}^{r_{wj}} 1 \left\{ r_{w_j} \neq r_{w_j}{}^* \right\} + \delta_T X_{t-1}{}^{r_{wj}{}^*} + 1 \sum_{k \neq r_{w_j}{}^*} \varepsilon_k + \varepsilon^{r_{wj}{}^*} \quad \textbf{(5.17)}$$

In this scheme, in the pre-bubble period the series follows a pure random walk. The bubble expansion period is $r_{w_j}{}^*$which involves a mildly explosive process with expansion rate δ_T. The process then collapses and continues its pure random walk behavior $\forall r_{w_j}, j \in J$.

- Unit root behavior in t_0 can be identified by :$\left.\frac{dX_t}{dX_{t-1}}\right|_{t=t_0} = 1$ **(5.18)**
- An emerging bubble can be identified by: $\left.\frac{dX_t}{dX_{t-1}}\right|_{t=t_1} > 1$, $\left.\frac{dX_t}{dX_{t-1}}\right|_{t=t_2} \leq 1$ **(5.19)** in the time period $[t_1, t_2]$
- A collapsing bubble can be identified by: $\left.\frac{dX_t}{dX_{t-1}}\right|_{t=\tau} < 1$ **(5.20)** in the time period $[t_3, t_4]$.

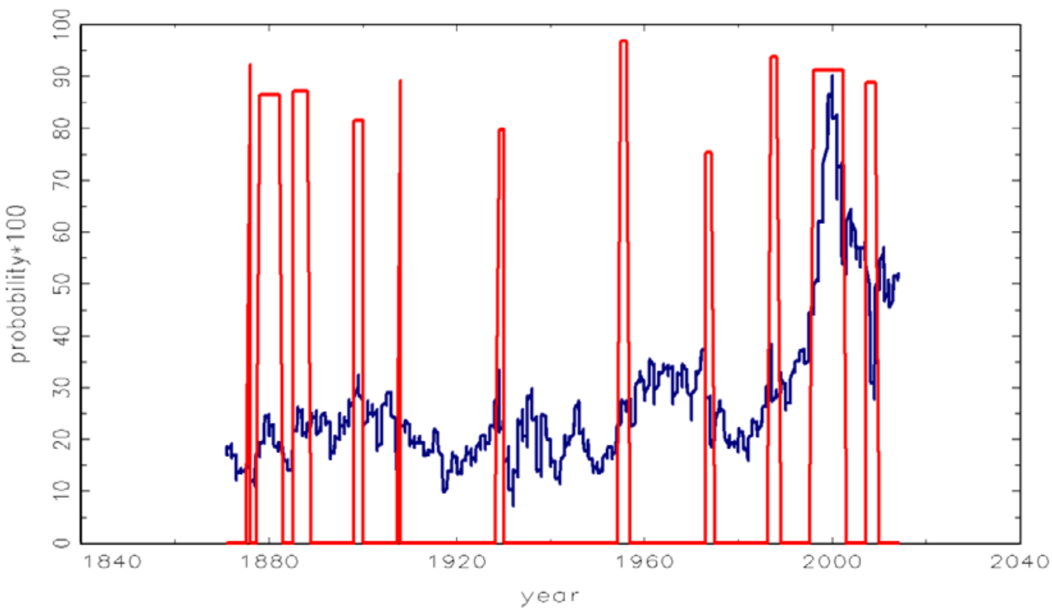
5.5 RESULTS AND DISCUSSION

Having analyzed the model and the proposed test, we continue by elaborating on the estimation technique and data used.

We use data on the stock price-dividend ratio S&P500 (1871.1-2014.6). The S&P 500, i.e. the Standard & Poor's 500, is a stock market index for the US and is based on the market capitalizations of 500 large companies having common stock listed on the NYSE or NASDAQ. More specifically, the S&P 500 index components and their weightings are determined by S&P Dow Jones Indices. It is one of the most commonly followed equity indices, and many consider it as being one of the best representations of the US stock market, and a bellwether for the U.S. economy (Phillips et *al.,* 2011).

The results of our analysis, using Bayesian techniques (Appendix D.2) are illustrated in Figure 5.1, below.

Figure 5.1. Time series and posterior probabilities of episodes



As can be seen in Figure 5.1 and in Table 5.1, the proposed specification is able to identify eleven (11) bubble episodes or bubble formations in the S&P500 index in the sample period (1871.1-2014.6).

Table 5.1. Bubble periods and Posterior Probabilities

Bubble Period in years.months	Probability (%)	Explanation
1875.7 - 1876.10	92.32	"America's Almost Civil War", crisis
1877.8 - 1882.6	86.49	Banking panic (Post Long Depression Period)
1885.11- 1888.5	87.12	"Baltimore" Crisis
1898.12- 1900.11	81.55	Cuba War of independence, Crisis

1907.3-1908.1	89.13	Banking panic 1907
1928.8- 1930.10	79.67	Great crash
1954.6 -1956.12	96.81	Postwar boom
1973.1-1974.2	75.21	Oil shock
1986.7 - 1988.9	93.80	Black Monday
1995.6- 2002.6	91.32	dot-com boom
2007.1- 2009.6	88.77	Subprime crisis

In comparison to PSY, we are able to identify four (4) more bubble episodes in the S&P500 index and miss only one. See Table 5.2, below.

Table 5.2: Comparison for bubble detection

Bubble Period in years.months	**Bubble Explanation**	**Bubble detected in the present chapter?**	**Bubble detected in PSY?**
1875.7 - 1876.10	"America's Almost Civil War", crisis	Yes	No
1885.11- 1888.5	"Baltimore" Crisis	Yes	No
1898.12- 1900.11	Cuba War of independence, Crisis	Yes	No
1973.1-1974.2	Oil shock	Yes	No
1917.08-1918.04	The 1917 Stock Market Crash	No	Yes

Another very interesting finding is that the bubbles do not have the same time duration, in comparison to PSY. See Table 5.3, below.

Table 5.3: Comparison between bubble durations

Bubble Period in years.months identified in the present chapter	Bubble Period in years.months identified in PSY	Earlier Detection of Bubbles in the present chapter compared to PSY?	How many months earlier was the bubble detected in the present paper compared to PSY?
1877.8 - 1882.6	1879.10-1880.4	Yes	14 months
1907.3-1908.1	1907.9-1908.2	Yes	6 months
1928.8- 1930.10	1928.11-1929.10	Yes	3 months
1954.6 -1956.12	1955.1-1956.4	Yes	7 months
1986.7 - 1988.9	1986.6-1987.9	No	-1 months
1995.6- 2002.6	1995.11-2001.8	Yes	5 months
2007.1- 2009.6	2009.2-2009.4	Yes	25 months

Hence, our bubble detection mechanism seems to be more sensitive to bubble formation.

As can be seen in Table 5.3, compared to PSY, the bubble episodes that we identify, in general, have longer duration. This means that the proposed specification is able to identify bubble episodes earlier, compared to PSY (2015). Therefore, the proposed specification could be thought of as an early warning device.

For instance, if we focus on the recent US subprime crisis, the proposed test for bubbles indicates that the bubble started in January 2007 and ended in June 2009. According to official data (CIA World Factbook, 2011), the US subprime bubble started in December 2007, i.e. almost 10 months after our proposed test suggests, i.e. $[2007.1 - 2009.6]$. However, the ending point of the identified bubble, and of the one provided by the official statistics, are exactly the same. This clearly implies that according to the proposed test, this 10-month period coincides with the build-up of the bubble.

Analytically, the proposed specification, based on the aforementioned dating algorithm, is capable of sufficiently answering the fundamental question of every EWM mechanism, which is the timing of detection, while taking into consideration the neglected non-linearities. The appropriate timing of an ideal EWM is crucial for policy makers as the EWMs need to signal the crisis early enough so that policy actions can be implemented in time to be effective. The time frame required to do so depends, *inter alia*, on the lead-lag relationship between changing a specific macroprudential tool and on the impact on the policy objective (CGFS, 2012).

For instance, in contrast to monetary policy, where it takes at least a year for interest rates to impact on inflation, this relationship is less well understood for macroprudential instruments. Yet, it is likely to be at least as long. For instance, banks have one year to comply with increased capital requirements under the countercyclical framework of Basel III (Basel Committee, 2010). In addition, data are reported with lags and policy makers do not act immediately on developments but observe trends for some time before changing policies (Bernanke 2004). This urges EWMs to start issuing signals well before a crisis occurs as is the case with the suggested approach.

In fact, early bubble identification could substantially aid policy makers, worldwide. The validity of this argument lies of the fact that whilst tools and actual policies differ across countries and financial institution, the key objective of macroprudential policies, which is the reduction of systemic risk, remains the same (e.g. Borio 2009; Disyatat 2010). In this context, a crucial component of the macroprudential approach based on EWMs is to address the procyclicality of the financial system by, for example, stipulating the accumulation of buffers in "good times" so that these can be drawn down in "bad times". See, among others, White (2008). Tools, which are already used in this regard, include countercyclical capital buffers or dynamic provisioning. See Cukierman (2013). One key challenge for policy makers is the identification of the different states in real time, with particular emphasis on detecting unsustainable booms that may end up in a financial crisis.

5.6 CONCLUSION

Despite the fact that the history of financial bubbles is rather long, only limited attention has been paid by the scientific community to the creation of a rigorous econometric test for the early detection of bubble formation. Probably, one of the main reasons behind the inability of most models to efficiently capture the formation of bubbles, is the fact that bubble formation has inherent non-linear characteristic which are difficult to be captured using standard econometric models.

Additionally, another equally important challenge for the econometric detection of bubbles is the dating of bubbles' occurance, in the sense that an econometric test should be able to accurately date the bubble periods detected in the sample. Accurate dating of financial bubbles could have important policy implications, especially for central bankers and policy makers, since it could substantially aid the implementation of policy actions that could potentially ease the consequences of bubbles.

However, only few papers in the literature use recursive estimation techniques for dating multiple bubble episodes. More precisely, a recent strand in the literature, attempts to detect and date bubble episodes based on the unit root behavior of key financial variables. In this chapter, we extended this strand of the literature by using ANNs in an attempt to formally approximate the basic unit root specification so as to account for neglected non-linearities. Moreover, we provided a recursive dating procedure for bubble episodes and we applied both our bubble detection test and its dating mechanism to the S&P500 index.

According to our findings, the proposed specification is fully capable of capturing the bubble episodes in the time sample examined. Additionally, the bubble periods identified are longer in comparison to PSY. More precisely, in all common bubble episodes our proposed specification identified the bubble, in the general case, earlier compared to PSY. In other words, our specification could be thought of as an early warning device for bubble formation, which in turn could have important implications, as we have seen.

In brief, the early identification of bubbles is of outmost importance for policy makers and central bankers. The importance of early identification lies in the timing of implementation of specific countermeasures that could potential prevent: a) the magnitude of a potential collapse through regulatory interventions in the financial markets; b) the downturn effects of bubble collapse in the economy through appropriate inflation targeting; and c) the devastating spillover effects in the global economy through interest rate and/or exchange rate setting.

Of course, there are still numerous issues that could serve as examples for further investigation. For example, from a theoretical point of view, one could explore the limit theory characteristics of the proposed approach or, from an empirical point of view, one could make an attempt to explore alternative NN architectures. Clearly, future research in capturing and modeling non-linearities in bubbles would be of great interest.

Chapter 6: Sector size, technical change and stability in the USA[30]

Despite the fact that we established a sound econometric and analytical framework on the identification of bubble formation, the question as to the driving forces of the US economic crisis, still remains unanswered. In this context, in the next chapter, we will focus on the sectoral behaviour of the U.S. economy. Analytically, we investigate whether sector size matters for sectoral technological change and stability, as expressed through the relevant quantitative measures and variables. To this end, we test a number of relevant models that express the various forms of this relationship. More precisely, we use panel data for the fourteen main sectors of economic activity in the U.S.A. over the period 1957-2006, just before the first signs of the US and global recession made their appearance.

6.1 INTRODUCTION

When examining which market structure favours technological change and innovation, we often refer to Joseph Schumpeter (Schumpeter 1939, 1942, 1976) who put technology in the center of his theoretical system. In brief, the Schumpeterian hypothesis argues that 'large firms with considerable market power, rather than perfectly competitive firms were the "most powerful engine of technological progress"' (Mokyr 1990, 267). This hypothesis argues that large economic units are more likely to promote innovation. It also claims that, in a generally unstable market structure, only large economic units could guarantee the stability that is necessary for technological change and development[31].

[30] Another version of this chapter has been published as follows: Konstantinos N. Konstantakis, Panayotis G. Michaelides and Theofanis Papageorgiou (2014), Sector size, technical change and stability in the USA (1957-2006): A Schumpeterian approach, *International Journal of Social Economics,* 41(10): 956-974.

[31] As we know, Schumpeter famously argued that: "[W]hat we are about to consider is that kind of change arising from […] the system which so displaces its equilibrium point that the new one cannot be reached from the old one by infinitesimal steps" (Schumpeter 1912, 64). Real economic growth and development depend primarily upon productivity increases based on technology and innovation. Thus, strictly speaking, Schumpeter did not discriminate between growth trend and business cycle fluctuations, so the observed raw data have been used to test the Schumpeterian hypothesis. In a next step, one has to decide about the time series representing the capitalist process. Although Schumpeter (1939) used many different series, nowadays it is commonly agreed to use aggregate output as an indicator of the capitalist dynamics. Of course, it has to be mentioned critically that this reduction of reality was not in the spirit of research at the time Schumpeter wrote his book on *Business Cycles.*

To this end, we test a variety of models that express the various forms of this relationship. More precisely, we use panel data for the fourteen (14) main sectors of economic activity in the U.S.A. over the period 1957-2006, just before the first signs of the US and global recession made their appearance.

In a nutshell, this work contributes to the literature in the following ways: First, it provides an extensive review of the literature on the subject and adopts two relevant methodological approaches. Second, based on these quantitative approaches, the chapter offers a complete investigation of two famous postulates of the Schumpeterian theory for the US economy, and it is the first, to the best of our knowledge, to do so by sector of economic activity, in a panel data framework. Third, the chapter uses a wide dataset (1957-2006) to examine the U.S economy up until the first signs of the US and global economic recession made their appearance.

The outline of this chapter is as follows: section 6.2 offers an extensive review of the literature on technological change; section 6.3 sets out the methodology employed; section describes 6.4 the estimation method and the available data; section 6.5 presents the empirical analysis, whereas section 6.6 discusses the results; finally, section 6.7 concludes the chapter.

6.2 BACKGROUND LITERATURE

Arrow (1962) argued that larger firms have greater incentive for R&D investments due to the fact that they have a better ability to catch the property rights from their innovations. One of the first empirical attempts was made by Mansfield (1964) with the use of U.S sectoral data. However, the findings were inconclusive. Scherer (1965) provided an analytical econometric framework under which the Schumpeterian hypothesis could be properly tested. Also, Scherer (1967) examined the optimal degree of market concentration that promotes the level of innovative activity under a game-theoretic framework and concluded that an increase in the number of economic units in the market increases the marginal payoff of R&D.

Next, Fisher and Temin (1973) constructed a model with R&D investments under profit maximization and showed that there was no reason for a positive relation between innovation and firm size. Kamien and Schwartz (1976) showed that intense rivalry would lead to an initial increase of the R&D expenditures by a firm, but at a later stage the expenditures would decline. They concluded that there is an optimal degree of rivalry that promotes innovation. Rodriguez (1979) argued that based on Fisher and Temin (1973), profit maximization implied negative profits and so their model is fundamentally flawed. Lury (1979) managed to construct an equilibrium model which showed that, under certain conditions, intense rivalry reduces firm individual incentives to innovate. Dasgupta and Stiglitz (1980) made an attempt to establish the microeconomic foundation of the Schumpeterian hypothesis by connecting the market concentration with the incentives in innovative activity.

In a seminal work for the US, Link (1980) provided empirical evidence which support the hypothesis by using data from the chemical industry of US, showing that firm size is a prerequisite for successful innovative activity. In a different framework, Griliches (1980) examined whether the slowdown in productivity that was witnessed in the U.S economy could be attributed to the drop of R&D expenditures. Despite his efforts, the results seem to be inconclusive. Again, Link (1981) provided evidence in favour of a positive relation between R&D expenditures and the productivity growth using data of fifty one (51) manufacturing firms in the U.S. Kamien and Schwartz (1982) introduced a model that incorporated the elements of market structure that could affect innovation. Their model offered interesting insights on the interdependence of market size and innovation with predominant the non-existence of a monotonically increasing relation between concentration and innovation.

Scherer (1983) investigated the relationship between R&D expenditures and patenting. The results showed that there is a positive relationship between the two, but also a trend that shows that large firms do not seem to promote innovation more than smaller ones. On the other hand, Bound et *al.* (1984) provided an investigation on R&D expenditures and patenting which showed that both large and small firms are more R&D intensive than average firms. Again, Griliches (1984) investigated the relationship between R&D intensity and TFP using data from 1960 to mid 1970s showing a significant relationship between the two.

Levin et *al.* (1984) provided a thorough analysis of a model that incorporated R&D spillovers. According to their findings R&D spillovers tend to promote technological adoption. Again, Levin et *al.* (1985) showed that new born industries seem to promote innovation more. Another important attempt to provide evidence on the linkage between firm size and innovation was made by Acs and Audretsch (1987). Their findings suggest that there is a set of conditions that seems to control which type of firms, small or large, promote innovation. Cohen et *al.* (1987) found that business size has no effect on R&D intensity but only on the probability of conducting R&D. Pavitt et *al.* (1987) investigated the distribution of units' size that develop important innovations and concluded that units with less than 1000 workers or more that 10,000 workers have an above average share of innovations per employ. In addition, Cohen and Levin (1989) concluded that 'the empirical results concerning how firm size and market structure relate to innovation are perhaps most accurately described as fragile'.

More recently, in a breakthrough paper, Aghion and Howitt (1992) argued that the innovative activity should be categorized by the magnitude of the impact of each type of innovation on economic growth. Thus, not all innovations are the same. Tirolle and Aghion (1994), established a game theoretic framework under which the Schumpeterian hypothesis can be both rationalized and endogeneized. Furthermore, Symeonidis (1996), in a survey article, argued that under certain circumstances there could be a positive relationship between market concentration, size of the firm and innovative activity.

Furthermore, Streb (1999) in a seminal paper examined the conditions under which a national industry could succeed in international competition. Andersen (2000) using a game-theoretic framework based on evolutionary games tried to investigate the role of pioneers as opposed to imitators in simple games in an attempt to examine whether the hypothesis works in certain games. However, the results were inconclusive. Furthermore, Gayle (2001) provided further evidence on the inconclusive nature of the research question. Dhawan (2001), in an inspired approach, measured the differences in productivity of both small and large firms according to their profitability which was related to the probability to survive. The findings suggested that small firms tend to be more profitable but less likely to survive.

Moreover, Nahm (2001), with the use of a data set from the bank of Korea, managed to separate Korean firms to scientific and non-scientific according to their R&D expenditures. The results showed that there is a threshold in firm size and independent R&D activity. Zachariadis (2002) used U.S manufacturing industry data to econometrically test the link of R&D to patenting, patenting to technological progress and technological progress to growth. Under this framework he found evidence of a positive linkage between R&D and growth. Nicholas (2003) provided an extended survey of the cliometric literature on the research question. According to his findings American firms of the 1920's exhibit a positive relationship between market power and innovative activities.

Relatively recently, Aghion et *al.* (2005) managed to derive an inverted U-shape relationship between innovation and competition in a general equilibrium framework, which is in favour of the hypothesis. In addition, Aghion and Griffith (2005) showed that in industries working very close to their technological frontier, innovation is driven by competition. Acs and Audretsch (2005) showed that the small firms play a vital role for R&D. In addition, Baudisch (2006) provided evidence in favour of the hypothesized relationship using data for the U.S footwear company. Hashmi and Biesebroeck (2010) provided empirical evidence, under a game theoretic framework established by Ericson and Pakes (1995), in support of the Schumpeterian hypothesis for the global automobile industry (1980-2005). Salies (2009), in the E.U. electrical utilities sector, showed a positive relationship between market structure, firm size and innovative activity. Mohnen et *al.* (2009), using panel data, provided evidence in favour of the hypothesis in specific sectors. Finally, Jinyoung et *al.* (2009) re-examined the relationship between R&D and productivity in small and large firms in the pharmaceutical and semiconductor industries. They found that R&D productivity is increasing in firm size, in the pharmaceutical industry. In a nutshell, the relevant literature seems to be controversial and inconclusive.

6.3 METHODOLOGY

We examine the relationship between the aggregate output of each sector (Y) as an expression of its size and its: (i) R&D expenses (R), and (ii) Total Factor Productivity (TFP).

The model that we employ here is based on Bound et *al.* (1984) with the use of cross-section Seemingly Unrelated Regression (SUR) model, following Arellano (1987).

R&D expenses

- $R_t = aY_t^b$ *or* $\ln R_t = \ln a + b \ln Y_t$ **(6.1)**

where $a>0$, $b \in R$ is the R&D elasticity with respect to the aggregate output.

For the Total Factor Productivity index we will have that:

TFP

- $(tfp)_t = aY_t^b$ *or* $Ln(tfp)_t = \ln a + b\ln Y_t$ **(6.2)**

Next, our investigation focuses on whether large units tend to fluctuate more than smaller ones. Although in the original spirit of Schumpeter's work, there exists no clear distinction between trend and cyclical component, we have to separate between growth and secular component in order to quantify the "economic fluctuations". In this context, we adopt a popular approach which regards cycles as fluctuations around a trend, the so-called "deviation cycles" (Lucas, 1997). Meanwhile, the business cycle component is regarded as the movement in the time series that exhibits periodicity within a certain range of time duration based on the seminal work by Burns and Mitchell (1946), and in line with the National Bureau of Economic Research (NBER).

Given that the trend is important for the propagation of shocks (Nelson and Plosser, 1982), we first have to examine the stationarity characteristics of each time series. If the results suggest that the time series are stationary in their first differences, then de-trending is highly relevant. The estimation of this trend for each time series is of great importance because it is necessary for the extraction of the cyclical component.

