TECHNICAL UNIVERSITY OF CRETE

SCHOOL OF PRODUCTION ENGINEERING & MANAGEMENT

Predicting the impact of groups of interest on the Greek economy using soft computing

Ph.D. Thesis

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ΠΟΛΥΤΕΧΝΕΙΟ ΚΡΗΤΗΣ

ΤΜΗΜΑ ΠΑΡΑΓΩΓΗΣ ΚΑΙ ΔΙΟΙΚΗΣΗΣ

Πρόβλεψη της επίδρασης των ομάδων συμφερόντων στην Ελληνική οικονομία με χρήση εύκαμπτης πληροφορικής

ΔΙΔΑΚΤΟΡΙΚΗ ΔΙΑΤΡΙΒΗ

Παπαδάκης Χαράλαμπος

Χανιά, Δεκέμβριος 2022

ΕΠΤΑΜΕΛΗΣ ΕΞΕΤΑΣΤΙΚΗ ΕΠΙΤΡΟΠΗ

Τίτλος: Πρόβλεψη της επίδρασης των ομάδων συμφερόντων στην Ελληνική Οικονομία με χρήση εύκαμπτης πληροφορικής /

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Στις γυναίκες της ζωής μου,

Μυρτώ,

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ΠΕΡΙΛΗΨΗ

Η παρούσα διδακτορική διατριβή μελετά την επίδραση των ομάδων συμφερόντων στην οικονομία της Ελλάδας, χρησιμοποιώντας εύκαμπτη πληροφορική, η οποία είναι ένας συνδυασμός ασαφούς λογικής, νευρωνικών δικτύων και γενετικών αλγορίθμων.

Ο Mancur Olson στο σημαντικό του βιβλίο "The Logic of Collective action" (1965), αναπτύσσει την θεωρία του θεωρώντας ότι ο κάθε άνθρωπος δρα ώστε να ικανοποιεί το προσωπικό του συμφέρον λαμβάνοντας πάντα υπόψη του το όφελος το οποίο μπορεί να έχει από μία συλλογική δράση αλλά και το κόστος. Έτσι ο Olson θέτει τα θεμέλια για την ελεύθερη συμπεριφορά των μελών των ομάδων, όπως και δημιουργεί μία ταξινόμηση των ομάδων συμφερόντων, καθώς το ατομικό όφελος επηρεάζεται από το μέγεθος της ομάδας και τη φύση των συμφερόντων που χαρακτηρίζουν την κάθε ομάδα. Στο επόμενο πρωτοποριακό βιβλίο του "The Rise and Decline of Nations" (1982), ο Mancur Olson αναπτύσσει εννιά επιπτώσεις που επιφέρει η δράση τους σε διάφορους τομείς σε μία χώρα και με εμπειρικά παραδείγματα από την εποχή των αυτοκρατοριών έως την σύγχρονη εποχή μας, αποδεικνύει την ορθότητα τους.

Η συγκρότηση, ο διαφορετικός τρόπος δράσης της κάθε ομάδας συμφερόντων απασχολεί πολλούς κοινωνιολόγους και πολιτικούς επιστήμονες μέχρι σήμερα, ενώ οι επιπτώσεις της δράσης τους επηρεάζουν πολλούς τομείς σε μία χώρα, όπως την οικονομία, την κοινωνική συνοχή, την δικαιοσύνη, την λειτουργία των θεσμών και πολλών άλλων. Από την σύγχρονη βιβλιογραφία υπάρχουν σημαντικές αναφορές και ενδείξεις για τη δράση των ομάδων συμφερόντων στην Ελλάδα κυρίως μετά την πτώση της δικτατορίας το 1974.

Η παρούσα διατριβή εστιάζει μόνο στην επιρροή της δράσης των ομάδων συμφερόντων στην οικονομία της Ελλάδας, βασιζόμενη κυρίως σε τρεις από τις εννέα επιπτώσεις όπως τις έχει αναπτύξει ο Olson (1982). Πιο αναλυτικά οι επιπτώσεις αυτές αναφέρουν ότι, α) οι χώρες με σταθερά σύνορα τείνουν να ενισχύουν την οργάνωση και δράση τον ομάδων συμφερόντων με την πάροδο του χρόνου, β) οι ομάδες συμφερόντων και συντεχνίες μειώνουν την αποτελεσματικότητα και το συνολικό εισόδημα των κοινωνιών στις οποίες λειτουργούν και κάνουν την

πολιτική ζωή πιο διχαστική, γ) οι ομάδες συμφερόντων επιβραδύνουν την ικανότητα μιας κοινωνίας να υιοθετήσει νέες τεχνολογίες και να ανακατανείμει τους πόρους, μειώνοντας έτσι τον ρυθμό οικονομικής ανάπτυξης.

Η μελέτη της επίδρασης των ομάδων συμφερόντων στην οικονομία μίας χώρας είναι ένα αντικείμενο πολυδιάστατο το οποίο εξαρτάται από πολλούς παραμέτρους και επηρεάζει πολλές οικονομικές μεταβλητές στην κάθε χώρα. Η διδακτορική διατριβή έχει δύο κύριους ερευνητικούς σκοπούς. Ο πρώτος είναι, να προσδιοριστούν οι οικονομικές μεταβλητές οι οποίες είναι κατάλληλες για να εκφράσουν την δράση των ομάδων συμφερόντων στην Ελλάδα, με συνδυασμό της μελέτης από την διεθνή βιβλιογραφία του μεγάλου αριθμού οικονομικών μεταβλητών που έχουν χρησιμοποιηθεί ερευνητικά και της χρήσης σύγχρονων μεθόδων ανάλυσης δεδομένων. Ο δεύτερος σκοπός είναι, η δημιουργία και η εφαρμογή ενός σύγχρονου μοντέλου πρόβλεψης, το οποίο με τις τιμές των παραπάνω κατάλληλων μεταβλητών για ένα ευρύ χρονικό διάστημα, τις οποίες θα χρησιμοποιεί ως μεταβλητές εισόδου και εξόδου θα κάνει αξιόπιστη πρόβλεψη των τιμών της μεταβλητής εξόδου.

Η διδακτορική διατριβή αποτελείται από πέντε κεφάλαια, όπου στο πρώτο κεφάλαιο γίνεται εκτενής αναφορά στον ορισμό, τα είδη και την δράση των ομάδων συμφερόντων στην Ελλάδα, όπως και παρουσιάζεται η θεωρία του Olson σχετικά την συλλογική δράση των ομάδων συμφερόντων και τις επιπτώσεις τους στην οικονομία των χωρών. Ως ομάδα συμφερόντων ονομάζεται μία οργάνωση που δημιουργήθηκε για να υπερασπιστεί τα συμφέροντα των μελών της και η οποία δύναται να ασκεί πιέσεις σε θεσμούς και δημόσιες αρχές με σκοπό να αποσπάσουν όφελος από αυτές. Οι ομάδες συμφερόντων αναλόγως το αντικείμενο ενδιαφέροντος τους μπορούν να διαχωριστούν σε επιχειρηματικές και οικονομικές, εργασιακές, επαγγελματικές, αγροτικές, περιβαλλοντικές, καταναλωτικές, ιδεολογικές, δημοσιοϋπαλληλικές, και κυβερνητικές. Μία ολοκληρωμένη θεωρία για την δημιουργία, τη οργάνωση και επιδράσεις των ομάδων συμφερόντων έχει αναπτυχθεί από τον Mancur Olson (1965) και (1982), θεωρώντας ότι τα άτομα που συμμετέχουν στις ομάδες συμφερόντων, νοιάζονται κυρίως για το προσωπικό τους όφελος και συνεπώς εστιάζουν στο όφελος αλλά και στο κόστος από την συμμετοχή τους σε μία συλλογική δράση, όπως και ότι τα οφέλη αλλά και το κόστος για το κάθε μέλος, επηρεάζεται από το μέγεθος της ομάδας και τη φύση των συμφερόντων που χαρακτηρίζουν μια ομάδα, (The Logic of

Collective Action, Olson 1965). Η δράση των ομάδων συμφερόντων έχει παρατηρηθεί και στην Ελλάδα όπου υπάρχει σχετική πλούσια βιβλιογραφία από την πτώση της δικτατορίας το 1974 και μετά, (Atsalakis et al. 2016, , Iordanoglou 2013, Lavdas 2007, Mavrogordatos 1988, Mavrogordatos 2009, Pelagidis and Mitsopoulos 2006, Spanou and Sotiropoulos 2011), και προφανώς έχει επηρεάσει την οικονομία της Ελλάδας, όπως προκύπτει και από τα αποτελέσματα της μελέτης της διατριβής, τα οποία δημοσιεύθηκαν και στο διεθνές περιοδικό Suntext Review of Economics & Business με στοιχεία δημοσίευσης Papadakis, H. Atsalakis, GS, Zopounidis, C., (2022). The Rise and Decline of Greece. *Suntext Review of Economics & Business* 3(3): 167.

Στο δεύτερο κεφάλαιο παρουσιάζεται μία αναλυτική παρουσίαση όλης της σχετικής βιβλιογραφικής έρευνας, σχετικά με διεθνείς δημοσιεύσεις που αφορούν την χρήση μεταβλητών στην έρευνα για την μελέτη της δράση των ομάδων συμφερόντων όπως και για την επίδραση τους στις οικονομίες των χωρών. Ως αποτέλεσμα της βιβλιογραφικής έρευνας έχει σχηματιστεί ένας πίνακας ο οποίος για κάθε δημοσίευση αναγράφει το ακριβές ερευνητικό πεδίο της δημοσίευσης, οι μεταβλητές που χρησιμοποιήθηκαν, οι πηγές των δεδομένων, το χρονικό διάστημα της έρευνας, το μοντέλο που χρησιμοποιήθηκε, όπως και τις σχετικές απαραίτητες σημειώσεις για κάθε δημοσίευση. Ολοκληρωμένη η βιβλιογραφική έρευνα δημοσιεύθηκε στο διεθνές περιοδικό International Journal of Sustainable Economics Management, με στοιχεία δημοσίευσης, "Papadakis, H., Atsalakis, G., (2019). Survey of Interest Groups Influence in an Economy, *International Journal of Sustainable Economies Management*, 8(2), 49-67".

Στο τρίτο κεφάλαιο, παρουσιάζεται όλο το θεωρητικό υπόβαθρο για την Ανάλυση Κύριας Συνιστώσας (Principal Component Analysis), μεθόδου ανάλυσης Δεδομένων, της θεωρίας της ασαφούς λογικής (fuzzy logic) και νευρωνικών δικτύων που συνθέτουν την εύκαμπτη πληροφορική (soft computing) και αποτελούν την βάση για τη δημιουργία του μοντέλου πρόβλεψης ANFIS (Adaptive Neural Fuzzy Inference System) που χρησιμοποιείται στην παρούσα έρευνα.

Νευρωνικά Δίκτυα είναι τα απλουστευμένα μοντέλα των ανθρώπινων νευρικών συστημάτων τα οποία προσομοιώνουν την ανθρώπινη ικανότητα να προσαρμόζεται σε συγκεκριμένες καταστάσεις και να εκπαιδεύεται από τις εμπειρίες του παρελθόντος. Τα συστήματα ασαφούς λογικής ασχολούνται με την αβεβαιότητα ή την ασάφεια που υπάρχει σε ένα σύστημα και διατυπώνουν ασαφείς κανόνες για να βρουν λύση στα προβλήματα. Η ασαφής λογική δεν λειτουργεί σε συγκεκριμένα όρια και παρέχει μία μεταβολή μετάβασης μεταξύ της συνάρτησης συμμετοχής των μεταβλητών για ένα συγκεκριμένο πρόβλημα. Οι δύο αυτές τεχνικές μπορούν να δώσουν αποτελεσματικές λύσεις σε ένα ευρύ φάσμα πολύπλοκων προβλημάτων που σχετίζονται με διαφορετικούς συνδυασμούς. Μπορούν όμως και να συνδυαστούν ώστε να συνδυάσουν τα πλεονεκτήματα τους και να ελαχιστοποιήσουν τις όποιες αδυναμίες τους. Συνεπώς ένα νευρο-ασαφές σύστημα μπορεί να οριστεί ως ένα ασαφές σύστημα που καθορίζει τις παραμέτρους του και επεξεργάζεται τα δεδομένα του χρησιμοποιώντας έναν αλγόριθμο εκμάθησης που βασίζεται στη θεωρία νευρωνικών δικτύων.

Στην κατηγορία των νευρο-ασαφών συστημάτων ανήκει και το μοντέλο ANFIS (Adaptive Network based Fuzzy Inference System) το οποίο αναπτύχθηκε από τον Jang (1992) και χρησιμοποιείται στην παρούσα έρευνα για την πρόβλεψη της επίδρασης των ομάδων συμφερόντων στην οικονομία της Ελλάδας. Το προσαρμοστικό δίκτυο (adaptive network) είναι ένα δίκτυο τροφοδοσίας πολλαπλών επιπέδων, στο οποίο κάθε κόμβος εκτελεί μία συγκεκριμένη λειτουργία στα εισερχόμενα σήματα και σε όλες τις παραμέτρους που αντιστοιχούν σε αυτόν τον κόμβο και συνδέονται μεταξύ τους μέσω κατευθυντικών συνδέσμων. Ορισμένοι ή όλοι οι κόμβοι σε ένα προσαρμοστικό δίκτυο είναι προσαρμόσιμοι, που σημαίνει ότι το αποτέλεσμα κάθε κόμβου εξαρτάται από τις παραμέτρους που σχετίζονται με αυτόν τον κόμβο και ο κανόνας εκμάθησης καθορίζει ότι αυτές οι παράμετροι πρέπει να αλλάξουν για να ελαχιστοποιηθεί ένα προκαθορισμένο μέτρο σφάλματος. Η νευρο-προσαρμοστική (neural-adaptive) τεχνική μάθησης διαθέτει μία μέθοδο για τη διαδικασία ασαφούς μοντελοποίησης στην εκμάθηση πληροφοριών σχετικά με ένα σύνολο δεδομένων. Υπολογίζει τις παραμέτρους της συνάρτησης μέλους που επιτρέπουν καλύτερα στο σχετικό σύστημα ασαφούς συμπερασμάτων να παρακολουθεί τα δεδομένα εισόδου-εξόδου.

Για κάθε μοντέλο πρόβλεψης είναι απαραίτητη να γίνεται η αξιολόγηση του, για κάθε αποτέλεσμα πρόβλεψης που προκύπτει από την λειτουργία του. Ως κριτήριο αξιολόγησης μεταξύ των διαφορετικών μεθόδων και μοντέλων έχει επικρατήσει από τη διεθνή βιβλιογραφία να είναι, ο υπολογισμός των αριθμητικών σφαλμάτων. Προφανώς το μοντέλο πρόβλεψης που παρουσιάζει τα μικρότερα αριθμητικά σφάλματα είναι και το πιο αξιόπιστο. Συνεπώς για κάθε εφαρμογή που τρέχει ο αλγόριθμος ANFIS θα υπολογίζονται και τα εξής αριθμητικά σφάλματα: Μέσο τετραγωνικό σφάλμα (MSE), Μέσο απόλυτο ποσοστό σφάλματος (MAPE), Μέσο απόλυτο σφάλμα (MAE), Ρίζα μέσου τετραγωνικού σφάλματος (RMSE).

Στο τέταρτο κεφάλαιο της διατριβής παρουσιάζονται αναλυτικά, η εφαρμογή της μεθόδου ανάλυσης δεδομένων Κύριας Συνιστώσας (PCA) για τον προσδιορισμό των κατάλληλων μεταβλητών που θα αποτελούν τους μεταβλητές εισόδου και εξόδου στο ANFIS μοντέλο πρόβλεψης, η παραμετροποίηση του ANFIS μοντέλου, όλα τα αριθμητικά σφάλματα για την αξιολόγηση του μοντέλου πρόβλεψης που προέκυψαν από τα “runs” του αλγορίθμου, ο σχολιασμός των βέλτιστων αποτελεσμάτων που προέκυψαν, όπως και η παρουσίαση των χαρακτηριστικών του ANFIS μοντέλου.

Οι μεταβλητές με τις περισσότερες αναφορές στην διεθνή βιβλιογραφία που σχετίζονται με την δράση των ομάδων συμφερόντων είναι οι εξής: Κατά κεφαλήν ΑΕΠ, Αριθμός ομάδων συμφερόντων, Ρυθμός ανάπτυξης ΑΕΠ, Έξοδα κυβέρνησης, πληθυσμός, διάρκεια πολιτικής σταθερότητας, Πολιτικά δικαιώματα, Επενδύσεις, ΑΕΠ, Φορολογικά έσοδα, πληθωρισμός, Ρυθμός ανάπτυξης ΑΕΠ κατά κεφαλήν, έσοδα κυβέρνησης ως ποσοστό του ΑΕΠ. Για αυτές τις μεταβλητές συλλέχτηκαν τα δεδομένα για την Ελλάδα από το χρονικό διάστημα του Α΄ τριμήνου 1999 έως και το Δ΄ τρίμηνο του 2019 και αφού προηγήθηκε τεστ Κανονικότητας (Normality test), υπολογισμός του συντελεστή συσχέτισης, και έγινε κανονικοποίηση των δεδομένων, στην συνέχεια εφαρμόστηκε η μέθοδος Ανάλυσης Κύριας Συνιστώσας, όπου προέκυψαν δύο ως καταλληλότερες μεταβλητές για την είσοδο του μοντέλου ANFIS, ο Ρυθμός Ανάπτυξης ΑΕΠ και τα Έξοδα Κυβέρνησης.

Ως μεταβλητή εξόδου για το μοντέλο ANFIS, μετά από έρευνα στην διεθνή βιβλιογραφία για την δράση των ομάδων συμφερόντων, η μεταβλητή που συνδέεται σημαντικά με τα αποτελέσματα της δράσης των ομάδων συμφερόντων προκύπτει ότι είναι η παραγωγικότητα της εργασίας και πιο συγκεκριμένα στο μοντέλο ως μεταβλητή εξόδου χρησιμοποιείται η παραγωγικότητα εργασίας ανά ώρα (Labor productivity per hour) για το χρονικό διάστημα από το Α΄ τρίμηνο του 1999 έως το Δ΄ τρίμηνο του 2019.

Μετά από τις απαραίτητες παραμετροποιήσεις και ρυθμίσεις του αλγορίθμου ANFIS, προέκυψε ο παρακάτω πίνακας 1 με τα τρία βέλτιστα αποτελέσματα, αφού ελήφθησαν υπόψιν όλες οι πιθανές περιπτώσεις, για τον αριθμό των επαναλήψεων (Epochs) 1000 και 1500, για το βήμα προόδου (step size) 0.01, 0.1 και 1, για το είδος της συνάρτησης συμμετοχής, τραπεζοειδής, τριγωνική, γκαουσσιανή, π, και καμπανοειδής, και για τον αριθμό των κανόνων 4, 6, 9, 12, 16, 20, 25, 30 και 36.

Πίνακας 1

Number of Application	Epochs	Step size	Membership function	Number of rules	MSE	RMSE	MAE	MAPE
1st	1500	0.1	Trapezoidal	20	0.2681	0.5178	0.3505	0.3771
2nd	1000 & 1500	1	Triangular	25	0.5555	0.7453	0.6559	0.7046
3rd	1000 & 1500	1	Gaussian2	20	0.5817	0.7627	0.6572	0.7049

Η επιτυχημένη πρόβλεψη με το μοντέλο ANFIS της εργασιακής παραγωγικότητας ανά ώρα για την περίοδο από το 3ο τρίμηνο του 2017 έως το 4ο τρίμηνο του 2019, με μοντέλο ANFIS το οποίο εκπαιδεύτηκε με τριμηνιαία δεδομένα για την περίοδο 1999 έως το 2017, επιβεβαιώνει την δράση των ομάδων συμφερόντων στην Ελλάδα και κατ’ επέκταση επιβεβαιώνει τη δεύτερη επίπτωση του Olson, όπου σε χώρες με πολιτική σταθερότητα και σταθερά σύνορα, ευνοείται η ανάπτυξη των ομάδων συμφερόντων, όπως και επιβεβαιώνεται η ορθότητα επιλογής της συγκεκριμένης μεταβλητής ως μεταβλητής εξόδου στο μοντέλο ANFIS.

Επίσης τα αποτελέσματα επιβεβαιώνουν την έβδομη επίπτωση της θεωρίας του Olson, στην οποία αναφέρει ότι οι διανεμητικοί συνασπισμοί λόγω των ομάδων συμφερόντων, επιβραδύνουν την ικανότητα μιας κοινωνίας να υιοθετήσει νέες τεχνολογίες και να ανακατανείμει τους πόρους ως απάντηση στις μεταβαλλόμενες συνθήκες, συνεπώς μειώνουν τον ρυθμό οικονομικής ανάπτυξης. Οι ομάδες συμφερόντων επιβραδύνουν την ανάπτυξη μειώνοντας τον ρυθμό με τον οποίο διανέμονται οι πόροι από τη μία δραστηριότητα στην άλλη ως απάντηση στις νέες τεχνολογίες ή συνθήκες. Ένας προφανής τρόπος με τον οποίο γίνεται αυτό είναι η απαίτηση κρατικών εγγυήσεων για την εξόφληση του χρέους για τις επιχειρήσεις σε ύφεση, καθυστερώντας ή αποτρέποντας τη μεταφορά πόρων σε τομείς όπου θα είχαν υψηλότερα ποσοστά παραγωγικότητας (Hicks, 1983).

Η αύξηση της παραγωγικότητας σημαίνει ότι οι πόροι θα πρέπει να ανακατανεμηθούν προκειμένου να διατηρηθεί η οικονομική αποτελεσματικότητα και η κοινωνία να έχει πλήρες όφελος από αυτήν την αύξηση της παραγωγικότητας. Η ανακατανομή αυτή των απαιτούμενων πόρων αποτρέπονται ή καθυστερούνται από την δράση των ομάδων συμφερόντων όπου με την πάροδο του χρόνου, δημιουργούν εμπόδια στην ανακατανομή των πόρων, ώστε να μειώνεται ο ρυθμός ανάπτυξης και το πραγματικό επίπεδο εισοδήματος (Atsalakis et al. 2016). Συνεπώς επιβεβαιώνεται και η τέταρτη επίπτωση της θεωρίας του Olson για την οικονομία της Ελλάδας, ότι συνολικά οι ομάδες συμφερόντων και οι συμπαιγνίες μειώνουν την αποτελεσματικότητα και το συνολικό εισόδημα των κοινωνιών στις οποίες λειτουργούν και κάνουν την πολιτική ζωή πιο διχαστική.

Στο πέμπτο κεφάλαιο παρουσιάζονται τα συμπεράσματα της έρευνας όπως και οι δυνατότητες για μελλοντική έρευνα στο συγκεκριμένο επιστημονικό πεδίο.

Ενώ η συνεισφορά αυτής της ερευνητικής διατριβής στην επιστημονική κοινότητα μπορεί να συνοψιστεί στις ακόλουθες καινοτομίες: α) είναι η πρώτη φορά που χρησιμοποιείται ένα προσαρμοστικό νευρωνικό ασαφές μοντέλο για να προβλέψει τον αντίκτυπο της δράσης της ομάδας συμφερόντων στην οικονομία μίας χώρας, β) αναπτύσσει μία ολοκληρωμένη μεθοδολογία προκειμένου να βρεθούν οι κατάλληλες οικονομικές μεταβλητές που θα χρησιμοποιηθούν ως μεταβλητές εισόδου ή εξόδου σε ένα μοντέλο πρόβλεψης, γ) για πρώτη φορά προτείνονται συγκεκριμένες μεταβλητές, ικανές να προσδιορίσουν την επίδραση των ομάδων συμφερόντων στις οικονομίες των χωρών και πιο συγκεκριμένα στην ελληνική οικονομία, δ) η έρευνα που αναπτύσσεται στην διατριβή επεκτείνει και συμπληρώνει ουσιαστικά την αυξανόμενη εμπειρική βιβλιογραφία για τις ομάδες συμφερόντων που μελετούν τις επιπτώσεις στην οικονομία μίας χώρας.

ABSTRACT

This thesis studies the impact of special interest groups on Greek economy, using soft computing. One aim is to highlight the economic variables which are most expedient to describe the act of interest groups as far as Greece is concerned. Furthermore the implementation of a contemporary forecast model, which by using input and output variables will be able to make a reliable forecast of the output variable values.

There are significant reports and indications in modern bibliography for the action of special interest groups in Greece mainly after the fall of the court in 1974. Based on the theory of Olson as described in his book “The Rise and Decline of Nations”, where developed analytically the implications of the special interest group’s action in a country, the present study focuses in the economic factor. With a thorough bibliographic survey, all the variables that have been used in the research for the impact of the interest groups are recorded. Having collected the data concerning Greece and proceeded to data normalization, where necessary, the first step was the correlation between the variables.

Principal Component Analysis methodology was followed in order to derive the fewest variables for the study on the economic impact of interest groups. The variables extracted are the Gross Domestic Product growth rate, and the Final Consumption Expenditure as input variables, the Labor Productivity as output variable. Ending up in the appropriate input and output variables a suitable forecasting model of soft computing was selected, the Adaptive Neural Fuzzy Inference System (ANFIS), in order to study the impact of special interest groups in Greek economy.

ANFIS is a hybrid model which combines the advantages of Neural Network and the Fuzzy logic. Trying out all the different configurations of the model, as well as the different membership functions, the step size, the number or fuzzy logic rules, the corresponding results were recorded. For each result that emerged, the required evaluation was done, which has as its main criterion the low arithmetical errors of the model. The optimum results emerged from the ANFIS forecasting model are presented in details along with the rules of the fuzzy logic and the corresponding diagrams. The forecasting diagrams of the variable output of the ANFIS model are highly satisfactory and in combination with the low arithmetical evaluation errors, reliably confirm the influence of the interest groups on the Greek economy.

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CHAPTER III

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CHAPTER I

INTRODUCTION

Many scientists from different scientific fields are related with the research for the interest groups. From a sociological point of view, it is interesting how they are formed, the causes of their creation and the effect they have on the social masses. Political scientists explore the political conditions that help the growth of these groups in a nation, as well as their mode of action depending on the political system of each country. An interesting research issue, is the implications of interest groups action in the political life, which has many peculiarities. Economists from their own point of view explore the impact of the action of interest groups on countries' economies.

This dissertation considers that interest groups behave as Mancur Olson explains in his book "The Logic of Collective Action" and will be developed below. It does not deal at all with the way or methods that interest groups use to achieve their goals, but with the effects of their actions on the economy of each country. Specifically for the effects, the main ones are also mentioned by Mancur Olson in his second book "The Rise and Decline of Nations" for witch, there are over 12,000 citations.

Although many related concepts can be found in the book, most attention has been given to Olson's concept of ‘‘institutional sclerosis’’. This concept refers the hypothesis that special interest groups will accumulate in stable societies over time and generally decrease the efficiency of the economy in which they act (Jac Heckelmann 2007). A summary of the central points of Olson's theory is presented in a next section.

The contributions of this dissertation may be summarized to the follow novelties: a) The main novelty of the proposed model lies that is the first time that an adaptive neural fuzzy model is used to forecast the impact of the action of the interest group in an economy, b) Another novelty is that in this dissertation, is developing a comprehensive methodology, in order to find out the appropriate economic variables to be used as input or output variables in a forecasting model, c) One more novelty is that for first time, specific variables are proposed, able to determine the impact of interest groups on the economies of countries and more specifically on the Greek economy, d) Reported research fundamentally extends and supplements the growing empirical literature on interest groups forecasting influence on an economy.

Primarily, Mancur Olson's theory will be developed at the first chapter as it forms the theoretical background of this doctoral dissertation. Also, in the first chapter is developed an empirical view of the action of interest groups and their effects in Greece economy. In the second chapter, are presented the results from the literature research, regarding to the variables that already have been used to investigate the influence of interest groups on the economies of countries. However, the appropriate variables that emerged from the literature research with the help of statistical data analysis methodology and with the use of soft computing and neural networks are presented at the third chapter. An adaptive intelligent forecasting system ANFIS (Adaptive Neuro Fuzzy Inference System) is developed in the forth chapter and with the data input of the appropriate variables, significant results emerged, regarding the impact of interest groups on the Greek economy.

The fifth chapter contains the conclusions of the research, as developed in the previous chapters and future research proposals for the further study of the impact of interest groups not only on the Greek economy but also in other countries.

1.1 Definition of interest groups

Labor unions are expected to strive for better working conditions and for higher wages for their members; cartels are expected to strive for lower labor cost but higher prices for the firms members; farm organizations are expected to fight for favorable legislation for their members; the state is expected to further the common interests of its citizens; and the corporation is expected to further the interests of its stockholders; . (Mancur Olson, 1965)

Notice that the interests of all these different types of organizations are expected to further for the part common interests: the cartel members' common interest in the higher prices of the products, the stockholders' common interest in higher dividends and stock prices, the farmers' common interest in favorable legislation, the union members' common interest in the increasing of the wages, the citizens' common interest in good government. It is not a random event, that the diverse types of organizations listed above, are supposed to work primarily for the common interests of their members.