There are several ways to test for the existence of unit roots. We used panel data unit root tests that are relevant for the investigation of the statistical properties in a panel data framework. Since panel data increases the power of the test by enhancing the time series dimension of the data by the cross section, the results could be considered as being more reliable. The most popular panel unit root tests are the LLC (Levin, Lin and Chu, 2002), the IPS (Im, Pesaran and Shin, 2003), the ADF - Fisher Chi-square (Maddala and Wu, 1999) and the PP – Fisher Chi-square (Choi, 2001).

In case the time series is non-stationary, then detrending based on Hodrick - Prescott (HP) filtering would be relavant, due to its widespread acceptance in the literature. See, for instance, Montoya and de Haan (2008), Danthine and Girardin (1989), Danthine and Donaldson (1993), Blackburn and Ravn (1992), Backus and Kehoe (1992), Dimelis et *al.* (1992), Fiorito and Kollintzas (1994), Christodoulakis et *al.* (1998), Dickerson et *al.* (1998). The robustness of the HP de-trending method is confirmed, among others, by Artis and Zhang (1997) and Dickerson et *al.* (1998). The linear, two-sided HP-filter approach is a method by which the long-term trend of a series is obtained using actual data. The trend is obtained by minimizing the fluctuations of the actual data around it, i.e. by minimizing the following function.

This method decomposes a series into a trend and a cyclical component. The parameter used for annual data equals to λ=100 (Baum et *al.,* 2001; Hodrick and Prescott, 1997; Kydland and Prescott, 1990). Thus, after the estimation of the cyclical components, we proceed to the empirical specification of the model.

Here, we test the Schumpeterian postulate which claims that large units tend to fluctuate more than smaller ones. In this context, we are based on Scherer's (1983) approach which is suitable for business cycles movements due to its quadratic form, able to capture the fluctuations. So the model is as follows:

- $\ln(Cycle)_t = b_0+b_1\ln Y_t$ **(6.3)**

and

- $(Cycle)_t = b_0+b_1Y_t+b_2Yt^2$ **(6.4)**

In brief, this work contributes to the literature in three distinct ways. First, it provides a well rounded review of the literature and adopts two relevant methodological approaches; second, based on these approaches the chapter offers a complete investigation of two famous postulates about the US economy. In the meantime, it is the first, to the best of our knowledge, to do so by sector of economic activity, in a panel data framework. Third, the chapter makes use of a wide dataset to examine the U.S economy for the period 1957-2006, just before the first signs of the US and global economic recession made their appearance.

6.4 ESTIMATION METHOD AND DATA

a. Estimation method

Fixed-effects methods have become increasingly popular in the analysis of longitudinal data for one compelling reason. They make it possible to control for all stable characteristics of the individual, even if those characteristics cannot be measured (Halaby, 2004; Allison, 2005).[32]

By construction, the unobserved panel-level effects are correlated with the lagged dependent variables, making standard estimators inconsistent. Arellano and Bond (1991)[33] derived a consistent generalized method of moments (GMM) estimator for this model. Building on the work of Arellano and Bover (1995), Blundell and Bond (1998) developed a system estimator that uses additional moment conditions. However, according to Arellano (1987), when using OLS in panel data, cross section weights should be used. In fact, if the number of periods (T) is two times greater than the number of cross sections (2*N*) then cross-section SUR should be used, where all individuals have their own regression parameters, but these are restricted to be constant over time. The regression relations for the different individuals are only related via the correlation of the error terms, but the error covariance across individuals is unrestricted. Baltagi (2008) noticed that the OLS estimator is biased and inconsistent even if the error terms are not serially correlated; the random effects estimator is also biased in a dynamic panel data model. Nevertheless, as T gets large, the fixed effects estimator becomes consistent. As Judson and Owen (1999) notice, for T=30 the bias could be significant. However, in this work, the number of periods is equal to T=50 and the number of sectors is fourteen (14), a fact which clearly implies that only a minor bias would be expected.

Also, fixed effects were calculated for the equations estimated for the fourteen (14) sectors under investigation. Furthermore, the model was estimated using the Generalized Linear Model (GLM). Formulated by Nelder and Wedderburn (1972), the GLM constitutes an extension of familiar regression models. A generalized linear model

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32 Fixed-effects methods can naturally be applied to linear models (Greene, 1990), logistic regression models (Chamberlain, 1980), Poisson regression models (Cameron and Trivedi, 1998) and linear dynamic panel-data and contain unobserved panel-level effects, fixed or random.

33 The Arellano and Bond (1991) estimator can perform poorly if the autoregressive parameters are too large or the ratio of the variance of the panel-level effect to the variance of idiosyncratic error is too large.

is defined as a model where the linear combination of X-variables is related to the outcome variable Y using a link function *g* and where the variance of the response variable is proportional to some function of the mean (Newson, 2001).

At this point, a major problem in examining technological change and one that makes it difficult to define or characterize it is that it can take many different forms (Rosenberg, 1982). In that sense, there is no generally accepted measure of technological change and all measures are imperfect. As a result, we use the two most popular measures in order to quantify technological change. R&D expenditures along with TFP[34] are typically used as proxies for technology. It is widely argued that there is convincing evidence supporting the cumulative R&D is the most important endogenous measure[35] of technology[36] whereas TFP is an exogenous measure of technology. Of course, another variable that could serve as an alternative indicator for technological change is patents[37]. However, as Smith (2006) has argued, patents reflect inventions rather than innovations. Therefore, patent data would provide only a crude proxy, at best, for what Schumpeter meant by technological innovation and technological change. In addition, sectoral data on patents were not readily available to us, based on the classification at hand. No doubt, further investigation based on patents would be useful.

Now, another important measure is sector size. In the literature, one can find a variety of measures that represent the size of a firm, such as the number of employees, the revenue and the capital stock. The advantages and disadvantages of each measure are thoroughly discussed in Degne (2010). In this study, following Scherer (1985) we express the size of the sector through its output, due to data availability.

b. Data

We make use of data regarding the U.S economy for the period 1957-2006, just before the first signs of the US and global recession made their appearance, based on the fourteen main sectors of economic activity: (RD) expresses the aggregate R&D expenses, (Y) expresses the gross sectoral output, (L) expresses the full time equivalent employees, and (K) expresses the net stock of physical capital. All data are in billions of US dollars (1957 prices), except for (L) that is measured in thousands of employees. The data come

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34 TFP approximates technological change as the residual of the growth equation.

35 For an extensive discussion on the determinants of technology in the Schumpeterian tradition, see Degne (2011).

36 Of course, a typical drawback, is that R&D expenses of a firm can capture only the input size and do not provide any information regarding the output side (Kleinknecht, 2001).

37 For an extensive discussion on patents see Griliches (2008), Degne and Streb (2010).

from various sources: *K* comes from the Bureau of Economic Activity, *L* from the Bureau of Labour Statistics, *RD* from the National Scientific Foundation of the U.S. and *Y* from the National Bureau of Economic Activity. In the next table (Table 6.1) there is a detailed description of the data that we used including the sectors of the U.S.A economy that we investigated.

Table 6.1: Data and Variables

	INDUSTRIAL SECTORS (U.S. ECONOMY)			
SECTORS	**DESCRIPTION**	**NACE CLASSIFICATION**	**VARIABLES AVAILABLE**	**SOURCE**
1	AGRICULTURE,FORESTRY AND FISHING	A01, A02, A03	OUTPUT (Y)	National Bureau of Economic Activity
2	MINING, PETROLEUM AND COAL PRODUCTS	B, C10-C12, C13-C15, C16, C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C31-C32, C33		
3	ELECTRICITY, GAS AND WATER	D, E36, E37-E39		
4	CONSTRUCTION	F		
5	FOOD & BEVERAGES, WOOD PRODUCTS AND FURNITURE, METAL PRODUCTS	I	CAPITAL (K)	Bureau of Economic Activity
6	WHOLESALE TRADE	G45, G46		
7	RETAILTRADE	G47		
8	TRANSPORT AND STORAGE	H49, H50, H51, H52, H53		
9	INFORMATION&TECHNOLOGY INDUSTRY	J58, J59-J60, J61, J62-J63, S95	R&D EXPENSES	National Scientific Foundation of the U.S
10	REAL ESTATE AND BUSINESS SERVICES,FINANCE AND INSURANCE	K64, K65, K66, L ,L68A, M71, M72, N77		
11	COMMUNICATION SOCIAL AND PERSONAL SERVICES	M73, M74-M75, N79, N80-N82, O, Q87-Q88, R90-R92, R93, S94, S96, T, U		
12	BUSINESS MANAGEMENT SERVICES	M69-M70, N78	LABOR (L)	Bureau of Labour Statistics
13	EDUCATIONAL ORGANIZATIONS	P		
14	HEALTH SERVICES	Q86		

Next, there is a Table 6.2 which presents the aggregate annual growth rates of the variables under consideration. It is worth mentioning that the growth rates of the variables are positive and significant. On the other hand, the growth of R&D intensity index has a negative sign, which in turn indicates that there is a decrease of the proportion of R&D expenses on output over time.

Table 6.2: Growth rates

Annual growth rate (1957-2006)	
Variable	**Growth (%)**
Y	11.6
RD	11.5
(RD/Y)	-4.1

6.5 EMPIRICAL RESULTS

The stationarity properties of the various macroeconomic time series have been checked by means of the ADF test for panel data and the empirical results are available upon request by the authors. The ADF test was applied both on the original variables and their first differences. All the variables of interest are non-stationary; however all their first differences are stationary.

Based on the methodology set out earlier, the first two models are estimated. See Table 6.3[38]. And, after extracting the cyclical component, we estimate the remaining two models. See Table 6.4.

[38] A Hausmann test to confirm the suitability of the fixed effects model over the random effects model would be relevant here and is available upon request by the authors.

Table 6.3: Estimation results

	equation 1	*equation 2*
Dependent Variables	**lnRD**	**lnTFP**
Constant	6.762	12.713
	(0.000)	(0.000)
ln (Sector Size)$_{it}$	0.156	0.076
	(0.002)	(0.000)
D_1 (1st oil crisis)	0.001	0.001
	(0.000)	(0.004)
D_2 (2nd oil crisis)	-0.001	-0.001
	(0.000)	(0.010)
R-squared	0.570	0.830
F-test	15.79	206.47
Durbin Watson Statistic	1.410	1.550

Notes:

p-values in parenthesis

D_1: A dummy variable that takes the value of 1 during the first oil crisis & 0 elsewhere

D_2: A dummy variable that takes the value of 1 during the second oil crisis & 0 elsewhere

Table 6.4: Estimation Results

	equation 3	*equation 4*
Dependent Variables	**lnCycle**	**lnCycle**
Constant	9.387	24.,821,30
	(0.000)	(0.000)
ln(Sector Size)$_{it}$	0.207	
	(0.000)	
(Sector Size)$_{it}$		-0.734
		(0.000)
(Sector Size)$^2_{it}$		0.000
		(0.000)
D_1 (1st oil crisis)	0.001	0.003
	(0.041)	(0.033)
D_2 (2nd oil crisis)	-0.001	-0.001
	(0.001)	(0.332)
R-squared	0.490	0.560
F-test	42.670	52.040
Durbin Watson Statistic	1.821	1.440

Notes:

p-values in parenthesis

D_1: A dummy variable that takes the value of 1 during the first oil crisis & 0 elsewhere

D_2: A dummy variable that takes the value of 1 during the second oil crisis & 0 elsewhere

We observe that the significance of the factors entering the estimated panel data models is tested using the available dataset and the framework proposed by Bound et *al.* (1984). The estimated coefficients are statistically significant in all cases, and consistent with the implied hypotheses. Meanwhile, the estimated models account, in most cases, for a satisfactory percentage of the variability of the dependent variable in the different sectors of economic activity in the USA, which - given the inevitable imperfections in this sort of panel data - is satisfactory (Mankiw et *al.,* 1992: 408).[39]

6.6 DISCUSSION

To begin with, we observe that the collapse of output following the first oil crisis is evident for the U.S economy (see Figure E.1, Appendix E). Between 1963 and 1972, there is a clear upward pattern in output that was stopped by the oil crisis, the effect of which is evident in the de-trended time series. Furthermore, the cyclical component follows the same pattern both in the total economy and in most of the sectors between 1979-1982 and 1990-1991. The 1990s began with a shallow recession (Basu et *al.,* 2001) and, according to the Economic Report of the President (1994), the speed of recovery was very slow. Furthermore, between 1991 and 1997 – the so-called "new economy" period – a sharp increase of output took place. Also, productivity growth coincided with an exceptionally good performance of the US economy (Mankiw, 2001). According to Norrbin and Schlagenhauf (1990), differences exist with respect to the magnitude of the fluctuations because of aggregate (national) shocks, industry group specific shocks and idiosyncratic factors. According to Basu et *al.* (2001) the 1990s experienced a boom in business investment of unprecedented size and duration. The 1970s was a decade characterized by an investment boom (just like the 1990s) but less prolonged that was due to investment in information technology (IT) equipment (computers plus communications equipment). Our findings are fully consistent with the aforementioned patterns. Finally, a clear decreasing pattern is evident after 2001, which may be related to the IT technology bubble and the terrorist attacks of 2001. The downward trend could

[39] We should stress the fact that all estimates of R&D and T.F.P. are subject to a margin error and the T.F.P. estimate is obviously contingent on an estimate of the capital stock (Stikuts, 2003). In other words, the methodology we used is popular and appropriate, but it should be treated with caution since the various parameters are estimated figures, and therefore, there is some uncertainty in their estimation and should not be treated as firm, precise measures.

be an early indicator of the then forthcoming U.S crisis. Regarding R&D expenditures the "oil crisis" caused the contraction of R&D expenditures until 1983. The tax-cut policy introduced by the Reagan government pushed profitability upwards and gave motives for investment. The increase in the US sectoral R&D expenditures might be related to this policy.

Our findings exhibit a positive relationship between the size of sectors, expressed by their aggregate output, and innovative activity. More precisely, the R&D expenses are positively affected by a change in the size of aggregate output, due to the positive and significant sign of the estimate. The model, in general, seems to be satisfactory and the remaining statistics suggest that there is no serious evidence for any econometric abnormality.

As far as the relationship between sector size and TFP is concerned, our empirical findings suggest that the elasticity of R&D with respect to T.F.P is positive and statistically significant which, in turn, implies that a change in output is accompanied by a change in T.F.P. The model's goodness of fit is over 80% accompanied by a high F-stat confirming the appropriability of the model. Also, there are no econometric problems present in our analysis.

Regarding the relationship between the size of aggregate output and the fluctuation of the output in a quadratic framework (Scherer, 1983), once again the results seem to confirm the hypotheses under consideration. The positive sign of the quadratic term in our model dominates the negative sign of the linear component. Therefore, in total there is a positive relationship between the dependent and the independents variables which is statistically significant. The values of the F-stat and the goodness of fit of the model suggest that our analysis is satisfactory from an econometric point of view. Once again, no evidence of econometric abnormalities are present in the results.

The relationship between the same variables but in a linear framework, which is in line with the work of Bound et *al.* (1984), exhibits a positive relationship. The statistical significance of the sign suggests that a change in aggregate output would be accompanied by a change in fluctuations. Thus, large sectors tend to fluctuate more, which is an immediate outcome of the Schumpeterian hypothesis. According to the results of our analysis, the model is satisfactory.

The dummy variables that are used in our analysis capture the effect of the two oil crises. The estimates are statistically significant but their impact, i.e. the value of the coefficient is small. The sign of the dummy variables remains unaffected throughout the econometric analysis suggesting that the relationship between innovation and the two oil crises is constant. The dummy variables are statistically significant in our models. The first oil crisis has a positive impact on the determinants of innovative activity since there was a major increase in the innovative activities of the sectors during the crisis in an attempt of the U.S economy to decrease its dependence from oil as an energy source towards other energy sources (Ikenberry, 1986). In specific, President Carter in 1976 dedicated unprecedented funding, to developing alternative energy in order to make the United States energy self-sufficient to reduce the volatility of the U.S. economy because of its dependence on oil (Brown, 2011). The negative sign of the second oil crisis is attributed to the fact that, a number of high profile energy technology development programs such as the breeder reactor program, the sun fuels program and the program of large scale solar energy demonstrations were all terminated (Dooley, 2008). This occurred during the Reagan Administration, which maintained that "only in areas where these market forces are not likely to bring about desirable new energy technologies and practices within a reasonable amount of time is there a *potential need for federal involvement*"[40]. As a consequence, a sharp decline in R&D expenses is evident after the second oil crisis[41].

To sum up, in general our results are consistent[42] with a large part of the literature. Our analysis suggests that there is a positive significant relationship between the two in the U.S economy. Our analysis, regarding the fluctuations' components of the aggregate output suggests that the relationship between the variables remains positive and significant, which in turn validates the hypothesis into consideration.

[40] U.S. Secretary of Energy James Edwards before the Senate Energy and Natural Resources Committee. February 23, 1981, as quoted in Fehner and Hall (1994).
[41] See, among others, Scherer (1992), Margolis and Kammen (1999), Helfat (1997), Dooley (1998), Margolis (1998), Kilian and Park (2009), Laitner and Stolyarov (2003).
[42] See, for instance, Meisel and Lin (1983), Malecki (1980), Link (1980).

6.7 CONCLUSION

The main purpose of this chapter has been to investigate two famous postulates of the Schumpeterian hypothesis and its implications for the U.S. economy. Analytically, we investigated whether sector size matters for sectoral (i) technological change and (ii) stability, as expressed through the relevant quantitative measures and variables. We tested a number of relevant models that express the various forms of this relationship. We used panel data for the fourteen (14) main sectors of economic activity in the U.S.A. over the period 1957-2006, just before the first signs of the US and global recession made their appearance.

Our research results give credit to the hypothesis that large economic units tend to invest more on R&D, but the units' propensity to invest in R&D declines for larger units in the US economy (1957-2006). The same is in force for Total Factor Productivity. Also, a rise in the sector size would lead to a subsequent rise in the sectoral fluctuations which is consistent with the respective hypothesis based on the Schumpeterian doctrine that large sectors tend to fluctuate more intensely than smaller ones due to the increasing amount of innovations introduced, which is inherently unstable and causes business cycles.

Part C

Chapter 7: What Drives Business Cycles in Greece?[43]

Probably, one of the most prominent victims of the global crisis is the Greek economy. Greece, since the beginning of 2010, experienced the second highest budget deficit and the second highest debt to GDP ratio in the EU, which in combination with the high borrowing costs, resulted in a severe crisis (Charter, 2010). Since then, a number of measures have been implemented in the country by the so-called "Troika" (ECB-EU-IMF). In the next chapter, we investigate the determinants of the Greek Business Cycle in the time period 1995-2014. To this end, we make use of a wide dataset in a quarterly format, which contains all the major macroeconomic and financial variables that have had a certain impact on the Greek economy.

7.1 INTRODUCTION

Just a few years ago, Greece had a developed economy with the 22nd highest standard of living in the world (Economist, 2005) and a 'very high' Human Development Index, ranking 25th in the world (United Nations, 2009). According to Eurostat (2009), Gross Domestic Product (GDP) per inhabitant in purchasing power standards (PPS) stood at 95% of the EU average. Meanwhile, OECD (2002) characterized the performance of the Greek economy since the early 1990s as 'remarkable', stressing the prevalence of high growth rates. The effective macroeconomic policies along with the liberalisation of product and financial markets were regarded as the main drivers behind this growth pattern. Also, an OECD (2007) survey reported that Greece's growth rate since 1997 has exceeded 4.5%, ranking second after Ireland among OECD countries. In brief, the reasons for this impressive performance were: (a) financial market liberalisation, (b) E.M.U. membership, (c) growing activity in export markets in south-eastern Europe, and (d) the fiscal stimulus given by the Olympic Games in 2004 (Belegri-Roboli and Michaelides, 2007).

However, in 2010 as a result of international and local factors, the Greek economy Greece faced a severe economic crisis. In fact, it experienced the second highest budget

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deficit and the second highest debt to GDP ratio in the EU, which in combination with the high borrowing costs, resulted in a severe crisis (Charter, 2010). Since then a number of austerity measures have been implemented by the so-called "Troika", i.e. ECB/EU/IMF.

Actually, Greece constitutes the first EMU country where a sovereign debt crisis made its appearance, after the introduction of the common currency. In view of this tremendous change, it is evident that the Greek GDP has fallen dramatically by approximately 20% (BoG, 2013), whereas unemployment rate has reached 27%, and youth unemployment 56% (EL.Stat., 2013). In this context, an investigation of the determinants of the Greek business cycle is of outmost importance.

In this work, we aim to investigate the determinants of the Greek business cycles in the time period 1995-2014, in attempt to identify the structural causes of the downturn of the Greek economy that led to the tremendous recent crisis. To this end, we make use of a wide dataset in a quarterly format, which contains all the major macroeconomic and financial variables that have had a certain, measurable, impact on the Greek economy, while we do not ignore the potential causal impact of key dummy variables i.e. Greek Debt crisis, EMU formation etc, following the short-run causality of Dufour et *al.* (2006) extended by Konstantakis and Michaelides (2015).

This work contributes to the literature in the following ways: (a) It the first - to the best of our knowledge - that uses a wide dataset in quarterly format, for the investigation of the determinants of Greek business cycles, in the time period 1995-2014; (b) It employs a number of relevant state-of-the-art econometric tests including causality testing; (c) It tests for the significant impact of elections on the Greek business cycle.

The remainder of this work is structured as follows: Section 2 provides an overview of the related literature acknowledging the significant role of the political situation in Greece; Section 3 provides the methodological framework upon which our investigation of the Greek business cycle is based; Section 4 provides the empirical results of our investigation; Section 5 discusses our findings; Finally, section 6 concludes.

7.2 BACKGROUND LITERATURE

Thus far, Greece has attracted only limited attention in the relevant literature probably due to its small size and economic power in comparison to the rest of the European countries and its "idiosyncratic" political characteristics. In an early study, Mouzelis (1977) argued that the 1960s coincided with a period when investment expanded for the first time to a considerable extent. According to his findings, this was an important step towards the 'industrialization' of the Greek economy. Alogoskoufis (1995) separated the performance of the Greek economy of the post - 1960 period into two distinct phases, and considered the end of the military dictatorship as the turning point. His findings are in line with Bosworth and Kollintzas (2001) who saw two distinct phases in the growth patterns of the Greek economy and placed the year 1973 as their demarcation date. Bosworth and Kollintzas (2001) traced the causes for the fall-off in TFP growth and argued that it was the result of a large number of negative developments such as "the worsening macroeconomic situation and a highly inefficient structure of the labor market" alongside the unsuccessful trade policy after E.U. accession. Additionally, Bosworth and Kollintzas (2001) did not attribute the deteriorating performance to the EC accession, a thesis which is consistent with Alogoskoufis (1995) and opposed to the conclusions reached by Giannitsis (1993).

Christodoulakis et *al.* (1993) compared the cyclical behavior of the Greek economy to that of other EC economies. In their study quarterly and annual data since 1960 were used and a RBC model was chosen as the methodological framework of their analysis. The authors argued that similarities exist in the propagation mechanism for business cycles in Greece in relation to other EC countries. The policy implication of this work is that the integration of the Greek economy within the EC under a set of uniform institutions and policies should not be a problem as far as business cycle is concerned.

Kaskarelis (1993) focused on the effects of monetary policy on output. The examination of several Greek macroeconomic time series suggested that monetary policy was able to explain, to a large extent, output fluctuations. In a similar vein, Karasawoglou and Katrakilidis (1993) investigated empirically the causal relationship between money growth, budget deficits and inflation in Greece over business cycle employing a tri-variate error-correction Granger model. The results provided evidence that deficits are inflationary when monetized.

Christodoulakis et *al.* (1996) offered a periodization of Greece's economic performance and focused on the reduction in industry protection following Greece's entry in the E.U. and the impact of uncertainties about the future political situation on investment as the underlying cause for their choice of the inflexion point.

Kollintzas and Vassilatos (1996) built a RBC model for Greece and investigated its ability to account for the stylized facts of post-war Greece. They concluded that the model does quite well in this respect. The model was also used to examine the effects of fiscal policy and transfers from abroad. The authors came to the conclusion that an increase in government consumption has an adverse effect on output and the productivity of factors of production although it is likely to increase foreign asset-holdings. On the other hand, an increase in the GDP share of government investment is conducive to output growth and higher productivity while lowering foreign-asset holdings. These predictions of the model led the authors to argue that the increases in the shares of government consumption, foreign transfers and domestic transfers in the post-1973 period have acted to reduce the performance of the Greek economy.

In an empirical approach, Tavlas and Zonzilos (2001) locate the point of structural break. An important conclusion is that a break seems to have taken place in the Greek economy in 1994. The authors attributed this change to the stable macroeconomic environment created thereafter and the implementation of structural reforms (*ibid*, p. 209). Skouras (2001) commented on the institutional reforms planned or implemented until 1985 and in a similar vein with Tsakalotos (1998), had noted that "the management of their implementation was dismal" (Skouras 2001, pp. 174-5). Nevertheless, Kollintzas and Vassilatos (1996) argued that increases in the shares of government consumption have led to the worsening of the performance of the Greek economy.

Other authors focus on the macroeconomic policies followed in the 1980s after the government change, which took place in 1981. For instance, Giannitsis (2005) noted that it is difficult to find reliable economic analyses supporting the economic policies of that period but argued that the criteria for its evaluation should not be strictly economic. In a different vein, Tsakalotos (1998) focused on the internal and external constraints facing social-democratic parties in power, which aimed at extending democracy and "promote coordination and cooperation between economic agents and groups". His main argument was that "the Greek context was not propitious for introducing measures for extending democracy to the economic sphere" (Tsakalotos. 1998:115).

Apergis and Panethimitakis (2007) examined the stylized facts of the Greek economy over the period 1960-2003. The authors investigated the behavior of basic macroeconomic variables in respect to the business cycle. They found that consumption fluctuated pro-cyclically just like real wages did. The later fact pointed to shocks that shifted the demand curve for labor. The same conclusions were reached when allowance was made for policy regime changes. The authors' conclusion was that real shocks drive the economy, implying that demand policies are ineffective.

Much recent effort has been put to investigate the question of the synchronicity of the business cycles in the EU area. This question has gained in importance in the context of the Economic and Monetary Union (EMU) where monetary policy has been delegated to the European Central Bank (ECB) and fiscal policy is restricted by the Stability and Growth Pact. The literature on the subject is becoming increasingly extensive and the results reached are worthy noticing. More precisely, in few studies where Greece is included explicitly it seems that a lack of synchronicity of the national business cycle with that of the Eurozone emerges as the main conclusion, a finding which is inconsistent with the findings, *inter allia*, by Christodoulakis et *al.* (1993). Also, see Montoya and Hann (2007) who pointed to the existence of a 'national border' effect. In a similar vein, Gallegati et *al.* (2004) found weak links among Mediterranean countries, including Greece, and the European continental area. Similar results are reached by Leon (2007) who used spectral analysis to analyse quantitatively the stochastic shocks of Greece and the Eurozone for the period 1980-2005 and concluded that the synchronization of the cycles in terms of correlation and their transmission mechanism becomes weaker over time. In a similar vein, Papageorgiou et *al.* (2010) found that while in the post-Maastricht period synchronization among the EMU counterparts seems to increase, in the period after the introduction of the common currency, divergence has increased especially for Greece and Ireland. Their results are consistent with the findings by Gouveia and Correia (2008) and Camacho et *al.* (2006).

Conclusively, all authors agree that the Greek economy entered a period of a recession in the mid-1970s, which interrupted the steady growth initiated by the wave of industrialization in the 1960s. The macroeconomic policies of the 1980s are related to this slowdown and most authors stress the absence of long-term planning.

A common point in all the analyses is the concentration of macroeconomic policies on consumption, neglecting both investments and the supply side of the economy. Also, they noted an important change in the policy regime occurring in the 1990s, which led to an acceleration of growth while restoring stability.

In brief, the literature suggests that, the recent economic history of Greece up until the recent crisis can be divided into three distinct periods: (i) The period extending from 1960 until some point in the middle 1970s where the Greek economy experienced rapid growth; (ii) A "halt" lasting until about the early or middle 1990s when most economic indexes showed a marked deceleration; (iii) From that point on until the outburst of the recent crisis the Greek economy experienced a period of steady growth.

7.3 METHODOLOGY

a. Defining Business Cycles

As we have seen, every time series can be decomposed into a cyclical component and a trend component:

$$c_t = y_t - g_t \quad \textbf{(7.1)}$$

where: c_t is the cyclical component of time series, y_t is the actual time series and g_t is the respective trend that the time series exhibits.

b. Filtering

A popular and appropriate method for extracting the business cycle component is the Baxter-King (BK) Filter (Baxter and King, 1999) and a large number of studies have used it, as of yet (e.g. Stock and Watson, 1999; Agresti and Mojon, 2001; Benetti, 2001; Massmann and Mitchell, 2004). The BK filter is based on the idea of constructing a band-pass linear-filter that extracts a frequency range corresponding to the minimum and maximum frequency of the business cycle. The algorithm consists of constructing two low-pass filters. The first passes through the frequency range $[0, \omega_{\max}]$, denoted $\overline{a}(L)$, where L is the lag operator, and the second through the range $[0, \omega_{\min}]$, denoted $\underline{a}(L)$. Subtracting these two filters, the ideal frequency response is obtained and the de-trended time series is:

$$y_t^{BK} = [\bar{a} - \underline{a}]y_t \quad \textbf{(7.2)}$$

c. Testing for white noise

In order to test whether the cycles extracted are not mere random walk processes, we test for white noise using the Ljung and Box (1978) test (Q-Stat), which tests the null hypothesis of white noise for a maximum lag length k:

d. Extracting Periodicities/Fourier Analysis

Next, we investigate the average length of the cycle based on the Fourier-transformed function of the cycle.

e. Multiple Regression Model

Our analysis tests for the significance of the factors that presumably influence GDP fluctuations in Greece. The relationship *f* is assumed to be linear and we use the cyclical component of the Greek GDP time series, for the period 1995-2014, when data are available.

According to the relevant literature, trade and interest rates are among the most important variables that are found to affect the business cycle. See*, inter alia*, Holland and Scott (1998), Baxter and King (2004) and Bower (2006). In this context, we make use of (i) imports and exports of the Greek economy to capture its trade relationship with the rest of the world economies, and of (ii) the 10-year bond yields to capture the cost of money. Furthermore, we use the Greek Foreign Direct Investments (FDI) in line with the seminal work of Bernake et *al.* (2000) and Dietrich (2002) and Faia (2003). The use of credit as a determinant of business cycles is consistent with the pioneering work of Kiyotaki and Moore (1997), while the use of Debt is in line with the works of Misnsky and Vaughan (1990), and Ziemann (2012). Additionally, the use of unemployment is in line with the findings of Cristiano et *al.* (2013), according to which unemployment is a key factor of the business cycle. Lastly, the dummy variables incorporated in our analysis are capable of capturing inherent characteristics of the Greek economy as well as the effect of key institutional events that could have a significant impact on the Greek business cycle.

Specifically:

$$Y_{cycle\ GR\ (t)} = f(Y_{cycle\ GR\ (t-1)}; X_t;\ D_t)\ \textbf{(7.3)}$$

where: $X_t = (Y_{cycleEU\ (t)}, FDI_{GR\ (t)}, C_{GR\ (t)}, DT_{GR\ (t)}, UN_{GR\ (t)}, IM_{GR\ (t)}, EX_{GR\ (t)},\ BY_{\ GR(t)})$ is a 1x7 vector of variables incorporating the (potential) key macroeconomic and financial determinants of Greek output fluctuations; $D_t = (EMU_{01}, GE, GC_{06}, Tr_{10}, PSI_{11})$ is a 5x1 vector of dummy variables that could potentially influence the Greek business cycle.

In order to appropriately select the determinants of Greek business cycles, we performed OLS backward elimination to the set of all the variables that enteredtheoriginal multiple linear regression model, using 10,000 bootstrapped replications.

f. Bootstrapped Regression

Consider the following multiple regression model:

$$Y_t = b_0 + b_1 X_{1,t} + \cdots + b_r X_{r,t} + u_t\ \textbf{(7.4)}$$

where: r is the number of independent variables of the model and $u_t \sim N(0, \sigma^2)$ is the error term. The boot-strapping algorithm is the following:

Step1: Estimate the regression coefficients $b_0, \dots, b_r$ using the original data and calculate the fitted values, $\widehat{Y_t}$, and the error term u_t for each observation $t \in T$.

Step 2: Select nbootstrapped samples from the residuals i.e. $u_{t_b} = [U_{t_{b_1}}, \dots, U_{t_{b_n}}]'$ and from these calculate the bootstrapped $Y_{t_b} = [Y_{t_{b_1}}, \dots, Y_{t_{b_n}}]'$, where $Y_{t_{b_t}} = \widehat{Y_t} + U_{t_{b_t}}$, $\forall t \in T$.

Step 3: Regress the bootstrapped values of Y with the independent variables and obtain the bootstrapped regression coefficients.

g. Backward elimination

In brief, the procedure of backward elimination used has the following steps:
Step 1:Initially, the model is set to be:

$$Y_t = b_0 + b_1 X_{1,t} + \cdots + b_r X_{r,t} + u_t\ \textbf{(7.5)}$$

where: r is the number of independent variables that enter the model and $u_t \sim N(0, \sigma^2)$ is the error term.

Then, the following ***r-1*** tests are carried out, $H_{0j}: b_j = 0, j = 1, \ldots, r-1$. The lowest partial F-test value F_L corresponding to $H_{0L}: b_L = 0$ or t-test t_L is compared with the preselected significance values F_0 and t_0. One of two possible steps (step2a and step 2b) can be taken.

Step 2a**:** If $F_L < F_0$ or $|t_L| < t_0$, then X_L can be deleted and the new original model is:

$$Y_t = b_0 + b_1 X_{1,t} + \cdots + b_r X_{r-1,t} + u_t \quad \textbf{(7.6)}$$

and we go back to step 1.

Step 2b**:** If $F_L \geq F_0$ or $|t_L| \geq t_0$, the original model is the model we should choose.

h. Swartz-Bayes Information criterion

For the selection of variables in our model, we also use the so-called Bayes information criterion (BIC) introduced by Schwartz (1978). Let $L_T(o)$ be the maximum likelihood of the full model described by the following equation:

$$Y_{cycle\ GR\ (t)} = f(Y_{cycle\ GR\ (t-1)}; X_t;\ D_t) \quad \textbf{(7.7)}$$

where: $t = 1, \ldots, T$ is the time dimension which corresponds to the number of observations and o denotes the number of unknown parameters of the above equation. Then, for each variable excluded by the model, $o = o-1, o-2, \ldots.$ the BIC is calculated by the following formula:

$$BIC^o = -2\ln\big(L_T(o)\big) + olnT \quad \textbf{(7.8)}$$

The optimum model parameters are those for which the BIC of the respective model exhibits the minimum values i.e. $BIC^* = argmin_{o \in O}\{BIC^o,\ o = o-1, o-2, \ldots.\}$.

Of course, the aforementioned selection strategy could easily be followed using some other relevant information criterion, e.g. R-squared, AIC, etc. However, we have decided to use BIC over other criteria following Breiman and Freedman (1983) and

Speed and Yu (1992) who have shown that BIC is an optimal selection criterion when used in finite samples, as we have seen.

i. Stepwise Short-Run Causality Testing

Furthermore, we investigate whether the independent variables have predictive power for the business cycles in Greece. In order to investigate the timing pattern of causality, Dufour et *al.* (2006), extended the work of Dufour and Renault (1998) by considering a class of VAR (p) models in different horizons h. Their choice for considering a VAR scheme was based on the bi-direction of causality. Of course, in cases where dummy variables enter the model one-sided non causality should be investigated. In what follows, following Dufour et *al.* (2006) we illustrate the one sided (non-)causality using a VAR (p) scheme augmented by an exogenous set of variables.

Consider the following VAR (p) model augmented by exogenous dummy and/or quantitative variables:

$$Y_t = a + \sum_{k=1}^{p} \pi_\kappa Y_{t-k} + \sum_{q=0}^{Q} \beta_q D_{t-q} + u_t \quad \textbf{(7.9)}$$

where: Y_t is an (1xm) vector of variables; a is a (1xm) vector of constant terms; D_t is a vector of (Lx1) qualitative (dummy) or quantitative variables and u_t is a (1xm) vector of error terms such that $E(u_t u_s) = \sigma_{ii} I$ if $t = s$ and $E(u_t u_s) = \sigma_{ij} I$ if$t \neq s$, where I is the identity matrix.

Following Dufour et *al.* (2006), the VAR(p) model described above corresponds to horizon h=1. In order to test for the existence of non-causality in horizon h, a model of the following form is considered:

$$Y_{t+h} = a^{(h)} + \pi^{(h)} Y_{t,p} + \beta^{(h)} D_{t,q} + u_{t+h}{}^{(h)} \textbf{(7.10)}$$

where: $Y_{t,p} = (Y_t, Y_{t-1}, \ldots, Y_{t-p+1})$, $\pi^{(h)} = (\pi_1{}^{(h)}, \ldots, \pi_p{}^{(h)})$, $\beta^{(h)} = (\beta_0{}^{(h)}$, $\beta_1{}^{(h)}, \ldots, \beta_q{}^{(h)})$ and $u_{t+h}{}^{(h)} = (u_{1,t+h}{}^{(h)}, \ldots, u_{m,t+h}{}^{(h)})$ for t=1,…,T-h and h<T.

The above equation can be compactly written using matrix notation as:

$$\boldsymbol{Y_{t+h}} = \boldsymbol{\Gamma X} + \boldsymbol{u} \quad \textbf{(7.11)}$$

where $\boldsymbol{Y_{t+h}} = [Y_{1,t+h}, \ldots, Y_{m,t+h}]$ is a (1xm) vector which denotes the m-quantitative variables that enter the model;

$\boldsymbol{X} =$
$[I_T; Y_{1,t-1}, \dots, Y_{1,t-p}; \dots; Y_{m,t-1}, \dots, Y_{m,t-p}; D_{1,t-1}, \dots, D_{1,t-q}; \dots; D_{l,t-1}, \dots, D_{l,t-q}]$is an (2m+l) x max{t-p+1, t-q+1} matrix that includes both quantitative and qualitatitive variables; $\boldsymbol{\Gamma} = [a_1, \dots, a_m; \pi_{1,1}, \dots, \pi_{1,p}; \dots; \pi_{m,1}, \dots, \pi_{m,p}; \beta_0, \dots, \beta_{0,q}; \dots; \beta_l, \dots, \beta_{l,q}]$ is the inverse of a (2m+l)x[max{p, q+1}] matrix of coefficients and $\boldsymbol{u} = [u_{1,t+h}, \dots, u_{m,t+h}]$ is a (1xm) vector of idiosyncratic shocks such that $\boldsymbol{u} \sim N(0, \boldsymbol{\Sigma})$ so that the variance covariance matrix is of the form: $\Omega = \Sigma \otimes I$where $\Sigma = (\sigma_{ij})$ and I the identity matrix, with $\det(\Omega) \neq 0$.

In order to test for non-causality of the quantitative/qualitative variables that enter the augmented VAR (p) model, at a given horizon h, we follow the algorithm proposed by Dufour et *al.* (2006).

Step 1: An augmented VAR model as in equation (7.11) is fitted for using GLS estimation and the Newey-West heteroskedasticity and autocorrelation consistent covariance (HAC) for horizon h=1 and we obtain the estimates $\widehat{\pi_\kappa}$, $\widehat{\beta_m}$and $\hat{\Omega}$.

Step 2: Using GLS estimate a restricted augmented VAR model described by the equation:

$$\boldsymbol{Y_{t+h}} = \boldsymbol{\Gamma X} + \boldsymbol{u}$$

where $R\boldsymbol{\Gamma}^{(\bar{h})} = r$ denote the restrictions imposed, and obtain the estimates $\widehat{\pi^{(h)}}$ and $\widehat{\beta^{(h)}}$.

Step 3: Compute the test statistic $\mathcal{D}$ for testing non-causality at horizon h i.e. we test the hypothesis $H_{0,D_i \nrightarrow Y_{jt}/I(D_i)}{}^{(h)}: \beta_{im} = 0, m = 0,1, \dots, M, i\epsilon\{1, \dots, l\}, j\epsilon\{1, \dots, m)$. We denote $\mathcal{D}_0^{(h)}$ the test statistic based on actual data.

Step 4: Draw N simulated samples from step 2 using Monte Carlo with $\pi^{(h)} = \widehat{\pi^{(h)}}$,$\beta^{(h)} = \widehat{\beta^{(h)}}$ and $\Omega = \hat{\Omega}$. Impose the constrains of non-causality at horizon h i.e. $\beta_{im} = 0, m = 0,1, \dots, M, i\epsilon\{1, \dots, l\}, j\epsilon\{1, \dots, m)$ and compute the test statistic for non-causality at horizon h, i.e. $\mathcal{D}_n^{(h)}, n\epsilon\{1, \dots, N\}$.

Step 5: Compute the simulated p-values based on the following formula:

$$\hat{p}_N[x] = \{1 + \sum_{n=1}^{N} I[\mathcal{D}_n^{(h)} - x]\}/(N+1)$$

Step 6: We reject the null hypothesis of non-causality at horizon h i.e. $H_{0,D_i \nrightarrow Y_{jt}/I(D_i)}{}^{(h)}$, at level α if $\hat{p}_N[\mathcal{D}_0^{(h)}] \leq \alpha$.

Of course, before estimating the proposed model a number of relevant tests need to take place as follows.

j. Structural Break Test

We begin our investigation by testing for the possible existence of a structural break in the dependent time series variable. We use the popular Clemente, Montañés and Reyes (1998) structural break test, which is based on the approach by Perron and Vogelsang (1992). The advantage of this method over other more traditional methods is that, among others, Perron and Vogelsang (1992) have developed unit-root test methods which include an unknown endogenously determined structural break, the so-called Perron and Vogelsang's (1992) or PV (1992) Innovational Outlier and Additive Outlier model.

Using standard notation, the popular PV (1992) models are as follows:

Innovational Outlier Model (IOM)

$$y_t = \mu + \delta DU_t + \theta D(T_b)_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + e_t \quad \textbf{(7.12)}$$

Additive Outlier Model (AOM) – Two Steps

$$y_t = \mu + \delta DU_t + \tilde{y}_t \quad \textbf{(7.13)}$$ and

$$\tilde{y}_t = \sum_{i=0}^{k} w_i D(T_b)_{t-i} + \alpha \tilde{y}_{t-1} + \sum_{i=1}^{k} c_i \Delta \tilde{y}_{t-i} + e_t \quad \textbf{(7.14)}$$

where: the intercept dummy represents a change in the level; the slope dummy represents a change in the slope of the trend function and $\tilde{y}$ represents the detrended series *y*.

The AOM tests for the presence of a sudden change in mean, while the IOM tests for a more gradual change. According to PV (1992, 303), these tests are based on the minimal value of the *t*-statistics on the sum of the autoregressive coefficients over all possible breakpoints. It is capable of expressing more than one structural break in the sample.

Obviously, this specific test that has been chosen, has one main advantage, namely that it identifies when the possible presence of a structural break occurred, and can, hence, provide helpful information for analyzing whether a structural break on a certain variable is associated with a particular event or period (economic crisis, government policy, etc).

k. Outliers

We continue by investigating for the possible existence of outliers in the dataset using the outliers test introduced by Billor et *al.* (2000). In brief, given a time series variable $x_t, t \in T$, the test is based on the following steps:

Step 1**:** Initially, select a subset of observations based on the Mahalanobis distance of the i=1,..T observations using the following equation:

$$D_i(\bar{x}, S) = \sqrt{(x_i - \bar{x})^T (S^{-1})(x_i - \bar{x})} \quad \textbf{(7.15)}$$

where: x_i denotes the observations, $\bar{x}$ their mean and S their covariance matrix, and we identify the $m = pc$ observations with the smaller distances, and we nominate these as the potential basic subset.