Purely individual or personel interests can be further, and usually more efficiently, by individual unorganized action. There is not obvious purpose in having an organization, when individual unorganized action can serve the interests of the individual as well as an organization. But when a significant number of individuals have a common or collective interest, for example when sharing a common individual purpose or objective, unorganized action will either not be able to advance that common interest at all, or will not be able to advance that interest adequately. Organizations can therefore perform a function when there are common or group interests, and though organizations often also serve purely personal, individual interests, their characteristic and primary function is to advance the common interests of groups of individuals. (Mancur Olson, 1965)

These organizations compose the interest groups, also called special interest groups (sig’s) or pressure groups. Consequently, as interest groups can call any association of organizations or individuals, usually formally organized, that, on the basis of one or more shared concerns, attempts to influence public policy in its favor. All interest groups have a common desire to affect government policy in order to gain benefits for themselves.

These groups attempt to achieve their goals by lobbying and attempt to bring pressure to bear on policy makers to gain policy outcomes in their favour.

As a natural outgrowth of the communities of interest, the interest groups exist in all societies from narrow groups to even wider organizations. The interests and politics are insuperable. Interests are a permanent, prevalent and essential aspect of all political systems. Furthermore, interest groups have been incorporated in all levels of government—national, state, provincial, and local—and increasingly they have occupied an important role in international affairs. The common goals and sources of interest groups obscure, however, the fact that they vary widely in their form and lobbying strategies both within and across political systems (Clive Th., 2021).

According to the extensive explanation of the entry of interest groups by "Britannica", the definition of interest groups could be "an organization created to defend interests, which exerts pressure on public authorities to extract decisions from them" (Schwartzenberg 1984:362; Meny, 1995:245; Heywood, 2008:379).

It is worth to note, that an interest group according to (Trumman D., 1971), transforms at a group of pressure, only when it tries to influence the decision of public authorities.

According to the above, an interest group can be defined, as the set of individuals, organizations or businesses that behave in such a way as to promote their common interest.

The interest group may consist of only two members. For example, only two companies that usually operate monopolistically as cartel in the sale of their products, keeping high the selling prices of their products and keeping low the purchase prices of the necessary raw materials from the producers. It is possible, however, that they are made up of thousands of members, such as trade unions and professional chambers.

The interest groups and their operation in order to promote their common interest has been recognized by the European Union and for this reason there is a relevant office in Brussels (Integrity Watch – EU Lobbyists) where these groups are registered and officially transfer their concerns and plans to the competent European bodies.

The role of interest groups in a society has been a fertile ground for study among political scientists, economists, sociologists and historians, among others. It is significant the way of the interest groups approach, that is, the perspective from which will be studied, as their role and function are multifaceted and multidimensional. For this reason, a study of interest groups, suggests three different proposals (Mach, 2015).

A first approach of interest groups starting from the view of the political science. Based on this approach, the research focuses on the relations between the special interest groups with the political actors, as well as on the developed strategies in order to influence the decisions of the political and administrative bodies. This is a usual approach when researching the actions of interest groups.

Another researching prospect by the economic sociology view is the impact from the action of interest groups on the socio-economic organization.

A third interesting approach by a sociological point of view, concerns the organization and the internal structure of interest groups with representation and the definition of their interests (Mach, 2015).

In this doctoral dissertation, as will be developed below, the approach to the groups of interest will be done mainly and only in terms of their impact on the economic environment, with respect to their political and social activity.

1.2 History and types of interest groups

The idea that associations or organizations operate in ordet to further the interests of their members is hardly novel, nor peculiar to economics; it goes back at least to Aristotle, who wrote, "Men journey together with a view to particular advantage, and by way of providing some particular thing needed for the purposes of life, and similarly the political association seems to have come together originally, and to continue in existence, for the sake of the general advantages it brings." (Aristotle Ethic's iii.9.1160a)

It is a fact that there are many historical examples, of great empires and cultures with power, wealth and with great cultural achievements, to suddenly decline and disappear over time.

The collapse of the Roman Empire in the West and its defeat by dispersed tribes, insignificant power and supremacy. The imposing empires of China, which were gradually subjugated to underdeveloped peoples, such as the Mongols or poor peasants who rebelled in the province. But also on the continent of America there are many examples of the collapse of great empires, such as the Indian cultures of pre-Columbian Central America, the Aztec empire before it was even destroyed by the Spaniards.

What was the cause of the collapse of these empires? Mancur Olson gives the answer indirectly in his book, Rise and Decline Nations (Olson 1982), the interest groups of that time, of course. The emperors and kings had their advisers, friends, officials, nobles who made up their "courtiers". " However, the cost of "maintaining" them was high. Each emperor also increased his "courtiers," or appointed government officials to oversee the people, collect taxes, and generally impose the king's orders. The cost of all this fell on the backs of the common people, the poor, where they were forced to pay higher and higher taxes either in money or in crops they cultivated. So from the earliest years of their emergence, interest groups have done what they continue to do today, binding state resources and wealth to sustain themselves, always standing by the side of those in power and managing their finances.

In the case of Greece (Lavdas, 2007), the first interest groups were the trade unions that aimed to coordinate protests and strikes. They first appeared in the shipbuilding industry in 1879. Other unions followed between 1879 and 1910 in various fields. The surrender of trade unionism was outlawed by the El. Venizelos government in 1914 and was considered obsolete. The establishment of the Hellenic General Confederation of Labor (General Confederation of Greek Workers, GSEE) in 1918 owed much to the activities of the Liberals, who then tried to control the organization. This proved particularly difficult, especially in view of the growing influence among the workers of the Socialist Workers 'Party (Socialist Workers' Party, SEK, the future Communist Party). The end of World War I, the rise of the Communists, and the severity of the "social issue" resulted in the inability of governments to control and direct the activities of interest groups. As a result, a number of repressive measures were deemed necessary after 1920 (Lavdas 2007).

Later, in the post-war years, political developments led to the development of state interactions with trade unions. As a result, trade unions - and unions in general - have gained prominence, a trend that has increased with the number of members remaining high throughout the post-war decades (Lavdas 2007).

There are many types, shapes and sizes of organizations, and there is a question if there is any unique purpose that would be characterize generally the organizations. One purpose that is nonetheless characteristic of most organizations, and surely of all organizations with an important economic aspect, is the furtherance of the interests of their members. (Olson, 1965). Certainly, some organizations may out of ignorance, fail to further their member's interests and others may be enticed into serving only the core of the leadership.

As noted in the previous chapter, there are numerous interest groups that differ in their function based on different dimensions-characteristics. Some of these dimensions may be:

a) The number and type of their members,
b) The foundation sources,
c) The level of their internal organization (the organs and their official internal structure),
d) The number of permanent employees,
e) The degree of involvement in politics,
f) The purpose they seek,
g) The services they offer to their members,
h) The competitiveness with others groups,
i) The strategies they use (Dur and Mateo, 2013).

All the interest groups can be divided into many different types, depending on the dimension (main characteristic) that is taken into account (as the most important assumption for its existence and operation), according to the above.

Taken into account as mainly characteristic the purpose that is seeking, the interest groups can be divided into 10 different types as described by (McIntosh M. 2018) for United States of America and these types, which are mentioned below, generally apply to other countries worldwide.

1.2.1. Business and Economic Interest Groups

Economic interest groups are further for more and more benefits and any kind of significant economic interest. There is a wide variation of economic interest groups, and each special type of interest group includes a large number of competing interest groups. The category of economic interest groups conclude those representing business, professional, labor and agricultural interests.

Business groups of interest generally promote corporate or employer interests. Large corporations and companies maintain their own professional lobbyists in order to work on behalf of their specific interests. Organizations and companies also create larger groups in order to to work together on common business interests (cartels).

“Because of how numerous and well funded business interest groups tend to be, there is always a concern that they are interfering with, rather than enhancing, the democratic process” (McIntosh M. 2018).

1.2.2. – Labor Interest Groups

Labor interest groups usually compose unions in order to advocate for the economic interests of workers and trade organizations. “In addition to representing their members, unions also often organize opportunities for direct citizen participation, along with public education and lobbying” (McIntosh M. 2018).

1.2.3 – Professional Interest Groups

Professional interest groups belongs to the type of economic interest group, which organize and represent professional workers. "While trade unions represent skilled and industrial labor, professional organizations represent skilled workers such as doctors, engineers, and lawyers", (McIntosh M. 2018).

These groups advocate for the economic interests of their members. These groups set rules and barriers for all candidate members of their organizations. The regulation contains rules about certification and compliance of professional codes of ethics. Professional organizations as expected provide direct economic benefits to their members. One significant benefit of all, concerns the access to personal or professional insurance as well as professional development opportunities.

A characteristic of professional organizations is that they serve to increase the income of their members without any added value or service.

1.2.4 – Agricultural Interest Groups.

Agricultural interest groups are further the economic interests of breeders, farmers and generally primary sector producers. These interests concern business and agricultural extension, as well as matters of local, national, and even international policy. These are about crop prices, government subsidies, international trade agreements land rentals and land use zoning.

In nowadays, agricultural interest groups are separated in sub-groups. There are various types of farms and farmers, which usually have conflicting interests. A policy that is beneficial to large scale agricultural business might be highly damaging for small family farms, for example.

Agricultural interest groups range from large agribusiness, to mid-sized groups and commodity crop farmers, to small groups advocating for policies that would support the renewal of small and local agriculture.

1.2.5 – Environmental Interest Groups

"Environmental interest groups are generally public-interest groups, as their work benefits a wider community beyond their own active membership. These groups advocate around conservation and ecological issues. Interest groups in general are groups represent people or organizations with common concerns and interests. These groups work to gain or retain benefits for their members, or to make general changes for the public good" (McIntosh M. 2018).

Today, extremely varied are the environmental interests groups, and while they are sharing some concern for conversation or the environment, many hold conflicting views about levels of conservation versus for example stewardship, and about appropriate strategies for pursuing their interests.

1.2.6 – Consumer Interest Groups

Consumer Interest Groups focus on the issues and interests of consumers. Can be considered public-interest groups since their work benefits consumers rather than providing exclusive economic benefits to a closed set of members.

"These groups focus on a number of different issues that include product safety, price issues, and consumer notification. They employ a variety of strategies– from lobbying to public campaigns. In these ways Consumer Interest Groups protect and represent consumers. They also provide important checks and balances to business interests, make market exchanges more transparent, and help consumers make more informed choices" (McIntosh M. 2018).

1.2.7 – Ideological Interest Groups

"These groups work to gain or retain benefits for their members, or to make general changes they perceive to be for the public good. Interest groups work through advocacy, public campaigns, and even directly lobbying governments to change public policy". There are a wide range of ideological interest groups that represent many different constituencies (McIntosh M. 2018).

1.2.8 – Public Interest Groups

“These groups work to gain or retain benefits for their members, or to make general changes for the public good. Interest groups work through advocacy, public campaigns, and even lobbying governments to make changes in public policy” (McIntosh M. 2018) . There are a wide variety of interest groups representing a variety of constituencies. For example, public interest groups work on issues that impact the general public, rather than a select group of members. These groups advocate for their ideals of general good, or common well-being. Few of the issues this public interest group address, is i the environment, the political system and the area of health.

1.2.9 – Single-Issue Interest Groups

By the name is suggested that these are groups “focus all of their energy on a single defining issue”. Their membership is often quite devoted to the issue, and motivated by participation in ongoing social movements or by personal experiences. The number of single-issue interest groups in the development countries is increasing more and more. “These groups focus on a diverse array of issues including taxation, abortion, and animal rights” (McIntosh M. 2018).

1.2.10 – Governmental Interest Groups

Government interest groups are a unique form of interest groups that represent the interests of local government to other governments or to central government. “In many cases local governments are seeking more funding to carry out their work and responsibilities” (McIntosh M. 2018). This support often comes in the form of federal grants. With other words, the local governments may advocate for increased direct decision making powers, and control over new policy areas.

“As with other interest groups many government interest groups also conduct work in public education and media campaigns in addition to their direct advocacy work”.

In this doctoral dissertation we will deal with determining the influence of groups that mainly affect economic interests. However, it is worth mentioning in general all the types of interest groups that we meet today, according to political scientists and sociologists, although all of them more or less have the ultimate goal of economic benefit.

1.3 Mancur Olson's theory – Logic of collective action

The Logic of Collective Action (1965), was the most seminal work of Mancur Olson, with more than 29.000 scholar cites (Sandler 2015). In it, Olson laid the foundation for free-riding behavior, created a taxonomy of groups, and extended the problems associated with collective action to a broad class of economic and non-economic phenomena (Dougherty 2003). The most important (main) points of Olson's theory will be briefly developed below.

Mancur Olson begins to develop his theory by assuming that “people are mainly self-interested and so focus on their own costs and benefits when engaging in collective action”. Next, Mancur Olson assumes that the relevant private costs and their benefits are affected by the group size and the core of the interests that characterize a ‘‘group”.

The group formation and behavior concerns many sociologists and political scientists until this day. There is the traditional theory which is expressed by two similar forms. The casual form, that implicitly assumes that “private organizations and groups are ubiquitous and this ubiquity is due to a fundamental human propensity to form and join associations”. (The Rulling class (Mosca 1939; Lowie 1948; Simmel 1950; Tocqueville 1956; Bryce 1910;Beard and Beard 1949; Bell 1960).

At the formal variant of the traditional theory is emphasized the universality of groups and attempts to explain the associations and groups affiliations of the present day as an aspect of the evolution of modern, industrial societies out of “primitive” societies that preceded them. It begins with the fact that “primary groups”, small groups like family and kinship groups, were predominant in primitive societies. But as society develops there is structural differentiation: new associations emerge to take on some of the functions that the family had previously undertaken.(Cooley, 1909; Homans, 1950; Parsons and Bales, 1955; Parsons et al. 1953).

It is characteristic of the traditional theory in all its forms that it assumes that participation in associations is virtually universal and that small groups and large organizations tend to attract members for the same reasons. Also, in so far as the traditional theory draws any distinction at all between small and large groups, it is apparently with respect to the scale of the functions they perform, not the extent they succeed in performing these functions or their capacity to attract members. It assumes that small and large groups differ in degree, but not in kind.

Olson considers two types of ends that groups may attempt to promote through collective action. These, in turn, have implications for a group's natural size. ‘‘Inclusive’’ groups attempt to advance ends for which the ‘‘more the merrier’’ rule holds. Groups focused on such interests, have benefits from increases in membership because costs fall as they are shared and/or because the effectiveness of collective action increases with numbers. In contrast, ‘‘exclusive’ groups attempt to advance aims for which average benefits fall as the number of group members increases. Such groups tend to include the smallest number of members sufficient to advance their ends" (Congleton 2015).

With respect to membership, he divides groups into three rough categories: small groups (privileged), intermediate groups, and large groups (latent).

In privileged groups, the members have private interests that greatly exceed their private costs for collective action, and so they are each inclined to pursue those interests even without a formal organization. An intermediate group is one in which no member has sufficient private interests to advance the collective interest on his or her own, although the group is small enough that any contributions made by others can easily be recognized. Intermediate groups require an organization to advance shared interests, but their organizations have relatively low monitoring and enforcement costs. Large groups tend to remain unorganized (and thus ‘‘latent’’) because they require a more sophisticated organization to advance shared interests. Individual contributions have essentially undetectable effects on average costs and benefits. Members of latent groups therefore are difficult to organize even when their aggregate net benefits from collective action are far larger than their aggregate organization costs. With respect to intermediate and latent groups, Olson argues that collective action requires organizing private rewards and/or punishments sufficient to motivate individual members. These are referred to as ‘‘selective’’ incentives (Congleton 2015).

In this point a question is composed; if it is true the issue, that large, primary groups and small associations attract members by the same way, and they are equally effective in performing their functions, or that they differ only in the size but not in their character?

To answer this question Mancur Olson used the term collective good, in a general sense, to refer to any good that provides benefits to more members than one individual. When individuals benefit from collective goods, coordinated effort, and sometimes enforcement, is required to assure provision (Doueghrty 2003). Also a public good refers to any good that is nonexcludable and nominal (Sandler 1992), while private goods have the opposite qualities.

The term "collective goods", has the meaning that most organizations produce goods or services that are available to every member, whether or not he has borne any of the costs of providing them. Economists admit that defense, law, and order are public goods that could not be marketed to individuals and the taxation is necessary. However, they have not taken account of the fact that private sector as well as government organizations produce public goods. The services the labor union provides for the worker it represents, or the benefits a lobby obtains for the group it represents, are public goods: they automatically go to every individual in the group, whether or not he helped bear the costs. It follows that, just as governments require compulsory taxation, many large private organizations require special (and sometimes coercive) devices to obtain the resources they need.

From this very spare characterization of individual incentives and group types, Olson deduces a number of broad conclusions, (Congleton 2015).

Among Olson's conclusions, the most mentioned is that: other things being equal, as larger is a group and smaller the average benefits associated with membership, as less likely a group is to be organized or effective at advancing shared interests. Conversely, as smaller the group and larger average member interests, then more likely it is to organize and advance its shared interests. A secondary implication is that all active groups, except a few ''privileged'' groups, have formal organizations of some kind that dispense rewards, punishments, or combinations of the two sufficient to induce members to advance their group's interests. "Privileged groups may also organize to increase their effectiveness" (Congleton 2015).

In his theory, Mancur Olson also mentions the implications for the manner in which large organizations tend to be organized. “Large organizations tend to have federal structures”. “A federal structure is used to create national, regional, and local privileged subgroups with sufficient interest in their organization’s objectives to invest their time and energy in advancing collective interests” (Olson 1965). A handful of ‘‘privileged’’ persons direct the organization as a whole, and similar ‘‘privileged’’ groups direct the regional and local subunits. In this manner, his theory can be used to explain the emergence of hierarchical organizational structures. Privileged subgroups throughout such organizations (e.g., leaders, activists, and coordinators) are encouraged with selective incentives to call forth the efforts of other less motivated members. Although large organizations are possible, in general, the groups that are most likely to obtain special privileges from governments are not latent groups, but small privileged groups. They can more easily organize to lobby governments for preferential laws and regulations than larger groups. To the extent that latent groups do organize, as with labor unions, their organizations will provide a variety of services that are available only to members. “They may secure discounts for useful services or inputs (as with insurance or healthcare), provide useful information through magazines and journals, and sponsor social events of interest to members. Lobbying by such groups is often simply icing on the cake of private services available to dues-paying members” (Congleton 2015).

1.4 The Implications of Olson’s theory

Mancur Olson continued his pioneering research and study on interest groups with his next book The Rise and Decline of Nations (1982). There are over 1.800 citations of this book, in which set out to develop the macroeconomic consequences of the interests groups. (Heckelman 2007). In this book, Olson uses an unique interest group model presented in the *Logic of Collective Action* (1965) [1] to underline the differences in national incomes, gdp growth rates, labor productivity, unemployment, and sustainability to business cycles.

Particulary, Olson refers that privileged groups and latent groups are to blame for many of the problems associated with life in society, because of their differences in the interests. Privileged groups are more effective at government lobbying for preferential policies, because they have relatively limited interests. These groups try to capture more and more of the benefits of the lobbied policies for additional economical profits or higher salaries. However, they will not tolerate any kind of the losses associated with their tax benefits or trade and regulatory privileges.

Latent groups bear more of those costs through higher product cost, transportation costs, and taxes. As the politically active groups increase, create more and more special privileges. Through the time, distributive politics tends to grow the complexity and rigidity of tax codes, regulatory law, entry barriers, tax codes, and other polices in order to create extra group privileges. That stiffness consequently, makes the economic, political and social system less competitive and less innovative. As privileges proliferate, inequality increases and economic growth is declining because of the losses from regulation and the increased rigidity. The members of latent groups, become relatively poorer because bear the costs without associated benefits, while members of well organized groups become relatively wealthier. Finally, because of the market's reduced ability to adjust to micro and macro economics shocks, the amplitude of the business cycles increases and the unemployment rises (Congleton 2015).

After his extensive analysis and drawing on a variety of historical examples, he summarized his argument with a set of nine general implications. These implications that introduced, form the distinction between encompassing and distributional organizations, they constitute the central core of Rise and Decline of Nations (Barkley 2007) and they are as follows: (Olson 1982)

1. "There will be no countries that attain symmetrical organization of all groups with a common interest and thereby attain optimal outcomes through comprehensive bargaining".
2. "Stable societies with unchanged boundaries tend to accumulate more collusions and organizations for collective action over time".

3. “Members of small groups have disproportionate organizational power for collective action, and this disproportion diminishes but does not disappear over time in stable societies”.
4. “On balance, special-interest organizations and collusions reduce efficiency and aggregate income in the societies in which they operate and make political life more divisive”.
5. “Encompassing organizations have some incentive to make the society in which they operate more prosperous, and an incentive to redistribute income to their members with as little excess burden as possible, and to cease such redistribution unless the amount redistributed is substantial in relation to the social cost of the redistribution”.
6. “Distributional coalitions make decisions more slowly than the individuals and firms of which they are comprised, tend to have crowded agendas and bargaining tables, and more often fix prices than quantities”.
7. “Distributional coalitions slow down a society’s capacity to adopt new technologies and to reallocate resources in response to changing conditions, and thereby reduce the rate of economic growth”.
8. “Distributional coalitions, once big enough to succeed, are exclusive, and seek to limit the diversity of incomes and values of their membership”.
9. “The accumulation of distributional coalitions increases the complexity of regulation, the role of government, and the complexity of understandings, and changes the direction of social evolution”.

Although Olson discusses all the implications in detail and in depth, he pays special attention to three of the implications, the number 2, 3 and 7. As confirmed by the literature only a handful of studies have directly tested implication 2. “The vast majority of the literature has instead either tested some variant of implications 4 and 7 or combined the three implications to relate stability to economic growth, leaving the role of special interest groups and distributional coalitions implicitly in the background” (Heckelman 2007).

In the literature there are plenty of studies that support Mancur Olson’s conclusions for these three implications. Heckelman 2007, in his study contains all the studies that lead to the confirmation and supporting of these three implications. Many scientific studies, with descriptive and empirical tests of institutional sclerosis, end up by supporting and confirming this theory as, Choi 1983; Hennart 1983; Whitely 1983; Olson 1984; Weede 1984; Weede 1986a; Weede 1986b; Bernholz 1986; Vedder and Gallaway 1986; Lane and Ersson 1986; Chan 1987; Olson 1990; Kirby 1992; Manzetti 1992; Waldow 1993; Milner 1994; Weyland 1996; McCallum and Blais 1997; Tag and Hendley 1998; Broadberry 1998; Crain and Lee 1999; Blankart 2001; Scruggs 2001; Hojman 2002; Coates and Heckelman 2003a; James 2003; Koubi 2005; Demir 2005.

The harmful effect of interest groups on economic growth is referred to as institutional sclerosis. Mancur Olson (1982), argued that special interest groups develop over time and that these groups compete for shares of the economic pie to the detriment of growth in the size of that pie. "Also provides evidence in favor of this theory using length of time of governmental stability as a proxy for the formation of interest groups" (Coates & Heckelman 2003).

In this doctoral thesis, is taken into account the theoretical background of Olson's theory and especially the three most important implications he has reported on it, which will be applied in following chapters. Of these three, we single out the seventh implication.

As more the distributional coalitions, therefore, the detrimental effects which exert on the economic growth are stronger. Olson further argued at the length of time that a region has been politically stable relates to the number of distributional coalitions that exist. Essentially, upheaval destroys these groups and stability allows them to form. "The longer in the past is an episode of upheaval, the more groups that will have formed, and the worse the consequences for subsequent economic growth" (Coates & Heckelman 2003).

1.5 The action of interest groups in Greece

In the second implication of Mancur Olson, in the *Rise and Decline of nations* (1982) [2], refers: "Stable societies with unchanged boundaries tend to accumulate more collusions and organizations for collective action over time". The meaning of the second implication is that countries which have stable political system and democratically elected governments, or countries which have stable borders (are not involved in any conflict or war), tend to accumulate interest groups and more collusions for collective action over time. Another factor which tends to be stronger in democratic nations is the sclerotic effect and remain dependent upon how strict a definition of democracy is used (Coates, Heckelman & Wilson, 2010).

Considering the period after the colonels' coup (1967-1974), this scenario seems to be confirmed for Greece. After the fall of the colonels' coup in 1974, Greece had had a stable democratic political system until today. Regarding the role of interests in the social life, important changes have been taking place since 1974 both on the legal institutional and on the socio-political front. The Constitution of 1975 protects the right to form unions and associations, to strike and generally marks an important shift to a democratic way (Lavdas 2007).

Thus, after 1974 Greek society includes, business associations, , freelancers' associations, ecclesiastical organizations, trade unions, unions and associations, chambers, groups of citizens in provincial towns, cultural clubs and many others (Iordanoglou 2013), where each group works hard in order to promote its interests.

Especially for the trade and labor unions, mainly in the public sector, they grew in the 1980s (Lavdas 2007) with powerful presidents who had a direct connection with the ministers of the government or even the prime minister. All political parties followed the model, to transform the occupational interest groups into "transmission belts" of their policies and therefore for their indirect control (Mavrogordatos 2009). The relationship between the parties and even the ruling party with the country's interest groups creates an environment of strengthening these groups and weakening the institutions.

A thorough analysis of the complicated interactions between the government branches, the interest groups, the voters and the media in the context of the weak Greek institutions, is provided by Pelagidis and Mitsopoulos (Pelagidis and Mitsopoulos 2006).

Some of the results of pressure from interest groups are due to the way in which the various interest groups in Greece acted, like their relations with the government officials, the general corruption of the public sector and especially the government corruption, the bureaucracy of the public sector, the pluralism, and even the premature or successive elections. On this subject, Greek economists and political scientists have reported extensively on newspaper articles and books (Mavrogordatos 1988; Mavrogordatos 2009; Pelagidis and Mitsopoulos 2006, Lavdas 2007, Atsalakis et al. 2016).

In Greece there are very active interest groups and their results reflected in the country‟s economy, as referred in the seventh implication of Olson‟s theory. Due to interest, distributional coalitions slow down a society‟s capability to adopt innovations of new technology and to reallocate resources in response to implemented reforms and thereby reduce the economic growth rate (Olson 1982).

It is remarkable the similitude between Greek interest groups and Vikings that use Mitsopoulos in the first chapter of the book, Understanding the crisis in Greece (Mitsopoulos and Pelagidis 2011). "These groups act within the society with a hit and run" strategy, exactly like the first Vikings, whenever they spot a pool of rent, such as an uncompetitive market for example". They also form immediately loose alliances with other groups whenever any pool of rent is threatened by a reform, as they realize that the groups whose rent they defend today will also rush to support them as soon as their pool of rent is threatened by another reform-minded politician or a European Union legislation/directive. In this process, these groups "fully take advantage of both the lack of checks in the system that would allow the interested general public to object to such a raid and the meticulously established lack of transparency" (Mitsopoulos and Pelagidis 2011).

Several interest groups in Greece have imposed many entry barriers in order to protect their interests, slow down that adaptation ability of new technologies mainly in the public sector, and divert the growth of incentives in society (Atsalakis et al. 2016). Goods and services are more expensive in Greece compared with European countries, due to the lack of healthy competition and market controls. The conclusion that emerged from a thorough analysis for Greece (Atsalakis et al. 2016), is that the special interest groups are detrimental to prudent governance, economic growth, full employment, social mobility and equal opportunities..

Those conclusions are confirmed by the speech of the Director of the Bank of Greece (Stournaras 2017) to The Hellenic American Union. In his speech referred that according to the World Economic Forum's World Competitiveness Report, the related indicators to the effective functioning of the institutions show stagnation and deterioration to Greece, taking the last place in the ranking (87th) for the year 2016. Significant barriers to entrepreneurship are according the report, the inefficient bureaucracy, high taxes on the country, delays in the administration of justice and the uncertain economic environment (Stournaras 2017).

Greece's membership in the Eurozone not even set a limit on the action of these groups, instead these groups found a fertile ground and accessible sources of funds from E.U. (European Union) in order to satisfy their financial interests. The result of this tactic was that Greece remained economically weak, without a stable and powerful fiscal policy, and totally unprepared for the following global economic crises that led Greece on the brink of economic collapse.

It took three Memorandum of Understanding (MoU) and 10 years since the beginning of the crisis in 2009 for it to emerge from the crisis and stabilize its economy.

This important effect has also been recorded in the study of Papadakis, H. and Atsalakis, G. (2018), in which a first classification of various European countries was made, based on the influence of interest groups on the economies of their countries. The survey covered the years 2000-2014 and included ten European countries: Belgium, Greece, Finland, France, Germany, Italy, Netherlands, Portugal, Spain and Sweden. The input variable for this study, were the annual data in absolute number for GDP, GDP per capita, tax revenue, GDP per capita growth, General government final consumption expenditure, population, Revenue (% percent of GDP), duration of political stability, Mobile cellular subscriptions, Government effectiveness, which had emerged from the bibliographic research of Papadakis, H. and Atsalakis, G. (2019).

The countries were rated of the scale zero to hundred (0-100), where “0” responded at the upper level of interest groups influence and “100” responded to the lowest influence of interest groups. Greece classified in the last place, except years 2009, 2011, 2012 which took the penultimate place. The research of Papadakis H. and Atsalakis G., concludes that extremely “active interest groups” create a significant influence on the economy of each country and this is an important reason for the financial crises that faced Greece two times, at 2009 and at 2015.

1.6 Lack of technological innovation in Greece

The lack of technological innovation in Greece is a cause of the retard growth of Greek economy as a result of the influence of special interest groups in the economy.