Step 2**:** Compute the discrepancies:

$$D_i(\overline{x_b}, S) = \sqrt{(x_i - \overline{x_b})^T ({S^{-1}}_b)(x_i - \overline{x_b})} \quad \textbf{(7.16)}$$

where: x_i denotes the observations,$\overline{x_b}$ the mean of the observations in the basic subset and S_b their covariance matrix..

Step 3**:** Set the new basic subset to all points with discrepancy less than $c_{npr}\chi_{p,a/n}$where ${\chi_{p,a}}^2$ is the 1-a percentile of a chi-square distribution with p degrees of freedom, $c_{npr} = c_{np} + c_{hr}$ is a correction factor; $c_{hr} = \max\left\{0, \frac{h-r}{h+r}\right\}$, $h = (n + p + 1)/2$, r is the size of the current basic subset and $c_{np} = 1 + \frac{p+1}{n-p} + \frac{2}{n-1-3p}$

Step 4**:** The stopping rule: Iterate Steps 2 and 3 until the size of the basic subset no longer changes.

Step 5: Nominate the observations excluded by the final basic subset as outliers.

l. Phillips –Perron Stationarity

To avoid any spurious effect, we continue our analysis by testing for the existence of unit roots in the various time series. There are several formal tests of stationarity, among which quite popular is the Phillips-Perron (PP) test. Phillips and Perron's test statistics can be viewed as Dickey–Fuller statistics that have been made robust to serial correlation by using the Newey–West (1987) heteroskedasticity -and autocorrelation- consistent covariance matrix estimator. The main advantage of the PP tests over the ADF tests is that the PP tests are robust to general forms of heteroskedasticity in the error term u_t. Another important advantage is that no *a-priori* specification of the lag length for the test regressionis required.

m. Rolling Window

Next, we use the rolling window methodology in order to investigate whether the respective estimated coefficients of the derived final model are stable over time. A common technique to assess the constancy of a model's parameters is to compute parameter estimates over a rolling window of a fixed size through the sample. If the parameters change at some point during the sample, then the rolling estimates capture this instability. In this work, we use recursive-rolling windows, holding he starting date fixed at 1995 (Q1) and varying the ending date holding a fixed window of 30 observations obtaining the respective estimates using 10,000 bootstrapped replications.

As we have seen, the rolling window is a methodology that repeats estimations using subsamples of the total data by shifting the start (and/) or end-points with a fixed window (Zivot and Wang, 2006). Consider an estimation with time series data using the rolling window as follows:

$$Y_{t,i} = a_i + b_i x_{t,i} + \varepsilon_i \text{ , } i = 1,..\text{n and n} < T \quad \textbf{(7.17)}$$

where n denotes the length of the sub-sample or window, T is the total number of observations of our \ time series, $Y_{t,i}$ denotes the dependent variable for each sample period, $x_{t,i}$ denotes the independent variable for each sample period and ε_i denotes the error term of each sample period which is typically assumed to be *i.i.d.* Therefore, for each i, the rolling windows approach estimates the above model using the T-n+1 sample length.

n. Correlation Matrix

In order to assess potential multi-collinearity among the independent variables of the selected model, we calculate the correlation matrix between the independent variables. As we know, the correlation among two time series variables, namely Y_t and X_t is given by the following formula:

$$corr(Y_t, X_t) = \frac{Cov(Y_t, X_t)}{s_{X_t} s_{Y_t}} \quad \textbf{(7.18)}$$

where $Cov(Y_t, X_t)$: is the covariance between the variables X_t and Y_t and s_{X_t} and s_{Y_t} are the respective standard deviations. In case, the correlation between the variables is appropriately small or almost equal to zero then the respective variables are uncorrelated and we have no indication for the possible existence of multicollinearity.

o. Normality test

We assess the normality of the residuals of the final model, using the Jarque-Bera normality test (1987). The test is based on the following formula:

$$JB = \frac{T}{6}\left(S^2 + \frac{1}{4}(K-3)^2\right) \quad \textbf{(7.19)}$$

where: T is the number of time series observations of the residuals, S is the Skeweness of the residuals and K the respective kyrtosis. The null hypothesis is a joint hypothesis of the skewness being zero and the excess kurtosis being zero.

p. Heteroscedasticity

We assess the whether the residuals of the selected model are homoscedastic using White's (1980) test. The test is based on the R^2 obtained by following an auxialiary regression:

$$\varepsilon^2{}_t = a_0 + \sum_{k=1}^{K} a_{k.1} X_{k,t} + \sum_{k=1}^{K} a_{k.2} X_{k,t}{}^2 + \sum_{j=1}^{K} \sum_{k=1,}^{K} a_{j.k} X_{k,t} X_{j,t}, j \neq k \quad \textbf{(7.20)}$$

where $\varepsilon^2{}_t$ are the squared residuals of the model, $X_{k,t}$ are the regressors of the model and $X_{k,t}X_{j,t}, j \neq k$ are the cross products of the regressors. Then White's test is an LM test given by the formula: $LM = nR^2$ which follows a chi-squared distribution. The null hypothesis of the test implies the existence of homoscedasticity.

7.4 EMPIRICAL ANALYSIS

The data used in our analysis come from the OECD database and are in quarterly format covering the period 1995 (Q1)-2014 (Q3) perfectly capturing the recent recession. All the quantitative variables used are in billions of euros in 2005 prices, with the exception of the variables that represent percentage points. For a detailed description of the relevant data and sources see Table E.1, Appendix.

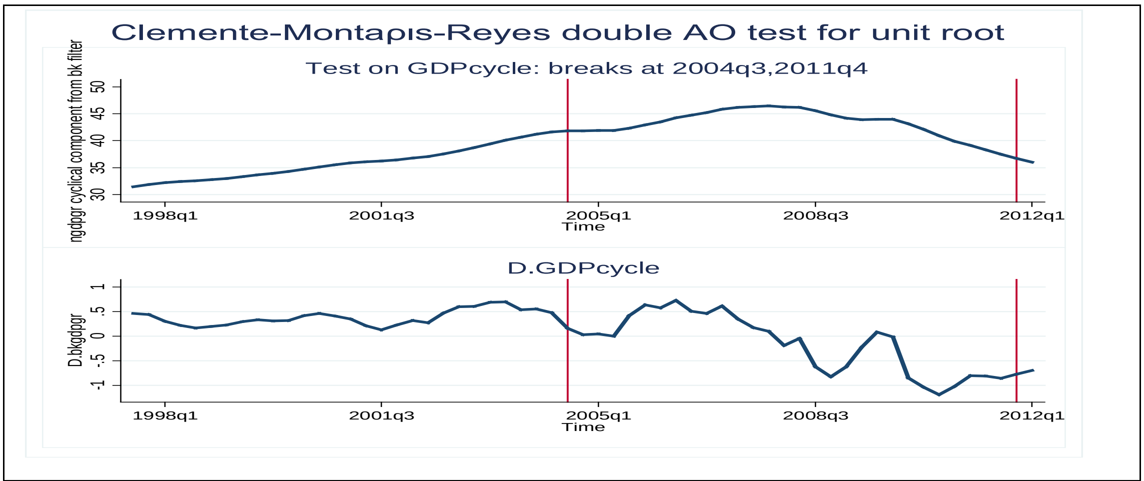
We begin our analysis by testing for the potential existence of structural breaks in Greek business cycles. In this context, the result of Clemente, Montañés and Reyes (1998) structural break test are presented in Table 7.1, while its graphical representation is presented in Figure 7.1.

Table 7.1: Clemente-Montanes-Reyes test for Greek GDP cycle(Ycycle)

	du1	du2	ϱ-1	Constant	Optimal Break point
Coefficient	8.25	-8.46	-0.12	34.84	2004 (Q3), 2011 (Q4)
t-stat	10.46	-6.7	-2.37		
p-value	0	0	-5.49 (5% critical value)		

The results presented in Table 7.1 and Figure 7.1, clearly indicate the existence of two structural breaks in the third quarter of 2004, i.e. 2004 (Q3) and in the fourth quarter of 2011, i.e. 2011 (Q4).

Figure 7.1: Structural Break Test for Greek GDP cycle



To this end, following common practice, we split our sample into two sub-periods. The first covers the period 1995 (Q1)-2003 (Q4) while the second covers the period 2005 (Q3)-2011 (Q4). Notice that, following common practice, we omitted the period 2003 (Q4)-2005 (Q2) due to the fact that it is very close to the first structural break and, hence, in this period the observations may exhibit structural abnormalities.

a. Empirical Analysis: Sub-period 1995 (Q1)-2003 (Q4)

First, we test for the possible existence of outliers in our dataset using the Bacon outliers test presented earlier.

Table 7.2: Bacon Outliers test, 1995 (Q1)-2003 (Q4)

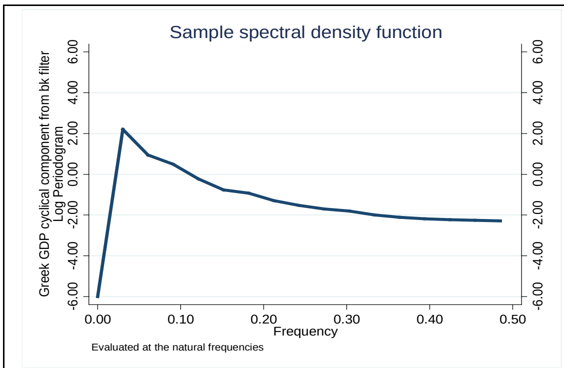
	Ycycle-GR	Ycycle-EU17	C	DT	UN	FDI	IM	EX	BY
Bacon Outliers at 5% level of significance (p-value=0.05)	0	0	0	2000 (Q1), 2003 (Q2), 2003 (Q3)	0	0	0	0	0

The results presented in Table 7.2 suggest that the variable of Greek Debt exhibit outliers in 2000 (Q1), 2003 (Q2) and 2003 (Q3), to this end these observations are excluded from the times series of Debt. The rest of the time series do not exhibit outliers at the 5% level of significance.

Now, we continue our analysis of the first sub-period by extracting - by means of Baxter King filtering - the business cycles components of the Greek GDP and the EU-17 GDP, using a moving average specification of three (3) quarters, a minimum business cycle period of 6 quarters and a maximum 32 quarters (see e.g. Baum et *al.,* 2007).

In order to test that the real business cycles components follow some distinctive pattern and are not mere random walks we test against white noise. According to our findings, which are available upon request, both cycles show some distinctive pattern since the null hypothesis of white noise is rejected in both cases. In this context, we examine the periodicities of the cyclical components using Fourier analysis (periodograms).

Figure 7.2: Periodograms of Greek GDP cycle and EU-17 GDPcycle, 1995(Q1)-2003(Q4)



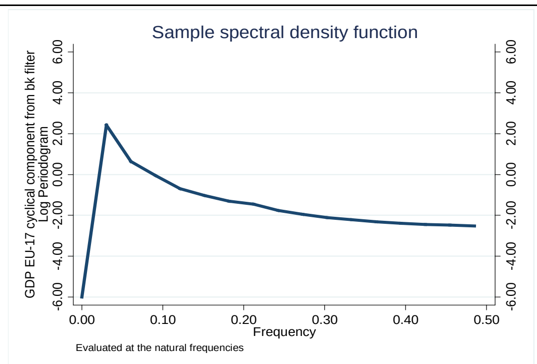


Figure 7.2 suggests that both cycles exhibit a dominant periodicity at a natural frequency of almost 5% which corresponds to 4-6 quarters i.e. 1.5 years.

Next, we proceed by examining the stationarity characteristics of our time series data.

Table 7.3: Phillips Perron Unit root test Original Variables 1995 (Q1)-2003 (Q4)

Variable	p-value	Newey-West Lags	Stationarity
C	0,85	3	No
DT	0,99	3	No
UN	0,23	3	No
FDI	0,11	3	No
IM	0,84	3	No
EX	0,14	3	No
BY	0,41	3	No

Table 7.4: Phillips Perron Unit root test First Differences 1995 (Q1)-2003 (Q4)

Variable	p-value	Newey-West Lags	Stationarity
C	0	3	Yes
DT	0	3	Yes
UN	0	3	Yes
FDI	0	3	Yes
IM	0	3	Yes
EX	0	3	Yes
BY	0	3	Yes

According to the results in Table 7.4, all the variables have a unit root and thus are not stationary in levels; however they are stationary in (first) differences. See Table 7.4. Therefore, we proceed to backward selection using stationary variables.

Table 7.5, presents the final model based on the backward selection method, obtained via 10,000 bootstrapped replications, while Table F.2 in the Appendix presents in detail the various steps of the backward elimination process as well as the Bayes Information Criterion (BIC) values for each step. Please note that the lag of the dependent variable has been included in the independent variables in order to purge the autocorrelation of the residuals.

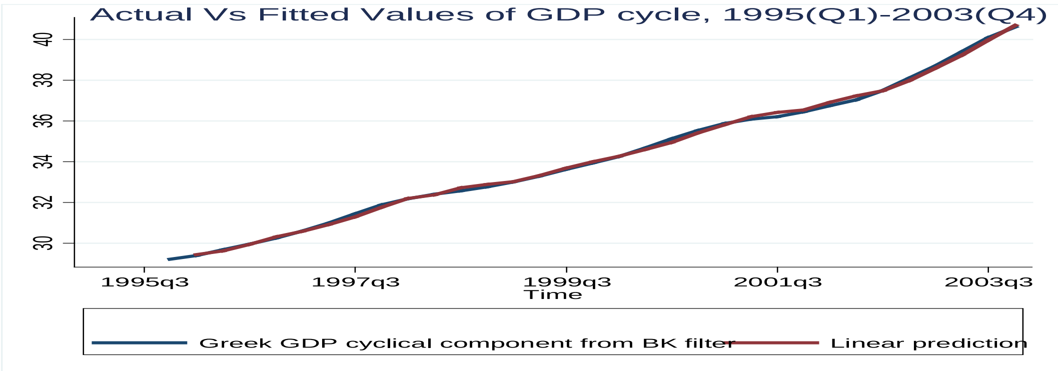
Table 7.5: Final model selection using 10,000 replications, 1995 (Q1)-2003 (Q4)

Variables	Coefficients	z-stat	p-value
GDPcycle(-1)	1.03	134.3	0
EMU	-0.12	-1.94	0.05
GE	0.1	1.97	0.05
BY	0.05	1.7	0.09
Intercept	-0.84	-3.32	0
Wald	23590.1		
R-squared adj	0.99		

The empirical results suggest that the Greek business cycle is positively and statistically significantly affected by its own past history (i.e. its own lag), Greek elections and Greek 10-year bond yields, while it is negatively and statistically significantly affected by the formation of the EMU. This in turn implies that the EMU formation acted as a stabilizer of the Greek cycle while both elections and 10-year bond yields have had a pro-cyclical character.

Additionally, the values of the BIC criterion in Table F.2 (Appendix), suggest that the final model selected exhibits the lowest BIC. Also, the adjusted R-squared statistic is very high, indicating that the final model is capable of capturing almost perfectly the variance of the dependent variable, i.e. the Greek business cycle. The almost perfect fitting of our model is illustrated in Figure 7.3, which presents the actual versus the fitted values.

Figure 7.3: Actual Vs Fitted values of GDP cycle



Furthermore, we obtain out-of-sample forecasts based on our model in order to assess its forecasting ability.

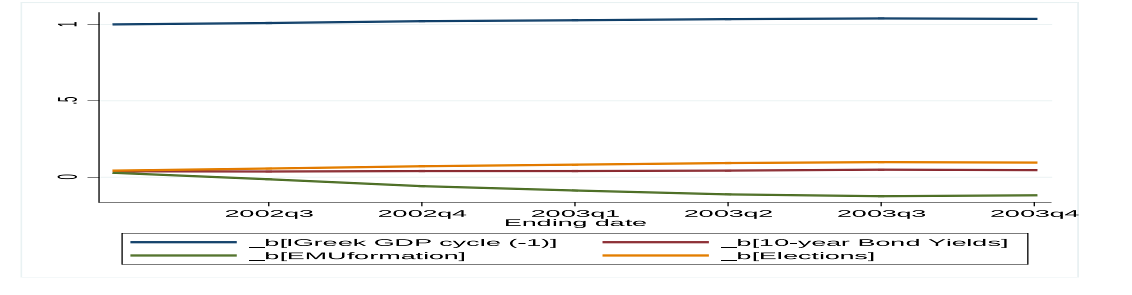
Table 7.6: Out of sample forecast, 2004 (Q1)-2004 (Q4)

Period	Greek GDP cycle	Forecasted Greek GDP cycle	Error	Squared error	RMSE
2004 Q1	41.18390	41.78198	-0.59808	0.357699686	1.089922
2004 Q2	41.65654	42.05027	-0.39373	0.155023313	
2004 Q3	41.81787	42.48385	-0.66598	0.443529360	
2004 Q4	41.85061	42.33194	-0.48133	0.231678569	

The results of our out-of-sample forecasts in Table 7.6 show that the model is almost perfectly able of forecasting the Greek GDP cycle.

Next, we proceed by testing for the time consistency of the parameters of our model, using Rolling Windows. In this context, Figure 7.4 presents the results of our rolling windows estimates.

Figure 7.4: Recursive Rolling windows estimates, starting date 1995 (Q1)



The results of recursive Rolling Windows, holding the starting date fixed in 1995(Q1) and using a window of 30 observations, with 10,000 bootstrapped replications, show that the coefficients remain practically unchanged over time.

We continue by obtaining the correlation matrix between the dependent variables (Table F.3, Appendix). The results suggest that there is no evidence of serious multi-collinearity among the dependent variables.

We now turn to the Jarque-Bera normality test for the residuals estimated by the final model selected via backward selection using 10,000 bootstrapped replications (Table F.4, Appendix). The results suggest that the null hypothesis of normality of the residuals cannot be rejected. Lastly, we test through White's test, whether the residuals are homoscedastic (Table F.5, Appendix). The results suggest that we cannot reject the null hypothesis of homoscedasticity.

Now, we assess the timing pattern of the results already obtained via the modified Dufour and Renault (1998) and Dufour et *al.* (2006) short run causality testing, presented in Table 7.8 using a horizon of four (4) quarters.

Table 7.8: Timing pattern of short run causality, 1995 (Q1)-2003 (Q4)

10-year bond yields *does not cause* Ycycle			Emu formation *does not cause* Ycycle		
Horizon	x-squared	p-value	Horizon	x-squared	p-value
1	6606.22	0	1	4428.09	0
2	6595.35	0	2	6521.74	0
3	6532.69	0	3	4532.84	0
4	6525.59	0	4	3901.58	0

Elections *does not cause* Ycycle		
horizon	x-squared	p-value
1	4623.95	0
2	4836.84	0
3	4812.25	0
4	4795.13	0

The results fare fully consistent with the finding of the backward regression, since all variables have a statistically significant impact on Greek business cycles irrespective of the time horizon of investigation.

b. Empirical Analysis: Sub-period 2005 (Q3)-2011 (Q4)

Following the same procedures as in the first sub-period, we begin our analysis by testing for the possible existence of outliers.

Table 7.8: Bacon Outliers test, 2005 (Q3)-2011 (Q4)

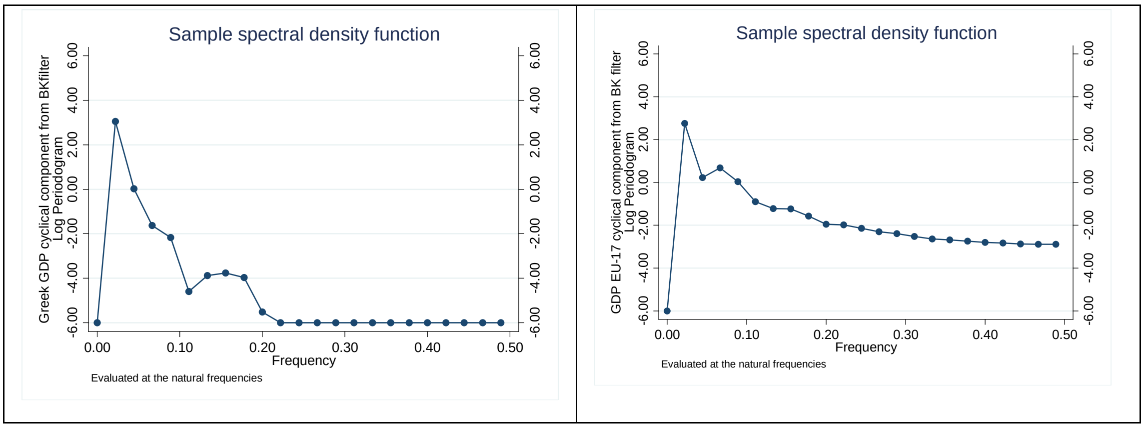
	Ycycle- GR	Ycycle-EU17	C	DT	UN	FDI	IM	EX	BY
Bacon Outliers at 5% level of significance (p-value=0.05)	0	0	0	0	0	0	0	0	0

The results in Table 7.8 suggest that all the time series are free of outliers at the 5% level of significance.

Next, we extract the business cycles components of the Greek GDP and the EU-17 GDP, using a moving average specification of three (3) quarters, a minimum business cycle period of 6 quarters and a maximum of 32 quarters (Baum et *al.,* 2007).

We continue by testing if our real business cycles follow some distinctive pattern and are not white noise. The results, which are available upon request by the authors, suggest that the null hypothesis of white noise is rejected, so our business cycles components follow some distinctive pattern. In this context, we investigate their periodicities using Fourier analysis (periodograms).

Figure 7.5: Periodograms of Greek GDP cycle and EU-17 GDPcycle, 2005 (Q3)-2011 (Q4)



The results in Figure 7.5 indicate that the Greek GDP cycle exhibits a short run cycle with periodicity of 4-6 quarters, i.e. 1.5 year as well as a medium run cycle with periodicity of 12-16 quarters i.e. 3-4 years. On the other hand, the EU-17 cycle exhibits a short run cycle of also 4-6 quarters i.e. 1.5 years while another cycle is present with periodicity of 8-10 quarters, i.e. 2.5 years. We proceed by examining the stationarity characteristics of the time series data.

Table 7.9: Phillips Perron Unit root test Original Variables, 2005 (Q3)-2011 (Q4)

Variable	p-value	Newey-West Lags	Stationarity
CR	0.35	2	No
DT	0.97	2	No
UN	0.97	2	No
FDI	0	2	Yes
IM	0.32	2	No
EX	0	2	Yes
BY	0.97	2	No

Table 7.10: Phillips Perron Unit root test First Differences, 2005 (Q3)-2011 (Q4)

Variable	p-value	Newey-West Lags	Stationarity
CR	0.03	2	Yes
DT	0	2	Yes
UN	0	2	Yes
IM	0	2	Yes
BY	0.1	2	Yes

According to the results of the Phillips-Perron unit root test in Table 7.9, most of the variables exhibit unit roots with the exception of Greek FDI and Greek Exports.

Nevertheless, according to Table 7.10, all variables were found to be stationary in their first differences at the 10% level of significance or higher.

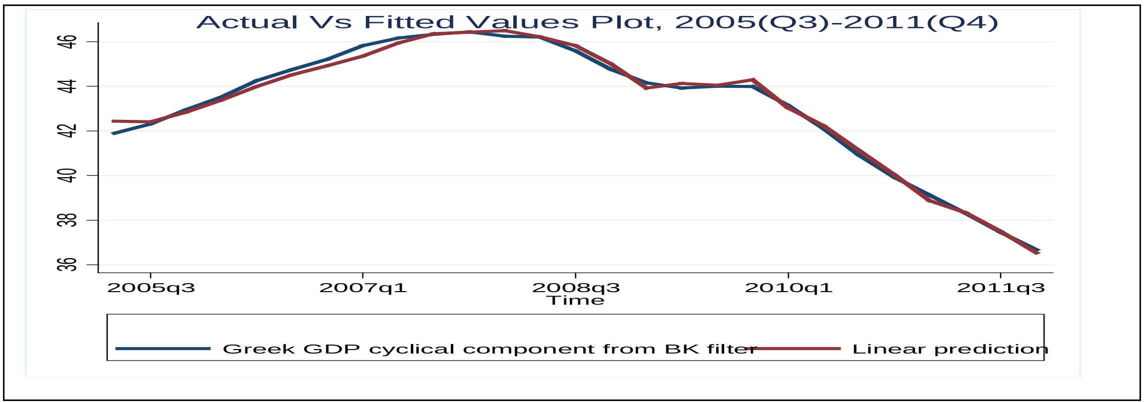
We proceed to the backward selection of our model using stationary variables. Table 7.11, presents the final model based on the backward selection method, obtained after 10,000 bootstrapped replications, while table E.6 (Appendix) presents the steps of backward elimination and the respective BIC values for each step. Please note that the lag of the dependent variable isincluded in the independent variables in order to purge the autocorrelation of the residuals.

Table 7.11: Final model selection using 10,000 replications, 2005 (Q3)-2011 (Q4)

Variables	Coefficients	z-stat	p-value
Ycycle(-1)	0.958	26.32	0
Ycycle EU-17	-0.002	-2.07	0.04
Tr	-0.928	-3.91	0
CR	0.492	2.25	0.02
IM	0.103	2.24	0.03
Intercept	6.082	3.04	0
Wald	2490.31		
R-squared adjusted	0.99		

The results of our backward selection indicate that EU-17 business cycle and the so-called "Troika" have a statistically significant negative impact on the Greek cycle, and hence exhibit a counter-cyclical character. On the other hand, Greek credit, Greek Imports and the lagged value of the Greek cycle all have a statistically significant positive impact on the Greek cycle, which in turn implies that they exhibit a pro-cyclical character. Additionally, the values of Bayes information criterion in Table E.6, in Appendix, suggest that the best model selected via backward selection exhibits the lowest BIC. Also, the adjusted R-squared statistic is very high, indicating that the model is capable of capturing almost perfectly the variance of the dependent variable, i.e. the Greek cycle. The excellent fitting of the model is illustrated in Figure 7.6, which presents the actual versus the fitted values.

Figure 7.6: Actual Vs Fitted Values Plot, 2005 (Q3)-2011 (Q4)



In line with our analysis of the first sub-period, we obtain the out-of-sample forecasts of the model in the second sub-period in order to investigate its forecasting ability.

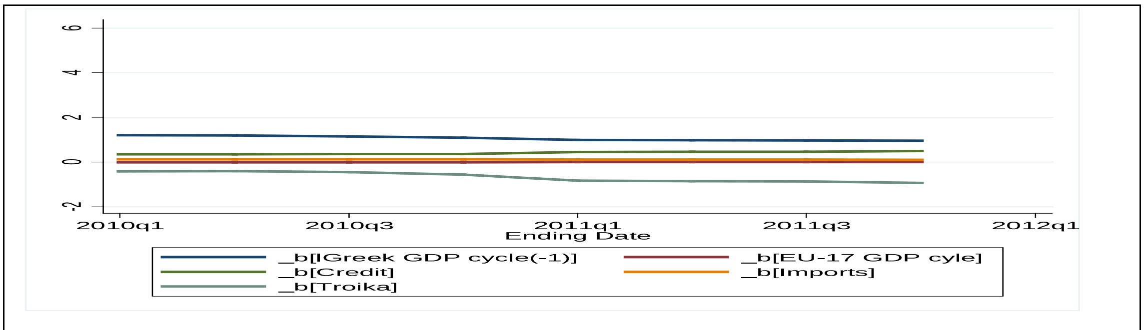
Table 7.12: Out of sample forecast, 2012 (Q1)-2012 (Q4)

Period	Greek GDP cycle	Forecasted Greek GDP cycle	Error	Squared error	RMSE
2012 Q1	35.985	35.764	0.221	0.048	0.908
2012 Q2	35.503	35.046	0.457	0.209	
2012 Q3	35.087	34.675	0.409	0.167	
2012 Q4	34.633	34.000	0.633	0.400	

The results of our out-of-sample forecasts in Table 7.12 show that the final model is almost perfectly capable of forecasting the Greek GDP cycle.

Finally, we proceed by testing the time consistency of the estimated parameters of our model, using Rolling Windows. In this context, Figure 7.7 presents the results of our rolling Windows Estimates.

Figure 7.7: Recursive rolling windows estimates, starting date 2005 (Q3)



The results of recursive Rolling Windows, holding the starting date fixed in 2005(Q3) and using a window of 20 observations, with 10,000 bootstrapped replications, show that the coefficients are stable over time.

Next, we assess the correlation coefficients between the dependent variables of our model (Table F.7, Appendix). The results suggest that there is no evidence of strong multicollinearity among the independent variables. We continue by testing for the normality of the residuals (Table F.8, Appendix) as well as for homoscedasticity of the residuals (Table F.9, Appendix). The results suggest that both the hypotheses of normality and homoscedasticity of the residuals, respectively, cannot be rejected.

Lastly, through the Dufour and Renault (1998) and Dufour et *al.* (2006) models, we assess the timing pattern of the results already obtained by means of the backward regression model. Table 7.13 presents the results of short run causality for a time horizon of four (4) quarters i.e. one (1) year.

Table 7.13: Timing pattern of Short run causality, 2005 (Q3)-2011 (Q4)

Credit *does not cause* Ycycle			**Ycycle EU-17 *does not cause* Ycycle**		
horizon	**x-squared**	**p-value**	**horizon**	**x-squared**	**p-value**
1	214.11	0	1	209.31	0
2	215.18	0	2	210.49	0
3	226.31	0	3	212.1	0
4	213.89	0	4	215.37	0
Imports *does not cause* Ycycle			**Troika *does not cause* Ycycle**		
Horizon	**x-squared**	**p-value**	**horizon**	**x-squared**	**p-value**
1	165.71	0	1	205.92	0
2	166.43	0	2	224.13	0
3	197.18	0	3	203.64	0
4	200.96	0	4	221.89	0

The results coincide are consistent with the findings of the backward regression approach since all variables have a statistically significant impact on the Greek cycle in every horizon tested up to four (4) quarters.

7.5 DISCUSSION

Following the empirical analysis presented earlier, the discussion section will focus, separately, on the two observed sub-periods of the Greek business cycle namely 1995 (Q1)-2003 (Q4) and 2005 (Q3)-2011 (Q4). Our identification of the first sub-period of the Greek economy is consistent with the periodization of Tavlas and Zonzilos (2001) who locate the point of structural break in the Greek economy in 1994.

In the first sub-period, 1995-2004, the Greek business cycle is characterized by an upward trend, which is attributed to the overall growth of the Greek economy that matched the growth of the rest of the EU-12 economies (Bosworth and Kollintzas, 2001). According to our findings (Table 7.5), elections in this period have a statistically significant pro-cyclical character, which implies that they played a key role in amplifying the Greek business cycle. This fact could be attributed to the fiscal and monetary policies implemented by the government of the Greek socialist party, PA.SOK, led by Constantinos Simitis, who managed to win two consecutive elections in 1996 and in 2000. The monetary and fiscal policies adopted by the government of PA.SOK, in the period 1996-2000, focused primarily on the preservation of the so-called stability growth pact (S.G.P) of Maastricht, in order to ensure that Greece will meet the required standards regarding the nominal convergence of Greece with rest of the European countries. Whereas, the fiscal policies adopted by the Greek government after 2000 and the introduction of the common currency, were characterized by an increased spending that was fueled by EMU financing. This finding is consistent, among others, with the works of Camacho et *al.* (2006), Gouveia and Correia (2008) and Papageorgiou et *al.* (2010) who argued that in the post-Maastricht period, synchronization among EMU countries seems to increase in the period after the introduction of the common currency, whereas divergence has increased, especially for Greece and Ireland.

Turning to Table 7.5, the 10-year Greek Bonds have a statistically significant pro-cyclical impact on the Greek business cycle. This pro-cyclical character could be attributed to the fact that, throughout the period under investigation, Greek Bonds gradually declined enabling the Greek government to attract external funding by the global market. More precisely, in the period of 1995-2000, the 10-year Greek Bond yields experienced a gradual decrease that was accompanied by the growth of the Greek economy,which benefited by two key factors. The first was the large numbers of immigrants that came to Greece from other Balkan countries, substantially enhancing the productive capabilities of the Greek economy. The second was the significant decrease of the total labor cost, which made Greek exports more appealing in the global market, strenghtening the Greek current account balance (IMF, 2006).

However, after 2000 and the introduction of the Euro currency, Greece benefited by the inflows of European credit that came from the European Central Bank (ECB). Thus, the Greek 10-year Bond yields faced a dramatic decrease in the global market, since Greece became an irrevocable member of the EMU, with a strong line of credit provided by the ECB. Lastly, EMU formation was found to have a statistically significant counter-cyclical impact on the Greek business cycle. The fact that EMU acted as stabilizer for the Greek economy could be attributed to the S.G.P of Maastricht that required all EMU members to sustain an overall current account deficit of 3%, which in turn prevented the Greek government of acquiring excessive external financing from the global market.

These findings based on backward regression are fully consistent with the results obtained through the modified stepwise causality methodology, according to which all the variables dictate the evolution of Greek business cycles irrespective of the time horizon investigated. Meanwhile, our overall findings are, in general terms, consistent with findings of Apergis and Panethimitakis (2007) who argued that Greece in the period of 1960-2004 was driven primarily by external shocks and not by the implemented policies.

In the beginning of 2005, only a few months after the completion of the Olympic Games of 2004, the Greek business cycle gradually entered a downward phase peaking in 2010, when Greece entered into the European Financial Stability Facility (E.F.S.F). According to our findings (Table 7.11), credit has a statistically significant pro-cyclical effect on the Greek business cycle in the sense that it amplifies it. This could be attributed to the fact that after the introduction of the common currency, Greek banks faced a strong credit inflow by the ECB with the smallest inter-banks rates in history.

As a result, the Greek banks needed a period of almost four (4) years to fully adjust their portfolio with the new credit line by the ECB. Once they adjusted, they substantially lowered their consumer screening standards and provided to the public a vast spectrum of new high-risk financial products, such as vacations loans, consumer loans etc. In addition, due to the extensive credit line provided by the ECB, they financed considerably the build-up of the Greek debt by adding to their portfolio Greek Bonds. This situation significantly deteriorated the Greek current account, amplifying the Greek business cycle.

Next, the Greek imports are found to have a statistically significant pro-cyclical character on the Greek business cycle. This could be attributed to the fact that after 2005 the extensive credit provided to the Greek consumers by the local banks and hence – indirectly – by the ECB, led Greece to an increase in its imports due to the increased demand pressures. As a result, the increased overall price of imports started to have a negative impact on the Greek current account balance and, thus, deepened the Greek crisis.

Finally, according to our findings, the EU-17 cycle and the "Troika"were found to have a statistically significant countercyclical effect on the Greek business cycle. The fact that these two variables act as stabilizers to the downfall of the Greek business cycle could be attributed to the internal depreciation that took place in Greece as well as to the low interest rates provided by the ECB which to loosened its monetary policy in an attempt to overcome the global crisis of 2007. In this context, "Troika's" policies led to the internal depreciation of the Greek economy cutting down at the same time the spending of the public sector which, in turn, contributed to the shrinkage of the Greek cycle, while the low interest rates were stabilizing the European cycle, as well. These findings are, again, fully consistent with the results obtained through the stepwise causality approach adopted, according to which all the variables dictate the evolution of Greek business cycles irrespective of the time horizon of our investigation.

7.6 CONCLUSION

Just a few years ago, Greece had a quite developed economy with the 22nd highest standard of living in the world and a 'very high' Human Development Index, ranking 25th in the world. Meanwhile, OECD (2002) characterized the performance of the Greek economy since the early 1990s as 'remarkable'. However, in 2010 as a result of international and local factors, the Greek economy Greece faced a severe economic crisis. In fact, it experienced the second highest budget deficit and the second highest debt to GDP ratio in the EU, which in combination with the high borrowing costs, resulted in a severe crisis (Charter, 2010). In view of this tremendous situation, the Greek GDP has fallen dramatically by approximately 20% (BoG, 2013), whereas unemployment rate has reached 27%, and youth unemployment 56% (EL.Stat., 2013). In this context, an investigation of the determinants of Greek business cycleswas of outmost importance.

Hence, we investigated the determinants of the Greek business cycles in attempt to identify the structural causes of the downturn of the Greek economy, in the time period 1995-2014. To this end, made use of a wide dataset in a quarterly format, which contained all the major macroeconomic and financial variables that could, potentially, affect the Greek economy. Additionally, we made use of the modified the concept of stepwise short-run causality of Dufour and Renault (1998) and Dufour et *al.* (2006) in order to investigate the causality of the key qualitative variables that enter the model.

Our work contributes to the literature in the following ways: (a) It the first, to the best of our knowledge, that uses a large dataset in quarterly format, for the investigation of the determinants of the Greek business cycle, in the time period 1995-2014; (b) It employs a number of relevant state-of-the-art econometric tests; (c) It acknowledges the significant role of elections on the Greek business cycle; (d) It introduces a relevant VAR model with exogenous variables for testing one sided non-causality accounting for the possibility of qualitatitve variables.

According to our analysis, all authors in the literature agree that the Greek economy entered a period of a recession in the mid-1970s, which interrupted the steady growth initiated by the wave of industrialization in the 1960s. The macroeconomic policies of the 1980s are related to this slowdown and most authors stress the absence of long-term planning. A common point of the analyses is the concentration of macroeconomic policies on consumption, neglecting both investments and the supply side of the economy. Also, they noted an important change in the policy regime occurring in the 1990s, which led to an acceleration of growth while restoring stability.

In brief, the literature suggests that, the recent economic history of Greece up until the recent crisis can be divided into three distinct periods: (i) The period extending from 1960 until some point in the middle 1970s where the Greek economy experienced rapid growth; (ii) A "halt" lasting until about the early or middle 1990s when most economic indexes showed a marked deceleration; (iii) From that point on up until the outburst of the recent crisis the Greek economy experienced a period of steady growth.

Consistent with the periodization of the Greek economy, our empirical findings showthat the Greek business cycle exhibits two structural breaks one in the third quarter of 2004, i.e. 2004 (Q3) and one in the fourth quarter of 2011, i.e. 2011 (Q4). As a result, we split the period into two sub-periods: one in the period 1995-2004 (upward phase) and one in the period after 2005 up until recently (downward phase). In the two sub-periods, we examined the determinants of the Greek business cycle using backward selection multiple linear regression on a relevant vector of macroeconomic and financial determinants, acknowledging the significant role of elections in the course of the Greek business cycle. In the sub-period 1995-2004, the 10-year bond-yields and the elections were found to have a pro-cyclical character on the Greek business cycle, while the formation of EMU was found to have a counter-cyclical character. In the second sub-period of 2005-2012, Greek credit and imports were found have a strong pro-cyclical character, while the overall EU-17 business cycle and troika seemed to have a countercyclical character on the Greek economy.

These findings are fully consistent with the results obtained through the stepwise step-by-step causality approach, according to which all the relevant variables dictate the evolution of Greek business cycles irrespective of the time horizon of the investigation. Further and more extended research on the topic seems to be of great interest focusing, among other things, on the implications of the Greek crisis for the Greek economy and society as well as for those of other countries in Europe and elsewhere.

Chapter 8: Macroeconomic Determinants in the Greek Car Sales Sector: Step-by-Step Causality Revisited[44]

Next, we turn to the investigation of the impact of the recent crisis in Greece on key sectors of the Greek economy. We focus on another sector of the Greek economy that has been severely hit by the recent crisis in Greece, namely the car sales sector. In order, to investigate the short-run causality among the main quantitative and qualitative factors that influence the sector, we will introduce a VAR model with exogenous variables for testing one-sided (non-)causality by extending the works of Dufour and Renault (1998) and Dufour et *al.* (2006). In this context, we will derive a test statistic for formally investigating one sided (non-)causality, while providing a simple algorithm for implementing the one sided (non-)causality test in a system framework and not equation-by-equation extending, thus, Dufour et *al.* (2006). We will illustrate our approach by using a monthly dataset including dummy variables on Total Car Sales in the area of Athens over the period 2003-2012

9.1 INTRODUCTION

In a seminal paper in *Econometrica,* Dufour and Renault (1998) introduced the notion of *step-by-step* or *short-run* causality. As we have seen, the Greek crisis has reached points that are directly comparable only to the Great Recession including an approximate 20% contraction of GDP in the period 2008-2013 and a very high unemployment rate equal to 27%. The car sales sector is an important industry for the Greek economy since it accounts for a significant part of government revenues, especially through the registration taxes that are directly implemented whenever a car sale takes place as well as through the presumptions implemented once a year. The car sales sector in Greece was significantly affected by the ongoing crisis with a reduction of total sales that exceeded 20%, which in turn affected government revenues. Hence, it is of great importance to investigate the step-by-step predictive ability of the various factors on the car sales industry fluctuations over the last 12 years, using monthly data.

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[44] Another version of this chapter has been published as follows: Konstantinos N. Konstantakis and Panayotis G. Michaelides (2015), Step-by-Step Causality Revisited: Theory and Evidence, *Economics Bulletin*, 35(2): 871-877.

In order to investigate the timing pattern of causality, Dufour et *al.* (2006) in the *Journal of Econometrics*, extended the work of Dufour and Renault (1998) *in Econometrica* by considering a class of VAR (p) models in different horizons h. Their choice for considering a VAR scheme was based on the bi-direction of causality. Of course, there are cases when we are interested only in one sided (non-)causality, e.g. in order to account for the recent global crisis. In such case, a dummy variable would have to be used to capture the impact of the recent global crisis on other variables of interest, e.g. local ones, such as the Total Car Sales in Greece. However, we have no serious reason to believe that the Total Car Sales in Greece and/or any other local variables of interest could have any causal predictive ability, even in the short run, on the global recession.

In other words, this means that the dummy variable used to capture the recent global recession should not be incorporated in the VAR model proposed by Dufour et *al.* (2006). It should rather be incorporated in an extended model in the form of an exogenous variable i.e. in simple words it should appear only in the right hand side of the block of VAR equations. Needless to say, this has serious implications for the test statistic that was proposed by Dufour et *al.* (2006) which is constructed to be bi-directional. Hence, a variable acting as exogenous would render the symmetric test statistic proposed by Dufour et *al.* (2006) meaningless.

In the meantime, the choice of Dufour et *al.* (2006) to estimate the VAR model using equation-by-equation OLS instead of SURE or 2S-GLS is inappropriate when the error terms are correlated across different equations, as Dufour et *al.* (2006, p. 346) themselves point out. In this work, we will set out a methodology for explaining how one sided (non-)causality can be tested using a VAR (p) scheme, augmented by an exogenous (set of) variable(s) in cases we are interested only in one sided causality between the variables, using 2S-GLS estimator which accounts for the possible error terms correlation across different equations.

In brief, the chapter contributes to the literature as follows: (i) It introduces a relevant VAR model with exogenous variables for testing one sided non-causality accounting for the possibility of dummy variables; (b) it derives a test statistic for formally investigating one sided non-causality; (c) it provides a simple algorithm for implementing one sided non-causality using 2S-GLS estimator which accounts for the possible error terms correlation across different equations; and (d) it illustrates this technique using a monthly dataset (2000-2012) on Total Car Sales in the area of Athens, Greece which was hit severely by the recent recession.

8.2 METHODOLOGY

Remark 1: In what follows, we illustrate how one sided (non-)causality can be tested using a VAR (p) scheme augmented by an exogenous set of variables in cases we are interested only in one sided causality between the variables.

a. Formulation of one sided non-causality

Here, we set out the one sided causality testing method taking into consideration the case where both dummy and quantitative time series variables are employed.

Consider the following VAR (p) model augmented by exogenous dummy and/or quantitative variables:

$$Y_t = a + \sum_{k=1}^{p} \pi_\kappa Y_{t-k} + \sum_{q=0}^{Q} \beta_q D_{t-q} + u_t \quad \textbf{(8.1)}$$

where: Y_t is an (1xm) vector of variables; a is a (1xm) vector of constant terms; D_t is a vector of (Lx1) qualitative (dummy) or quantitative variables and u_t is a (1xm) vector of error terms such that $E(u_t u_s) = \sigma_{ii} I$ if $t = s$ and $E(u_t u_s) = \sigma_{ij} I$ if$t \neq s$, where I is the identity matrix.