In many productive sectors of the country could use new technologies in order to help significantly to improve the derived product or service, or to help them in advertising and sale of that product. As an example, it is noticed the tourism sector which is the "heavy industry" of the country and participates with the highest rate in the creation of the country's GDP. However hoteliers not seem willing to use new technologies in their businesses, either to acquire the customers the best hotel experience during their vacations, or for the organization and management of their tourist unit.

The government even today, subsidize unemployed to create their own jobs, by directing them in classic professions, such as doctors, engineers, trade, retail stores, instead directs them in innovative and specialized professions or to subsidize a new idea in startup's companies.

There are many examples in Greece the last five decades that confirm the action of interest groups to slow down the technical progress and innovation in the country. It is interesting to develop the more obvious sources of purely rational resistance to innovation, as Mokyr (2000) studies in his article.

Fear of job cuts

A major fear of workers, mostly unskilled, is that technological change can break down their jobs. Therefore, trade unions oppose any innovative change as they consider that not only will new jobs be created to register new members, but that redundancies will follow, so that their members, and thus their power, will be reduced. Employees know that it is very difficult to stop a technological breakthrough planned for their sector, but they can delay it. Thus, in the "Greek public sector, the phenomenon of workers has been observed to invent bureaucratic obstacles to prevent their installation and use, or deliberately not to use computers or other applications to delay the implementation of any technological reform" (Dachs 2018, Mitsopoulos and Pelagidis 2011, Spanou and Sotiropoulos 2011). A prominent example is the reform of e-government in Greece, where digital signatures, digital certificates, , e-documents between government services and citizens were proceeding very slowly.

Financial cost

When new technologies and products replace the old ones, large companies may lose a significant market share or even go out of the market. The major shareholders of these companies react by trying to delay or block the introduction of new technologies, especially if the adaptation in new technologies seams difficult or has high cost.

Negative effects

New technologies are being criticized by groups with different economic interests because of the negative effects they may appear. Genetically modified food, nuclear power, large department stores and wind farms, as well as many other innovative practices, cause fear in society because of the negative effects they may cause. There is the state's duty to choose what to stop and which to allow it to be implemented. For many years, Greece had to turn on the production of energy to renewable energy sources. Many groups in the name of environmental degradation block the installation of wind turbines and photovoltaic systems, but they do not react at all to the operation of the Public Power Company plants, which emit thousands of tons of polluting gases from the burning of coal and oil (Juma 2016).

Uncertainty

Every innovation creates uncertainty and market shifts for who is going to get more profitable than its implementation. "There is uncertainty when the state does not legislate in time for operating rules and does not explain the benefits of users" (Dachs 2018). Especially when uncertainty grows for a large professional team, then it exerts the strongest political pressures to put barriers to the development of this innovation. Nowadays, an example of this is the application of the "sharing economy", with the most famous application of the short-term lease of real estate by individuals and professionals of Airbnb, Homeaway etc and in the transport sector of Uber, Beat, etc. Airbnb already booms in Greece as it is still a customer approach channel for accommodation facilitating access to the vast global market. It works as an online broker between two clients to reach a mutual agreement, receiving a fee from both parties. It threatens online travel agencies such as Booking.com, Expedia, etc. In Greece, many accommodation is still illegally hired through various platforms (one of which is Airbnb), since the state has not set up the site provided by the law, where it will be registered and each accommodation will be certified, and each booking will be booked before the arrival of the customer. The result is the creation of unfair competition due to concealment of incomes and a more favorable tax treatment than legally registered businesses renting their accommodation, which pay excessive taxes and insurance contributions. This unfair competition creates reactions from the affected professionals. The state is obstructing and does not implement the relevant legislation, resulting in the uncontrolled rental of dwellings that there are no houses for long-term lease, which causes further reactions.

It is noteworthy that in recent years there has been little effort to improve the stabilization of the economic environment by reducing taxation and attracting new investments, as well as the digital transformation of the state.

1.7 The economic rise and decline of Greece

On 1st of January 2002, eleven European countries and one more, Greece, acquired the "euro" as a common currency, starting to adhere the Economic and Monetary Union (E.M.U.) of the European Union.

The successful course of the convergence of Greek fiscal figures and the achievement during 2000 of the criteria for converging the Maastricht Treaty has as a result the successful accession to the E.M.U. of the European Union. The criteria for converging the Maastricht Treaty for Greece were the reduction of the general government deficit, of inflation, of public debt, to obtain a stable exchange rate mechanism and to balance the long-term lending rate.

Greece between 2001 to 2005 had violated the deficit criterion of the Stability Pact (below 3%), which was intended to ensure that states after joining the eurozone and fulfilling the Maastricht criteria, would continue to meet the convergence criteria. However, under the tolerance of European Union, the economy of the country between 2002 to 2009 had been evaluated by three famous international rating agencies with A (or even A+ by Moody's) and belonged to the group of countries with high creditworthiness (Michalopoulos 2011).

Greece was faced with a unique historical opportunity as all the doors of the international markets were wide open. As an financial equal member of the Eurozone, Greece could be borrowed from international markets, any amount, any time, and mainly with a small interest rate.

Figure 1.7.1 shows the five year bonds landing rate, between 2002-2008, which was ranged from 3.6% to 5% and that was historically low levels. It is worth to mention by the figure that the years before 1995, the rate exceeded 20%.

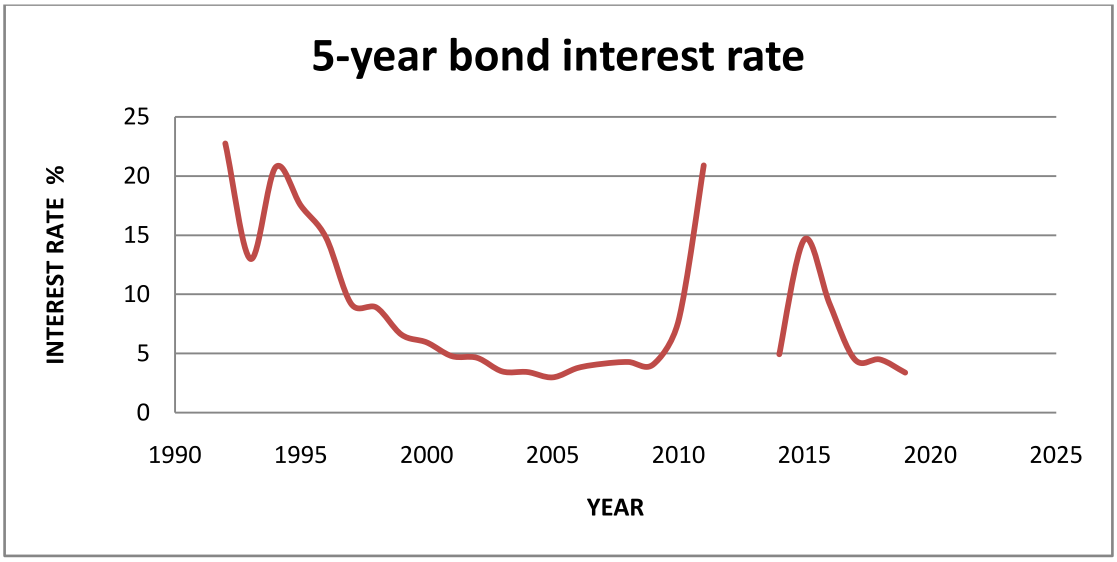

Figure 1.7.1 Average annual interest rate on the 5-year bond landing rate of Greece, years 1992-2019. (Source: Bank of Greece).

Greece had an unique opportunity in front of her, to borrow uninterruptedly money with extremely low interest. Greek government in cooperation with the banking system applying in common an organized plan, could lay the foundations for significant enhancement of productivity, technology, re-industrialization of Greek products and exports in order to create new jobs, make the Greek economy more competitive, and to shield the economy in the upcoming financial crises. Instead, the funding from ten-year bonds in early 2000, were spent on the Olympics Games of

2004 and on the construction of new high-cost sports facilities that are ultimately abandoned until today.

Another fact was the gigantism of the public sector within 8 years, in the period 2002-2010, where the civil servants doubled, figure 1.7.2. The borrowing from the international markets covered the expenses for new recruitments in the public sector, as salary increased by providing higher benefits to specific union groups for purely pre-election purposes, while the state-owned plutocratic classes received government grants and subsidies which forward to foreign banks.

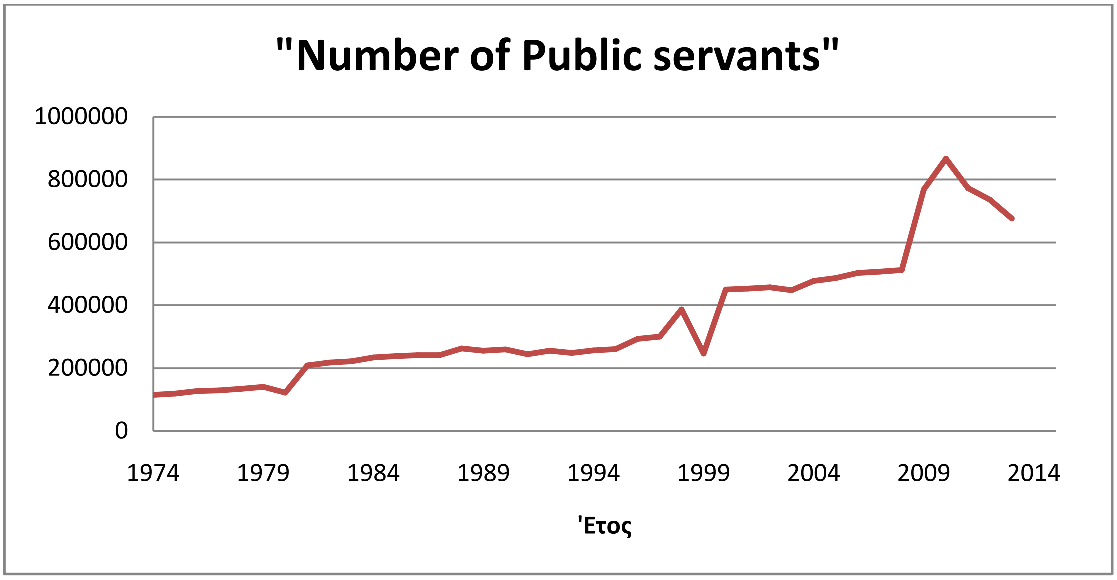

Figure 1.7.2. Greek public servants, for years 1974 - 2013.

The highlight of Greek economy in 2009 with a very high GDP simultaneously with high private consumption, was not sustainable. This prosperity was not due to entrepreneurship, or to investment, the use of new technologies, the high export index, or the exploitation of natural wealth, but was due to foreign borrowing. These loans were not invested to increase productivity but were consumed in overheads and expenses. In 2010, the interest rate loan was so high for Greece that was almost prohibitive to borrow, consequently joined to the International Monetary Fund (IMF) for lending.

Since 2009 until 2019, the 5-year and 10-year bonds lending rates have been on the rise, above 10%, making international lending prohibitive.

As emerged from the figure 1.7.2, Greece between 2012 - 2013 could not access international markets in order to borrow. The high interest rates for Greece were prohibitive, disastrous for the economy, so was forced to turn under the supervision of the European Commission, the European Bank and the International Monetary Fund (IMF) in order to cover the debts by signing the first Memorandum of Understanding (MoU).

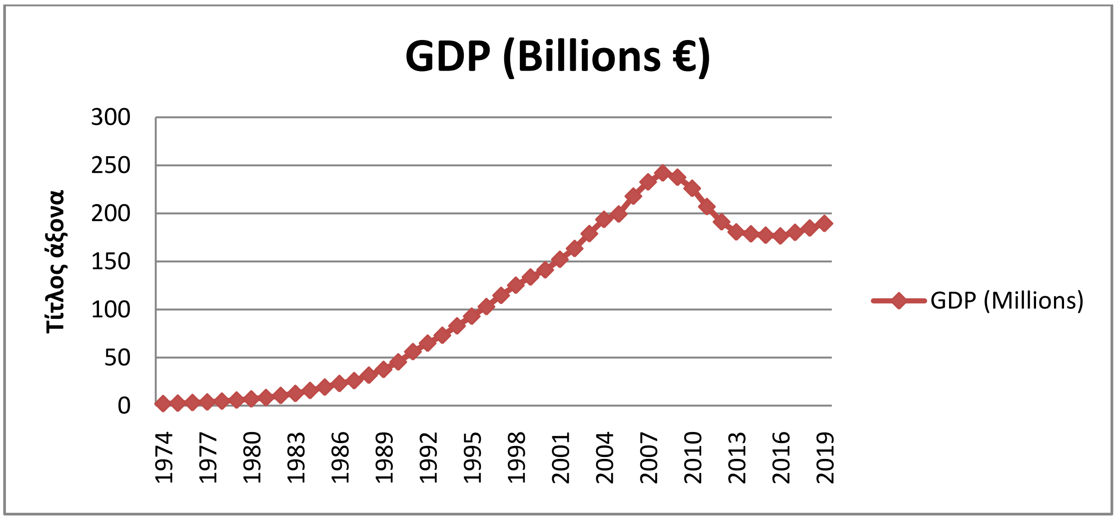

Figure 1.7.3. “GDP of Greece” (Source: Hellenic Statistic Authority)

From the figure 1.7.3 it is worth to note few values such as, 2,23 billion euro GDP in 1974, 7,1 billion euro few years later in 1981 and 56,1 billion euro GDP in 1991, which that means that Greek GDP multiplied eight times in the period 1981-1991. The cause to which this increase of GDP, when at the same period of time the Greek public sector was growing fast as well the government spending, was due to the borrowing from the International markets with generally high interest rates.

The level of borrowing from foreign countries was low for Greece in 1974 and that was exploited by the Greek government between 1981-1990. The government burdened continuously loans the Greek economy without limit, or a strategic plan that could create new jobs in the private sector or to develop the productive sector. The purpose of the borrowing was just to satisfy the interest groups. Atsalakis, et al. 2019, refer in their study that, “over the last 40 years interest groups have absorbed more than 800 billion euro of subsidies and loans and all they have done is to almost lead to bankrupt”.

Greece from 1974 onwards, when its state stabilized, the course of its economy reaches the highest point in 2008 and then follow the fall that brings it to the brink of bankruptcy in 2012 and further decline in 2015. Back from this route is hidden the action of interest groups, just as Mancur Olson describes in his theory and presented analytically in the paper of Papadakis et al. (2022), specifically for the case of Greece.

CHAPTER II

BIBLIOGRAPHY REVIEW

2.1 Literature survey: Impacts of interest groups on economy

Interest groups are a major field of research for scientists such as political scientists, sociologists who study the action of these groups and focus on the political and social conditions that cause their formation, their political influence and their adverse effects on the countries society. As regards the impact on the country's economy, Olson (1965) and (1982) was the first to present a comprehensive theory on the formation, the purpose of operation and the results of interest groups' activity in the economy. Studying the literature it is noted that economists study the basic theory of Olson (1982) on the formation of interest groups and also focus on the confirmation of their impact on the economies.

The focus on these articles is significant in order to study the variables used in the research in the main fields below: a) test on the implications of the Olson hypothesis, b) examination of the impact, in any way, of interest groups on the economic growth and development, c) examination of the impact of interest groups not only on financial but also on political and social fields, d) examination of the factors which affect the formation of interest groups. In correspondence to the above classification in main research domains, the surveyed articles may be classified in four categories:

Peter Murrell (1984) in his study, tests eleven (11) hypotheses using as dependent variable the number of interest groups in a particular country in 1970. More analytical, tests the relation between number of interest groups and number of industries, number of regions, population, democracy, party fractionalization, tax revenue, decentralization, duration of political stability, per capita income, the amount of diversity in a country. As a result at his study ends up that, population, decentralization of government and length of time of modernization are determinants of interest groups activity.

Weede (1984) at his cross-sectional regressions defines as dependent variables, gross domestic product growth rates for 1960-1980, gross national product per capita, and average percentages of unemployment in the national work force

(1960-1980). There are four independent variables, government revenue as a percentage of GDP in 1965, average post-war legislative strength of socialistic parties, Hewitt's index of full democracy properly modified, and social security spending as percentage of GDP in 1965, which will be checked the degree of their impact on unemployment and economic growth. Weede's regressions results do not show a significant relation between GDP growth rate and the independent variables for the whole sample of countries. Continuing his research Weede (1986), investigates three proposals about economic growth. First, the proposal that difference in the size of the agricultural sector reallocates resources to other sectors of the economy, second, that long lasting democracies suffer from an accumulation of distributional coalitions whose rent-seeking activities retard economic growth and third, that the welfare state contributes to economic decline. In the purely cross-sectional analyses, none of the propositions in his paper received unambiguous support. By contrast, the pooled analyses clearly support the conclusions that high agricultural employment provides that distributional coalitions and price distortions in aging democracies retard growth and that the welfare state also interferes with economic growth. In author's view, "the cross-sectional analyses amount to a fairly limited test of the propositions under study, whereas the pooled analyses simultaneously test the cross-national and the cross-time implications of his propositions". Therefore, the pooled analyses are preferable and the conclusions acceptable.

Mueller and Murrell (1986) test and develop hypotheses concerning the impact of interest groups on government size. The basic hypothesis that has been tested is, if the relative size of government is positive related to the multitude of organized interest groups or to others variables. Their study concludes that the most important variables which explain government size are the population, the voters percentage and the number of interest groups,.

Vedder and Gallaway (1986) developed a model to explain differential income growth that incorporates some 11 independent variables. The model is estimated using ordinary least squares regression analysis for the 48 contiguous states for the 1970-1982 time period. The results end up that only the variables originally used by Olson as the age of state and Union and the labor union membership as a percent of nonagricultural employment in 1970, are statistically significant at the one percent level, compared to the others variables.

Lane and Ersson (1986) in their study test the argument that institutionalization leads to the decline of nations slowing down the rate of economic growth. For this reason restrict their model by including politically relevant variables in order to search for evidence for the long-run variation in economic growth. The article concludes, that institutionalization expressed as an index developed by Choi , has a strong direct negative impact on economic growth, confirming the institutional sclerosis as developed by Olson. Also the length of time of institutionalization matters for the understanding of the variation in national growth rates especially in the post-War period.

In particular, the study of McCallum and Blais (1987) concerned with the causes for the different growth rates of countries over past 25 years. The mainly points of the research are the roles, of the government and of special interest groups as emphasized by Olson (1982).

Chan (1987), analyses the hypothesis that countries which have undergone more severe forms of civil war and (or) foreign occupation have normally weaker distributional coalitions. These countries are more likely to be able to achieve faster financial rate growth and equitable distribution of income and social welfare. The pertinent regression results for the Asian-Pacific rim countries, confirm Olson's implication, that countries with higher growth rate had experienced greater trauma in the form of civil war, insurgency movements, foreign military occupation or colonialism.

Nardinelli et al. (1987), tests Olson's hypothesis that differences in rates of economic growth in different American states can be explained by differential accumulations of common interest groups. In addition to the Olson Hypothesis Nardinelli et al., test one of its leading competitors: the catch-up hypothesis. Finally, no evidence consistent in the Olson's hypothesis that differences in state growth can be explained by the age of the state. One main result that emerged by the regression analysis is that only initial incomes explain the variation on the growth of state income.

The empirical study for the implications of Olson continues by Wallis and Oates (1988), that firstly attempt an econometric analysis of the size of government and following the description and discussion of these results, they move on to a new econometric study of the relationship between the age of states and their rates of economic growth. Test for a long period an extension of the Olson-Choi regression analysis, back to the beginning of the twentieth century. The results provide a weak support for the Olson hypothesis, they found significant negative association between age and the rate of economic growth.

Also, Gray and Lowery (1988) develop a model with series of equations that are more consistent with the complex set of relationships posited by Olson. The model is then partially tested with U.S. state data for the period of late 1970s and early 1980s and the results provide little support for the Olson construct.

Kennelly and Murrel (1991), examine the way if it is possible, the variations in interest group formation to be explained by the variations of industrial and political characteristics. Another issue that check out in their paper is the significance of a variety of political and industry variables. An important result of the empirical test, is that the length of time that interest group formation is possible, support Olson's hypothesis on the gradual accumulation of interest groups. Instead the government size, has not a significant reaction on interest groups formation, like the other variables tested.

Quiggin (1992), shows that "the strong versions of the Olson hypothesis suggesting that destructive shocks may have positive net benefits cannot be sustained by a valid empirical test. It follows that transitional costs must be taken into account in any policy program aimed at reducing the influence of interest groups".

Tang and Hedley (1998), researches the differential economic growth rates among developing countries. Combining a statist perspective with Olson's theory of interest groups formation, this research presumes that nations with weak distributional coalitions will more likely experience high growth and state intervention will be effective. As a result of the study the variables, age of a nation since its last upheaval, concentration of last ownership and urbanization stand out as stronger measures of distributional coalitions.

Crain and Lee (1999) use "annual panel data on the America states to identify which variables are robust to small changes in the conditioning information set". The results provide a set of core variables as a starting point for future research that relies on state growth regressions.

Heckelman (2000), studies the instrumental variable routines which increase the estimated impact of special interests on the economy. He outlines the problem of proxy variables showing that in bivariate regressions the slope coefficients will be biased downward and presents the empirical results which support the econometric theory that larger elasticity will result when the errors-in-variables problem is correctly accounted for. Finally, he analyses the indirect evidence that special interest groups grow over time in stable environments and lead to lower growth.

Cole and Chawdhry (2002) use data from 43 contiguous U.S. states for the 1980-90 period in their paper, in order to test the proposal, that rent-seeking activity (RSA) is harmful to economic growth. Their model takes into account the issues of endogeneity, causality and the lag structure of a large number of variables. The Rent Seaking Activity is measured indirectly, by the number of these organizations compared to the size of the state's economy, the raw numbers of interest organizations, the interaction between lobbying regulations, the size of state government bureaucracy, the number of interest organizations, and the rigor of their enforcement. As expected, all the above variables have a strong causal effect on economic growth.

In his paper, Bischoff (2003) studies the impact of the duration of political stability on the number of interest groups and their effect on the economic development. He uses an empirical cross-sectional regression analysis using data from 21 OECD countries to investigate the issues mentioned above. The results of his study give support to the following conclusion: The number of interest groups within a country is not influenced by the duration of its political stability whereas GNP per capita is found to have a significantly positive influence.

Coates and Heckelman (2003a) test the impact of the number of special interest groups per capita on the nation's economic growth rate. They use Murrell's (1984) measure of the number of special interest groups in the OECD nations in 1970 to explain growth rates for the decade from 1970 to 1980.

In the second study of the same year, Coates and Heckelman (2003b) continue their study with a further test of the Olson hypothesis, examine the relationship between real domestic investment to real GDP. The results indicate that interest groups have a different effect on physical investment in OECD and non-OECD countries. For OECD countries, it is confirmed the support of the hypothesis that interest groups harm investment in physical capital. For developing countries, interest groups either have a slight beneficial impact, or none effect on physical investment.

Using cross-country data, Knack (2003) "investigates the impact of associational memberships on generalized trust and economic performance". The results of standard cross-country investment and growth regressions, in which a group of membership variables is included as regressors, provide little support of groups as distributional coalitions with harmful effects on economic performance.

Coates and Wilson (2007) explore whether there is a measurable and meaningful relationship between interest group activity and the long-run performance of national stock markets. In particular, using data on a cross-section of countries, they examine whether a count of the number of interest groups in a country provides an explanation for average annual stock returns and the standard deviation of annual stock returns, over the period 1970-2000. "Interest groups are thought to influence economic activity through two primary channels: resource allocation and technological change (or lack thereof)". The findings of the study, strongly confirm the proposal that the multitude of interest groups is negatively related to the volatility of national stock market returns. The negative relationship revealed between interest group activities and average returns is consistent with Olson's institutional sclerosis hypothesis, and suggests that interest groups reduce incentives to risk-taking, potentially lowering the rate of economic growth.

Coates et al. (2007) explore the relationship between special-interest groups and volatility of GDP growth. In an unbalanced group which consist 108 countries, they found a negative significant relationship between the volatility of GDP growth and the number of interest groups in a country. Coates et al, continue their studies on special interest groups exploring by an empirical view the relation between economic growth and special-interest groups. In their analysis they exploit more recently data about the multitude of groups observed across countries and time in order to mitigate the establishment problems which concerned newer studies. Also, they examine the effect of groups on two sources of economical growth, the technological development and the capital accumulation, in addition to the impact of groups on output growth. The findings are consistent with Olson's (1982) claim that societies with plenty interest groups grow slower, less capital is accumulated and as expected the productivity growth is reduced.

Coates et al. (2007b) attempt to discern empirically the factors that contribute to interest activity by providing a test of several theories of group formation in a panel setting such as a nation's stability, socioeconomic development, political system, size and diversity.

In "Interest groups and economic performance: some new evidence", Horgos and Zimmermann (2009), survey the existing results from the cross-sectionally tests on Olson's theory, with special focus on studies using the number of lobbies as an exogenous variable. Also, using data from the period 1973-2006, they present the field's first time-series analysis of the effects of the number of interest groups on the German lobby list and macroeconomic performance, gauged in terms of economic growth and inflation.

Coates et al. (2010), explore the relation between investment and the activity of interest group activity by analyzing an unbalanced group of observations for 126 countries over three period times.

Heckelman and Wilson (2013) investigate whether the impact of institutions depends not just on their current state but also on how they came to be.

Cole (2014), "re-examines the issue, incorporating a potentially important aspect, the implicit suggestion by some of the theoretical works that the extent and the intensity of the growth effects of special interest groups may differ significantly over different time frames". More specifically, this study uses a dynamic panel error-correction method which is developed in the paper of Pesaran et al. (1999) and determine properly whether these effects, if any, occur mostly in the short or in the long run, based on data from a group of 48 U.S. states for the period 1975-2004.

2.2 Variables and related data sets survey

This section presents a table in which the articles are sorted in chronological order. For the better display of all variables and data sets, it is very helpful the creation of table 2.2.1, which comprises nine columns. The first column gives the names of the authors' articles , the second one the title of the article, the third one lists the variables that have been used in their study, the fourth one gives the main research domain of each study, the fifth one lists the source data, the sixth one the sample size, the seventh one the period time of the research, the eighth one the model used in their analysis and in the last column , one may see notes which mainly explain the definitions of the variables.

With regard to the articles, the number of variables used ranging from 3 to 33. Quiggin (1992), in his study to test implications of Olson hypothesis and Coates and Heckelman (2003a), in their examination of the relationship between interest groups and investment in physical capital, use only three variables each. The number of variables used in most of the articles is over 10, up to a maximum of 33. Two articles with a large number of variables are: Coates et al. (2007) that use 26 different variables and Crain and Lee (1999) where 33 variables have been used.

The chronological study period that the articles are mainly concerned with, is after 1960, with the exceptions of Nardinelli et al. (1987) whose study begins in 1929 and Wallis and Oates (1988) whose study begins in 1902. Few studies have as a period time of research just one separate year, like these of: Murrell (1984), Mueller and Murrell (1986), Kennelly and Murrel (1991), Quiggin (1992), and Bischoff (2003). In the rest of the articles, the research period time spans over four years.

Most articles explore the development of interest groups in OECD countries and in the States of America. Except for the article of Horgos and Zimmermann (2009) which focuses only on Germany, all the other articles focus on a group of countries. The number of countries that form the countries' groups commences with 17 OECD countries in McCallum and Blais (1987) and ends with 140 countries in Coates et al. (2007b).

TABLE 2.2.1. Bibliographic research, articles sorted in chronological order.