Note that the exogenous variables D_t ought to have a lag structure in order to be able to properly apply the concept of short-run causality.

Remark 2: Extending the work by Dufour et *al.* (2006), we propose an estimation strategy which accounts for the fact that the various disturbances might be contemporaneously correlated, due the same set of regressors that account for the exogenous variables.

Following Dufour et *al.* (2006), the model described in (9.1) corresponds to horizon h=1. In order to test for the existence of non-causality in horizon h, a model of the following form is considered:

$$Y_{t+h} = a^{(h)} + \pi^{(h)} Y_{t,p} + \beta^{(h)} D_{t,q} + u_{t+h}{}^{(h)} \quad \textbf{(8.2)}$$

where: $Y_{t,p} = (Y_t, Y_{t-1}, \dots, Y_{t-p+1})$, $\pi^{(h)} = (\pi_1{}^{(h)}, \dots, \pi_p{}^{(h)})$, $\beta^{(h)} = (\beta_0{}^{(h)}, \beta_1{}^{(h)}, \dots, \beta_q{}^{(h)})$ and $u_{t+h}{}^{(h)} = (u_{1,t+h}{}^{(h)}, \dots, u_{m,t+h}{}^{(h)})$ for t=1,…,T-h and h<T.

Equation (8.2) can be written in matrix form as:

$$\boldsymbol{Y_{t+h}} = \boldsymbol{\Gamma X} + \boldsymbol{u} \quad \textbf{(8.3)}$$

where $\boldsymbol{Y_{t+h}} = [Y_{1,t+h}, \dots, Y_{m,t+h}]$ is a (1xm) vector which denotes the m-quantitative variables that enter the model; $\boldsymbol{X} = [I_T; Y_{1,t-1}, \dots, Y_{1,t-p}; \dots; Y_{m,t-1}, \dots, Y_{m,t-p}; D_{1,t-1}, \dots, D_{1,t-q}; \dots; D_{l,t-1}, \dots, D_{l,t-q}]$ is an (2m+l) x max{t-p+1, t-q+1} matrix that includes both quantitative and qualitatitive variables; $\boldsymbol{\Gamma} = [a_1, \dots, a_m; \pi_{1,1}, \dots, \pi_{1,p}; \dots; \pi_{m,1}, \dots, \pi_{m,p}; \beta_0, \dots, \beta_{0,q}; \dots; \beta_l, \dots, \beta_{l,q}]$ is the inverse of a (2m+l)x[max{p, q+1}] matrix of coefficients and $\boldsymbol{u} = [u_{1,t+h}, \dots, u_{m,t+h}]$ is a (1xm) vector of idiosyncratic shocks such that $\boldsymbol{u} \sim N(0, \boldsymbol{\Sigma})$ so that the variance covariance matrix is of the form: $\Omega = \Sigma \otimes I$ where $\Sigma = (\sigma_{ij})$ and I the identity matrix, with $\det(\Omega) \neq 0$.

Proposition 1: (*Asymptotic normality of GLS in a stationary VAR (p, h))*

Any VAR (p, h) model described in (8.1) that can be written in the following form, is asymptotically normally distributed:

$$\boldsymbol{Y_{t+h}} = \boldsymbol{\Gamma X} + \boldsymbol{u} \ \textbf{(8.4)}$$

Where $\boldsymbol{u} \sim N(0, \Omega)$ and the variance covariance matrix is of the form: $\Omega = \Sigma \otimes I$ where $\Sigma = (\sigma_{ij})$ and I the identity matrix, with $\det(\Omega) \neq 0$ and $\frac{1}{T}\boldsymbol{X'X} \to^{\boldsymbol{p}}_{\boldsymbol{T}\to\infty} \boldsymbol{\Delta_p}$ with $det\ (\boldsymbol{\Delta_p}) \neq 0$.

Proof: It is a straightforward application of the sketch provided in Dufour et *al.* (2006, p. 343) (Proposition 1) using GLS estimation instead of LS.

b. Distribution of the test statistic for non-causality at horizon h

For a given horizon $\bar{h}$, we need to test the hypothesis that: $H_0{}^{(\bar{h})}: D_i \nrightarrow Y_{jt}/I(D_i)$ i.e. the i-th dummy variable does not cause in horizon h the j-th quantitative variable.

Theorem 1: (*Asymptotic distribution of the test criterion for one-sided non-causality at horizon h in a VAR (p) augmented by exogenous quantitative/qualitative variables)*

Under Proposition 1 and the assumption that:

$$H_{0_{D_i \nrightarrow Y_{jt}/I(D_i)}}{}^{(\bar{h})}: R\boldsymbol{\Gamma}^{(\bar{h})} = r \text{ in } \boldsymbol{Y_{t+h}} = \boldsymbol{\Gamma X} + \boldsymbol{u}$$

then: $V(\widehat{\boldsymbol{\Gamma}^{(\bar{h})}}) \to^{\boldsymbol{p}}_{\boldsymbol{T}\to\infty} \boldsymbol{\Delta_p}^{-1}\boldsymbol{V_{ip}}\boldsymbol{\Delta_p}^{-1}$ and is distributed as follows:

$$\mathcal{D}\left({H_0}^{(\bar{h})}\right) = T\left[R\boldsymbol{\Gamma}^{(\bar{h})} - r\right]'\left[R'{\boldsymbol{\Delta}_p}^{-1}\boldsymbol{\Omega}^{-1}\boldsymbol{\Delta}_p R\right]\left[R\boldsymbol{\Gamma}^{(\bar{h})} - r\right] \sim \chi^2(\max\{p, q+1\}).$$

Proof: In equation (8.4) we need to test ${H_{0_{D_i \nrightarrow Y_{jt}/I(D_i)}}}^{(\bar{h})}: {\beta_i}^{(\bar{h})} = 0$ given that $\forall h \epsilon \{1, \dots, \bar{h} - 1\}$ it holds that ${\beta_i}^{(h)} = 0$, which in turn yields :

$${H_{0_{D_i \nrightarrow Y_{jt}/I(D_i)}}}^{(\bar{h})}: R\boldsymbol{\Gamma}^{(\bar{h})} = r$$

Where $R = [0, \dots, 0_m; 0, \dots, 0_{2mxp}, ; 0, \dots, 1_i, \dots 0_{lx(q+1)}]$

Now, we have that the GLS estimator $\widehat{\boldsymbol{\Gamma}^{(\bar{h})}}$, for $\boldsymbol{\Gamma}^{(\bar{h})}$ is :

$$\widehat{\boldsymbol{\Gamma}^{(\bar{h})}} = \boldsymbol{\Gamma}^{(\bar{h})} + (\boldsymbol{X}'\boldsymbol{\Omega}^{-1}\boldsymbol{X})^{-1}\boldsymbol{X}'\boldsymbol{\Omega}^{-1}\boldsymbol{u}$$

Hence:

$$\sqrt{T}(\widehat{\boldsymbol{\Gamma}^{(\bar{h})}} - \boldsymbol{\Gamma}^{(\bar{h})}) = (\frac{1}{T}\boldsymbol{X}'\boldsymbol{\Omega}^{-1}\boldsymbol{X})^{-1}\frac{1}{\sqrt{T}}\boldsymbol{X}'\boldsymbol{\Omega}^{-1}\boldsymbol{u}$$

Under standard regularity conditions (White 1999):

$$\sqrt{T}(\widehat{\boldsymbol{\Gamma}^{(\bar{h})}} - \boldsymbol{\Gamma}^{(\bar{h})}) \to^{L}_{T\to\infty} N(0, V(\widehat{\boldsymbol{\Gamma}^{(\bar{h})}})) \quad \textbf{(8.5)}$$

with $\det(V(\widehat{\boldsymbol{\Gamma}^{(\bar{h})}})) \neq 0$.

Remark 3: The $V(\widehat{\boldsymbol{\Gamma}^{(\bar{h})}})$ can be consistently estimated using the Newey-West heteroskedasticity and autocorrelation consistent covariance (HAC) matrix estimator extending Dufour et *al.* (2006, p. 346) who suggested using it without however implementing it:

$$V\left(\widehat{\boldsymbol{\Gamma}^{(\bar{h})}}\right) = HAC = \widehat{Q_0} + \sum_{j=1}^{k} w(j,k)(\widehat{Q_j} + \widehat{Q_j}')$$

where: $\widehat{Q_j} = \frac{1}{T}\sum_{t=j+1}^{T} X_t u_t u_{t-j} X_{t-j}, \forall j = 1, \dots, k$

and $w(j,k)$ is a lag window, and k is the lag truncation parameter.

$$\widehat{V_T}(\widehat{\boldsymbol{\Gamma}^{(\bar{h})}}) \to^{p}_{T\to\infty} V(\widehat{\boldsymbol{\Gamma}^{(\bar{h})}})$$

Now, suppose that $\frac{1}{T}\boldsymbol{X}'\boldsymbol{X} \to^{p}_{T\to\infty} \boldsymbol{\Delta_p}$with $det\ (\boldsymbol{\Delta_p}) \neq 0$, and let:

$$V_{ip} = Var\left(\frac{1}{\sqrt{T}}\boldsymbol{X}'\boldsymbol{\Omega}^{-1}\boldsymbol{u}/\boldsymbol{X}\right) = \frac{1}{T}Var(\boldsymbol{X}'\boldsymbol{\Omega}^{-1}\boldsymbol{u}/\boldsymbol{X}) \Leftrightarrow$$

$$V_{ip} = Var\left(\frac{1}{\sqrt{T}}\boldsymbol{X}'\boldsymbol{\Omega}^{-1}\boldsymbol{u}/\boldsymbol{X}\right) = \frac{1}{T}\boldsymbol{X}'Var(\boldsymbol{\Omega}^{-1}\boldsymbol{u}/\boldsymbol{X})\boldsymbol{X} \quad \textbf{(8.6)}$$

Therefore, it is easy to infer that:

$$Var[(\frac{1}{T}\boldsymbol{X}'\boldsymbol{\Omega}^{-1}\boldsymbol{X})^{-1}\frac{1}{\sqrt{T}}\boldsymbol{X}'\boldsymbol{u}] = \boldsymbol{\Delta_p}^{-1}V_{ip}\boldsymbol{\Delta_p}^{-1} \quad \textbf{(8.7)}$$

Combining equations (9.7) and (9.5) we get that:

$$V(\widehat{\boldsymbol{\Gamma}^{(h)}}) \to^{p}_{T\to\infty} \boldsymbol{\Delta_p}^{-1}V_{ip}\boldsymbol{\Delta_p}^{-1} \quad \textbf{(8.8)}$$

Meanwhile, in order to test for non-causality of the quantitative/qualitative variables that enter as exogenous in the augmented VAR (p) model, at a given horizon h, we propose the following modified algorithm which builds on Dufour et *al.* (2006).

Step 1: An augmented VAR model as in equation (3) is fitted for using GLS estimation and the Newey-West heteroskedasticity and autocorrelation consistent covariance (HAC) for horizon h=1 and we obtain the estimates $\widehat{\pi_\kappa}$, $\widehat{\beta_m}$and $\hat{\Omega}$.

Step 2: A restricted augmented VAR model using GLS estimation as described in equation (4) is fitted and we obtain the estimates $\widehat{\pi^{(h)}}$ and $\widehat{\beta^{(h)}}$.

Step 3: We compute the test statistic $\mathcal{D}$ for testing non-causality at horizon h i.e. we test the hypothesis $H_{0,D_i \nrightarrow Y_{jt}/I(D_i)}{}^{(h)}: \beta_{im} = 0, m = 0,1, \dots, M, i\epsilon\{1, \dots, l\}, j\epsilon\{1, \dots, m)$. We denote $\mathcal{D}_0^{(h)}$ the test statistic based on actual data.

Step 4: We draw N simulated samples from equation (4) using Monte Carlo with $\pi^{(h)} = \widehat{\pi^{(h)}}$,$\beta^{(h)} = \widehat{\beta^{(h)}}$ and $\Omega = \hat{\Omega}$. We impose the constrains of non-causality at horizon h i.e. $\beta_{im} = 0, m = 0,1, \dots, M, i\epsilon\{1, \dots, l\}, j\epsilon\{1, \dots, m)$ and we compute the test statistic for non-causality at horizon h, i.e. $\mathcal{D}_n^{(h)}, n\epsilon\{1, \dots, N\}$.

Step 5: We compute the simulated p-values based on the following formula:

$$\hat{p}_N[x] = \{1 + \sum_{n=1}^{N} I[\mathcal{D}_n^{(h)} - x]\}/(N+1)$$

Step 6: We reject the null hypothesis of non-causality at horizon h i.e.$H_{0,D_i \nrightarrow Y_{jt}/I(D_i)}{}^{(h)}$, at level a if $\hat{p}_N[\mathcal{D}_0^{(h)}] \le a$.

In what follows, we apply the proposed methodology for testing short run causality effects of a number of macroeconomic and dummy variables on the cyclical component of Car Sales in the area of Athens, Greece, which was severely hit by the recent recession.

8.3 EMPIRICAL ANALYSIS

a. Data and Variables

The data used are monthly for the period 2000-2012. The data regarding Total Car Sales in the Area of Athens come from AMVIR (Association of Motor Vehicle Importers Representatives); Unemployment and GDP come from the Hellenic Statistical Authority (EL.STAT), while the data on Fuel prices come from the Observatory of Fuel Prices. All quantitative variables in the model are in constant 2005 prices in millions €.

In what follows, we make use of the following notation: $TScycle_t$ is the cyclical component of Total car sales in Athens, extracted by means of Baxter King Filtering; $GDPcycle_t$ is the cyclical component of Greek GDP extracted by means of Baxter King Filtering; UN_t is the local unemployment rate; GDP_t is the Greek GDP; F_t is the fuel price; C_t is the dummy variable of the global recession taking the value 1 in the time interval (2006 (M4)-2012 (M12)) and 0 elsewhere; P_t is the dummy variable of presumptions taking the value 1 in the time period 2009 (M5)-2009 M(8) and 0 elsewhere; RT_t is the dummy variable of the registration taxes taking the value of 1 in the period 2004 (M1) - 2008 (M12) and 0 elsewhere and L_t is the dummy variable of the loans directed to the car market taking the value 1 over the period 2003 (M1)- 2008 (M12) and 0 elsewhere.

b. Econometric estimation

We start by examining the stationarity characteristics of the time series. According to Table 8.1, the majority of time series variables were found to be non-stationary, except for GDP cycle and Car Total Sales cycle that were expected to be found stationary, as filtered time series. Nevertheless, all variables exhibit stationarity in first differences (Table 8.2). In this context, all variables with the exception of the cyclical variables are regarded to be integrated of degree one i.e. I(1).

Table 8.1: ADF test original variables

Variable	p-value	Stationarity
GDP	0.36	No
Unemployment	0.99	No
Fuel price	0.59	No
TScycle	0	Yes
GDPcycle	0.03	Yes

Table 8.2: ADF test first differences

Variable	p-value	Stationarity
GDP	0	Yes
Unemploymer	0.04	Yes
Fuel price	0.01	Yes

In the presence of I(1) variables we have to examine the existence of cointegrating relationships. To this end, Table 8.3 presents the results of Johansen's test.

Table 8.3: Johansen Cointegration Test

Max rank	LogLikelihood	Eigenvalue	Tracestatistic	Criticalvalues	Cointegration
0	-2490.57		156.69	47.21	No
1	2461.04	0.34	97.61	29.68	
2	2435.42	0.3	46.39	15.41	
3	2418.09	0.22	11.73	3.76	
4	2412.23	0.08			

The results indicate that there is no cointegration among the variables therefore we proceed with studying the timing pattern of causality. Before proceeding to the non- causality tests we examined the time horizon, i.e. the maximum lag legth of the VAR model using AIC (Table 8.4).

Table 8.4: Lag length selection using Akaike Information Criterion (AIC)

Lag	LL	df	p-value	AIC
9	-1954.16	16	0.01	32.77
10	-1934.77	16	0.01	32.72
11	-1899.3	16	0.01	32.42
12	-1836.17	16	0	31.69
13	-1826.45	16	0.24	31.88
14	-1815.17	16	0.13	31.93
15	-1794.31	16	0.05	31.97

According to Table 8.4, twelve (12) lags were selected as the optimum. In this context, we proceed by testing for one sided non-causality for an horizon of twelve (12) periods based on the methodology presented earlier using 10,000 bootstrapped replications. The results are presented in Table 8.5.

Table 8.6: Step-by-step causality results

RT_t does not cause $TSCycle_t$			PT_t does not cause $TSCycle_t$			L_t does not cause $TSCycle_t$		
Lag	χ^2	p-value	Lag	χ^2	p-value	Lag	χ^2	p-value
1	314.41	0	1	315.15	0	1	314.96	0
2	36.13	0	2	36.36	0	2	36.12	0
3	0.88	0.64	3	1.63	0.44	3	1.17	0.55
4	9.48	0	4	11.6	0	4	10.35	0
5	7.43	0.01	5	10.66	0	5	9.39	0
6	6.32	0.02	6	6.56	0.02	6	8.88	0
7	4.26	0.05	7	3.42	0.04	7	7.35	0
8	1.32	0.35	8	4.52	0.05	8	4.44	0.04
9	0.99	0.44	9	1.44	0.33	9	2.15	0.12
10	0.88	0.56	10	1.01	0.42	10	1.51	0.35
11	0.76	0.66	11	0.95	0.48	11	0.79	0.66
12	0.75	0.68	12	0.89	0.52	12	0.69	0.75

C_t *does not cause* $TSCycle_t$

Lag	χ^2	p-valu
1	313.95	0
2	35.93	0
3	1.58	0.45
4	12□38	0
5	11.32	0
6	10.75	0
7	4.65	0.03
8	4.44	0.04
9	1.63	0.24
10	1.49	0.32
11	0.9	0.42
12	0.92	0.39

UN_t *does not cause* $TSCycl$

Lag	χ^2	p-valu
1	316.11	0
2	36.47	0
3	0.728	0.69
4	9.52	0
5	7.45	0.01
6	12.45	0
7	13.62	0
8	13.25	0
9	2.16	0.11
10	1.56	0.22
11	1.62	0.17
12	1.55	0.21

F_t *does not cause* $TSCycle$

Lag	χ^2	p-valu
1	326.46	0
2	43.61	0
3	33.25	0
4	19.79	0
5	12.25	0
6	4.65	0.03
7	4.32	0.05
8	4.29	0.05
9	1.79	0.25
10	1.66	0.28
11	1.59	0.33
12	0.82	0.49

$GDPcycle_t$ *does not cause* $TSCycle_t$

Lag	χ^2	p-value
1	314.28	0
2	35.36	0
3	0.457	0.79
4	11.7	0
5	10.58	0
6	4.33	0.05
7	1.68	0.23
8	0.97	0.32
9	0.88	0.44
10	0.32	0.85
11	0.12	0□91
12	0.09	0.96

GDP_t *does not cause* $TSCycle_t$

Lag	χ^2	p-value
1	455.47	0
2	90.53	0
3	47.05	0
4	50.02	0
5	4.66	0.02
6	4.44	0.04
7	1.49	0.32
8	0.78	0.65
9	0.69	0.78
10	0.53	0.88
11	0.1	0.95
12	0.06	0.99

The results of the short run causality tests (Table 8.5) suggest that all macroeconomic variables cause the evolution of Total Sales cycles immediately (i.e. the p-value is approximately equal to 0), and for almost eight (8) quarters when most of the causality effects die out completely (i.e. the p-value is greater than 0.10).

8.4 CONCLUSION

The present chapter introduced a VAR model with exogenous variables for testing one sided non-causality by extending the works of Dufour and Renault (1998) and Dufour et *al.* (2006). In this context, it derived a test statistic for formally investigating one sided non-causality, while providing a simple algorithm for implementing the one sided non-causality test in a system framework and not equation by equation through OLS extending, thus, Dufour et *al.* (2006). We illustrated our approach by using a monthly dataset including dummy variables on Total Car Sales in the area of Athens over the period 2003-2012. According to our findings all macroeconomic variables cause the evolution of Total Sales cycles immediately and for almost eight (8) quarters when most of the causality effects die out completely.

CONCLUDING REMARKS

The present Doctoral Thesis attempted to shed light on basic aspects of the crisis and its consequences both at the international and national levels, respectively. In this context, throughout the eight chapters of the Thesis, a variety of econometric and analytical techniques have been developed and used in order to sufficiently tackle the research questions posed.

Analytically, in the first chapter, we estimated a GVAR model in order to study the transmission of the Debt crisis between EU15 and USA, on a quarterly basis, in the 2000 (Q1) – 2011 (Q4) time span. Our work is based on the global variables of trade and credit, which act as transmission channels, whereas EU15 is being treated as a single economy.

In general, in both countries, we did not witness any factor that could create a long lasting effect in their key macroeconomic variables. The results suggested that EU-15 is more vulnerable to incoming shocks from US, since the reaction of its macroeconomic variables examined is less smooth and more lasting compared to those of the US. The difference in the smoothness of the response between the two economies could be attributed to the fact that in the USA the Federal Reserve Bank reacted more effectively to the incoming shocks by implementing both monetary and fiscal adjustments. In contrast, the EU15 fiscal policy is implemented at a country-to-country level, while monetary policy is implemented by ECB at an aggregate level, thus, coordination problems could arise.

In the second chapter, we established an upgraded compact (macro)econometric tool that could incorporate both the complex interdependencies that exist between the various economic entities and the fact that in the global economy more than one of these entities could have a predominant role. In this context, we have extended the GVAR model of Chudik and Pesaran (2013), featuring one dominant economy, in order to incorporate more than one dominant entity. Additionally, based on the trade weight matrix that lies in the core of the GVAR framework, we have provided both an analytical procedure and an *ex-post* econometric criterion for the selection of dominant entities. We illustrated the dynamics of the proposed SGVAR model by assessing, among other things, the impact of a shock in the economic activity of the BRICs on the US and EU17 economies, respectively.

In brief, the second chapter of the Thesis contributed to the research conducted on GVAR in the following ways: (a) it proposed system estimation for GVAR with *K* dominants; (b) it formally estimated a GVAR with two (2) dominant economies; (c) it set out a formal method for indentifying the number of dominant entities in a GVAR framework; (d) it set out a novel method based on network theory for selecting the dominant entities; (e) it compared the estimation results of GVAR using one dominant and two dominant economies, respectively; (e) it estimated the impact of a shock in the economic activity of the BRICs on the US and EU17 economies, respectively.

The purpose of the third chapter was threefold. First, it tried to answer some fundamental economic questions regarding the determinants of business cycles in the EU-12 (1996-2013), using Dynamic panel data analysis. Second, it tried to acknowledge the significant role of Political Business Cycles (PBC) investigating their indirect role on the business cycle of the EU-12 economies to the overall business cycles. Third, it made an attempt to shed light on the dynamics of the recent crisis by using cluster analysis.

The results suggested that all EU-15 economies share similar short-term and mid-term cycles of approximately 2 and 6-8 years, respectively. Cross-correlation results between the cyclical variable of GDP and the rest of the fiscal variables suggested that the dynamics of the German economy differ significantly, compared to the rest of the EMU countries. Furthermore, Social benefits, Social Transfers and Gross Debt were found to be the most significant counter-cyclical fiscal variables, while taxation - both direct and indirect - is the major pro-cyclical variables. This result is also consistent with the use of the Toda-Yamamoto causality test. In addition, elections and institutions seemed to directly affect the key fiscal variables of the model, suggesting that manipulation of fiscal determinants is possible through political variables. In fact, both Quality of institutions and Elections seemed to have an indirect pro-cyclical effect on the EU-12 business cycle. Lastly, the results of cluster analysis suggested the existence of three major core clusters, including three major EU economies, while the recent crisis has led a number of smaller economies to cluster together.

Despite the vulnerability of the EU economy when compared to the US economy, the global recession was primarily triggered by the crisis in the USA. In this context, we attempted to shed light on the relationship between the quantity of money and economic activity, in the US economy. More precisely, in chapter four we examined the relation between the fluctuations in the quantity of money and the fluctuations in economic activity, i.e., the cyclical components of each variable.

The main finding of our research was that fluctuations in output/profitability cause fluctuations in the quantity of money, but fluctuations in the quantity of money *did not* cause fluctuations in output/profitability, giving priority to a *macroeconomic* point of view, where economic conjecture in the total economy, expressed through profitability and output, shapes the quantity of money, and not vice-versa. Our empirical findings, thus, implied a revision of the belief that the quantity of money is the causal factor.

In a broader context, based on our analysis, the monetary policies implemented by the Federal Reserve Bank before 2006, were not found to be causal on the total economic activity of the US economy. However, the mortgage bubble of 2006, evolved into a global crisis, which was comparable to the crisis of 1929. In this context, chapter five focused on the main question of whether such bubbles could be modeled and identified at an early stage. More precisely, the chapter attempted to detect and date non-linear bubble episodes. To do so, we used Neural Networks to capture the neglected non-linearities. Also, we provided a recursive dating procedure for bubble episodes.

Based on the related literature, we used recursive estimation techniques for dating multiple bubble episodes, while attempting to detect and date bubble episodes based on the unit root behavior of key financial variables. More precisely, we extended the literature in the field by using ANNs in an attempt to formally approximate the basic unit root specification so as to account for neglected non-linearities.

According to our findings, the proposed specification is fully capable of capturing the bubble episodes in the time period examined. Additionally, the bubble periods identified are longer in comparison to previous works in the literature. Therefore, in general terms, our specification could be thought of as an early warning device for bubble formation, which in turn could have important implications.

Despite the fact that we established a sound econometric and analytical framework on the identification of bubble formation, the question regarding the driving forces of the US economiy, still remains unanswered. In this context, in chapter six, we focused on the sectoral behaviour of the U.S. economy. Analytically, we investigated whether sector size matters for sectoral (i) technological change and (ii) stability, as expressed through the relevant quantitative measures and variables. We tested a number of relevant models that express the various forms of this relationship by using panel data for the fourteen (14) main sectors of economic activity in the U.S.A. over the period 1957-2006, just before the first signs of the US and global recession made their appearance.

Our research results gave credit to the veiw that large economic units tend to invest more on R&D, but the units' propensity to invest in R&D declined for larger units in the US economy (1957-2006). The same was in force for Total Factor Productivity (T.F.P.).

Finally, in the last part of the present Thesis, we focused on the Greek economy as whole and on a key sector. The Greek economy is one of the most prominent victims of the global crisis. In this context, in chapter seven we investigated the determinants of the Greek business cycles in attempt to identify the structural causes of the downturn of the Greek economy, in the time period 1995-2014. To this end, we made use of a wide dataset in a quarterly format, which contained all the major macroeconomic and financial variables that could, potentially, affect the Greek economy. Additionally, we made use of the modified concept of stepwise short-run causality of Dufour and Renault (1998) and Dufour et *al.* (2006) in order to investigate the causality of the key qualitative variables that enter the model.

This chapter, contributed to the literature in the following ways: (a) It was the first, to the best of our knowledge, that used a large dataset in quarterly format, for the investigation of the determinants of the Greek business cycle, in the time period 1995-2014; (b) It employed a number of relevant state-of-the-art econometric tests; (c) It acknowledged the significant effect of elections on the Greek business cycle; (d) It introduced a relevant VAR model with exogenous variables for testing one sided non-causality accounting for the possibility of qualitatitve variables.

According to our analysis, which was consistent with the periodization of the Greek economy, our empirical findings showed that the Greek business cycle exhibited two structural breaks one in the third quarter of 2004, i.e. 2004 (Q3) and one in the fourth quarter of 2011, i.e. 2011 (Q4). As a result, we splitted the period into two sub-periods: one in the period 1995-2004 (upward phase) and one in the period after 2005, up until recently (downward phase). In the two sub-periods, we examined the determinants of the Greek business cycle using backward selection multiple linear regression on a relevant vector of macroeconomic and financial determinants, acknowledging the significant role of elections in the course of the Greek business cycle. In the sub-period 1995-2004, the

10-year bond-yields and the elections were found to have a pro-cyclical character on the Greek business cycle, while the formation of EMU was found to have a counter-cyclical character. In the second sub-period of 2005-2012, Greek credit and imports were found have a strong pro-cyclical character, while the overall EU-17 business cycle and the "troika" seemed to have a countercyclical character on the Greek economy.

These findings are fully consistent with the results obtained through the stepwise step-by-step causality approach, according to which all the relevant variables dictate the evolution of Greek business cycles irrespective of the time horizon of the investigation.

Lastly, in the final chapter of the Thesis, chapter eight, we focused on a sector of the Greek economy that has been severely hit by the recent crisis in Greece, namely the car sales sector. In order to thoroughly investigate the short-run causality among the main quantitative and qualitative factors that influence the sector, we introduced a VAR model with exogenous variables for testing one-sided (non-)causality by extending the works of Dufour and Renault (1998) and Dufour et *al.* (2006). In this context, we derived a test statistic for formally investigating one sided (non-)causality, while providing a simple algorithm for implementing the one sided (non-)causality test in a system framework and not equation-by-equation extending, thus, Dufour et *al.* (2006). According to our findings all variables cause the evolution of Total Sales cycles immediately and for almost eight (8) quarters when most of the causality effects die out completely.

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APPENICES

Appendix A

Table A1: Lag Selection Criterion

Lags	US variables	EU-15 variables
	SBIC	SBIC
0	93.06	93.68
1	93.01	93.62
2	93.36	93.98
3	93.90	94.51
4	93.98	94.53

Table A2: Trade Weights Table

Trade Statistics Table			
	US	**EU-15**	**Rest**
US	0	0.21	0.79
EU	0.18	0	0.82

Note: Trade weights are computed as shares of exports and imports displayed in rows by region such that a row, but not a column, sums to one. *"Rest" gathers the remaining countries.

Appendix B

Table B.1: LLC Stationarity Test (original & first differenced variables)

Variable	t-stat(adjusted)	p-value	Stationarity
GDP	-5.43	0.00	Yes
SB	3.67	0.99	No
Δ(SB)	-4.48	0.00	Yes
ST	0.98	0.83	No
Δ(ST)	-0.12	0.00	Yes
GD	-1.94	0.03	Yes
UN	-5.26	0.00	Yes
I	□ 2.98	0.00	Yes
DT	-4.64	0.00	Yes
GDPcycle	-7.63	0.00	Yes
GDPEMUcycle	-8.47	0□ 00	Yes

Where Δ is the first difference operator

Figure B.1: GDP cycle-Social Benefits

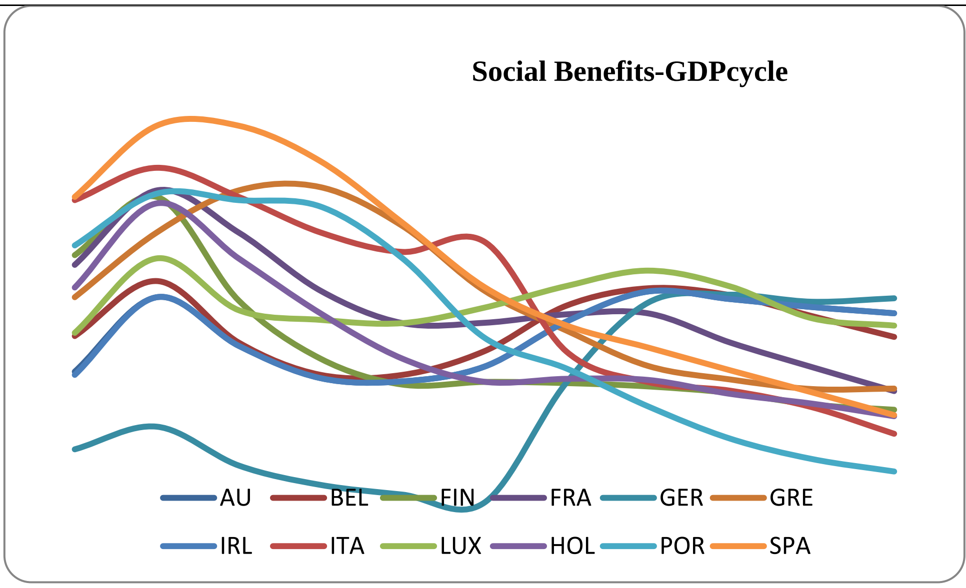


Figure B.2: GDP cycle-Social Transfers in Kind

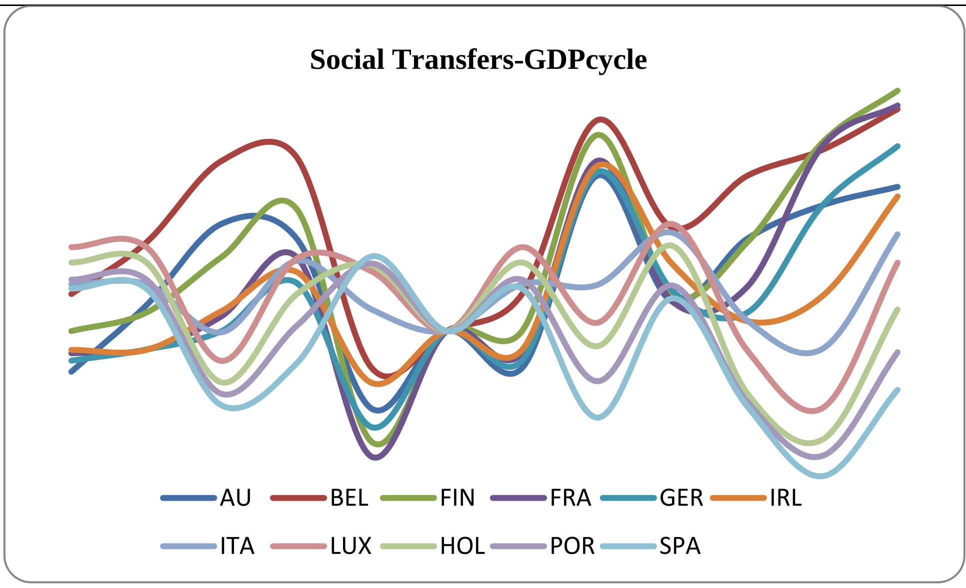


Figure B.3: GDP cycle- Aggregate EMU cycle

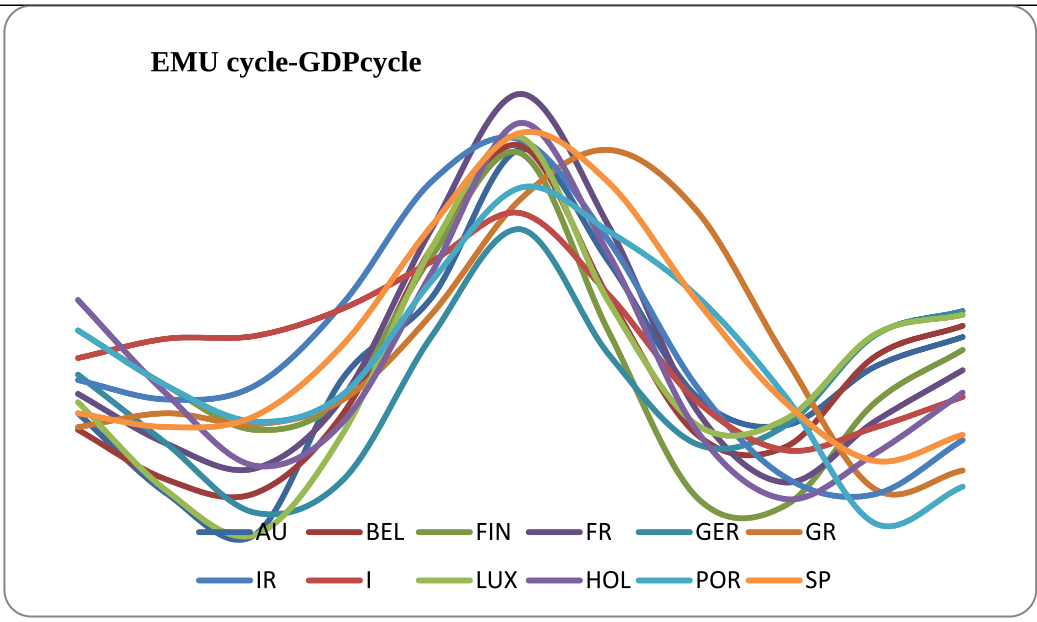


Figure B.4: GDP cycle-Government Capital Expenditures

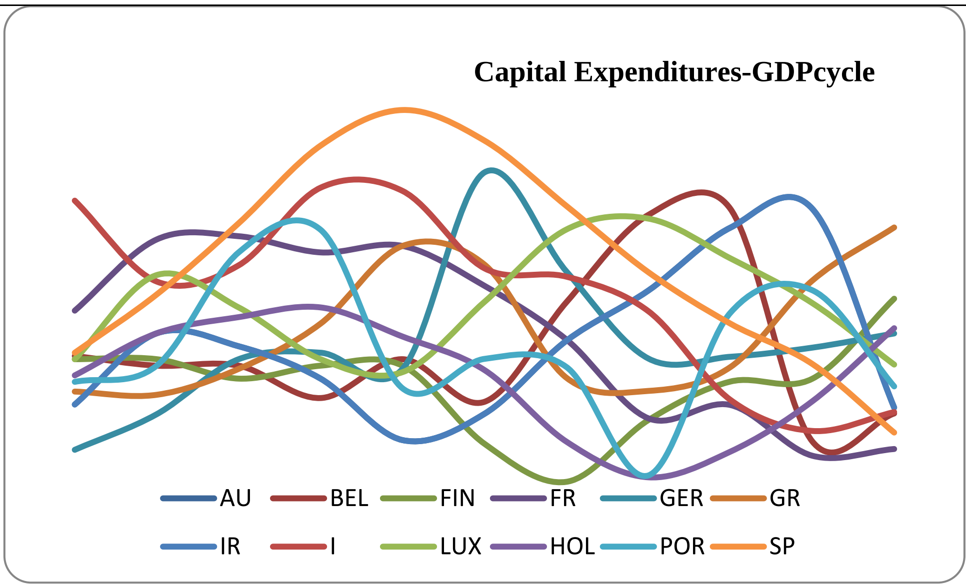


Figure B.5: GDP cycle - direct Taxes

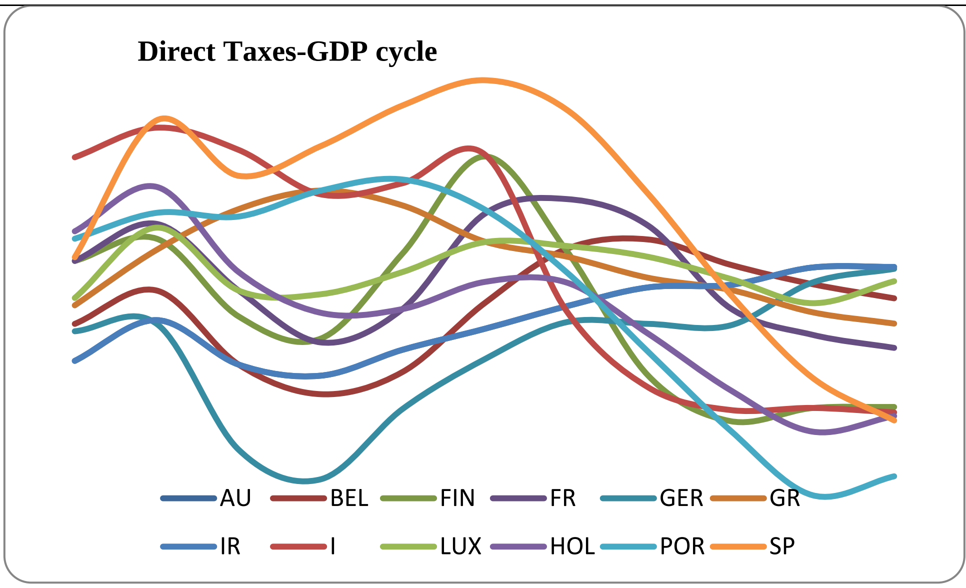
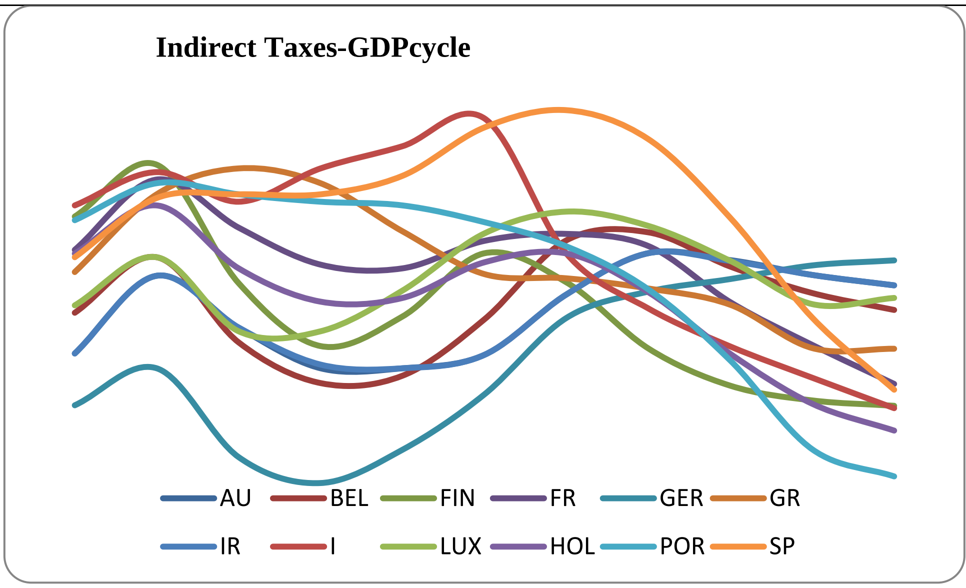


Figure B.6: GDP cycle-Indirect Taxes



Appendix C

Appendix C.1: Figures of Economic Fluctuations, Filters (HP) and (BK)

Figure C.1: Y (Gross Domestic Product)

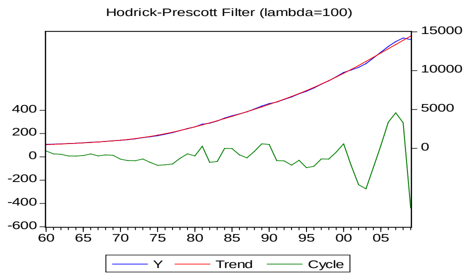


Figure C.2: K (Net Capital Stock)

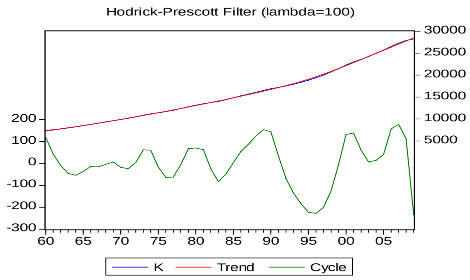


Figure C.33: W(wages)

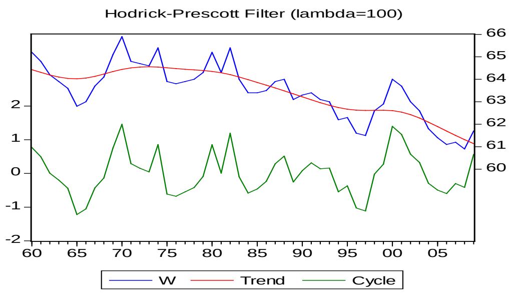


Figure C.4: Π (Profit rate)

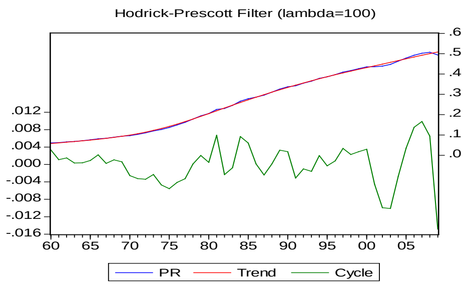


Figure C.5: M3 (Quantity of Money)