Author's name	Title	Input variables	Research domain	Source data	Sample size	Period-time of research	Model	Notes
Murrell (1984)	**"An examination of the factors affecting the formation of interest groups in OECD countries"**	Number of industries[(1)], Number of distinct regions in a country, number of regions, population, degree of democracy in a country[(2)], citizens paticipation in democratic decision making[(3)], degree of political fractionalization[(4)], tax revenues as a proportion of GDP, employment in government as a percentage of total employment, percentage of tax revenues collected at the state, the age of political institutions in a country, GDP per capita, a proxy for the level of development [(5)], ethnolinguistic fractionalization, linguistic fractionalization, the proportion of the adult population which voted in an election in the 1960's	**factors affect the formation of interest groups**	World Guide to trade Associations, K.G.Saur	24 OECD countries	year 1972	Corellation tests, t-statistic, stepwise regression	[(1)]"for which there was a positive production level in 1970, [(2)] calculated for 1969, is a linear combination with essentially arbitrary weights, of variables measuring freedom to form organization, freedom of expression, right to vote etc,[(3)]combination of variables measuring press freedom, government sanctions, freedom of group opposition, [(4)]the probability that two randomly selected members of the legislature come from different parties, [(5)]percentage of male labor force in agriculture / newspaper circulation per 1000 population in 1965",
Weede (1984)	**"Democarcy, creeping socialism, and ideological socialism in rent-seeking societies"**	"Gross national product per capita, gross domestic product growth rates in the 1960-1980 period, average percentages of unemployment in the national work force (1966-1980), Hewitt's index of full democracy[(6)], government revenue as a percentage of GDP in 1965, social security spending as a percentage of GDP in 1965, average post-war legislative strength of socialist parties[(7)]"	**Explores the case that creeping socialism by increasing government control of the economy should reinforce the rent-seeking society and the corresponding negative effects on growth and employment**	World Bank, Organization for Economic Cooperation and Development, Hewitt 1977	19 Industrial democracies	1960-1980	Regression analysis	[(6)]"Hewitt defines full democracy by the simultaneous fulfillment of three requirements: universal adult male suffrage, secret ballot, and responsible government, [(7)]taken from Hewitt, 1977: 459",

Mueller and Murrell (1986)	**"Interest groups and the size of government"**	Total outlays of government as a percentage of GDP, total tax revenue as a percentage of GDP, Government final consumption as a percentage of GDP, population in millions, per capita GDP as a percentage of U.S. per capita GDP x 10, ethnic fractionalization(8), number of interest groups(9), political fractionalization(10), skewness of income distribution(11), degree of enfranchisement(12), median income(13), start of modernization(14), government centralization(15), educational level(16), dummy variable(17)	**Seek to explain the relative size of government across countries**	OECD, IMF, United Nations, Taylor and Hudson 1972, Sawyer 1976, Black(1966)	24 OECD countries/ 10 Non OECD countries	1970	Regression analysis using Ordinary Least Squares	(8)the probability that two randomly selected members of the population will not be from the same ethnolinguistic group,(9)a count of the number of interest groups listed for each country in a standard reference work, (10)the probability that two randomly selected members of parliament will not be from the same party, (11)total income of the middle quintile of households in the income, (12)percentage of adult population voting in a general election, (13)mean income multiplied by skewness of income distribution, (14)average of the years in which a country began the political government level, (15)percentage of tax revenues collected at the central government level, (16)percentage of adult population able to read, (17)Switzerland=1; other countries=0
Weede (1986)	**"Sectoral reallocation, distributional coalitions and the welfare state as determinants of economic growth rates in industrialized democracies"**	GDP growth, GDP growth rate per capita, agricultural employment/civilian employment, age of democracy in 1971, social security transfers/GDP	**Applies cross-sectional and pooled regression analyses of growth rates on employment in agriculture**	OECD, Weede 1984	19 nations	1960-1982	Regression analysis	

Vedder and Galloway (1986)	**"Rent-seeking, distributional coalitions, taxes, relative prices and economic growth"**	Income growth[(18)], age of state, labor union membership[(19)], average level of benefits received[(20)], , the proportion of the population receiving benefits[(21)], income taxes[(22)], corporate income taxes[(23)], sales taxes[(24)], minerals[(25)], agriculture[(26)], sunshine[(27)]	**Develop a model to explain differential income growth in 48 contiguous states of America**	Statistical Abstract of the United States, U.S. Department of Commerce	48 contiguous states of America	1970-82	Least squares regression analysis	[(18)]personal income growth in percentage terms for the 1970-82 period for the 48 geographically contiguous states of America, [(19)]as a percent of nonagricultural employment in 1970, [(20)] at the beginning of the period by recipients of aid to families with dependent children, [(21)]as the aid to families with dependent children, [(22)]the change from fiscal year 1970 to fiscal year 1982 in payments per $1000 in personal income taxes for individual income taxes, [(23))]the change from fiscal year 1970 to fiscal year 1982 in payments per $1000 in personal income for corporate income taxes, [(24))]the change from fiscal year 1970 to fiscal year 1982 in payments per $1000 in personal income for sales taxes, [(25)]capturing per capita output of minerals at a date late in the period under examination, [(26)]measuring total farm marketing per capita in the various states, [(27)]the average number of days of sunshine
Lane and Ersson (1986)	**"Political institutions, public policy and economic growth"**	GDP average growth rate, GDP per capita average growth rate, GNP per capita, economic maturity[(28)], institutionalization[(29)], structure of interest groups[(30)], corporatist interest mediation[(31)], consociationalism[(32)], party government[(33)], public policy[(34)]	**test the argument that institutionalization leads to the decline of nations slowing down the rate of economic growth**	OECD outlook, OECD Historical statistics	24OECD countries	1960-83	Regression analysis	[(28)]a "measure of the size of the tertiary sector, [(29)]an index developed by Choi which taps the length of the period that a nation has had a political structure intact (Choi 1983), [(30)]focus on the structure of the trade unions: a unionization index (Therborn 1984, Kjellberg 1983, Miele 1983, Korpi 1983) and a centralization index (Heady 1970), [(31)]corporatist avenues to national decision-making may result in encompassing decision-making: two corporatization indices (Shmitter 1981, Wilensky 1976),[(32)]indicators that measure the amount of political competition in the composition of government: a consociationalism index (Lijphart 1979) and an index of oversized cabinets (Lijphart 1984), [(33)]measure the composition of governments in the following way: an index of socialist and bourgeois dominance (Schmidt 1983); government durability (Lijphart 1984), [(34)]measures of the size of the public sector since 1960:total outlays, transfer payments and final government consumption"

McCallum and Blais (1987)	**"Government, special interest group, and economic growth"**	Growth rate of total output, rate of technical progress, growth rate of inputs of capital and labor average annual percentage change of real gross domestic product or GDP, government final consumption expenditures as a percentage of GDP, social security transfers as a percentage of GDP, net lending of government and total taxation as a percentage of GDP, social security payments, number of years since the first constitution, number of special interest groups, population, degree of wage bargaining is centralized, ratio of per capita GDP.	**focus on the role of government and the role of special interest groups investigate the reasons why different countries have grown at different rates.**	OECD, Historical Statistics	17 industrial countries- OECD members	4 time periods 1960-1967, 1967-73, 1973-79, 1979-83	Regressio nanalysis (t-statistics)	
Chan (1987)	**"Growth with Equity: a test of Olson's theory for the Asian Pacific-Rim Countries"**	GNP growth[35], internally-introduced trauma[36], military deaths in civil war, externally-introduced trauma[37], Japanese occupation forces[38], combined trauma rating	**Analyze the Olson's hypothesis for distributional coalitions**	U.S. Arms Control and Disarmament Agency, Small & Singer(1982), James (1951)	Asian Pacific-rim countries	1966-83	Regressio n analysis	[35]average "annual rate of GNP increase during 1961-1983,[36]five point scale, rating the severity of civil war or domestic insurgency, [37]five-point scale, rating the severity of foreign occupation or colonialism, [38]disposition of Japanese overseas forces on the day of its surrender in World War II"
Nardinelli, et al. (1987)	**"Explaining differences in state growth: Catching up versus Olson"**	Real per capita income in the state, initial income[39], state age[40],initial share federal government[41], initial share state and local government[42],initial share agriculture[43], initial share manufacturing[44], initial education[45]	**Test Olson's hypothesis for differences in rates of economic growth of the different American states.**	U.S. Bureau of Economic Analysis	States of America	1929-82	Regressio n analysis	[39]state " income in the initial year (1929 or 1954), [40]1982 minus date of admission to the union for the eleven confederate states 1865 and 1954 were substituted for the date of admission in some regressions, [41]share of state income accounted for by federal salaries in the initial year, [42]share of state income accounted for by state and local salaries in the initial year, [43]share of state income obtained from agriculture in the initial year, [44]share of state income obtained from manufacturing in the initial year, [45]percentage of population 18 and older completing high school,"

Wallis and Oates (1988)	**"Does Economic Sclerosis Set in with Age? An Empirical Study of the Olson Hypothesis"**	State and local revenues as a percentage of per-capita income, state and local expenditures as a percentage of per-capita income, number of years since statehood, number of years since statehood; statehood for confederate states=1865, state population(46), fraction of state population living in urban areas, fraction of state population living on farms, fraction of state population that is white, land area in square miles, population density per square mile, per-capita income, fiscal concentration of state-local sector by revenue measure(47), fiscal concentration of state-local sector by expenditure measure	**Test the Olson hypothesis**	National Bureau of Economic Research, National Science Foundation, U.S. Censuses of Government, the decennial Censuses of Population	States of America	Decades between 1902-82	Regression analysis	(46)measured in thousands, (47)state revenues as a fraction of combined state and local revenues
Gray and Lowey (1988)	**"Interest group politics and economic growth in the U.S. States"**	Number of interest groups(48), group size(49), level of nonencompassingness(50), level of business nonencompassingness(51) , economic growth, time(52), interest group power(53), interest group power relative to government(54), labor and proprietor's income, per capita labor and proprietor's income, private nonfarm income, per capita private nonfarm income, manufacturing income, per capita manufacturing income	**develop a model with series of equations that are more consistent with the complex set of relationships posited by Olson**	Olson(1983), Choi(1979, Marquis Academic Media(1978), Lange & Garrett(1974-80), Conover & Gray (1983)	U.S. states	1975, 1980, 1975-80	Regression analysis	(48)number of union and business interest groups in 1975 were obtained from Marquis Academic Media(1978), (49)for unions indicated by the percentage of the labor force that is unionized and for business interest groups were measured by the percentage of the state's labor force employed in manufacturing and services, (50)measured by the ratio of the number of union organizations employing registered lobbyists to the size of the unionized sector of the labor force, (51)measured by the ratio of the number of firms employing registered lobbyists to the number of trade associations employing lobbyists, (52)number of years since state admitted to the union, (53)measured as the result of multiplying the number of groups, size of group and nonencompassingness, (54)interest group power divided by Klingman-Lammers index(1984) -Encompassing groups: those that embrace a large proportion of the members of the society-

Kennelly and Murrell (1991)	**"Industry characteristics and interest group formation: An empirical study"**	Proportion of demand by households, Square root of predicted level of imports, square root of predicted level of exports, share of output earned by labor, consumer's elasticity of demand(55), free-rider effects; number of firms(56),number of potential products, size of industry(57), length of time in which group formation possible(58), size of government(59), multiple jurisdictions under federalism(60), uncertainty/fluctuations(61), per capita GDP, country size(62), possible bias in data(63)	**Examine the way in which variations in interest group formation are explained by variation in industrial and political characteristics**	World Guide to Trade Associations (1982), U.N. International Standard Industrial Classification	75 industrial sectors in 10 countries	1982;	Regression analysis	(55)measures "only the final demand component; the intermediate demand elasticity is missing, (56)Four-firm concentration ratios, (57)value added, (58)date of beginning of modernization process, (59)predicted tax revenue as a percentage of GDP/ predicted subsidies as a percent of GDP, (60)number of sub-divisions in federal systems (0 for unitary countries), (61)fluctuations in GDP 1950-1979, (62)population, (63)dummy for Fed. Rep. Germany"
Quiggin (1992)	**"Testing the implications of the Olson hypothesis"**	Political stability(64), per capita GDP(65), Choi's index of institutional sclerosis	**Testing the implications of the Olson Hypothesis, that accumulations of interest groups build up over time and retard economic performance**		OECD countries	1976	Regression analysis	(64) two "measures of stability are given, the first is the number of major constitutional shifts over the period since 1980 and the second is the approximate period since the most recent constitutional change, (65)in 1976 (using the criteria of Summers and Heston 1984, 1988 and Dowrick and Nguyen 1989",
Tang and Hedley (1998)	**"Distributional coalitions, state strength, and economic growth: Toward a comprehensive theory of economic development"**	rate of growth in gross national product per capita, year of last turmoil, percentage of land concentration(GINI)(66), percentage of the total labor force(67), working days lost due to industrial, level of urbanization in 1970, government revenue as percentage of GDP, government expenditure as percentage of GDP, state index(68)	**Examine the impact of the state and the presence of distributional coalitions of interest groups on the economic growth and development of these 20 countries**	World Bank (1992)	8 countries fron Asia-Pacific region & 12 from Latin America	1965-1990	Reggresion analysis	(66)measure the strength of landowning classes, (67) around 1975, (68) the averaged values of level of government consumption, military manpower, total fertility rate denotes social control capability.

Crain and Lee (1999)	**“Economic growth regressions for the American States: A sensitivity analysis”**	“Real per capita personal income, share of the population ages 18-64, percent of the population with a B.A. or better, industry diversity[(69)], manufacturing share of GSP, service share of GSP, state and local total revenue as a share of income, state and local tax revenue as a share of income, real state and local total revenues per capita, real state and local total tax revenues per capita, state and local expenditure as a share of income, real state and local expenditure per capita, government share of gross state product, private capital as a share of gross state product, public capital as a share of gross state product, total capital as a share of gross state product, private capital to labor ratio, public capital to labor ratio, total capital to labor ratio, religious affiliation diversity[(70)], church members as percent of population, black population share[(71)], local share of state and local total tax revenue, percent of population living in metropolitan area, population per square mile, residence adjusted personal income as a share of total, percent housing units owner occupied, business association revenues as a share of income, other membership organization revenue as a share of income, real revenue of business associations per capita, real revenues of other membership organizations per capita, number of business associations per capita, number of other membership”	**Use extreme-bounds analysis to assess the sensitivity of numerous control variables identified in the state growth literature**	BEA Regional Projections to 2045, Statistical Abstract of the United States, Bureau of the Census, Munnell (1990), Holtz-Eakin (1993), Churches and Church Membership, City and County Databook, Census of Service Industries	48 contiguous States of America	1977-1992	Extreme-bounds analysis	[(69)]is calculated as “the sum of the squared share of private, non-farm GSP originating in eight industries: agricultural services; mining; construction; manufacturing; transportation and utilities; wholesale and retail trade; finance, insurance and real estate; and services, [(70)]calculated as the sum of the squared share of total adherents comprising four broad denominations: Baptists, Catholics, Methodists and all others , [(71)]black percent of population”,

		organizations per capita, percent of employed member of labor organization, real energy prices						
Heckelman (2000)	**“Consistent estimates of the impact of special interest groups on economic growth”**	average annual growth rate, strength of the SIGs in each country in 1970(72) / initial level of GDP, the ratio of Gross Domestic Investment as percent of GDP, the ratio of general government consumption to GDP, total population, percent of population in urban areas	**Estimation of the impact of SIGs on economic growth**	World Bank (1994)	42- (22OECD +20 OTHERS) / 34 countries	1970-80 / 1970-80	Regression OLS, Wald, Barlett, Durbin methods/ Regression OLS, Wald, Barlett, Durbin methods	(72)is proxied by the number of SIGs as estimated by Murrell (1984)
Cole (2002)	**“Rent seeking and economic growth: evidence from a panel of U.S.States”**	Economic growth(73), state's real per capita output, private physical investment rate, public physical investment rate, human capital investment(74), local tax revenues per capita, expenditure on police and fire protection per capita, measure of public services, energy price in the state's industrial sector, measure of the state's industrial mix(75), measures of rent-seeking activity (RSA)(76), state’s initial-period real per capita gross state product, lobbying regulation and their rigor of their enforcement, number of interest	**Investigate the relationship between state economic growth a-nd Rent-Seeking Activity (RSA)**	Bureau of Economy Analysis, Bureau of the Census, Governmental Finances, County and City Data, State Energy Price and Expenditure Report of the Department of Energy, Gray and Lowery (1996)	43 contiguous states	1980-1990	VAR model	(73)as the “nominal gross state product deflated by the GDP price index and divided by the state population,(74)as the percentage of the state’s population with 16 years or more of education (75) measured as the ratio of state manufacturing output to gross state product, (76) are based on Buchanan's (1980) suggestion involving government bureaucracy(state government employment as a percentage of employment in the state and retail trade sector) and lobbying activity (raw numbers of interest organizations registered to lobby in a state’s legislature and the average number of real gross state product in dollars behind each organization in the state)”

		organizations registered to lobby.						
Bischoff (2003)	**“Determinants of the increase in the number of interest groups in western democracies: Theoretical considerations and evidence from 21 OECD countries”**	number of trade associations excluding chamber of commerce, duration of political stability of a country, total population in 1997, degree of economic development[(77)], ratio of imports to GDP, Government purchases in GDP, Share of urban population in 1997	**Investigate the impact of the duration of political stability on the number of interest groups and their effect on the economic development**	World Bank, OECD	21 OECD countries	years 1973, 1999	Regressio n analysis	[(77)] approximated by gross national product per capita
Coates, Heckelman (2003a)	**“Absolute and relative effects of interest groups on the economy”**	Special interest groups per capita, government share of GDP, ratio of groups per capita to the government’s share of GDP, growth rate 1970-80, growth rate 1980-90, number of special interest groups, initial GDP, investment as a percentage of GDP, urbanization rate	**Test Olson’s hypothesis**	World Bank, Murrell (1984)	22 OECD countries	1970-1980	Regressio n analysis	
Coates, Heckelman (2003b)	**“Interest groups and investment: A further test of the Olson hypothesis”**	number of interest groups, income[(78)], total physical investment[(79)] , private physical investment[(80)]	**Examine the relationship between interest groups and investment in physical capital**	Barro and Lee (1993) data set	42 (OECD & non-OECD) countries	1970-1974	Reggresio n analysis	[(78)] measured as the logarithm of GDP per capita, [(79)] ratio of real domestic investment to real GDP, [(80)] ratio of real private domestic investment to real GDP

Knack (2003)	**"Groups, growth and trust: Cross-country evidence on the Olson and Putnam hypotheses"**	growth[(81)] , investment[(82)] , initial per capita income, mean years of schooling[(83)], a property rights index[(84)], log of inflation[(85)]	**tests empirically the impact of group memberships on generalized trust and on economic performance**	World Values Surveys (WVS)	38 countries	1980-1999	Regression analysis	[(81)]average annual increase in per capita income, [(82)]gross "fixed capital formation as a share of GDP, [(83)]completed for the over 25-population, averaged over 1980, 1985, 1990 and 1995,[(84)]constructed from International Country Risk Guide data averaged over 1982-97, [(85)]averaged over 1980-98"
Coates and Wilson (2007)	**"Interest group activity and Long-run stock market performance"**	average annual real stock return, standard deviation of annual real stock returns, interest group activity[(86)] , natural log of GDP, natural log of the number of interest groups, natural log of population size, initial GDP, total schooling[(87)], revolutions[(88)], investment share[(89)], openness to trade[(90)], Government size[(91)], inflation[(92)], black market premium[(93)], corruption, rule of law[(94)], bureaucratic quality[(95)], democracy[(96)], repudiation of contracts[(97)], risk of expropriation[(98)], regulation procedures[(99)], regulation costs[(100)], market capitalization[(101)], value traded[(102)], turnover ratio[(103)], private credit[(104)]	**Explore whether there is a measurable and meaningful relationship between interest group activity and the long-run performance of national stock markets**	World Guide to trade Associations, K.G.Saur, World Banks's World Development Indicators, World Banks's World Development Indicators, Global Financial Data Inc.	55 countries (23 categorized as developed economies and 32 as developing)	1970-2000	Regression analysis	[(86)] count "of the total number of "trade associations" in a country in 1970, [(87)]initial value of average years of total schooling in the population over 25, [(88)]initial number of revolutions,[(89)]initial share of gross fixed capital formation in GDP,[(90)]initial share of exports plus imports in GDP,[(91)]initial share of government consumption expenditure in GDP, [(92)]initial percent change in the CPI, [(93)]initial black market exchange rate premium, [(94)]reflects the extent to which events conform to law, [(95)] refers to the quality of government bureaucracy,[(96)]average annual value of a measure of the general openness of political institutions,[(97)]indicates the likelihood a government will modify or repudiate a contract with a foreign business, [(98)]evaluates the risk of confiscation of property, [(99)]is the number of procedures required to start a firm, [(100)] measures the cost of obtaining legal status to operate a firm, [(101)]is the average of the annual value of listed shares divided by GDP, [(102)]is the average of the annual value of trades divided by GDP, [(103)]is valued traded divided by market capitalization, [(104)]is domestic credit to the private sector as a share of GDP"
Coates et al. (2007)	**"Special-interest groups and Volatility"**	Standard deviation of annual real per capita GDP, standard deviation[(105)], interquartile range of annual real per capita GDP, interquartile range[(106)], Initial GDP[(107)], inflation[(108)], annual share of trade in GDP, private credit[(109)], political rights[(110)], investment profile[(111)], population, 1973 year dummy[(112)], 1985 year dummy[(113)], latitude in degrees,	**Explores the relationship between special-interest groups and volatility of GDP growth**	World Guide to Trade Associations,	108 countries	1973-1982, 1985-1994, 1995-2004	Reggresion model	[(105)]interacted "with a dummy variable indicating an annual growth rate sign change during the relevant decade/interacted with the fraction of years in which an annual growth rate sign occurred during the relevant decade, [(106)] interacted with a dummy variable indicating an annual growth rate sign change during the relevant decade/interacted with the fraction of years in which an annual growth rate sign occurred during the relevant decade,[(107)] log of real GDP per capita in USD, [(108)]annual percent change in the CPI,[(109)]annual share of domestic"

		OECD dummy[114]						"credit provided by banking sector in GDP, [110] index of the degree of freedom in the electoral process, political pluralism and participation, and functioning of government, using an inverse of the original 1-7 scale such that higher values represent more political rights, [111]index of investment risk, with values from 0 (very high risk) to 12 (very low risk),[112] dummy variable indicating the 1973-1982 subsample, [113] dummy variable indicating the 1985-1994 subsample, [114]indicating OECD membership prior to 1985"
Coates et al. (2007a)	**"Special-interest groups and growth"**	GDP growth (average)[115], Capital stock growth (average[116]), Productivity growth (average)[117], initial GDP[118], schooling[119], volatility[120], log of the total population, inflation(average and initial value)[121], trade(average and initial value)[122], government size(average and initial value)[123], private credit(average and initial value)[124], investment profile (average and initial value)[125], corruption (average and initial value)[126], law and order(average and initial value)[127], bureaucracy quality (average and initial value)[128], political rights (average and initial value)[129], latitude in degrees, Muslim dummy[130], OECD dummy[131], Institutional instability[132]	**explore empirically the relation between special-interest groups and economic growth**	World Guide to trade Associations, K.G.Saur, World Banks's World Development Indicators	82 countries are included in the 1985 subsample/ 87 countries included in the 1995 subsample	1985-1994, 1995-2004	Regression model	[115]growth of "annual real per capita GDP, [116]growth of annual real per capita capital stock, [117]growth of annual real per capita productivity growth,[118]log of real GDP per capita in USD, [119]log of average years of schooling in the total population over 25, [120] standard deviation of annual real per capita GDP growth ovet the periods 1985-1994 and 1995-2004,[121]annual percent change in the CPI, [122]annual share of trade in GDP, [123]annual share of government consumption expenditure in GDP, [124]annual share of domestic credit provided by banking sector in GDP,[125]index of investment risk, with values from 0 (very high risk) to 12 (very low risk); index components are contract viability/expropriation, profits repatriation and payments delays,[126]index of corruption within the political system, with values from 0 (very high corruption) to 6 (very low corruption),[127] combined index of the strength and impartiality of the legal system along with popular observance of the law, with values from 0 (a low rating) to 6 (a high rating), [128]index of the institutional strength and quality of the bureaucracy, with values from 0 (high risk) to 4 (low risk),[129]index of the degree of freedom in the electoral process, political pluralism and participation and functioning of government, using an inverse of the original 1-7 scale such that higher values now represent more political rights, [130]dummy variable indicating majority Muslim population, [131]dummy variable indicating OECD membership prior to 1985, [132]year of most recent fundamental regime shift, significant constitutional change, or independence"

Coates et al. (2007b)	**"Determinants of interest groups formation"**	Institutional upheaval[133], initial take off date[134], violent turmoil[135], income per capita, agriculture share[136], urban share[137], import share[138], newspapers[139], telephones[140], mail[141], democracy[142], number of parties[143], number of industries[144], population, government spending[145], linguistic fractionalization, ethnic fractionalization, religious fractionalization	**Provides a test of several theories of group formation in a panel setting**	World Bank's World Development Indicators, Encyclopedia Britannica, Black(1966), Banks Cross-National time series data archive, U.N. Yearbook of industrial statistics, {Alesina, Devleeschauwer, Easterly, Kurlat, Wacziarg(2003)}	140 countries	1969, 1975, 1981, 1989, 1992	Regression analysis	[133]number of "years since most recent fundamental regime shift, significant constitutional change or independence, [134]number of years since the average of years in which "consolidation of modern leadership" and "economic and social transformation began", [135]number of years since last turmoil, as defined by Tang and Hedley(1998); Small and Singer(1982); Lacina and Gleditsch(2005), [136]share of labor force in agriculture, average of three years prior to beginning of period, [137]urban share of population, average of three years prior to beginning of period, [138]share of imports in GDP, average of three years prior to beginning of period, [139]daily newspaper circulation per capita, average of three years prior to beginning of period (log form), [140] telephones per capita, average of three years prior to beginning of period (log form), [141]mail per capita, average of three years prior to beginning of period (log form), [142]measure of democracy and autocracy, average of three years prior to beginning of period, 0 to 10 values reflect democracy, -10 to 0 values reflect autocracy, [143]measure of political fractionalization within the legislature, average of three years prior to beginning of period, [144]number of industries, 1969, 1975, 1981, 1989, 1992 (log form), [145]share of government consumption expenditures in GDP, average of three years prior to beginning of period"
Horgos and Zimmermann (2009)	**"Interest groups and economic performance: some new evidence"**	Real "GDP, private consumption, gross investment, public debt, consumer price index (cpi), number of interest groups[146], percentage change in GDP, inflation rate", reunification dummy[147], political dummy[148]	**Investigate the interests groups effects on macro-variables in Germany**	Federal Statistical office in Germany, Bundestag (Germany's national parliament)	GERMANY	1970-2006	Prais-Winston method	[146] number of "registered interest groups in Germany since 1973, [147]express the effect of German reunification (with values of one for the years after 1991), [148] extract different political attitudes of the German government (with values of one for years with a center-right government, led by the Christian Democrats)"

Coates et al. (2010)	**"The political economy of investment: Sclerotic effects from interest groups"**	Number of interest groups[(149)], investment ratio[(150)], real GDP per capita, government spending as a percent of GDP, political rights[(151)], civil liberties[(152)], investment profile[(153)], corruption[(154)], year[(155)], colonial[(156)], OECD dummy[(157)], polity[(158)], relative price of capital[(159)], political violence[(160)], inflation rate, standard deviation of domestic inflation rate for past 7 years, private credit[(161)], black market premium[(162)], real interest rate[(163)], education[(164)]	**Relationship between interest group activity and investment**	World Guide to trade Associations, K.G.Saur, World Banks's World Development Indicators	126 countries	1985-1989, 1995-1999, 2000-2004	Regression using OLS estimation with White-corrected standard errors	[(149)]number of "interest groups in a country does not include chambers of commerce, [(150)]gross capital formation as a percent of GDP, [(151)]index of relative ranking from one (best) to seven (worst), [(152)]index of relative ranking from one (best) to seven (worst), [(153)]index of investment risk from 0 (very high risk) to 12 (very low risk), [(154)]index of perceived corruption from 0 (very high risk) to 12 (very low risk), [(155)]individual dummy variables for each cross section unit, [(156)] individual dummy variables for most recent colonization by France, [(157)]dummy variable indicating OECD membership prior to 1985, [(158)]index of the extent of regime authority from -10 (hereditary monarchy) to +10 (consolidated democracy), [(159)]price index of investment divided by price index of GDP, [(160)]magnitude score of international, civil and ethnic violence and warfare, [(161)]domestic credit provided by banks and other financial institutions as a percent of GDP, [(162)] log of (1+difference between official exchange and black market rate), [(163)] lending rate adjusted for inflation, [(164)]average number of years of education"
Heckelman and Wilson (2013)	**"Institutions, Lobbying, and Economic performance"**	Population, numbers of interest groups, democracy[(165)], stability[(166)], fractionalization[(167)], education[(168)], initial level of GDP, investment[(169)], growth[(170)] , average of the annual share of general government final consumption in GDP, economic freedom index[(171)]	**Relationship between democracy, interest groups and policy volatility**	World Guide to trade Associations, K.G.Saur, World Banks's World Development Indicators, World Banks's World Development Indicators	121 countries	1985-1989, 1995-1999, 2000-2004	Regression analysis	[(165)]computed as "a straight average of the political rights and civil liberties values (PRLC),[(166)] index of political violence taken from the Major Episodes of Political Violence database, [(167)] developed by Alesina et al. (2003), [(168)]representing the average number of years of schooling for the entire population, [(169)]gross capital formation to GDP ratio, [(170)]average annual growth rate of real per capita GDP, [(171)]is a broad indicator of economic freedom, comprised of five distinct areas covering Government size, Legal structure, Sound Money, International trade, regulation"

Cole (2014)	**"Short and long term growth effects of special interest groups in the U.S.States: A dynamic panel error-correction approach"**	growth rate level of real per capita income, state per capita income, state Gini coefficient, ratio of state and local tax revenues to state personal income, strength of special interest groups(172), human capital investment (173)	**estimating growth effects of SIG's activity**	Regional accounts data-Bureau of Economic Analysis	48 contiguous U.S. states	1975-2014	Autoregressive distributed lag (ARDL)	(172)measured "by the percentage of each state's public and private nonagricultural wage and salary employees who are union members, (173) measured as the proportion of the state population with at least high school diploma and the proportion with at least a college degree"

The main method for data processing is regression analysis, with the exception of : Murrell (1984) who uses corellation tests and the t-statistic method, Crain and Lee (1999) that use extreme bounds analysis, Cole and Chawdhry (2002) who use a VAR model to investigate the relationship between state economic growth and rent-seeking activity, Horgos and Zimmermann (2009) who make use of the Prais-Winston method to investigate the interests groups' effect on macro variables in Germany and Cole (2014) that employs the Autoregressive distributed lag to estimate the growth effect of special interest groups' activity.