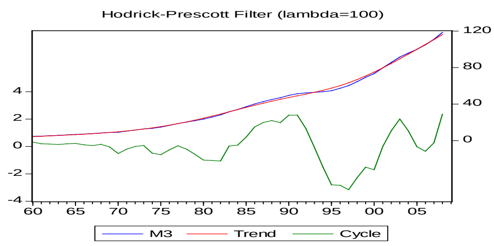


Figure C.6: Y (Gross Domestic Product)

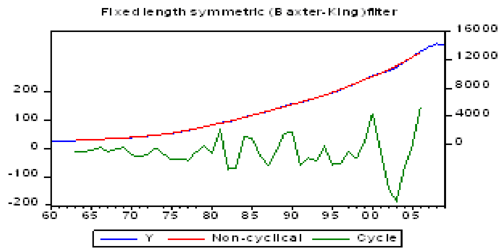


Figure C.7: K (Net Capital Stock)

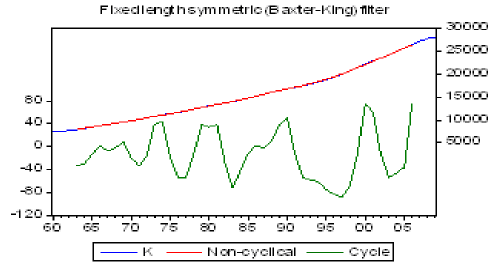


Figure C.8: W (Wages)

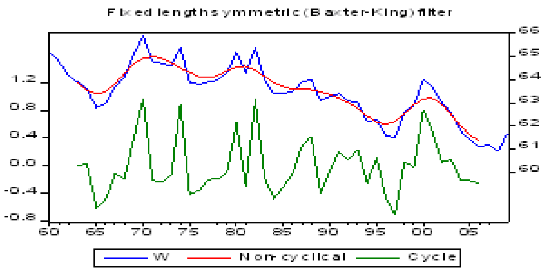


Figure C.9: Π (Profit rate)

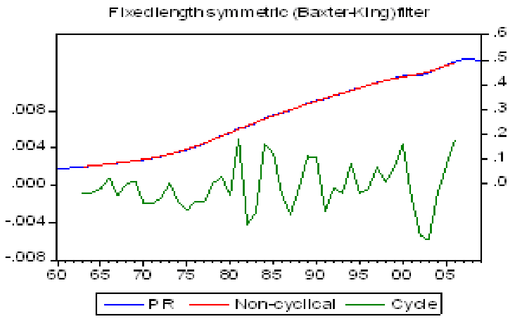
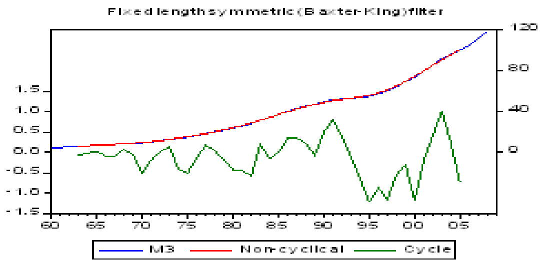


Figure C.10: M3 (Quantity of Money)



Appendix C.2: Correlation

	ϒ & M3	
I	**HP**	**BK**
8	0.2613	-0.0737
7	0.3093	-0.0041
6	0.3686	-0.0199
5	0.4418	0.0025
4	0.5318	0.1346
3	0.6416	0.3341
2	0.7744	0.3664
1	0.9326	-0.1441
0	0.9984	-0.3894
-1	0.9265	-0.069
-2	0.7657	0.146
-3	0.6334	0.0701
-4	0.5268	-0.0734
-5	0.4425	-0.0686
-6	0.3763	0.1393
-7	0.3235	0.1532
-8	0.2799	0.0712

Table C.1

	Π& M3	
i	**HP**	**BK**
8	0.2515	0.1226
7	0.3045	0.2415
6	0.3654	0.2245
5	0.4373	0.0219
4	0.5234	-0.0493
3	0.6264	0.0282
2	0.7482	0.1113
1	0.8902	-0.0511
0	0.9669	-0.3935
-1	0.9288	-0.2832
-2	0.8165	0.188
-3	0.7159	0.1587
-4	0.6261	0.0839
-5	0.5459	0.0343
-6	0.4742	0.0714
-7	0.4105	0.0833
-8	0.3543	-0.0526

Table C.2

Appendix D.1: Mathematical Appendix

Theorem 1: Consider $X \subseteq \mathbb{R}^N$ a compact subset of $\mathbb{R}^N$ and C(X) the space of all real valued functions defined on X. Let $\varphi: X \to \mathbb{R}$ be a non-constant, bounded and continuous function. Then, the family:

$\mathcal{F} = \{F(x) \equiv \sum_{i=1}^{N} a_i \varphi(w_i^T x + b_i), a_i, b_i \in \mathbb{R}, w_i \in \mathbb{R}^N\}$ is dense on $C(X)$.

Proof: See Hornik (1991).

Definition 2: If $x_{t_i}, i \in I$ is an arbitrary time series such that $x_{t_i} \in \mathbb{R}^N \forall i \in I$, and $\forall i \in I, \forall t \in T$, we define $\bigcup_{i \in I} x_{t_i} \subset \mathbb{R}^N$ to be the time series set.

Proof of Theorem 2

The proof is trivial and is based on the fact that any closed and bounded subset of $\mathbb{R}^N$ is compact (e.g. Rudin, 1976).

Proof of Theorem 3

Without loss of generality, let $g: \mathbb{R}^N \to \mathbb{R}$ be a function of the form $g(x_{t_i-1}) = \rho x_{t_i-1}$. Then, the function $k: \mathbb{R}^N \to \mathbb{R}$ is defined as the product of functions $g: \mathbb{R}^N \to \mathbb{R}$ and $F(x_{t_i-1}): \mathbb{R}^N \to \mathbb{R}$, i.e. $k(x_{t_i-1}) \equiv g(x_{t_i-1}) \cdot F(x_{t_i-1})$.

(i) Let $i \in I$ and $t \in T$. $F(x_{t_i-1}): \mathbb{R}^N \to \mathbb{R}$ is non-constant by definition when $a_n \neq 0$, for some $n \in \mathbb{N}$. In order to prove that $k: \mathbb{R}^N \to \mathbb{R}$ is also non-constant, it suffices to prove that $g: \mathbb{R}^N \to \mathbb{R}$ is non constant. But, by definition, $\rho \in \mathbb{R}$ and $x_{t_i-1} \neq 0$ for some $t \in T$, and, hence $g: \mathbb{R}^N \to \mathbb{R}$ is non constant.

(ii) Let $i \in I$ and $t \in T$. Since $F(x_{t_i-1}): \mathbb{R}^N \to \mathbb{R}$ is bounded, in order to prove that $k: \mathbb{R}^N \to \mathbb{R}$ is bounded, it suffices to prove that $g: \mathbb{R}^N \to \mathbb{R}$ is bounded i.e. $|g(x_{t_i-1})| <$

M, $M \in \mathbb{R}$. By construction, $g: \mathbb{R}^{\mathrm{N}} \to \mathbb{R}$ is bounded since $\rho \in \mathbb{R}\ \forall t \in T$. Hence, there exists a $M \in \mathbb{R}$ such that $\left|g\left(x_{t_i-1}\right)\right| < M, \forall i \in I$. Hence, $g: \mathbb{R}^{\mathrm{N}} \to \mathbb{R}$ is bounded.

(iii) Let $i \in I$ and $t \in T$. The function $k: \mathbb{R}^{\mathrm{N}} \to \mathbb{R}$ is continuous as the product of the continuous functions $F\left(x_{t_i-1}\right): \mathbb{R}^{\mathrm{N}} \to \mathbb{R}$ and $g\left(x_{t_i-1}\right): \mathbb{R}^{\mathrm{N}} \to \mathbb{R}$.

Proof of Theorem 4

From Theorem 2, the set of time series is compact. From Theorem 3, any function of the form $k(x_{t_i-1}) \equiv \rho x_{t_i-1} \cdot F(x_{t_i-1})$, $\rho \in \mathbb{R}$ is continuous, bounded and non-constant. Hence, from Theorem 1, the family: $\mathcal{F} = \{k(x_{t_i-1}) \in \mathrm{C}\left(\bigcup_{j\in J} G_j\right): k(x_{t_i-1}) \equiv \rho x_{t_i-1} \cdot F(x_{t_i-1}), F\left(x_{t_i-1}\right) \equiv \sum_{n=1}^{N} a_n \varphi(\beta_n \cdot x_{t_i-1})$, with a_n, $\beta_n \in \mathbb{R} \forall n \in \mathbb{N}$, $\rho \in \mathbb{R} \neq \infty\}$ is dense in $\mathrm{C}(\bigcup_{j\in J} G_j)$.

Proof of Proposition 1

Let x_{t_i}, $i \in I$ be an arbitrary time series of length *T*>0. Then the proposed specification implied by equation (12) for x_{t_i} is:

$$x_{t_i} = \rho a_1 {x_{t_i-1}}^{\beta_1+1} + \rho a_2 {x_{t_i-1}}^{\beta_2+1} + \cdots + x_{t_i-1} + \varepsilon_t$$

By application of the lag operator L, we get:

$$x_{t_i} = \rho a_1 L {x_{t_i}}^{\beta_1+1} + \rho a_2 L {x_{t_i}}^{\beta_2} + \cdots + L x_{t_i} + \varepsilon_{t_i}$$

Using the linearity of the lag operator, we get:

$$x_{t_i} = \rho a_1 L x_{t_i} {x_{t_i}}^{\beta_1} + \rho a_2 L x_{t_i} {x_{t_i}}^{\beta_2+1} + \cdots + L x_{t_i} + \varepsilon_{t_i}$$

$$x_{t_i}\left(1 - L\left(\rho \alpha_1 {x_{t_i}}^{\beta_1} + \rho \alpha_2 {x_{t_i}}^{\beta_2} + \cdots + 1\right)\right) = \varepsilon_{t_i}$$

Therefore, x_{t_i} is a stationary process of the form $x_{t_i} = \frac{\varepsilon_{t_i}}{1 - L(\rho\alpha_1 + \rho\alpha_2 + \cdots + 1)}$ when $1 - L(\rho\alpha_1 + \rho\alpha_2 + \cdots + 1) \neq 0$, $\beta_n \in |B(0, \varepsilon)|$, $\varepsilon > 0$. This, in turn, implies that: $\rho \sum_{n=1}^{N} \alpha_n \neq 0$. Thus: $\sum_{n=1}^{N} \kappa_n \neq 0$, since: $\rho a_n = \kappa_n \forall\ n \in \mathbb{N}$. This completes the proof.

Appendix D.2: Econometric Appendix

The proposed approach uses a Bayesian approach because it has numerous advantages related to overcoming the over-fitting problem associated with the traditional approaches, but also due to its increased flexibility. Probably, the main advantage of our approach is the possibility of mixing different pieces of information (sample information, prior information, etc) in order to construct a model that accounts for the stochastic character of the variables.

Analytically, the main reason for using a Bayesian approach is that it facilitates representing and taking fuller account of the uncertainties related to model and parameter values. In contrast, most decision analyses based on maximum likelihood or least squares estimation involve fixing the values of parameters that may, in actuality, have an important bearing on the final outcome of the analysis and for which there is considerable uncertainty. Hence, one of the major benefits of the Bayesian approach is the ability to incorporate prior information, which, along with other numerical methods, makes computations tractable for virtually all parametric models. See, for instance, Carlin and Lewis (2000), Robert (2001) and Wasserman (2004).

We statistically assess, using Bayesian techniques, the following system of equations:

$$\left.\begin{array}{c} \Delta x_{t_i} = {\kappa_1}^{r_{w_j}} \cdot {x_{t_i-1}}^{{\delta_1}^{r_{w_j}}} + {\kappa_2}^{r_{w_j}} \cdot {x_{t_i-1}}^{{\delta_2}^{r_{w_j}}} + \cdots + {\kappa_N}^{r_{w_j}} \cdot {x_{t_i-1}}^{{\delta_N}^{r_{w_j}}} + \sum_{i=1}^{N} {b_i}^{r_{w_j}} \Delta x_{t_i-p} + {\varepsilon_t}^{r_{w_j}} \\ \sigma_{t_i}^2 = {a_0}^{r_{w_j}} + {a_1}^{r_{w_j}} \sigma_{t_i-1}^2 + {a_2}^{r_{w_j}} {\varepsilon_{t_i-1}}^2 \end{array}\right\} \textbf{(D.1)}$$

The model needs an identification condition for κ_i's, since we are unable to identify them with any alternative procedure. In this context, we begin by imposing the identification conditions $\kappa_1 < \kappa_2 < \kappa_3 < \ldots < \kappa_N$

We, then, approximate the marginal likelihood of the model using the Laplace approximation (DiCiccio et *al.,* 1997). This procedure is fast and easy to apply, which is important in this context where repeated MCMC simulations have to be considered. It also has the advantage that it takes into consideration both the suitability of the model and the overfitting problem. The Laplace approximation to the log marginal likelihood of the model is:

$$L_K = -\frac{T+1}{2} log|\boldsymbol{A}| + \frac{d+L}{2} \log(2\pi) + \frac{1}{2} log\left|\widehat{\boldsymbol{\Delta_K}}\right| \textbf{ (D.2)}$$

where: $\widehat{\boldsymbol{\Delta}_{\boldsymbol{K}}}$ is an estimate of the covariance matrix of the ML estimator of $\boldsymbol{\Theta}_{\boldsymbol{K}}$ (inverse Hessian of the log likelihood). This can be approximated by the covariance of the MCMC draws, after convergence and using thinning or an autocorrelation – consistent estimate.

Bayesian inference is performed through a Markov Chain Monte Carlo (MCMC) procedure (Tierney, 1994) that resembles the Gibbs sampler using 1,500,000 iterations, the first 500,000 of which are discarded to mitigate start up effects. The long MCMC is needed to guarantee convergence starting from arbitrarily different initial conditions for the parameters. Convergence is assessed from ten different chains in terms of computed posterior probabilities for the different episodes as well as for the specific period during which the episodes occur.

Using the proposed specification for the detection of financial bubbles for each MCMC draw of parameters (Tierney, 1994), we compute the derivatives of $k(x_{t_i-1}) \equiv g\left(x_{t_i-1}\right) \cdot F(x_{t_i-1})$ that are used for the identification of unit root behavior and thus for the formation and collapse of bubbles.

The number of nodes is selected from all possible combinations using the marginal likelihood in (20), which can be computed relatively easily and efficiently. The model with the highest marginal likelihood is selected. In this context, by approximating the marginal likelihood of the model using the Laplace approximation following DiCiccio et *al.* (1997), we finally select the number of nodes to be *N*=3. Next, we compute posterior probabilities that we have a bubble or collapse during certain periods.

It should be noted that the parameter estimates are updated from their previous values using sampling-importance resampling (Smith and Gelfand 1992). The size of the resample in SIR was set to 10% of the original MCMC samples. Also, the length of the initial sub-sample r_{w_j}, i.e. $r_{w_0}$is 10, sufficiently small so as to ensure that no bubble will be missed and, meanwhile, that there are enough observations for estimation, in a Bayesian framework.

Of course, we need to ensure the robustness of our results, in the sense that they do not depend critically on the assumptions and calculation on which they were based. As a result, our analysis was applied to numerous logically and empirically plausible priors selected from relevant classes of priors (Berger 1985). In this context, in Table 5.1, we present the baseline priors of $\kappa's$, $\delta's$ and $a's$, as well as a set of alternative priors, which are centered at *m* and have standard deviations *s*.

Table D.1: Priors

Parameter	**Baseline Priors**	**Alternative priors (m)**	**Alternative priors (s)**
$\kappa_1, \kappa_2, \ldots$	$N(0,10)$	$N(0,100)$	$\lvert N(0,100) \rvert$
$\delta_1, \delta_2, \ldots$	$\lvert N(1,0.01) \rvert$	$\lvert N(1,0.1) \rvert$	$\lvert N(0,0.1) \rvert$
a_0, a_1, a_2	$\lvert N(0,10) \rvert$	$\lvert N(0,100) \rvert$	$\lvert N(0,100) \rvert$

We produced 10,000 computations under the specified alternative priors and the calculated results – which are available upon request by the authors – were not found to be sensitive to the alternative priors used. This clearly implies that we can safely proceed based on these findings. For a detailed discussion on the theoretical foundations of prior selection see, for instance, Kass and Wasserman (1996).

Appendix E

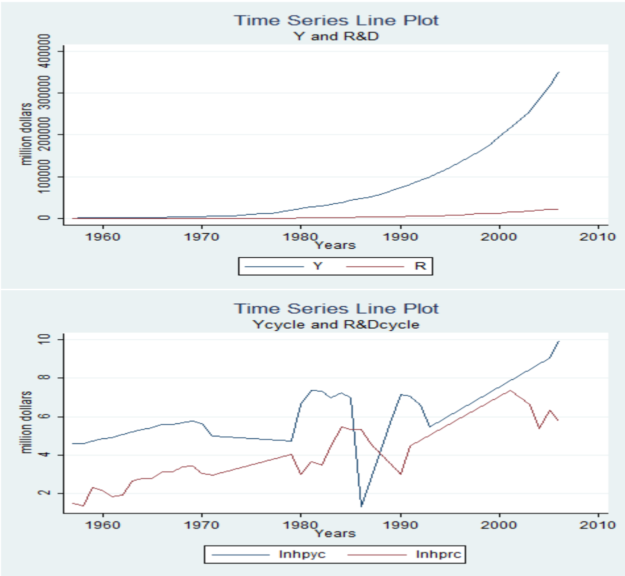


Figure E.1: Aggregate data on Total output and R&D expenses in the U.S. economy (1960-2010).

Figure E.2: Aggregate data on the cyclical components of Total output and R&D expenses in the U.S. economy (1960-2010).

Appendix F

Table F.1: Description of Data and Sources

Variables	Description	Data and Sources
$Y_{cycle\ GR\ (t)}$	The cyclical component of the BK filtered quarterly GDP time series for Greece, in year t.	Extracted by means of BK filtering in the Variables of Greek GDP and EU-17 GDP, coming from the OECD database in billions of euros in 2000 prices, covering the period 1995(Q1)-2014(Q3).
$Y_{cycleEU\ (t)}$	□ The cyclical component of the BK filtered quarterly GDP time series for EU17, in year t	
$FDI_{GR\ (t)}$	The Foreign Direct Investment inflows to the Greece, in year t.	OECD□ database, in billions of euros in 2005 prices, coveving the period 1995(Q1)-2014 (Q3).
$CR_{GR\ (t)}$	The Current account Credit in Greece, in year t.	
$DT_{GR\ (t)}$	The Greek outstanding Debt, in year t.	
$UN_{GR\ (t)}$	The percent of Greek unemployment, in year t.	OECD database, percent, covering the period 1995 (Q1)-2014 (Q3).
$IM_{GR\ (t)}$	The value of Greek Imports, in year t.	OECD database, in billions of euros in 2005 prices, covering the period 1995 (Q1)-2014 (Q3).
$EX_{GR\ (t)}$	The value of Greek Exports, in year t.	
$BY_{GR(t)}$	The 10-year yield of Greek Bonds, in ye□ r t.	OECD database, percent, covering the period 1995 (Q1)-2014(Q3).
Cr_{06}	The dummy variable for the global recession taking the value 1 during 2006(Q3)-2009 (Q4) and 0 elsewhere.	Constructed by the author
Tr_{10}	The dummy variable for Troika's measures taking the value 1 in the period 2010 (Q1)-2014 (Q3) and 0 elsewhere.	
EMU_{01},	The dummy variable for the formation of EMU taking the value of 1 during the period 2000 (Q1)-2001 (Q4) and 0 elsewher□ .	
GE	The dummy variable for Greek elections that take the value of 1 in the quarter that elections took place as well as in the following quarter after the elections, and 0 elsewhere.	
PSI_{11}	The dummy for the PSI taking the value of 1 in the period 2011(Q3)-2012(Q2) and 0 elsewhere	

Table F.2: BIC and Steps of Backward elimination using 10,000 bootstrapped replications, 1995 (Q1)-2003 (Q4)

Steps of Backward elimination	Omitted Variables in each step	P-value>P	BIC
1	None	-	-19.568
2	FDI	0.925	-19.229
3	EX	0.947	-22.684
4	IM	0.921	-26.13
5	CR	0.847	-29.524
6	DT	0.635	-31.941
7	UN	0.374	-34.377
8	Ycycle EU-17	0.401	-36.763

Table F.3: Correlation matrix of the dependent variables, 1995(Q1)-2003(Q4)

Dependent Variables	BY	EMU	GE
BY	1	-	-
EMU	-0.18	1	-
GE	0.03	0.23	1

Table F.4: Jarque-Bera Normality test for the residuals, 1995(Q1)-2003(Q4)

Chi-squared	1.16
P-value	0.57

Table F.5: White's Heteroscedasticity test, 1995(Q1)-2003(Q4)

White's LM statistic	3.99
P-value	0.13

Table F.6: BIC and Steps of Backward elimination using 10,000 bootstrapped replication, 2005 (Q3)-2011 (Q4)

Steps of Backward elimination	Omitted Variables in each step	P-value>P	BIC
1	None		31.444
2	UN	0.977	28.213
3	PSI	0.959	25.046
4	FDI	0.853	25.681
5	DT	0.773	22.823
6	BY	0.772	19.931
7	GC	0.654	17.058
8	EX	0.213	16.416
9	ELE	0.325	14.86

Table F.7: Correlation matrix of the dependent variables, 2005 (Q3)-2011 (Q4)

Dependent Variables	Ycycle EU-17	IM	CR	Troika
Ycycle EU-17	1	-	-	
IM	-0.16	1	-	
CR	0.05	0.28	1	
Troika	0.56	-0.19	0.07	1

Table F.8: Jarque-Bera Normality test for the residuals, 2005 (Q3)-2011 (Q4)

Chi-squared	0.15
P-value	0.92

Table F.9: White's Heteroscedasticity test, 2005 (Q3)-2011 (Q4)

White's LM statistic	0.26
P-value	0.87