CHAPTER III

METHODOLOGY

3.1 Variables

Generally in Statistical Analysis, a variable is defined as anything that is capable of more than one value. It accepts more than one value, which does not necessarily have to be arithmetical (Emvalotis et al. 2006). The values of the variable may also refer to some property. In the statistical analysis, a classification system has been established that distinguishes variables into two types: in qualitative and in quantitative variables.

Qualitative variables get values that do not have arithmetic properties. They are distinguished into nominal variables and ordinal variables.

a) Nominal, are the variables whose total values have no property.

b) Ordinal, are the variables that for the total values can be defined a provision for them.

Quantitative variables take arithmetical values and are expressed by a unit of measurement. They are divided into interval variables and ratio variables.

a) Interval, are the variables whose equals differences between their values imply equal differences for the characteristic that the variable measures. The spatial scale allows the subjects to be ranked.

b) Ratio, are the variables whose values correspond proportionally to the quantity of the characteristic they measure.

Quantitative variables are also divided into continuous and discrete. The continuous (quantitative) variable is capable of all values of a range of values, with a minimum lower limit, the minimum value and a maximum upper limit, the maximum value of a set of real numbers. Distinct (quantitative) variables are capable of selected values, which must be integers.

Another type of variable discrimination and classification refers to independent and dependent variables. This typology is often found in the elaboration of research projects and especially in the section on the formulation of research hypotheses.

An independent variable is a variable that causally affects one or more dependent variables. Dependent variable is called the variable whose values depend on the changes of the independent variable (Emvalotis et al. 2006).

3.1.1 Normal distribution

Many statistical analyzes require the normality of the sample values to be analyzed. Thus, normality testing should be the first and perhaps most basic test for a statistically correct analysis of a survey data.

Definition on Normal Distribution (Panaretos 2000):

Let X be a (completely) continuous random variable. X follows the normal distribution with parameters m and σ^2, $\sigma>0$ ($X \sim N(\mu,\sigma^2)$), if

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-1}{2}(\frac{x-m}{\sigma})^2} \, , \; -\infty < x < +\infty, \; \sigma > 0 \qquad (3.1.1.1)$$

Properties:

a) The normal distribution is symmetrical around the point $x=\mu$.
b) It has a bell shape with a predominant value at the point $x = \mu$. At this point,

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \qquad (3.1.1.2)$$

and therefore σ determines the maximum of the function. It is obvious that the function *f(x)* at the point $x = \mu$, is inversely proportional to the value of p (Panaretos 2000).

To check if the distribution of a variable is compatible with the normal distribution, it applies the Kolmogorov-Smirnov test, which is stated in the two hypotheses:

H_0: The distribution is NOT statistically significantly different than normal,

H_1: The distribution is statistically significantly different from the normal.

From the above hypotheses, it is clear that in order for the condition of normal distribution to be satisfied, the null hypothesis must be valid.

With SPSS application, this criterion can be calculated but also the probability that it has been made wrong, if we accept that the data of the sample do not follow the normal distribution. This probability level is called significant level and symbolized by "sig". Usually when sig, has values higher than 0,05 is accepted that the normal distribution applies to the sample values (Nikita 2012).

3.1.2 Significant level

In practice, it is often necessary to assess whether an event is possible to occur or not. In order to make statistical decisions, it is necessary to make assumptions. A very basic hypothesis, called a null hypothesis and symbolized by H_0, accepts that the differences in two or more samples are due only to random errors, so there are no statistically significant differences between the samples. An alternative hypothesis of H is denoted by H_1.

If an hypothesis that is true, is rejected based on statistical data, then it is considered to be a type I error. On the contrary, if an incorrect assumption is accepted, then it is considered to be a type II error. It is important to note that in trying to reduce a type I error, the likelihood of a type II error and vice versa increases.

The level of significance is the probability of making a type error when the null hypothesis is true as an equality (Anderson et al. 2011). This probability is denoted by α and the values where usually used, are $\alpha = 0.05$ or $\alpha = 0.01$. This means that the probability of rejecting a correct probability is less than 5% when $\alpha = 0.05$ and less than 1% when $\alpha = 0.01$ (Nikita 2012).

At this point, it should be noted that statistical tests are likely to make decisions based on probability, as well as respond only positively to the rejection of the null hypothesis.

In every test of significant level, SPSS calculates the p-value, the probability of making a mistake by rejecting the null hypothesis. Given the significance level α at 0.05 (5%), the following applies:

- If $p<\alpha$, then H_o hypothesis, rejected
- If $p>\alpha$, then H_0 hypothesis, then it is not rejected

Obviously, all statistical case studies assume that the sample data, follow the normal distribution, as mentioned above (Nikita 2012)

3.1.3 Correlation coefficient

Consider two random variables X, Y and n pairs of observations (x_1,y_1), (x_2,y_2), (x_3, y_3), …. (x_i, y_i).

Given that the data of the variables have not been affected in any way by the researchers, we can look for a possible correlation between the values of the two variables. The appropriate (parametric) statistical indicator in order to assess whether there is a correlation between two variables is the Pearson r correlation coefficient. The term parametric refers to the Pearson coefficient, as it is used only when the data follows the normal distribution. If they do not follow the normal distribution, then the Spearman ρ correlation coefficient, which belongs to the non-parametric methods, is calculated.

The formula for r, can be expressed as follows (Weiers 2011):

$$r = \frac{n(\sum x_i y_i) - (\sum x_i)(\sum y_i)}{\sqrt{n(\sum x_i^2) - (\sum x_i)^2} \cdot \sqrt{n(\sum y_i^2) - (\sum y_i)^2}} \quad (3.1.3.1)$$

Where r=coefficient of correlation, n=number of data points

The Pearson r correlation coefficient is a statistical indicator that has a specific range, so that it makes sense on its own and without linking it to significant levels or other information. The range that r can take is from -1 to +1. The first size shows us a perfectly negative relationship (inversely proportional relationship), while the second shows a perfectly positive (directly proportional) relationship between the two variables. Zero represents zero relationship between two variables.

Between the second range (-1 to +1), various categorizations have been proposed that refer to the evaluation of the size of the index. One of them is the following (Emvalotis 2006):

0.00-0.20 Zero relationship

0.21-0.40 Small relationship

0.41-0.60 Moderate relationship

0.61-0.80 Strong relationship

> 0.81 Extremely strong relationship

Positive values of r do not necessarily indicate a higher degree of linear correlation than the degree of linear correlation indicating negative values of r. The degree of linear correlation is determined by the absolute value of r and not by the sign of r. The sign of r determines only the type of correlation (positive or negative).

There will be no need to refer the Spearman ρ correlation coefficient, as the data of the variables that will be studied below, after the necessary check according to the Kolmogorov-Smirnov criterion, it appears that the data sets belong to normal distributions.

3.2 PRINCIPAL COMPONENT ANALYSIS

3.2.1 Introduction

The Principal Component Analysis (PCA) was originally defined in a statistical context by Pearson (1901) via an extension of the geometric argument just presented. But the more usual definition in terms of successive maximization of variance came thirty (30) years later by Hotelling in 1933 (Joliffe 1990) .

The central idea of principal component analysis is to reduce the dimensionality of a data set consisting of a large number of interrelated variables (Joliffe 2002, Hardle 2007, Papadimitriou 2007) while retaining as much as possible of the variation present in the data set. This is achieved by transforming to a new set of variables, the principal components (PCs), which are uncorrelated, and which are ordered so that the first few retain most of the variation present in all of the original variables (Joliffe 2002).

The main advantage of the method is that it is applied without any a priori assumption, for the variables that can participate (Nikita 2012, Papadimitriou 2007, Joliffe 2002, Petridis 2015). Then, the main elements of the Principal Component Analysis will be presents, as it has been developed by (Pearson 1901, Hotelling 1933, Jackson 1991, Jofille 2002, Papadimitriou 2007).

3.2.2 Analytic presentation of PCA

We assume that for this study, a set of data n observations is available, each of which is characterized by the values it receives in P arithmetical variables, X_1, X_2, X_3, …X_p. The value displayed in the data table for the variable X_j in observation i will be denoted by x_{ij}.

The analysis of principal components is a statistical method whose main purpose is to describe the data table X (n, P) = x_{ij}.

Consider each line i of table X, as a point in the space of P dimensions. The values obtained by the observation I in P variables (x_i: i = 1, 2,., P) are considered as the coordinates of the corresponding point in the P axes of this space. Therefore, all the information provided by the X data table can be compared to a cloud of n points in R^P space. The goal is to be able to observe the cloud of points in a space with less dimensions than the original ones, even m (m <P).

To achieve this, we try to define a linear combination of dimensions m that passes as close as possible to the center of mass of the original cloud of the data points, that is, the average of the squares of the x_i distances of the cloud points from this linear combination to be minimal and each x_i point to be depicted in this linear combination from its projection.

If we set m = 0 to the dimension, it means that we are looking for a point that is as close as possible to the center of the points, which is none other than the center of mass G of the cloud.

$$G = \frac{1}{n}\sum_{i=1}^{n} x_i \quad (3.2.2.1)$$

If we set m = 1, this means that we are looking for a line that passes as close as possible to the center of mass G of the cloud of points. This line Δ_1 will pass through the center of mass of the cloud G and is called the first major axis of the cloud. If we take G as the beginning of this axis, we have created the first main component Y_1.

If we set m = 2 the dimension of the desired linear combination, we try to set a level that passes as close as possible to the center of mass G of the cloud. This level is as close as possible to the center of mass G of the cloud. This level passes through the center of mass G and contains the first main axis Δ_1. So to define the level completely, it is enough to define a second straight line Δ_2, passing through the center of mass and rectangular on the first main axis. This second straight line Δ_2, is the second axis. The coordinates of the projections of the points (observations) x_i on the second main axis Δ_2, are taken again, as beginning the center of mass G, which now coincides with the beginning of the axes and create the second main component Y_2.

The determination of the linear combination can be generalized for the dimensions m = 3, m = 4, …, m = P. Because the main components are not related to each other, they allow us to study the position of the projections of the x_i points on them, as well as the correlations between the initial variables x_i and the main components Y_j. In this way, is managed to reduce the serious problem that arises when the dimensions of the data table we are studying are large.

In each line i of the table of data X, corresponds the point x_i : = (x_{i1}, x_{i2}, …, x_{ip}) of the space R^P. N symbolizes the cloud of the x_i points of the R^P space.

The center of mass G of cloud N is defined by the formula:

$$G = \frac{1}{n}\sum_{i=1}^{n} x_i \quad (3.2.2.2)$$

Where $x_i = (\overline{x_1}, \overline{x_2}, \dots, \overline{x_p})$ and $\overline{x_j} = \frac{1}{n}\sum_{i=1}^{n} x_{ij}$ (3.2.2.3), the mean value of x_i variable.

Also the square of the distance of the x_i point from the center of mass G is denoted by the formula: $d^2(x_i, G) = \sum_{j=1}^{p}(x_{ij} - \overline{x_j})^2$ (3.2.2.4)

The scattering of cloud N around the center of mass G is measured by the formula:

$$I(N, G) = \frac{1}{n}\sum_{i=1}^{n} d^2\,(x_i, G) \quad (3.2.2.5)$$

And finally is formed: $I(N, G) = \sum_{j=1}^{P} S_j^2$ (3.2.2.6), where $S_j^2 = \frac{1}{n}\sum_{i=1}^{n}(x_{ij} - \bar{x}_j)^2$ (3.2.2.7) the covariance of x_i variable.

The magnitude of I(N,G), which expresses the scattering of the cloud N around the center of mass G, is called in the data analysis the total inertia of the cloud N with respect to the center of mass G.

Let $u_1, u_2, \ldots, u_m$ be a system of m, rectangles between them in pairs vectors of the vector space R^P.

Symbolize with L, $= \{x: x = \sum_{k=1}^{m} a_k\, u_k\}$, its subsoil of R^P created by the vectors $u_1, u_2, \ldots, u_m$.

Even, an h vector of R^P. The linear combination $h + L = \{z: z = h + x, x \in L\}$ passing through the point which defined by the h vector and is parallel to the subsurface L. That is, the vector h causes a parallel shift of the subspace L. The dimension of the new linear combination h + L is the same as the dimension of L (with the parallel displacement the dimension of the subsurface does not change).

Let us now consider a y vector of R^P. There is a single x vector of L that is closest to y. This is none other than the rectangular projection $P_L(y)$ of L. This projection is characterized by the orthogonality between the y- $P_L(y)$ vector and of $u_1, u_2, \ldots, u_m$. This property mathematically determines the projection of the relationship:

$$P_L(y) = \sum_{k=1}^{m}(y' u_k)u_k' \qquad (3.2.2.8)$$

The projection of the y vector on the linear combination h + L is given by the relation

$$P_{h+L}(y) = h + P_L(y - h) \qquad (3.2.2.9)$$

This relationship defines the projection of y vector on h + L as a transfer by h of the projection of y - h on L.

As mentioned above, by analyzing the main components, we try to define that linear combination of h + L, m dimensions, which passes as close as possible to the middle of the cloud of the N points. Or more specifically, we want to define the linear combination h + L, which minimizes the quantity,

$$I(N, h + L) = \frac{1}{n}\sum_{i=1}^{n} d^2\,(x_i, P_{h+L}(x_i)) \qquad (3.2.2.10)$$

Next, consider the subspace L, the two vectors h and g, as well as the parallels to L, h + L and g + L subspaces. Consider the x_i vector and symbolize with y_i and z_i its projections in the subspaces, g + L and h + L.

Applying Huggens transformation :

$$I(N, h + L) = I(N, g + L) + d^2(y, P_{h+L}(g)) \qquad (3.2.2.11)$$

the inertia transformation: $I(N, g) = I(M, g) + I(N, g + L)$ (3.2.2.12) and by using the formula: $d^2(x_i, g) = d^2(y_i, g) + d^2(x_i, y_i)$ (3.2.2.13)

We conclude that the linear combination $g + L$ that minimizes $I(N, g + L)$ is the same that maximizes the inertia $I(M, g)$ at the same time,

$$\frac{1}{n}\sum_{i=1}^{n} d^2(x_i, g) = \frac{1}{n}\sum_{i=1}^{n} d^2\,(y_i, g) + \frac{1}{n}\sum_{i=1}^{n} d^2\,(x_i, y_i) \quad (3.2.2.14)$$

3.2.3 Eigenvalues and Loadings

Now, we consider the vector subspace L=(u_1, u_2, …, u_m) of the R^P vector space, created by the system of m, rectangles in pairs, vectors u_1, u_2, …u_m.

It is known, for the variance –covariance table $S = [S_{ik}]$, the valid formula:

$$S = \frac{1}{n}\sum_{i=1}^{n}(x_i - g)(x_i - g)' \ (3.2.3.1)$$

Therefore, it appears that the inertia of the cloud interpreted by the linear combination g + L is: $I(M, g) = \sum_{i=1}^{m} u_k' \, S u_k$ (3.2.3.2)

The ideal combination of dimensions m, that is, the subsurface that can best interpret the cloud of points N, will be of the form g + L. The subspace L is a vector space m of dimensions, created by the rectangles per two vectors u_1, u_2, …, u_m of which the maximum possible inertia of the cloud is interpreted, as $\sum_{k=1}^{m} u_k' \, S u_k$ (3.2.3.3)

It turns out that the determination of the subsurface L, is given by the characteristic vectors u_1, u_2, …,u_m of the variance - covariance table, which correspond to the largest values of λ_1, λ_2, …, λ_m arranged in descending order.

It is also known that the inertia of the cloud that will be interpreted by this ideal linear combination will be equal to:

$$I(M, g) = \sum_{k=1}^{m} \lambda_\kappa \quad (3.2.3.4)$$

The variances of the main components are called, characteristic roots or **eigenvalues** λ_m and number as many components as, in addition it is valid for them that $\lambda_1 > \lambda_2 > \lambda_3 ... > \lambda_m$. An important feature of the characteristic roots is that their sum is equal to the sum of the variations of the initial variables (Petridis 2015).

it is also shown that the correlation between the initial variable x_j and the main component function u_k is given by the quotient:

$$\frac{\sqrt{\lambda_k}}{S_j} u_{kj} \quad (3.2.3.5)$$

This quotient for any correlation between the initial variables and the main components is called loadings and shows the intensity of the action that the initial variables develop to create the components. The higher the loads, the more important the candidate variables are for the formation of the main components (Petridis 2015).

3.3 Soft computing

Soft computing, is a collection of methodologies that aim to exploit the tolerance for imprecision and uncertainty to achieve tractability, robustness and low solution cost (Zadeh 1994). According to Zadeh (1994), soft computing has differences from the conventional (hard) computing. Unlike hard computing, the soft computing is tolerant of imprecision, uncertainty, partial truth, and approximation. Role model for soft computing is the human mind. The guiding principle of soft computing is: Exploit the tolerance for imprecision, uncertainty, partial truth, and approximation to achieve tractability, robustness and low solution cost (Rajnish and Verna 2015).

The basic ideas underlying soft computing in its current formulation have links to many earlier influences, among them Zadeh's 1965 paper on fuzzy sets; the 1973 paper on the analysis of complex systems and decision processes; and the 1979 paper on possibility theory and soft data analysis. The inclusion of neural computing and genetic computing in soft computing came at a later point (Rajnish and Verna 2015).

The principal constituents of soft computing are fuzzy logic (FL), neural network theory (NN) and probabilistic reasoning (PR), with the latter subsuming belief networks, genetic algorithms, parts of learning theory and chaotic systems (Zadeh 1994).

Each of these constituent methodologies has its own strength. The seamless integration of these methodologies forms the core of soft computing. The synergism allows soft computing to incorporate human knowledge effectively, deal with uncertainty and learn to adapt to unknown or changing environment for better performance (Jang, Sun and Mizutani 1997).

It is important to note that, soft computing is not collection of these techniques; rather, it is a partnership in which each of the partners contributes a distinct methodology for addressing problems in its domain. In this perspective, the principal constituent methodologies in soft computing, are complementary rather than competitive. Furthermore, Artificial Neural network, fuzzy logic and genetic algorithm are soft computing methodologies that can be combined to form hybrid systems with excellent skills and results (Rajnish and Verna 2015).

Such a hybrid system is also the Adaptive Neuro Fuzzy Inference System (ANFIS) that will be developed next and it is the basic model of this doctoral dissertation research. ANFIS is based on the philosophy of neural networks, and its disadvantages are overcome by the use of fuzzy logic.

3.4 Fundamentals of Neural Networks

The study of computer systems based on human brain standards took its first steps in 1943 by McCulloch and Pitts, who designed the first elementary neural network. Donald Hebb, designed the first learning law for artificial neural networks (Hebb, 1949). Frank Rosenblatt (1958, 1962) with several other researchers (Block, 1962; Minsky and Papert, 1988) introduced and developed a large class of artificial networks called perceptrons. As well as Rosenblatt, Windrow and Hoff (1960) developed a learning rule that is closely related to the perceptron learning rule, in order to describe cognitive processes, including pattern recognition, speech recognition and time series predictions (e.g., weather models). Other early contributors included Anderson (1972), Amari (1977), Grossberg (1976), Kohonen (1988), Fukushima (1983), to name a few of the outstanding researchers in this field. These contributions were chronicled by Anderson and Rosenfeld (1988). The majority of the early models, had two layers of neurons (an input layer and an output layer), with a single layer of interconnections with weights that were adjusted during training (Dayhoff and Leo 2001).

The attractiveness of NNs comes from the remarkable information processing characteristics of the biological system such as nonlinearity, high parallelism, robustness, fault and failure tolerance, learning, ability to handle imprecise and fuzzy information, and their capability to generalize (Jain et al., 1996).

The computing world has a lot to gain from neural networks, also known as artificial neural networks or neural net. The neural networks have the ability to learn by example, which makes them very flexible and powerful. For neural networks, there is no need to devise an algorithm to perform a specific task, that is, there is no need to understand the internal mechanisms of that task. These networks are also well suited for real time systems because of their response and computational times which are because of their parallel architecture (Dayhoff and Leo 2001).

3.4.1 Advantages of Neural Networks

Neural networks, with their remarkable ability to derive meaning from complicated or imprecise data, could be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques. A trained neural network could be thought of as an "expert" in a particular category of information it has been given to analyze. This expert could be used to provide projections in new situations of interest and answer “what if” questions. Other advantages to use an NN are:

l. Adaptive learning: An ability to learn how to do tasks based on the data given for training or initial experience.

2. Self-organization: An NN can create its own organization or representation of the information it receives during learning time.

3. Real-time operation: NN computations may be carried out in parallel. Special hardware devices are being designed and manufactured to take advantage of this capability.

4. Fault tolerance via redundant information coding: Partial destruction of a neural network leads to the corresponding degradation of performance (Sivanandam and Deepa 2007).

3.4.2 Biological Neural Networks

A Neural Network (NN) is an efficient information processing system which simulates in characteristics with a biological nervous system. The human nervous system consists of billions of neurons of various types and lengths relevant to their location in the body (Schalkoff 1997). Every biological neuron has three major functional units – dendrites, cell body and axon. The dendrites receive signal from other neurons and pass them over to the cell body. The axon, which branches into collaterals, receive signals from the cell body and carries them away through the synapse (a microscopic gap) to the dendrites of neighboring neurons (Jain et al. 1996). Every stimulus received by the human body is converted into a light electrical signal which is spread from neuron to neuron, via dendrites, and through the central nervous system ends up in the brain, which will decide how to react due to the stimulus it initially felt. Because a neuron has a large number of dendrites/synapses, it can receive and transfer many signals simultaneously. This simplified mechanism of signal transfer constituted the fundamental step of early neurocomputing development (McCulloh and Pitts 1943) and the operation of the building unit of NNs.

Several key features of the processing elements of artificial neural networks are suggested by the properties of biological neurons, such as:

1. The processing element receives many signals
2. Signals may be modified by a weight at the receiving synapse.
3. The processing element sums the weighted inputs.
4. Under appropriate circumstances (sufficient input), the neuron transmits a single output.
5. The output from a particular neuron may go to many other neurons (Fausett 1994).

3.4.3 Artificial Neural Networks Structure

An artificial neural network is an information-processing system that has certain performance characteristics in common with biological neural networks.

Artificial neural networks have been developed as generalizations of mathematical models of human cognition or neural biology, based on the assumptions that:

1. Information processing occurs at many simple elements called neurons.
2. Signals are passed between neurons over connections links.
3. Each connection link has an associated weight, which, in a typical neural net, multiplies the signal transmitted.
4. Each neuron applies an activation function (usually nonlinear) to its net input (sum of weighted input signals) to determine its output signal (Fausett 1994).

In more detail, NNs possess large number of highly interconnected processing elements called *nodes* or *units* or *neurons*, which usually operate in parallel and are configured in regular architectures. Each neuron is connected with the other by a connection link. Each connection link is associated with weights which contain information about the input signal. This information is used by the neuron net to solve a particular problem. NN's collective behavior is characterized by their ability to learn, recall and generalize training patterns or data similar to that of a human brain. NNs can be applied to a wide variety of problems, such as storing and recalling data or patterns, classifying patterns, performing general mappings from input patterns to output patterns, grouping similar patterns, or finding solutions to constrained optimization problems (Sivanandam and Deepa 2007).

Each neuron has an internal state of its own, which is the function of the inputs the neuron receives and is called the *activation* or *activity level* of neuron. The activation signal of a neuron is transmitted to other neurons and can send only one signal at a time, which can be transmitted to several other neurons.

To depict the basic operation of a neural network, consider a neuron Y, which receives inputs from neurons X_1, X_2, and X_3. The activations (output signals) of these neurons are x_1, x_2, and x_3, respectively. The weights on the connections from X_1, X_2, and X_3 to neuron Y are w_1, w_2, and w_3, respectively. The net input, y_{in} to neuron Y is the sum of the weighted signals from neurons X_1, X_2, and X_3, i.e.,

$$y_{in}=w_1x_1 + w_2x_2 + w_3x_3 \qquad (3.4.3.1)$$

The activation y of neuron Y is given by some function of its net input:

$$y=f(y_{in}) \qquad (3.4.3.2)$$

Let suppose further that neuron Y is connected to neurons Z_1 and Z_2, with weights v_1 and v_2, respectively. Neuron Y sends its signal y to each of these units. However, the values received by neurons Z_1 and Z_2 will be different, because each signal is scaled by the appropriate weight, v_1 or v_2. In a typical net, the activations z_1 and z_2 of neurons Z_1 and Z_2 would depend on inputs from several or even many neurons (Fausett 1994).

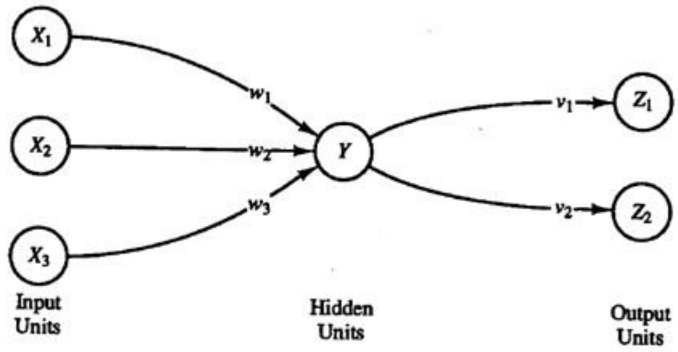

Figure 3.4.3.1. A very simple neural network.

Although the neural network in Figure 3.4.3.1, is simple, the presence of a hidden unit, together with a nonlinear activation function, gives the ability to solve many more problems only with input and output units.

A neural network is characterized by (Sivanandam and Deepa 2007) :

a) *Architecture*, its pattern of connections between the neurons
b) *Training*, its method of determining the weights on the connections (also called *learning algorithm*)
c) *Activation function*.

And will be briefly developed in the next sections.

3.4.4 Architecture of Neural Networks

It is convenient to visualize neurons as arranged in layers. Typically, neurons in the same layer behave in the same manner. The arrangement of neurons into layers and the connection patterns within and between layers is called the *net architecture*. Many neural nets have an input layer in which the activation of each unit is equal to an external input signal. Neural nets are often classified as single layer or multilayer (Fausset 1994) or distinguished, based on the connection patterns, as feed-forward networks or recurrent (feedback) networks (Jain et al. 1996).

A *single-layer* network has one layer of connection weights. The nodes can be distinguished as *input nodes*, which receive signals from the outside world and output nodes, from which the response of the net can be read (Fausett 1994).

A *multilayer network* is a net with one or more layers (or levels) of nodes between the input nodes and the output nodes. Typically, there is a layer of weights between two adjacent levels of nodes. The layers that are formed between the input and output layer are called hidden layer. Multilayer nets can solve more complicated problems than can single-layer nets, but training may be more difficult (Sivanandam and Deepa 2007).

Feed-forward networks are static, that is, produce only one set of output values rather than a sequence of values from a given input. These networks are memory-less in the sense that their response to an input is independent of the previous network state (Jain et al. 1996).

Feedback networks are generally, dynamic systems. When a new input pattern is presented, the neuron outputs are computed. Because of the feedback paths, the inputs to each neuron are then modified, which leads the networks to enter a new state (Jain et al. 1996).

3.4.5 Learning of Neural Networks

The ability of a NN to learn is a fundamental trait of intelligence. A precise definition of learning is difficult to formulate. As a learning process in the NN context can be viewed as the problem of updating network architecture and connection weights so that a network can efficiently perform a specific task (Jain et al. 1996). The methods of training (setting the values of the weights) can be distinguished in two types: supervised and unsupervised (Fausset 1994).

The training that is accomplished by presenting a sequence of training vectors, or patterns, each with an associated target output vector, is called as supervised training. The weights are then adjusted according to a learning algorithm (Fausset 1994).

Self-organizing neural nets group similar input vectors together without the use of training to specify what a typical member of each group looks like or to which group each vector belongs. A sequence of input vectors is provided, but no target vectors are specified. The net modifies the weights so that the most similar input vectors are assigned to the same output unit. This type of training is called unsupervised (Fausset 1994).

3.4.6 Activation Functions

i) As mentioned above, the basic operation of an artificial neuron involves summing its weighted input signal and applying an output, or activation function. For the input units, this function is the identify function,

Identify function: $f(x) = x$ for all x. (3.4.6.1)

ii) Single-layer nets often use a step function to convert the net input, which is a continuously valued variable, to an output unit like the binary (1 or 0). This binary step function is also known as the threshold function or Heaviside function:

$$f(x) = \begin{cases} 1 & if\ x \geq \theta \\ 0 & if\ x < \theta \end{cases} \qquad (3.4.6.2)$$

iii) A sigmoid function with range from 0 to 1, is often used as the activation function for neural nets in which the desired output values either are binary or are in the interval between 0 and 1. To emphasize the range of the function is called the binary sigmoid and the formula for two values of the steepness parameter σ, and its derivative are:

$$f(x) = \frac{1}{1+\exp(-\sigma x)} \qquad (3.4.6.3)$$

$$f'(x) = \sigma f(x)[1 - f(x)] \qquad (3.4.6.4)$$

iv) The logistic sigmoid function can be scaled to have any range of values that is appropriate for a given problem. The most common range is from -1 to 1, and this sigmoid is called the bipolar sigmoid (Fausett 1994). The formula and its derivative are:

$$g(x) = 2f(x) - 1 = \frac{2}{1+\exp(-\sigma x)} - 1 = \frac{1-\exp(-\sigma x)}{1+\exp(-\sigma x)} \qquad (3.4.6.5)$$

$$g'(x) = \frac{\sigma}{2}[1 + g(x)][1 - g(x)] \qquad (3.4.6.6)$$

3.5 Fuzzy logic

Fuzzy logic, introduced by Zadeh L., in his seminal work "Fuzzy sets" which described the mathematics of fuzzy set theory (1965). Nine years later Mamdami (1974) applied the fuzzy logic in a practical application to control an automatic steam engine (Mamdami and Assilion 1974), and the idea of fuzzy logic became increasingly well known. In 1976, Blue Circle Cement and SIRA in Denmark (Hombland and Ostergaard 1982), developed an industrial application to control cement kilns, which began to operation in 1982. More and more, fuzzy implementations have been reported since the 1980s, including those applications in industrial manufacturing, automatic control, automobile production, banks, hospitals, libraries and academic education. Fuzzy logic techniques have been widely applied in all aspects in today's society (Bai and Wang 2007).

3.5.1 Fuzzy sets

A fuzzy set is an extension of a crisp set. Crisp set allow only full membership or no membership at all, whereas fuzzy sets allow partial membership. A fuzzy set is a set having degrees of membership between 1 and 0. The membership in a fuzzy set need not be complete, i.e. member of one fuzzy set can also be member of other fuzzy sets in the same universe. Fussy sets can be analogous to the thinking of intelligent people. If a person has to be classified as friend or enemy, intelligent people will not resort to absolute classification as friend or enemy. Rather, they will classify the person somewhere between two extremes of friendship and enmity (Sivanandam and Deepa

2007). Similarly, vagueness is introduced in fuzzy set by eliminating the sharp boundaries that divide members from nonmembers in the group. There is a gradual transition between full membership and non-membership, not abrupt transition.

Assume, a fuzzy set A in the universe of discourse U, and if an element x is a member of this fuzzy set A, this mapping can be defined as a set of ordered pairs and it is given by

$$A = \{(x, \mu_A(x)) | x \in U\} \qquad (3.5.1.1)$$

Where $\mu_A(x)$ is the degree of membership of x in A, it indicates the degree that x belongs to A and is called the membership function (MF). The degree of membership $\mu_A(x)$ assumes values in the range from 0 to 1, i.e., the membership is set to unit interval [0,1] or $\mu_A(x) \epsilon\ [0,1]$ (Zadeh 1965). If the value of the membership function $\mu_A(x)$ is restricted to either 0 or 1, then A is reduced to a classical set and $\mu_A(x)$ is the characteristic function of A.

There are other ways of presentation of fuzzy sets allowing partial membership to be expressed. Let, a fuzzy subset A with an element x has a membership function of $\mu_A(x)$, when the universe of discourse U is discrete and finite, this mapping can be expressed as

$$A = \frac{\mu_A(x_1)}{x_1} + \frac{\mu_A(x_2)}{x_2} + \cdots = \sum_i \frac{\mu_A(x_i)}{x_i} \qquad (3.5.1.2)$$

When the universe of discourse U is continuous and infinite, the fuzzy set A can be represented as (Zadeh 1965),

$$A = \int \frac{\mu_A(x)}{x} \qquad (3.5.1.3)$$

In the above two representations of fuzzy sets for discrete and continuous universe, the numerator in each representation is the membership value in set A that is associated with the element of the universe present in the denominator. For discrete and finite universe of discourse U, the summation symbol in the representation of fuzzy set A does not denote algebraic summation but indicates the collection of each element (Sivanandam and Deepa 2007).

Compared with a classical set, a fuzzy set allows members to have a smooth boundary. In other words, a fuzzy set allows a member to belong to a set to some partial degree. For instance, still using the temperature as an example, the temperature can be divided into three categories: LOW (-40 ^{0}C ~ 0 ^{0}C), MEDIUM (0 ^{0}C ~ 30 ^{0}C) and HIGH (30 ^{0}C ~ 70 ^{0}C) from the point of view of the classical set, which is shown in Figure 3.5.1.1(a).

In the classical set, any temperature can only be categorized into one subset, either LOW, MEDIUM, or HIGH and the boundary is clear. But in the fuzzy set such as Figure 3.5.1.1(b), these boundaries become vague or smooth. One temperature can be categorized into two or maybe even three subsets simultaneously. For example, the temperature 10 ^{0}C, can be considered to belong to LOW, but at the same time it can belong to MEDIUM. The dash-line in Figure b, represents the classical set boundary (Bai and Wang 2007).

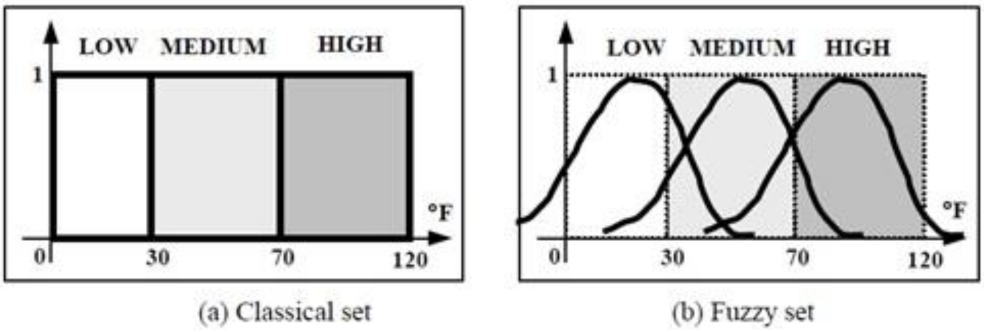

Figure 3.5.1.1. Representation of classical set (a) and fuzzy set (b).

3.5.2. Fuzzy Inference System (FIS)

A fuzzy inference system (FIS) essentially defines a nonlinear mapping of the input data vector into a scalar output, using fuzzy rules. The mapping process involves input/output membership functions, fuzzy if-then rules, aggregation of outputs sets and defuzzification. A general model of a fuzzy inference system (FIS) (Jang 2003), is shown in the figure 3.5.2.1 (Jang 1993).

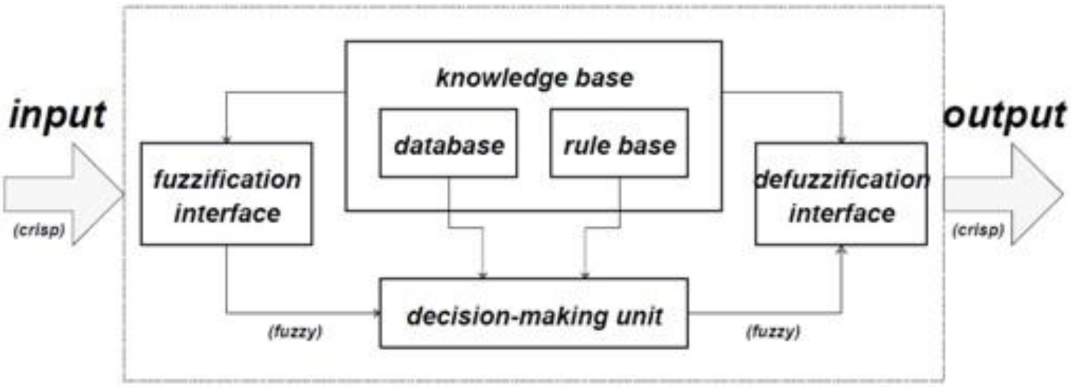

Figure 3.5.2.1. Fuzzy Inference System (FIS).

It can be seen from the figure 3.5.2.1 that a Fuzzy inference system is composed of five functional blocks (Jang 1993):

- **A rule base** containing a number of fuzzy if-then rules
- **A database** which defines the membership functions of the fuzzy sets used in the fuzzy rules
- A **decision making unit** which performs the inference operations on the rules
- A **fuzzification interface** which transforms the crisp inputs into degrees of match with linguistic values
- A **defuzzification interface** which transform the fuzzy results of the inference into a crisp output

These five components are developed in the next paragraphs.

3.5.2.1 Fuzzy Control Rules

As was mentioned by Zadeh (1973), conventional techniques for system analysis are intrinsically unsuited for dealing with humanistic systems, whose behavior is strongly influenced by human judgment, perception and emotions. This belief triggered Zadeh to propose the concept of linguistic variables (Zadeh 1971), as an alternative approach to modeling human thinking and serves to summarize information and express it in terms of fuzzy sets instead of crisp numbers.

Before, move on the fuzzy rules, it is necessary to define the linguistic variables, first.

A **linguistic variable** is characterized by a quintuple (*x, T(x), U, G, M*) in which *x* is the name of the variable; *T(x)* is the term set of *x* – that is, the set of its linguistic values or linguistic terms; *U* is the universe of discource; *G* is a syntactic rule which generates the terms in *T(x)*; and *M* is a semantic rule which associates with each linguistic value *A* its meaning *M(A),* where *M(A)* denotes a fuzzy set in *U* (Zadeh 1971). That was the formal definition of linguistic variables and follows an example (Jang et al. 1997) which helps to clarify the preceding definition.

If age is interpreted as a linguistic variable, then its term set *T(age)* could be:

T(age) = { young, not young, very young, not very young, ...,
Middle aged, not middle aged, ...,
Old, not old, very old, more or less old, not very old, ...,
Not very young and not very old, ... }

where each term in *T(age)* is characterized by a fuzzy set of a universe of discource *U*= [0, 100]. Usually, is used "*age is young*" to denote the assignment to the linguistic value "*young*" to the linguistic variable *age*. By contrast, when age is interpreted as a numerical variable, is used the expression "*age=20*" instead to assign the numerical value "*20*" to the numerical variable *age*.

Fuzzy control rules can be considered as the knowledge of an expert in any related field of application. The fuzzy rule is represented by a sequence of the form IF-THEN, leading to algorithms describing what action or output should be taken in terms of the currently observed information, which includes both input and feedback if a closed-loop control system is applied. The law to design or build a set of fuzzy rules is based on a human being's knowledge or experience, which is dependent on each different actual application.

A fuzzy rule (also known as fuzzy if-then rule) assumes the form (Jang et al. 1997)

if *x* is A then *y* is B,

where A and B are linguistic values defined by fuzzy sets on universe of discourse X and Y, respectively. Often "x is A" is called the antecedent or premise, while "y is B" is called the consequence or conclusion.

A fuzzy "IF-THEN" rule associates a condition described using linguistic variables and fuzzy sets to an output or a conclusion. The "IF" part, is mainly used to capture knowledge by using the elastic conditions, and the "THEN" part can be utilized to give the conclusion or output in linguistic variable form. This "IF-THEN" rule is widely used by the fuzzy inference system to compute the degree to which the input data matches the condition of a rule (Zadeh 1994).

Fuzzy mapping rules

Fuzzy mapping rules provide a functional mapping between the input and the output using linguistic variables. The foundation of a fuzzy mapping rule is a fuzzy graph, which describes the relationship between the fuzzy input and the fuzzy output.

Fuzzy mapping rules work in a similar way to human intuition or insight, and each fuzzy mapping rule only approximates a limited number of elements of the function, so the entire function should be approximated by a set of fuzzy mapping rules (Bai and Wang 2007).

Fuzzy Implications Rules

A fuzzy implication rule describes a generalized logic implication relationship between inputs and output. The foundation of a fuzzy implication rule is the narrow sense of fuzzy logic. Fuzzy implication rules are related to classical two-valued logic and multiple valued logic (Yen and Lagari 1999).

The inference engine defines mapping from input fuzzy sets into output fuzzy sets. It determines the degree to which the antecedent is satisfied for each rule. If the antecedent of a given rule has more than one clause, fuzzy operators are applied to obtain one number that represents the result of the antecedent for that rule. It is possible that one or more rules may fire at the same time. Outputs for all rules then aggregated. During aggregation, fuzzy sets that represent the output of each rule are combined into a single fuzzy set. Fuzzy rules are fired in parallel, which is one of the important aspects of an FIS (Kulkarni 2001).

3.5.2.2. Membership functions

Generally, fuzzification involves two processes: derive the membership functions for input and output variables and represent them with linguistic variables. This process is equivalent to converting or mapping classical set to fuzzy set to varying degrees.

Membership functions can have multiple different types, such as the triangular waveform, trapezoid waveform, Gaussian waveform, bell-shaped waveform, sigmoidal waveform and S-curve waveform. The exact type depends on the actual applications. For those systems that need significant dynamic variation in a short period time, a triangular or trapezoidal waveform should be utilized. For those systems that need very high control accuracy, a Gaussian or S-curve waveform should be selected (Bai and Wang 2007).

A more convenient and concise way to define a membership function is to express it as a mathematical formula. The formulas for the different types of membership functions are defined below (Jang et al 1997).

A **triangular membership function** is specified by three parameters *α*, *b*, and *c* as follows:

$$f(x;\alpha,b,c)=\begin{cases}0 & for\ x<\alpha\\ \frac{x-\alpha}{b-\alpha} & for\ \alpha\le x<b\\ \frac{c-x}{c-b} & for\ b\le x<c\\ 0 & for\ c\le x\end{cases} \qquad (3.5.2.2.1)$$

The parameters *α*, *b*, *c* with $a<b<c$ determine the x coordinates of the three corners of the underlying triangular MF.

A **trapezoidal membership function** is specified by four parameters {*a*,*b*,*c*,*d*} as follows:

$$f(x;a,b,c,d)=\begin{cases}0 & for\ x<\alpha\\ \frac{x-\alpha}{b-\alpha} & for\ a\le x<b\\ 1 & for\ b\le x<c\\ \frac{d-x}{d-c} & for\ c\le x<d\\ 0 & for\ d\le x\end{cases} \qquad (3.5.2.2.2)$$

The parameters α, b, c, d (with $a<b<c<d$) determine the x coordinates of the four corners of the underlying trapezoidal MF.

The **π-shaped membership function** is given by (Giarratano and Riley, 1993)

$$f(x;b,c) = \begin{cases} S\left(x; c-b, c-{}^{b}/_{2}, c\right) & for\ x \le c \\ 1 - S\left(x; c, c+{}^{b}/_{2}, c+b\right) & for\ x > c \end{cases} \qquad (3.5.2.2.3)$$

where $S(x;a,b,c)$ represents a membership function defined as

$$S(x;a,b,c) = \begin{cases} 0 & for\ x < a \\ \frac{2(x-a)^2}{(c-a)^2} & for\ a \le x < b \\ 1-\frac{2(x-c)^2}{(c-a)^2} & for\ b \le x \le c \\ 1 & for\ x > c \end{cases} \qquad (3.5.2.2.4)$$

In the last formula a, b and c are the parameters that are adjusted to fit the desired membership data.

A **Gaussian membership function** is specified by two parameters σ and c :

$$f(x;\sigma,c) = exp\left[\frac{-(x-c)^2}{2\sigma^2}\right] \qquad (3.5.2.2.5)$$

A Gaussian membership function is determined completely by c and σ, c represents the MFs center and σ determines the MFs width.

A **generalized bell membership function** (or **bell MF**) is specified by three parameters {a, b, c}:

$$f(x;a,b,c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}} \qquad (3.5.2.2.6)$$

where the parameter b is usually positive. If b is negative, the shape of this MF becomes an upside-down bell. This MF is a generalization of the Cauchy distribution, so it is also referred to as the **Caushy MF.**

A sigmoidal membership function is defined by

$$f(x;a,c) = \frac{1}{1+\exp[-a(x-c)]} \qquad (3.5.2.2.7)$$

Where a controls the slope at the crossover point x=c.

3.5.2.3 Fuzzification

The rule base contains linguistic rules that are provided by experts. It is also possible to extract rules from numeric data. Once the rules have been established, the FIS can be viewed as a system that maps an input vector to an output vector. The fuzzifier maps input numbers into corresponding fuzzy memberships. This is required in order to activate rules that are in terms of linguistic variables. The fuzzifier takes input values and determines the degree to which they belong to each of the fuzzy sets via membership functions (Zadeh 1994).

In real-life world, the quantities that we consider may be thought of a crisp, accurate and deterministic, but actually they are not so. They possess uncertainty within themselves. The uncertainty may arise due to vagueness or imprecision and in this case the variable is probably fuzzy and can be represented by a membership function.

For a fuzzy set $A = \{\mu_\iota / x_i | x_i \in X\}$, a common fuzzification algorithm is performed by keeping μ_ι constant and x_i being transformed to a fuzzy set Q(x_i) depicting the expression about x_i. The fuzzy set Q(x_i) is referred to as the Kernel of fuzzification. The fuzzified set $\underline{A}$ can be expressed as,

$$\underline{A}=\mu_1 Q(x_1) + \mu_2 Q(x_2) + \cdots + \mu_n Q(x_n) \quad (3.5.2.3.1)$$

This process of fuzzification is called support fuzzification (s-fuzzification). There is another method of fuzzification called grade fuzzification (g-fuzzification) where x_i is kept constant and μ_ι is expressed as a fuzzy set (Kulkarni 2001).

3.5.2.4. Defuzzification

A fuzzy inference system maps an input vector to a crisp output value. In order to obtain a crisp output, is necessary a defuzzification process. The input to the defuzzification process is a fuzzy set and the output is a single number. Many defuzzification techniques have been proposed in the literature as, the centroid, the maximum, the maxima, height, and modified height method. The most common method of defuzzification is the centroid (Kulkarni 2001), which will be described as follows.

Centroid defuzzification method

The defuzzifier determines the center of gravity (centroid) y_i' of B uses that value as the output of the Fuzzy Logic System. For a continuous aggregated fuzzy set, the centroid is given by

$$y' = \frac{\int_S \; y_i \mu_B(y)dy}{\int_s \; \mu_B(y)dy} \qquad (3.5.2.4.1)$$

where S denotes the support of $\mu_B(y)$. Often, discretized variables are used so that y' can be approximated as shown in the next equation, which uses summations instead of integration

$$y' = \frac{\sum_{i=1}^{n} y_i \mu_B(y_i)}{\sum_{i=1}^{n} \mu_B(y_i)} \qquad (3.5.2.4.2)$$

The centroid defuzzification method finds the balance point of the solution fuzzy region by calculating the weighted mean of the output fuzzy region. It is the most widely used technique because, the defuzzified values tend to move smoothly around the output fuzzy region (Kulkarni 2001).

Maximum-decomposition method

In this method, the defuzzifier examines the aggregated fuzzy set and chooses that output y for which $\mu_B(y)$ is the maximum. Unlike the centroid method, the maximum-decomposition method has some properties that are applicable to a narrower class of problems. The output value method is sensitive to a single rule that dominates the fuzzy rule set. Also, the output value tends to jump from one frame to the next as the shape of the fuzzy region changes (Kulkarni 2001).

Center of maxima

In a multimode fuzzy region, the center of maxima technique finds the highest plateau and then the next highest plateau (Kulkarni 2001).

Height defuzzification

In this method, the defuzzifier first evaluates $\mu_B(y)$ at $y_1^{'}$ and then computes the output of the fuzzy logic system, where denoted the center of gravity of fuzzy sets B_i. Output y_h in this case is given by

$$y_h = \frac{\sum_{i=1}^{m} y_i^{'} \mu_B(y_i)}{\sum_{i=1}^{m} \mu_B(y_i)} \qquad (3.5.2.4.3)$$

Where *m* represents the number of output fuzzy sets obtained after implication and $y_i^{'}$ represents the centroid of fuzzy region *i*. This technique is easy to use because the centers of gravity of commonly used membership functions are known ahead of time. Regardless of whether minimum or product inference is used, the fuzzy inference process essentially defines the mapping of the given vector of crisp values to an output crisp value using fuzzy rules stored in the knowledge base. This fuzzy inference process is known as *Mamdani's* fuzzy inference method (Mamdani 1977).

Sugeno (1977) suggested a fuzzy inference method that it is similar to Mamdani's. In *Sugeno's* method, (Sugeno 1977) the first two parts: mapping inputs to fuzzy membership function and applying fuzzy operators, are the same as in Mandani's method. The main difference is the evaluation of the output membership function. In Sugeno's method, the output membership function is a constant or a linear function. A fuzzy rule for the zero-order Sugeno method is of the form, if x is A and y is B then C=K, where A and B are fuzzy sets in the antecedent and K is a constant. The first order Sugeno model has rules of the form, if x is A and y is B then C=*p*x+*q*y+*r*, where A and B are fuzzy sets in the antecedent and *p*, *q*, *r* are constants.

3.5.3 Advantages and drawbacks of Fuzzy Logic Systems

The field of Fuzzy Logic systems applications has been growing the last decade. Fuzzy logic is not the only way to reason with ambiguous concepts but it seems to be the most apt to function approximation, for example in control engineering. Some of the most important advantages by using fuzzy logic are developed below (Albetros and Sala 1998; Kulkarni 2001; Vieira et al. 2004):

Advantages

- Flexible, intuitive knowledge base design.
- Have the ability to model any nonlinear function to any arbitrary degree of accuracy
- Based on rules that can be specified with a natural language
- Validation, consistency, redundancy and completeness can be checked in rule bases. That could speed up automated learning and improve user interpretability.
- Can be built from expert knowledge
- Tolerant to imprecise data
- Ambiguousness, fuzzy logic is an ideal way of expressing uncertain information.
- Can be used to complement other techniques, such as neural networks or genetic algorithms.

But fuzzy logic systems are not the perfect solution for all cases. Its most significant drawbacks will be summarized as follows (Albetros and Sala 1998; Vieira et al. 2004):

Drawbacks

- Manual tuning in large-scale industrial applications. Time consuming returning even if applied to a similar plant in other location.
- Many researchers proposed different ways to solve a given problem through fuzzy logic which lead to ambiguity. There is no a systematic approach to solve a given problem through fuzzy logic.
- Proofs of its characteristics is difficult or impossible in most cases because every time we do not get mathematical description of our approach
- Works on precise as well as imprecise data so most of the time accuracy is compromised.
- Many unclear options: thousands of different fuzzy system configurations may arise depending on conjunction, disjunction, implication and defuzzification choices.
- Dimensionality: Cartesian product of partitions is the most used way of setting up antecedents in multi-dimensional models. That is a very inefficient and memory-intensive setting for most functions.

- During the optimization of the fuzzy system, a change in the Membership function can require a change in the rules, as well as a change in the rules can require a change in the Membership function.
- Comprehensibility, a rule-based system needs to get enough rules to be accurate.
- Lack of self-learning capability.

3.6 Hybrid Soft Computing

Neural Networks are the simplified models of the human nervous systems simulating the human ability to adapt to certain situations and to learn from the past experiences. The fundamentals of artificial neural networks developed at section 3.4 of this doctoral thesis, as well as the basics of fuzzy logic systems at section 3.5.

Fuzzy logic systems deal with uncertainty or vagueness existing in a system and formulating fuzzy rules to find a solution to problems. Fuzzy logic does not operate on accurate boundaries and it provides a transition between membership and non-membership of the variables for a particular problem.

The above two techniques individually have provided efficient solutions to a wide range of simple and complex problems pertaining to different domains. Also, these two techniques can be combined together in whole or a part and may be applied to find solution to the problems, where the techniques do not work individually. The main idea of the concept of hybridization is to overcome the weakness in one technique while applying it and bringing out the advantage of the other technique, by combining them.

Every soft computing technique, including the genetic algorithm for which it was not necessary to develop in this doctoral dissertation, has particular computational parameters which make them suited for a particular problem and not for others. It has to be noted that neural networks are good at recognizing patterns but they are good at explaining how they reach their decisions. On the contrary, fuzzy logic is good at explaining the decisions but cannot automatically acquire the rules used for making the decisions. The same happens, for the optimization of membership function in fuzzy modeling, which neural networks offer the possibility to solve this difficulty. These types of limitations and even more, act as a central force which drive to the creation of hybrid soft computing systems where two or more techniques are combined in suitable manner that overcomes the limitations of individual techniques and ends in the optimal solution.

The importance of hybrid system is based on the varied nature of the application domains. Many complex domains have several different component problems each of which may require different types of processing. When there is a complex application which has two distinct sub-problems, then a neural network and fuzzy logic can be used for solving these individual tasks, respectively. The use of hybrid systems is growing rapidly with successful applications in areas such as engineering design, stock market analysis and prediction, forecasting methods, medical diagnosis, process control, credit card analysis, and many more cognitive simulations (Sivanandam and Deepa 2007).

3.6.1 Neuro-Fuzzy Systems

The first studies of the neuro-fuzzy systems date of the beginning of the 90's decade, with Lin and Lee 1991, Jang 1992, Berenji and Khedkar 1992, Nauck and Kurse 1993. The majority of the first applications were in process control. Gradually, its application spread for all the areas of the knowledge like, data analysis, data classification, imperfections detection and support to decision making, etc., (Veira et al. 2004).

Neural networks and fuzzy systems can be combined to join its advantages and to cure its individual illness. A neuro-fuzzy system, can be defined as a fuzzy system that determines its parameters by processing data samples by using a learning algorithm derived from neural network theory (Sivanandam and Deepa 2007). Alternately, it is a hybrid intelligent structure of neural networks with human-like reasoning style of fuzzy systems.

3.6.2 Types of Neuro-Fuzzy Systems

All the combinations of techniques based on neural networks and fuzzy logic are called neuro-fuzzy systems. The different combinations of these techniques can be divided, according to Nauck et al. 1997, in the following classes:

Cooperative Neuro-Fuzzy System

In this type of system, both artificial network and fuzzy system work independently from each other. The neural networks are only used in an initial phase and then undertake the fuzzy system.

There is a pre-processing phase where the neural networks mechanisms of learning, attempt to determine some sub-blocks of the fuzzy system. After the fuzzy sub-blocks are calculated the neural network learning methods are taken away, executing only the fuzzy system.

Concurrent Neuro-Fuzzy System

A concurrent system is not a neuro-fuzzy system in the strict sense, because the neural network works together with the fuzzy system. The inputs enters in the fuzzy system, are pre-processed and then the neural network processes the outputs of the concurrent system or in the reverse way. In this type of systems, the results are not completely interpretable, what can be considered a disadvantage.

Hybrid Neuro-Fuzzy Systems

According to Nauck et al. 1997, definition, "A hybrid neuro-fuzzy system is a fuzzy system that uses a learning algorithm based on gradients or inspired by the neural networks theory, to determine its parameters through the patterns processing".

A neuro-fuzzy system can be interpreted as a set of fuzzy rules and created from input output data or initialized with the *á priori* knowledge in the same way of fuzzy rules. The resultant system by fusing fuzzy systems and neural networks has as advantages of learning through patterns and the easy interpretation of its functionality (Vieira et al. 2007).

There are several different ways to develop hybrid neuro-fuzzy systems. Most models are similar in its essence, but they present basic differences. These models are (Vieira et al. 2007):

- **Fuzzy Adaptive Learning Control Network** (FALCON), Lin and Lee 1991,
- **Adaptive Network based Fuzzy Inference System** (ANFIS), Jang 1992,
- **Generalized Approximate Reasoning based Intelligence Control** (GARIC), Berenji and Khedkar 1992,
- **Neuronal Fuzzy Controller** (NEFCON) Nauck and Kurse 1997,
- **Fuzzy Inference and Neural Network in Fuzzy Inference Software** (FINEST) Tano, Oyama and Arnould 1996,
- **Fuzzy Net** (FUN) Sulzberger, Tshichold and Vestli 1993,
- **Self Constructing Neural Fuzzy Inference Network** (SONFIN) Juang and Lin 1998,
- **Fuzzy Neural Network** (NFN) Figueiredo and Gomide 1999,
- **Dynamic/Evolving Fuzzy Neural Network** (EFuNN and dmEFunn) Kasabov and Song 1999.

From all the models that belong to the hybrid neuro-fuzzy systems category, will be developed in detail only the Adaptive Network Fuzzy Inference System (ANFIS), as it is the type of model that will be used in the research of this doctoral thesis.

3.7 Adaptive Neuro-Fuzzy Inference Systems (ANFIS)

ANFIS, is thought to belong to the adaptive networks, which are using the learning algorithms of neural networks. The adaptive network consists of adaptive and non-adaptive nodes. Essentially, the adaptive network is a multi-layer feed-forward network, in which each node performs a specific function on the incoming signals and on all the parameters corresponding to that node. The nodes are connected through directional links. Some or all nodes are customizable, which means that the result of each node, depends on the parameters associated with that node and the learning rule specifies that these parameters must be changed to minimize a predefined error measure. The operation type of each node can vary from node to node and the choice of operation of a node depends on the total processing on the inputs and outputs that the adaptive network must perform.

In detail, the architecture, the operating levels of nodes, as well as the learning algorithm are presented below.

3.7.1 ANFIS Architecture

For simplicity, it is assumed that the fuzzy inference system under consideration has two inputs, x and y, and one output, f. It is assumed that the rule base contains two fuzzy "if-then" rules of the Takagi and Sugeno type (Takagi and Sugeno 1983):

Rule 1: If x *is* A_1 *and* y *is* B_1*, then* $f_1 = p_1 \cdot x + q_1 \cdot y + r_1$ (3.7.1.1)

Rule 2: If x *is* A_2 *and* y *is* B_2*, then* $f_2 = p_2 \cdot x + q_2 \cdot y + r_2$ (3.7.1.2)

Where p_1, p_2, q_1, q_2, r_1 and r_2 are linear parameters and A_1, A_2, B_1 and B_2 are non linear parameters, in which A_1 and B_1 are the membership functions of ANFIS (antecedent), p_1, q_1, r_1 are the consequent parameters (Pratama et al. 2011).

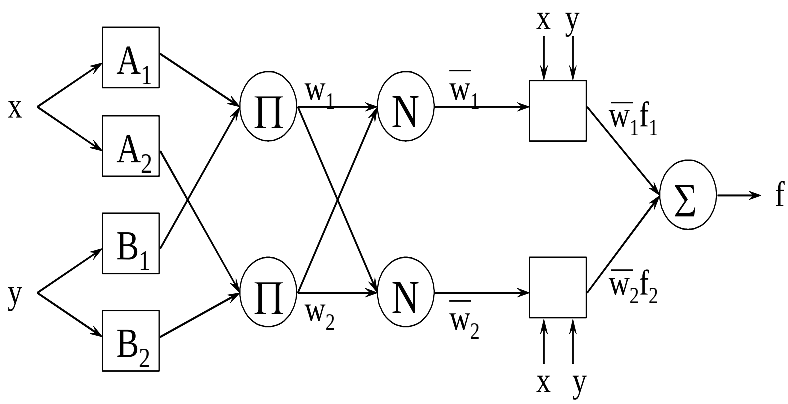

Figure 3.7.1.1: Basic architecture of ANFIS (Jang, 1993)

The corresponding equivalent ANFIS architecture is as shown in Figure 3.7.1.1, where nodes of the same layer have similar functions.

3.7.1.1 Layers of ANFIS

The fuzzy inference system is under consideration of two inputs v, d and one output f. A brief summary of five layers of the ANFIS model will be developed below according to the pioneering study of Jang (1993).

Layer 1

Every node i in this layer is an adaptive node which produce membership grade of linguistic variable. Each adaptive node is a square node with square function, represented as:

$$O_{1,i} = \mu_{A_i}(x) \quad for\ i = 1, 2, or \qquad (3.7.1.1)$$

$$O_{1,i} = \mu_{B_{i-2}}(y) \quad for\ i = 3, 4, \qquad (3.7.1.2)$$

where x (the input to node i) and A_i (the linguistic label: small, large, etc.) are associated with this node function. In other words, $O_{1,i}$ is the output of the ith node of layer 1 A_i and it specifies the degree to which the given x satisfies the quantifier A_i. Usually $\mu_{A_i}(x)$ is chosen since, along the bell curve, its maximum is equal to 1 and its minimum is equal to 0, such as in the generalized bell function:

$$\mu_{A_i}(x) = \frac{1}{1+\left[\left(\frac{x-c_i}{a_i}\right)^2\right]^{b_i}} \qquad (3.7.1.3)$$

In terms of the Gaussian function, the equation is as follows:

$$\mu_{A_i}(x) = e^{-\left(\frac{x-c_i}{a_i}\right)^2} \qquad (3.7.1.4)$$

where a_i, b_i, c_i constitute the parameter set. As the values of these parameters change, the bell-shaped functions vary accordingly, thereby exhibiting various forms of the membership function along the linguistic label A_i. Parameters in this layer are referred to as *premise parameters*.

Layer 2

This layer checks weights of each membership function, it receives input values from the first layer and act as a membership function to represent fuzzy sets of respective input variables (Walia et al, 2015). Every node in this layer is fixed node labeled Π, which multiplies the incoming signal and sends the product out. The output in this layer can be represented by the equation:

$$O_{2,i} = w_i = \mu_{Ai}(x) * \mu_{Bi}(y), \ i = 1, 2. \qquad (3.7.1.5)$$

Layer 3

Every node in this layer is a fixed node marked with circle labeled N. The i-th node in this layer, calculates the ratio of the i-th rule’s firing strength to the sum of all rules firing strengths:

$$O_{3,i} = \overline{w}_i = \frac{w_i}{w_1 + w_2}, \quad \text{i=1,2} \qquad (3.7.1.6)$$

For the sake of convenience, the output of this layer will be called *normalized firing strengths.*

Layer 4

This layer provides output values resulting from the inference of rules. The output is simply a product of normalized firing rule strength and first order polynomial. Weighted output of rule represented by node function as:

$$O_{4,i} = \overline{w}_i \cdot f_i = \overline{w}_i (p_1 \cdot x + q_i \cdot y + r_i) \quad (3.7.1.7)$$

where $\bar{w}_i$ is the output of layer 3 and $\{p_i, q_i, r_i\}$ is the parameter set. Parameters in this layer will be referred to as *consequent parameters*.

Layer 5

This layer is called output layer which sums up all the inputs coming from layer 4 and transforms fuzzy classification results into crisp values. This layer consists of single fixed node marked with circle and labeled as "Σ". This node compute summation of all incoming signals calculated as:

$$overall\ output = O_{5,i} = \sum_i \overline{w}_i \cdot f_i = \frac{\sum_i w_i \cdot f_i}{\sum_i w_i} \quad (3.7.1.8)$$

A different way to express the overall output is the following equation:

$$f = \frac{w_1}{w_1+w_2} f_1 + \frac{w_2}{w_1+w_2} f_2 + \cdots + \frac{w_n}{w_{n-1}+w_n} f_n \quad (3.7.1.9)$$

$$f = \overline{w_1}(p_1 Q + q_1 M + \cdots + m_1 F + r_1) + \cdots + \overline{w_n}(p_n Q + q_n M + \cdots + m_n F + r_n) \quad (3.7.1.10)$$

It is observed that given the values of premise parameters, the overall output can be expressed as a linear combination of the consequent parameters. Particularly, the output f in figure 3.7.1.1 can be written as,

$$f = \frac{w_1}{w_1+w_2} f_1 + \frac{w_2}{w_1+w_2} f_2 \quad (3.7.1.11)$$

$$= \overline{w_1} f_1 + \overline{w_2} f_2 \quad (3.7.1.12)$$

$$= (\overline{w_1} x) p_1 + (\overline{w_1} y) q_1 + (\overline{w_1}) r_1 + (\overline{w_2} x) p_2 + (\overline{w_2} y) q_2 + (\overline{w_2}) r_2 \quad (3.7.1.13)$$

Which is linear in the consequent parameters $(p_1, q_1, r_1, p_2, q_2\ and\ r_2)$.

3.7.2 Learning algorithms of ANFIS

Neuro-adaptive learning techniques endow with a method for the fuzzy modeling procedure to learn information about a data set. It computes the membership function parameters that best allow the associated fuzzy inference system to track the given input/output data. The parameters associated with the membership functions changes through the learning process (Walia et al. 2015).

In order to be more efficient, the task of the learning algorithm for this architecture is to tune all the modifiable parameters, to formulate the ANFIS output match the training data. To improve the rate of convergence, the hybrid network can be trained by a hybrid learning algorithm combining least square method and gradient descent method can be used (Jang 1993). The least squares method can be used to identify the optimal values of the consequent parameter on the layer 4 with premise parameter fixed. Gradient vector provides a measure of how well the fuzzy inference system is modeling the input/output data for a given set of parameters. When the gradient vector is obtained, any of several optimization routines can be applied in order to adjust the parameters to reduce some error measure (Kamel and Hassan 2009).

When the premise parameters are not fixed, then the search space becomes larger and the convergence of the training becomes slower. The hybrid algorithm is composed of a forward pass (LSM) and a backward pass (GDM). Once the optimal consequent parameters are found, backward pass starts. In the backward pass, errors are propagated backward and the premise parameters corresponding to the fuzzy sets in the input domain updated by gradient descent method (Choi et al. 2015).

ANFIS uses a combination of least squares estimation and back-propagation for membership function parameter estimation. Two passes in the hybrid learning algorithm for ANFIS shown in Table 3.7.2.1.

Table 3.7.2.1. Two passes in the hybrid learning procedure for ANFIS

	forward pass	backward pass
premise parameters	fixed	gradient descent
consequent parameters	least squares estimate	fixed
signals	node outputs	error rates

It has been proven that this hybrid algorithm highly efficient in training the ANFIS (Jang 1993).

3.8 Model evaluation

Nowadays, the science of forecasting has evolved with new and more advanced forecasting models, which aim at reliable forecasts in any subject requested. As a criterion of evaluation between the different methods and models used has prevailed to be, the calculation of arithmetical errors. Obviously the prediction model that presents the lowest errors is the most reliable.

Many researchers have studied evaluation methods between forecasting models such as J. Scott Armstrong with "Principles of Forecasting" (2001), (Carbone and Armstrong 1982, Mentzer and Kahn 1995, McCarthy et al. 2006, Fildes and Goodwin 2007, Makridakis 1993) in order to find out the most reliable. As emerged from the survey research the most popular and frequent criteria, were the calculation of the following arithmetic errors: Mean Square Error (MSE), Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and the Mean Absolute Percentage Error (MAPE).

In this doctoral thesis there will not be comparison between prediction models, but the calculation of evaluation errors will be done, as the low value of errors is a significant criterion of the reliability of the model will be used.

The definition of these arithmetic errors is:

If a vector of *n* prediction is generated from a sample of *n* data points on all variables and Y is the vector of observed values of the variable being predicted, with $\hat{Y}$ being the predicted values then,

Mean Square Error (MSE) = $\frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2$. (3.8.1)

If a vector of *n* prediction is generated from a sample of *n* data points on all variables and Y is the vector of observed values of the variable being predicted, with $\hat{Y}$ being the predicted values then,

Root Mean Square Error (RMSE) = $[\frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2]^{1/2}$. (3.8.2)

Mean Absolute Error (MAE) = $\frac{\sum_{i=1}^{n}|y_i - x_i|}{n}$, (3.8.3)

where y_i is the prediction and x_i the actual value.

Mean Absolute Percentage Error (MAPE) = $\frac{1}{n}\sum_{i=1}^{n}\left|\frac{x_i - y_i}{x_i}\right|$, (3.8.4)

Where x_i is the actual value and y_i the forecast value.

CHAPTER IV

MODEL APPLICATION

4.1 Model description

The model that is used in this doctoral thesis is based in the Adaptive Neural Fuzzy Inference System (ANFIS), has the architecture as described in 3.7.1 paragraph and is developed with the help of the MATLAB software. The data set of the variables which are selected according to international literature and described below in paragraph 4.4, has the role of input data. Another data set for the variable which has the role of output data as the choice of this variable explained in the paragraph 4.6. The ANFIS model is used as a forecasting algorithm, in order to have the optimal fitting for the evaluation output data. The optimal fitting of the evaluation data, it is proved by the corresponding graph as well as by the low evaluation errors of the model.

In more details, this adaptive system uses a hybrid learning algorithm to identify parameters of Sugeno-type fuzzy inference systems. It applies a combination of the least squares method and the back-propagation gradient descent method for training FIS membership function parameters to emulate a given training data set. The network learns in two main phases. In the forward phase of the learning algorithm, consequent parameters identify the least squares estimate. In the backward phase, the error signals, which are the derivatives of the squared error with respect to each node output, propagate backward from the output layer to the input layer. In the backward pass, the premise parameters are updated by the gradient descent algorithm. Learning or training phase of the neural network is a process to determine parameter values to sufficiently fit the training data (Walia et al. 2015).

With the data set of training which contain input and output data pairs of the selected appropriate variables, starts the training of FIS. It is significant for the training procedure to remain low the training errors. As training error is defined the difference between the output value of the training data and the output value of the fuzzy inference system respectively at the same training data input value (Sivanandam and Deepa, 2007).

As developed in the paragraph 3.5.2.2. there are many different types of Membership functions. The given input and output data sets are tested with all the types of Memberships functions, with different values of step size in order to find the minimal errors for the evaluation data. The optimum results of the runs of the designed ANFIS model will be presented in detail in the paragraph 4.7.

4.2 Selecting the appropriate variables

In the bibliography review, that developed in the second chapter is given high importance to the study of variables used in the international published papers for the scientific issue of special interest groups. As can be seen in the table 1, hundred different variables used in the analyzes of the articles. The aim is to focus on the variables that are used more times in different articles so it is most possible to better reflect the effect of interest groups, in order to use them in the research (Papadakis and Atsalakis 2019).

The variables with most references in articles, as they arise from the table 1, in descending order are:

a) *GDP per capita,* (Mueller et al. 1986, McCallum et al. 1987, Nardinelli et al. 1987, Wallis et al. 1988, Kennelly et al. 1991, Quiggin 1992, Crain et al. 1999, Coates et al. 2003, Knack 2003, Coates et al. 2007, Coates et al. 2010)

b) Number of interest groups, (Murrell 1984, Mueller et al. 1986, Crain et al. 1999, Heckelman 2000, Cole et al. 2002, Bischoff 2003, Coates et al. 2003a, Coates et al. 2003, Coates et al. 2007, Horgos et al. 2009, Coates et al. 2010, Heckelman et al. 2013)

c) GDP growth rate, (Weede 1984, Weede 1986, Vedder et al. 1986, Lane et al. 1986, McCallum et al. 1987, Chan 1987, Wallis et al. 1988, Gray et al. 1988, Heckelman 2000, Cole et al. 2002, Knack 2003, Coates et al. 2007a, Horgos et al. 2009, Heckelman et al. 2013)

d) Government spending, Mueller et al. 1986, McCallum et al. 1987, Heckelman 2000, Cole et al. 2002, Coates et al. 2007a, Coates et al. 2007b, Coates et al. 2010, Heckelman et al. 2013) *e) Population*, (Murrell 1984, Mueller et al. 1986, McCallum et al. 1987, Crain et al. 1999, Heckelman 2000, Coates et al. 2007, Coates et al. 2007a, Coates et al. 2007b, Heckelman et al. 2013)

f) Duration of political stability, (Murrell 1984, Weede 1986, Vedder et al. 1986, McCallum et al. 1987, Chan 1987, Kennelly et al. 1991, Quiggin 1992, Tang et al. 1998, Coates et al. 2007a, Coates et al. 2007b)

g) political rights/ democracy, (Knack 2013, Coates et al. 2007, Coates et al. 2007a, Coates et al 2007b, Coates et al. 2010, Heckelman et al. 2013)

h) Investment, (Heckelman 2000, Cole et al. 2002, Coates et al. 2003a, Knack 2003, Coates et al. 2007, Coates et al. 2007a, Horgos et al. 2009, Coates et al. 2010, Heckeleman et al. 2013).

i) GDP, (Heckelman 2000, Coates et al. 2007, Coates et al. 2007a, Coates et al. 2007b, Horgos et al. 2009, Heckelman et al. 2013)

j) Tax revenues, (Mueller et al. 1986, Vedder et al. 1986, Crain et al. 1999, Cole 2014)

k) Inflation, (Knack 2003, Coates et al. 2007, Coates et al. 2007a, Horgos et al. 2009, Coates et al. 2010)

l) GDP per capita rate of growth, (Weede 1986, Tang et al. 1998, Coates et al. 2007, Cole 2014)

m) Government revenue as percentage of GDP, (Weede 1984, Wallis et al. 1988, Crain et al 1999).

The aim of data analysis that follows, is to find out and select the appropriate variables which best reflect the action of interest groups in a country's economy, in accordance to the bibliographic research. These variables will be used as input variables in the model that presented in the previous chapter 4.1.

Before proceeding with the analysis of the data for the selection of the appropriate variables, it is necessary, at this point, to explain how are considered some of the above variables.

As *Duration of political stability* consider the "age of state" in Vedder and Gallowey (1986) , "number of years since the first constitution" McCallum and Blais (1987) "state age" Nardineli, Wallace and Warner (1987), "number of years since state admitted to the union" , "years since statehood" Wallis and Oates (1988), "length of time in which group formation possible" Kennelly and Murrell (1991), "political stability" Quiggin (1992), "years of last turnoil" Tang and Hendley (1998), "duration of political stability of a country" Bischoff (2003), "Institutional instability" Coates et al. (2007a), and "institutional upheaval" Coates et al. (2007b).

As *political rights/ democracy*, consider the "degree of democracy in a country" Murrell (1984), "Hewitt's index of full democracy" Weede (1984), "age of democracy in 1971" Weede (1986), "a property rights index" Knack (2003), "democracy" Coates and Wilson (2007), "political rights" Coates, Heckelman and Wilson (2007), "political rights (average and initial value)" Coates et al. (2007a), "democracy" Coates et al. (2007b), "political rights" Coates et al. (2010), and "democracy" in Heckelman and Wilson (2013).

4.3 Input Variable Analysis

Before the beginning of data analysis, according to the methodology that developed in the previous chapters 3.1 and 3.2, is necessary at first to be removed the variables that have not a really reason to participate in the analysis. Secondly, is necessary to concern the period of time in which there are available data for all the variables with respect to the second implication of Olson's theory. The analysis of the data refers the same time period for all the involved variables involved. Thirdly, it is noticed the data sets sources.

For the variable *"Number of interest groups"*, there are not reliable data, as there is not any official institution in Greece (or out of Greece), that has measured or approached, or even forecasted the number of interest groups which operate in Greece. As mentioned in the introduction chapter, the term "interest groups" has a general and wide meaning and that make it impossible to be counted by any institution. It would be possible to do an estimation if add up the members of all Greek champers, the trade unions and the labor unions. In the international literature there is this a way of estimating the number of interest groups, but in the case of Greece this effort has two disadvantages. First, every year the number of the unions remain almost constant without significant changes, so it does not help the study and second and more important that there isn't a complete picture of the real number of interest groups. According to Iordanoglou (2013), after 1974 in modern Greek society includes business associations, trade unions, chambers, associations and unions based on their place of origin, ecclesiastical organizations, freelancers' associations, informal grouping of people in provincial towns, and many others where each group operates by its own way in order to promote its interests. For all the above reasons, the variable "*b) Number of interest groups",* is rejected from the group of variables under consideration.

The variable *"Population"*, shows the number of the citizens of the general population. The Hellenic Statistical Authority id the official institution in Greece, which makes the national population-housing census every ten years. The last one, was in 2021 and the next one is expected in 2031 (H.S.A. 2021) . This means that the value of "Population" would remain constant for each year, and would change every ten years. A variable with constant value for each decade, loose the meaning of the variable, so for this reason is rejected from the analysis group.

Especially for Greece, the variable *"Duration of political stability"*, can be recorded as a duration of "political stability" Quiggin (1992), or the "years of last turmoil" Tang and Hendley (1998). As was sufficiently developed in Chapter 1.5 of this doctoral dissertation, the study period of the interest groups action, according to implications of Olson's theory, starts after the fall of the dictatorship in 1974. Therefore, starting the counting from the year 1974, one unit will be added for each subsequent year, so this variable would take the values 1,2,3,4,5 etc. Consequently, the presence of a variable with such values in the following analysis is not essential, so it is rejected.

The last variable that is not capable of our study is the *"political rights/ democracy"*. This variable in every study from the international literature has had and a different meaning or definition and has been calculated only for one year at a time.

In the study of Murell (1984) was calculated for year 1969, as a linear combination with essentially arbitrary weights of variables, measuring freedom to form organization, freedom of expression, right to vote etc. At the same time in Weede (1984) had the definition of "Hewitt's index of full democracy" where, Hewitt considers that full democracy occurs if the following factors appear simultaneously: universal adult male suffrage, secret ballot, and responsible government. Weede (1986) refers to it as "age of democracy in 1971", while Knack (2003) had taken values as “a property rights index”. In the study of Coates and Wilson (2007) as “democracy” had taken the average annual value of a measure of the general openness of political institutions. In the study of Coates, Heckelman and Wilson (2007) the “political rights” was measured as an index of the degree of freedom in the electoral process, political pluralism and participation, and functioning of government, using an inverse of the original 1-7 scale such that higher values represent more political rights. The same definition used as the “political rights” variable, Coates et al. (2007a) in their study, as “democracy” in the study of Coates et al. (2007b) the variable reported the democracy and autocracy, as average of three years prior to beginning of period, (0 to 10 values reflect democracy, -10 to 0 values reflect autocracy). In the study of Coates et al. (2010) as “political rights” indicated an index of relative ranking from one (best) to seven (worst) concerning the political rights of the country and the “democracy” variable in study of Heckelman and Wilson (2013) was computed as a straight average of the political rights and civil liberties values (PRLC).

As follows, the variable “democracy” or “political rights” is not a variable with a specific fixed definition and in plenty research tasks has the role of a qualitative variable which indicates the level of democracy or political rights of the country. As far as Greece is concerned, after the fall of the dictatorship in 1974, when there was a real violation at the political rights of citizens, democracy was established in the country, with the restoration of democratic legitimacy, in July 1974. The Government of National Unity set as its first aim the consolidation of the Republic and partially reinstated the Constitution of 1952. The first democratic parliamentary elections (November 17, 1974) and the referendum on the form of the regime (December 8, 1974), which advocated the rule of the non-monarchical democracy, was followed by the Constitution of 1975. This Constitution, although ultimately voted only by the parliamentary majority, gradually gathered during the implementation, in view of the wider possible acceptance by the country's political forces. (Hellenic Parliament: Constitutional History)

The country's new constitutional charter introduced the government of a presidential parliamentary democracy, containing from the outset a broad list of individual and social rights adapted to the demands of the times. The rule of law was effectively protected, and the country's participation in international organizations and

- indirectly - in the then EEC (in the way it was consisted at the time) was foreseen. (Hellenic Parliament: Constitutional History).

The Consumer Price Index (CPI), is a widely used measure of inflation and therefore reflect the effectiveness of the government‟s economic policy. The CPI is an significant indicator of price changes in the economy and may act as a guide for the government and businesses, in order to make decisions about the economy. CPI takes in account the prices at beverages, food, transportation, housing, recreation, apparel, medical care, education and communication and other goods and services. The inflation reflects the change in the purchasing power of the currency. As the prices of goods and services rise, so does inflation. When the inflation is rising, an adjustment in income and in the cost of living is leading.

By an economic sense, an investment is defined as the purchase of goods that are not consumed today but will be used in future in order to create wealth. In finance, an investment is a monetary asset purchased by the idea that the asset will provide income in the future or will be sold later at a higher price with profit. In order to have a competent picture of investments in Greece, mainly from foreign investors which shows whether they trust Greece for investments, despite the inside action of interest groups, is the Foreign Direct Investment (FDI).

A foreign direct investment (FDI), is “an investment made by a firm or individual in one country into business interests located in another country”. Generally, FDI takes place when an investor establishes foreign business operations or acquires foreign business assets in a foreign company. However, FDIs are distinguished from portfolio investments in which an investor merely purchases equities of foreign-based companies.

In summary, the variables that will be tested below are:

1. *“GDP per capita”*,
2. *“GDP growth rate”*,
3. *“Government spending”*,
4. *“Investment”*,
5. *“GDP”*,
6. *“Tax revenues”*,
7. *“Inflation”*,

8. *“GDP per capita rate of growth”*,
9. *“Government revenue as percentage of GDP”*.

From the first quarter of 1999 to the fourth quarter of 2019, a complete data set is collected, consequently the variables will be tested in this common period of time. The data set source for each variable is shown on the next table 4.3.1. In more details the variables “GDP per capita”, “GDP growth rate”, “General Government Total expenditure”, “GDP”, “GDP per capita rate of growth”, have been collected from the Hellenic Statistical Authority, the variables “Investment” and the “Tax Revenues” from CEIC data, the “Inflation” from the OECD, and the “Government revenue as percentage of GDP”, has been collected from IMF.

All the variables are quantitative variables, more specifically, the “GDP”, “Government spending”, “Tax revenues” are measured in millions euro, the “Foreign Direct Investment (FDI)” is calculated as a percentage of GDP, the “GDP growth rate” has been calculated as the percentage change for the corresponding quarter of the previous year (y-o-y), the “government spending”, because of its general concept, contains the data of “Total expenditure of General Government”, as reported by the Hellenic Statistical Authority.

4.3.1 Table sources of Data

Variables	Source	Source Link	Time period
"GDP per capita"	Hellenic Statistical Authority	https://www.statistics.gr/en/statistics/eco	Q1 1999 - Q4 2019
"GDP growth rate" (y-o-y)	Hellenic Statistical Authority	https://www.statistics.gr/en/statistics/eco	Q1 1999 - Q4 2019
"General Government Total expenditure"	Hellenic Statistical Authority	https://www.statistics.gr/en/statistics/eco	Q1 1999 - Q4 2019
"Investment – FDI"	CEIC Data	https://www.ceicdata.com/en/country/greece	Q1 1999 - Q4 2019
"GDP"	Hellenic Statistical Authority	https://www.statistics.gr/en/statistics/eco	Q1 1999 - Q4 2019
"Tax revenues"	CEIC Data	https://www.ceicdata.com/en/country/greece	Q1 1999 - Q4 2019
"Inflation – CPI"	OECD	https://data.oecd.org/greece.htm	Q1 1999 - Q4 2019
"GDP per capita rate of growth"	Hellenic Statistical Authority	https://www.statistics.gr/en/statistics/eco	Q1 1999 - Q4 2019
"Government revenue" (% GDP)	IMF	https://www.imf.org/en/Countries/GRC	Q1 1999 - Q4 2019

4.4 Input Data Analysis

In this section will be derived from the total of nine variables of the previous analysis, which and how many variables are optimal to be used in the ANFIS model described in 4.1 section, as input variables.

The methodology steps, that will be followed in this analysis are: at first is necessary a normality tests for all the variables, secondly a correlation test to find out the variables with high correlation, and thirdly by the application of the Principle Component Analysis will be derived the finals significant variables, which reflect the action of interest groups in Greek economy by the optimist way.

4.4.1 Normality test

As described in 3.1.2 section for normality test, the Kolmogorov-Smirnov criterion can be calculated as well as the probability that it has been made false, if we accept that the data of the sample do not follow the normal distribution. This probability level is called significant level and symbolized by “sig”. Usually when sig, has values higher than 0,05 is accepted that the normal distribution applies to the sample values (Nikita 2012). The values for the probability level are presented in the follow table 4.4.1.1, as emerged by the SPSS application.

Table 4.4.1.1. SPSS Results for one sample Kolmogorov-Smirnov tests

	Kolmogorov-Smirnov		
	Kolmogorov-Smirnov	N	Sig.
“Growth rate” y-o-y	1,236	80	0,094
“Tax revenue”	0,749	80	0,63
“CPI”	1,273	80	0,053
“Final consumption expenditure”	0,955	80	0,322
“FDI” (%GDP)	1,165	80	0,133
“Gen Govern. Revenue”	0,53	80	0,941
“GDP”	0,951	80	0,327
“GDP per capita”	0,926	80	0,358
“GDP per capita growth rate”	0,982	80	0,301

.

As emerged by the table 4.4.1.1, the significant level for all the variables is higher than 0.005, so it is retained the null hypothesis H_0, that the distribution is NOT statistically significantly different than normal.

4.4.2. GDP group variables analysis

It is important that the data set of the nine variables under examination appear a normal distribution, because this will allow the correlation test and hereupon applying PCA method in order to choose the main variables. In the group consisted of these nine variables, there are four of them which are related to GDP,

1) "GDP per capita"
2) "GDP growth rate"
3) "GDP per capita rate of growth"
4) "GDP"

We set that these variables form an individual group ans a correlation test will be conducted among them. The data of these variables as reffered to table 1 in 4.3 paragraph, concern the period from first quarter of 1999 to fourth quarter of 2019. By using the SPSS application, the correlation coefficients are calculated between the variables and are showed in the following table 4.4.2.1.

Table 4.4.2.1 Correlation matrix for the four variables related to GDP.

	GDP millions	GDP per capita	GDP per capita growth rate	GDP growth rate
"GDP millions"	1,000	,999	-,424	-,460
"GDP per capita"	,999	1,000	-,418	-,456
"GDP per capita growth rate"	-,424	-,418	1,000	,829
"GDP growth rate"	-,460	-,456	,829	1,000

As emerged by the table, the correlation coefficient between "GDP" and "GDP per capita" is almost 1, (0,999). Therefore these two variables not only have a high correlation, but are almost identical. For this reason, one of the two variables is eliminated from the group and the study for the three variables continues, in order to get the main one, by applying PCA method.

With the help of the SPSS application the method of the Principal Component Analysis (PCA) is applied and the following tables 4.4.2.2 and 4.4.2.3, are obtained.

Table 4.4.2.2. Total Variance Explained

Initial Eigenvalues			Extraction Sums of Squared Loadings		
Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %

2,159	71,958	71,958	2,159	71,958	71,958
,671	22,382	94,340			
,170	5,660	100,000			

Extraction Method: Principal Component Analysis.

Table 4.4.2.3 Component Matrix

	Component
	1
GDP growth rate	,923
GDP per capita growth rate	,910
GDP per capita	-,692

Extraction Method: Principal Component Analysis.

1 components extracted.

By the application of PCA it is emerged that only one variable has initial eigen value higher than 1, and therefore more specifically, it takes the value 2,159 with 71,958% variance. The variable with the higher component value (0,923) as emerged by the component matrix, is the "GDP growth rate". Therefore, as principal component from the GDP group, is emerged the "GDP growth rate".

4.4.3 Selecting the appropriate input variables for ANFIS

After the selection of the most appropriate variable from the group of " GDP-variables", the final group of variables which the analysis will proceed further, is formed as follows:

1. "GDP growth rate"
2. "Government spending"
3. "Investment (FDI)"
4. "Tax revenues"
5. "Inflation (CPI)"
6. "Government revenue"

Initially, in this group of variables, the correlation is checked as well, and the correlation coefficients which emerged are presented in the table 4.4.3.1. As shown in the table, the variables "Tax revenue" and "Gen Government Revenue" have a high correlation coefficient with each other, (takes the value 0.887). This value can be explained, because the tax revenues of a country are included in general government revenues. Also these variables have a high correlation with the "Final Consumption Expenditure" of "General government spending" variable, with correlation coefficient values of 0.775 and 0.712 respectively. In this case too, the high correlation is explained as higher are the revenues of Greek state for the period of 1999-2009 that concerns the study, the higher its costs. While for the rest of the study period time 2010-2019, expenditures (Government spending) are reduced and "government revenues" are reduced accordingly.

Therefore, due to the high correlation between these three variables, the variables "Tax Revenue" and "General Government Revenue" are removed from the group.

From the initial group of nine variables, there are four left

1. "Government spending"
2. "Investment"
3. "Inflation"
4. "GDP growth rate"

After the application of Principal Component Analysis method, the most significant variable will arise, which will be used as input variables in ANFIS model.

Using SPSS, the results by the PCA method are shown in the table 4.4.3.2(a-e).

It is important to note that four variables of the final group of variables, have low correlation coefficient values, as shown in the table 4.4.3.2.a of Correlation Matrix. Also in the table 4.4.3.2.c of Total Variance are shown two values higher of 1, for the initial eigen-values, which means that these two variables are the main components of the group and they are also able to replace all the rest variables in the study that will follows. From the Component matrix (table 4.4.3.2.d), which is also verified by the Rotated Component Matrix (table 4.4.3.2.e), are emerged the variables with the higher value of component at 0.882 and -0.584. These values correspond to the variables "GDP growth rate" and "Final Consumption Expenditure", so these two variables, will be the two input variables in the ANFIS model.

Table 4.4.3.1 Correlations results

		GDP Growth rate	Tax revenues	Inflation (CPI)	Final consumption expenditure	Investment (FDI)	Gen Govern. Revenue
"Growth rate y-o-y"	Pearson Correlation	1	-,490**	,359**	-,393**	,077	-,455**
	Sig. (2-tailed)		,000	,001	,000	,497	,000
	N	80	80	80	80	80	80
"Tax revenue"	Pearson Correlation	-,490**	1	-,156	,875**	,165	,887**
	Sig. (2-tailed)	,000		,168	,000	,143	,000
	N	80	80	80	80	80	80
"CPI"	Pearson Correlation	,359**	-,156	1	,113	-,219	-,180
	Sig. (2-tailed)	,001	,168		,318	,050	,110
	N	80	80	80	80	80	80
"Final consumption expenditure"	Pearson Correlation	-,393**	,875**	,113	1	,022	,812**
	Sig. (2-tailed)	,000	,000	,318		,844	,000
	N	80	80	80	80	80	80
"FDI"	Pearson Correlation	,077	,165	-,219	,022	1	,235*
	Sig. (2-tailed)	,497	,143	,050	,844		,036
	N	80	80	80	80	80	80
"Gen Govern. Revenue"	Pearson Correlation	-,455**	,887**	-,180	,812**	,235*	1
	Sig. (2-tailed)	,000	,000	,110	,000	,036	
	N	80	80	80	80	80	80

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.4.3.2(a-e) PCA results

Table 4.4.3.2.a Correlation Matrix

		"Growth rate"	"CPI"	"Final consumption expenditure"	"FDI"
Correlation	"Growth rate"	1,000	,359	-,393	,077
	"CPI"	,359	1,000	,113	-,219
	"Final consumption expenditure"	-,393	,113	1,000	,022
	"FDI"	,077	-,219	,022	1,000

Table 4.4.3.2.b Communalities

	Initial	Extraction
"Growth rate"	1,000	,807
"CPI"	1,000	,779
"Final consumption expenditure"	1,000	,670
"FDI"	1,000	,451

Extraction Method: Principal Component Analysis.

Table 4.4.3.2.c Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1,485	37,129	37,129	1,485	37,129	37,129	1,429	35,729	35,729
2	1,222	30,556	67,684	1,222	30,556	67,684	1,278	31,956	67,684
3	,934	23,361	91,046						
4	,358	8,954	100,000						

Extraction Method: Principal Component Analysis.

Table 4.4.3.2.d Component Matrix[a]

	Component	
	1	2
"Growth rate"	,882	-,171
"Final consumption expenditure"	-,584	,773
"CPI"	,585	,661
"FDI"	-,152	-,654

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Table 4.4.3.2.e Rotated Component Matrix[a]

	Component	
	1	2
“Growth rate”	,862	,255
“Final consumption expenditure”	-,783	,239
“CPI”	,214	,856
“FDI”	,167	-,650

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

4.5 Output Variable Analysis

As mentioned in detail in the chapters 1.3 and 1.4 according to Olson's theory, interest groups aim to commit resources from the productive process and the wealth of the country. Special interest groups slow down growth by reducing the rate at which resources are distributed from one activity or sector to another in response to new technologies or conditions. An obvious way to do this is by "demanding government guarantees on debt redemption for businesses in recession, delaying or preventing the transfer of resources to areas where they would have higher productivity rates" (Hicks 1983). Increasing productivity means that resources should be reallocated if they are to maintain economic efficiency, and society should fully exploit the rise in productivity.

Especially for Greece:

i) a large share of the workforce concerns the public sector, either as employees in it or as customers who need to be served by public services. Many studies have reported on this, noting the large scope of the public sector, with hundreds of thousands of employees, at the same time as its low level of service and efficiency. (Lavdas 2007, Mavrogordatos 2009)

ii) the interest groups are "feeding" by the state budget (Mitsopoulos and Pelagidis 2011)

iii) the interest groups action, has as an aim the to reduce the competitiveness (Atsalakis et al 2016)

iv) one of the results of the interest group's action, is that they significantly affect the productivity of the country, with a tendency to reduce it. (Atsalakis et al 2016)

All the above factors, such as diligence, wealth of the country, GDP, competitiveness are directly affected by the influence of interest groups in Greece. These factors are also related to the labor productivity as defined and calculated, by Eurostat.
Gross domestic product (GDP) is a measure for the economic activity. It is defined as the monetary value of all the finished goods and services produced within a country's borders in a specific time period and includes anything produced within its borders by the country's citizens and foreigners. GDP per person employed is intended to give an overall impression of the productivity of national economies expressed in relation to

the European Union average. If the index of a country is higher than 100, this country's level of GDP per person employed is higher than the EU average and vice versa. Basic figures are expressed in PPS, i.e. a common currency that eliminates the differences in price levels between countries allowing meaningful volume comparisons of GDP between countries. It is significant to note that “persons employed” does not distinguish between full-time and part-time employment.
Labor productivity per hour worked is calculated as real output per unit of labor input (measured by the total number of hours worked). Measuring labor productivity per hour worked provides a better picture of productivity developments in the economy than labor productivity per person employed, as it eliminates differences in the full time/part time composition of the workforce across countries and years. (Eurostat)

Therefore the variable “Labor Productivity per hour worked”, is chosen as the output variable in the ANFIS model whose results will be presented next.

4.6 Algorithm configuration

According to the architecture that described in 3.7.1 and following the characteristics of the ANFIS model, as reported in 4.1, the next figure 4.6.1 shows the basic structure of the ANFIS algorithm. The data sets of two variables form the two inputs of the model, the adaptive system that uses a hybrid learning algorithm to identify parameters of Sugeno-type fuzzy inference system is the core of the model which create the output. The variables, GDP growth rate, General Government Expediture and the Labor productivity are suitable for the study, as emerged after a detailed study in the paragraphs 4.2, 4.3, 4.4 and 4.5.

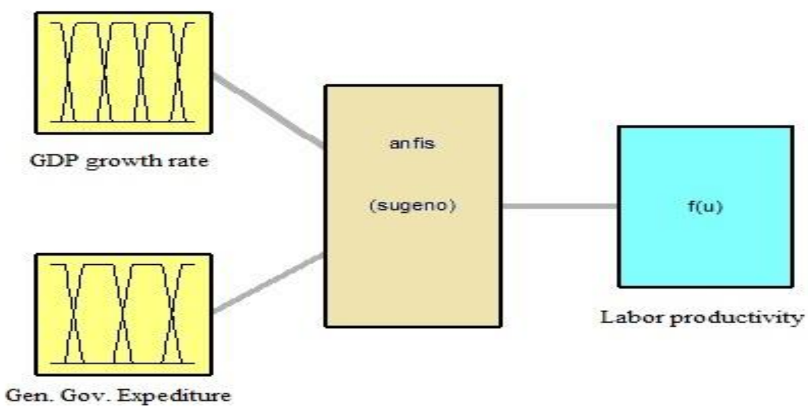

Figure 4.6.1. The basic structure of the ANFIS algorithm, GDP growth rate and Government Expenditure as input data, Labor productivity as output variable and the Sugeno-type inference system.

The quarterly data (1996-2019) for GDP growth rate is the first input, the quarterly data (1996-2019) for the General Government Expenditure is the second input, and the quarterly values for the same period for the Labor productivity form the output.

The data for these three variables concern the quarterly values for the period from the first quarter of 1996 to the fourth quarter of 2019, where for this period is studied the impact of interest groups on the Greek economy. The values of the data for the input and output variables are depicted in the next figure 4.6.2.

The source for the data of the variable GDP growth rate (y-o-y) is the Hellenic Statistical Authority and has been calculated as the percentage change for the corresponding quarter of the previous year (y-o-y), The source for the data of the variable General Government Total Expenditure is the Hellenic Statistical Authority and is measured in millions euro. The output variable, Labor productivity per hour worked, is calculated as real output per unit of labor input (measured by the total number of hours worked). The source of the Labor productivity per hour worked, is Eurostat.

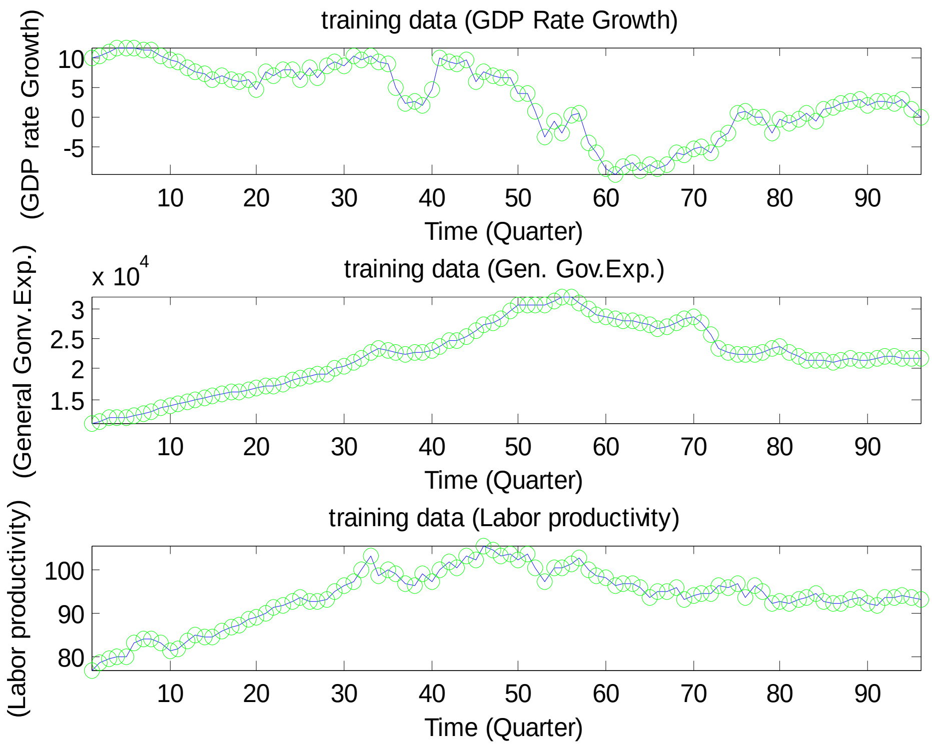

Figure 4.6.2. The values of, GDP rate growth, General Government Expenditure, Labor productivity (1996-2019).

In the architecture of the ANFIS model, training is a significant procedure in the operation of the algorithm, as developed in the 3.7.2.. The model is used in this doctoral thesis has been trained for the period from Q1 of 1996 to Q2 of 2017. For the last ten values of the output variable "Labor productivity", the model gives its forecasts which will be compared with the actual values of the variable of the specific quarters. Therefore, of the total data, the 90 percent were used for algorithm training and 10 percent for the evaluation of the algorithm. In the next figure 4.6.3 are displayed the training data for input 1 (GDP rate growth) and input 2 (General Government Expenditure).

Also other parameters that have been configured, in order to the optimal operation of the algorithm are the number of the repetitions (epochs), which takes the values: 500, 1000, 1.500 and the step size (ss), which takes the values: 0.1 , 0.001 , and 1.

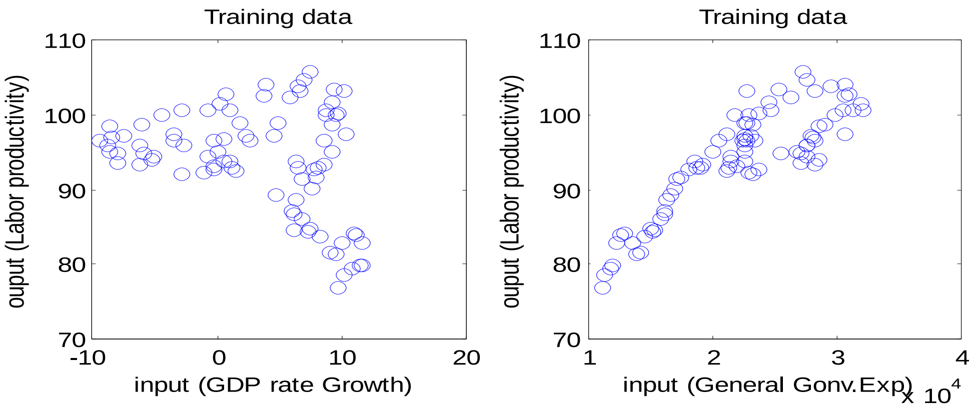

Figure 4.6.3. Displayed the input training data (1999-2017).

As mentioned in 3.5.2.3 the fuzzification involves two processes, firstly, derive the membership functions for input and output variables and secondly represent them with linguistic variables. There are many types of membership functions, triangular, trapezoidal, π-shaped, Gaussian, generalized bell and sigmoidal, where all the types were used in order to find the function that shows the optimum results.

Of particular importance are the fuzzy logic rules that have been applied to each of the runs to get the optimum prediction results. The fuzzy logic rules differ as they depend on the total number of rules applied to each run. Then, for each diagram the exact fuzzy logic rules taken into account by the prediction algorithm, will be reported.

How to choose the best diagram and therefore the optimum forecast, two criteria are taken into account. From an empirical point of view, the diagram image of whether the prediction points are closer to the actual points, and from a mathematical point of view, the arithmetic errors. The arithmetic errors, MSE, RMSE, MAE, MAPE, have been extensively reported in 3.8, will be calculated in a separate table and obviously the lower the error values, the more reliable the forecasting.

4.7 Evaluation Results

For the description of the model and for the model configuration, there are so many different parameters that affect the operation of the model, as developed in 4.1 and 4.6. It is significant to check all possible combinations that arise with confidence the optimal combination that will be chosen. In order to achieve this aim, the study begins with the evaluation of the model for every different simulation, based on the different numbers of Membership Functions for input 1 and input 2. As mentioned in 3.8, the evaluation of the model is inferred from the calculated arithmetic errors of the results and the lower the error values the more efficient its operation and the more reliable its results. Therefore, after each simulation based on the different type of Membership Functions, the configuration of the algorithm with the lower arithmetical errors will be reported, so when all the simulations are completed, they will be compared with each other and the three configurations with the lower errors will be selected.

Starting the configuration of the model it is necessary to study all the parameters on which it depends and are important for its optimal operation. The membership function, the number of rules, the number of iterations (epochs), the step size (ss), the percentage of training data are the parameters which we will investigate in detail below.

The number of repetitions was chosen to be over 1000, as in the simulation it is observed that after 500 repetitions the errors are significantly reduced. Therefore, in the first group of tables with the arithmetic errors results (MSE, RMSE, MAE, MAPE) that follows, the number of iterations (epochs) is constant at **1000**, as it is kept constant and equal to **1** the step size (ss). All possible types of member functions are tested with possible combinations of nodes numbers for each input (1 and 2).

Table 4.7.1. Arithmetic errors for, epochs=1000, ss=1, Mf's type: Triangle

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	1	TRIMF	2	2	4,2512	2,0618	1,9817	2,1320
1000	1	TRIMF	2	3	5,0420	2,2454	2,1437	2,3067
1000	1	TRIMF	3	2	5,1145	2,2615	1,8939	2,0403
1000	1	TRIMF	3	3	4,6978	2,1674	2,0701	2,2273
1000	1	TRIMF	3	4	11,8004	3,4352	3,2366	3,4814
1000	1	TRIMF	4	3	2,0413	1,4287	1,2766	1,3733
1000	1	TRIMF	4	4	1,0352	1,0174	0,8964	0,9641
1000	1	TRIMF	4	5	5,6992	2,3873	2,1681	2,3284
1000	1	TRIMF	5	4	-	-	-	-
1000	1	TRIMF	5	5	0,5555	0,7453	0,6559	0,7046
1000	1	TRIMF	5	6	14,8720	3,8564	3,6466	3,9172
1000	1	TRIMF	6	5	1,5190	1,2325	1,0362	1,1134
1000	1	TRIMF	6	6	3,6655	1,9146	1,7058	1,8350

In the table 4.7.1, epochs, the step size and the type of membership function (triangular) remain constant but the number of MF's for each input variable changes from the value pair (2,2) to (6,6). The algorithm for the pair (5,4) for each input node, doesn't extract any result and for the pair (5,5) gives the lower arithmetic errors.

Table 4.7.2. Arithmetic errors for, epochs=1000, ss=1, Mf's type: Generalized bell

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	1	GBELL	2	2	5,0729	2,2523	2,1422	2,3038
1000	1	GBELL	2	3	5,2581	2,2932	2,1981	2,3639
1000	1	GBELL	3	2	4,9919	2,2343	2,1353	2,2966
1000	1	GBELL	3	3	5,0943	2,2580	2,1377	2,2994
1000	1	GBELL	3	4	1,2760	1,1296	0,9987	1,0726
1000	1	GBELL	4	3	6,7035	2,5891	2,3992	2,5815
1000	1	GBELL	4	4	1,1006	1,0491	0,8795	0,9437
1000	1	GBELL	4	5	0,9994	0,9997	0,8257	0,8865

1000	1	GBELL	5	4	6,5077	2,5510	2,3823	2,5607
1000	1	GBELL	5	5	1,6816	1,2968	1,1374	1,2224
1000	1	GBELL	5	6	7,3973	2,7198	2,5422	2,7307
1000	1	GBELL	6	5	7,1781	2,6792	2,3499	2,5178
1000	1	GBELL	6	6	10,7137	3,2732	2,8294	3,0349

In the table 4.7.2, epochs, the step size remain constant as the 4.7.1 table but change the type of membership function from triangular to a Generalized bell. The number of MF's for each input variable changes from the value pair (2,2) to (6,6) and for the pair (4,5) extract the lower arithmetical errors.

Table 4.7.3. Arithmetic errors for, epochs=1000, ss=1, Mf's type: Gaussian

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	1	GAUSS	2	2	5,6533	2,3777	2,2888	2,4619
1000	1	GAUSS	2	3	4,6219	2,1499	2,0566	2,2121
1000	1	GAUSS	3	2	6,8303	2,6135	2,4766	2,663
1000	1	GAUSS	3	3	5,1061	2,2597	2,161	2,3224
1000	1	GAUSS	3	4	9,3483	3,0575	2,8211	3,0327
1000	1	GAUSS	4	3	5,2355	2,2881	2,2012	2,3663
1000	1	GAUSS	4	4	2,4002	1,5492	1,4501	1,5589
1000	1	GAUSS	4	5	14,7767	3,8441	3,6042	3,871
1000	1	GAUSS	5	4	8,9431	2,9905	2,7959	3,0037
1000	1	GAUSS	5	5	4,9383	2,2222	2,0825	2,2376
1000	1	GAUSS	5	6	1,5298	1,2368	1,0878	1,1696
1000	1	GAUSS	6	5	7935	281,6107	181,2012	195,4529
1000	1	GAUSS	6	6	4,2453	2,0604	1,934	2,0777

In the table 4.7.3, epochs, the step size remain constant as the 4.7.1 table but change the type of membership function from a generalized bell to a Gaussian. The number of MF's for each input variable changes from the value pair (2,2) to (6,6), and the lower arithmetical errors are given from the pair (5,6), that means the first input has 5 MF's and the second input has 6 MF's.

Table 4.7.4. Arithmetic errors for, epochs=1000, ss=1, Mf’s type: Gaussian-2

Epochs	ss	MF’s TYPE	NUMBER OF MF’s FOR INPUT1	NUMBER OF MF’s FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	1	GAUSS2	2	2	6,0037	2,4502	2,3329	2,5085
1000	1	GAUSS2	2	3	4,3857	2,0942	2,0133	2,1657
1000	1	GAUSS2	3	2	6,3713	2,5241	2,3976	2,5783
1000	1	GAUSS2	3	3	6,3327	2,5165	2,3836	2,5365
1000	1	GAUSS2	3	4	3,1722	1,7811	1,6656	1,7911
1000	1	GAUSS2	4	3	3,5167	1,8753	1,7456	1,878
1000	1	GAUSS2	4	4	3,4586	1,8597	1,7129	1,8415
1000	1	GAUSS2	4	5	0,5817	0,7627	0,6572	0,7049
1000	1	GAUSS2	5	4	5,6976	2,387	2,2185	2,3854
1000	1	GAUSS2	5	5	3,1777	1,7826	1,6554	1,7801
1000	1	GAUSS2	5	6	9,1673	3,0278	2,731	2,9337
1000	1	GAUSS2	6	5	1,4152	1,1896	1,0094	1,0837
1000	1	GAUSS2	6	6	3.482.400,00	1.866.100,00	1.400.300,00	1.503.700,00

In the table 4.7.4, epochs, the step size remain constant, but change the type of membership function from a generalized bell to a Gaussian-2 membership function. The number of MF’s for each input variable changes from the value pair (2,2) to (6,6), which the last one, has as a result extremely high arithmetic errors. In contrast, the lower arithmetic errors are given by the pair (4,5), that means the first input has 4 MF’s and the second input has 5 MF’s.

Table 4.7.5. Arithmetic errors for, epochs=1000, ss=1, Mf’s type: Trapezoid

Epochs	ss	MF’s TYPE	NUMBER OF MF’s FOR INPUT1	NUMBER OF MF’s FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	1	TRAP	2	2	4,4532	2,1103	2,0111	2,1634
1000	1	TRAP	2	3	4,9163	2,2173	2,1136	2,2734
1000	1	TRAP	3	2	6,5971	2,5685	2,4436	2,6275
1000	1	TRAP	3	3	7,179	2,6794	2,5216	2,7114
1000	1	TRAP	3	4	6,6425	2,5773	2,4533	2,6365
1000	1	TRAP	4	3	5,8346	2,4155	2,3051	2,4791
1000	1	TRAP	4	4	6,2499	2,5	2,375	2,5538
1000	1	TRAP	4	5	-	-	-	-
1000	1	TRAP	5	4	-	-	-	-

1000	1	TRAP	5	5	-	-	-	-
1000	1	TRAP	5	6	-	-	-	-
1000	1	TRAP	6	5	-	-	-	-
1000	1	TRAP	6	6	7,0587	2,6568	2,496	2,6814

In the table 4.7.5, epochs, the step size and the type of membership function (trapezoid) remain constant but the number of MF's for each input variable changes from the value pair (2,2) to (6,6). The algorithm for all possible combinations between 4,4 to 6,5 for each input's number of MF's, doesn't extract any result, and the lower arithmetic errors are given by the pair (4,3), that means the first input has 4 MF's and the second input has 3 MF's.

Table 4.7.6. Arithmetic errors for, epochs=1000, ss=1, Mf's type: π (PI).

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	1	PI	2	2	7,044	2,654	2,4835	2,6701
1000	1	PI	2	3	4,5988	2,1445	2,0452	2,1999
1000	1	PI	3	2	6,8836	2,6237	2,5091	2,698
1000	1	PI	3	3	5,653	2,3776	2,241	2,4102
1000	1	PI	3	4	2,8927	1,9733	1,8111	1,945
1000	1	PI	4	3	5,3056	2,3034	2,218	2,3854
1000	1	PI	4	4	2,692	1,6407	1,448	1,5546
1000	1	PI	4	5	2,3144	1,5213	1,4326	1,5407
1000	1	PI	5	4	5,3946	2,3226	2,1253	2,2831
1000	1	PI	5	5	1,7877	1,337	1,1543	1,2434
1000	1	PI	5	6	3,5785	1,8917	1,77	1,8957
1000	1	PI	6	5	3,5785	1,8917	1,77	1,8957
1000	1	PI	6	6	20,562	4,5345	3,812	4,0938

In the table 4.7.6, the membership function is (π-shaped) remain constant with the number of MF's for each input variable changes from the value pair (2,2) to (6,6) and it is the last, that epochs remain constant and equal to 100, and step size constant and equal to 1. It is observed that the lower arithmetic errors are given by the pair (5,5). The research continues, keeping the epochs constant at **1000** and changing the step size slightly to 0,1.

Table 4.7.7. Arithmetic errors for, epochs=1000, ss=0,1, Mf's type: Triangle

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	0,1	TRIMF	2	2	2,3467	1,5319	1,42	1,5284
1000	0,1	TRIMF	2	3	5,2562	2,2926	2,1916	2,3582
1000	0,1	TRIMF	3	2	11,8526	3,4428	3,1339	3,3712
1000	0,1	TRIMF	3	3	15,6792	3,9597	3,5931	3,8663
1000	0,1	TRIMF	3	4	1,5717	1,2537	1,1125	1,1962
1000	0,1	TRIMF	4	3	2,9806	1,7265	1,596	1,7173
1000	0,1	TRIMF	4	4	1,0964	1,0471	0,9283	0,9985
1000	0,1	TRIMF	4	5	13,3921	3,6595	3,0092	3,2268
1000	0,1	TRIMF	5	4	17,2445	4,1526	3,9465	4,2392
1000	0,1	TRIMF	5	5	9,9105	3,1481	2,9043	3,1194
1000	0,1	TRIMF	5	6	1,4324	1,1968	1,1065	1,1910
1000	0,1	TRIMF	6	5	28,5993	5,3478	4,8478	5,2056
1000	0,1	TRIMF	6	6	11,7393	3,4263	3,1716	3,4067

In the table 4.7.7, epochs, the step size (ss=0,1) and the type of membership function (triangular) remain constant but the number of MF's for each input variable changes from the value 2 to 6. Comparing the table 4.7.1 with 4.7.7, significant differences appear in the results. For low values of MF's numbers, the arithmetic errors are lower, but for higher values of the input nodes the errors are higher. In the table 4.7.7 the lower arithmetic errors are given by the pair (4,4), that means the first input has 4 MF's and the second input has 4 MF's.

Table 4.7.8. Arithmetic errors for, epochs=1000, ss=0,1, Mf's type: Generalized bell

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	0,1	GBELL	2	2	9,0323	3,0054	2,8380	3,0513
1000	0,1	GBELL	2	3	5,5437	2,3545	2,2169	2,3841
1000	0,1	GBELL	3	2	6,9025	2,6275	2,5054	2,6942
1000	0,1	GBELL	3	3	3,9820	1,9955	1,8999	2,0439
1000	0,1	GBELL	3	4	0,7998	0,8943	0,7227	0,7749
1000	0,1	GBELL	4	3	7,8716	2,8056	2,6157	2,8139
1000	0,1	GBELL	4	4	1,1358	1,0657	0,9632	1,0353

1000	0,1	GBELL	4	5	8,4672	2,9098	2,7716	2,9789
1000	0,1	GBELL	5	4	10,8810	3,2986	3,1174	3,3485
1000	0,1	GBELL	5	5	3,2713	1,8087	1,6742	1,7982
1000	0,1	GBELL	5	6	1,5643	1,2507	0,9803	1,0528
1000	0,1	GBELL	6	5	2,3829	1,5437	1,4113	1,5153
1000	0,1	GBELL	6	6	38,1510	6,1899	5,6201	6,0268

In the table 4.7.8, the epochs and the step size remain constant as the 4.7.7 table but is changing the type of membership function from triangular to a Generalized bell. The number of MF's for each input variable varies from 2 to 6, and the lower arithmetic errors are given by the pair (3,4), that means the first input has 3 MF's and the second input has 4 MF's.

Table 4.7.9. Arithmetic errors for, epochs=1000, ss=0,1, Mf's type: Gaussian

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	0,1	GAUSS	2	2	5,6635	2,3798	2,2912	2,4645
1000	0,1	GAUSS	2	3	4,8566	2,2038	2,1137	2,274
1000	0,1	GAUSS	3	2	7,361	2,7131	2,5514	2,7433
1000	0,1	GAUSS	3	3	7,2326	2,7062	2,5366	2,7274
1000	0,1	GAUSS	3	4	1,3694	1,1702	1,0491	1,1293
1000	0,1	GAUSS	4	3	7,1366	2,6714	2,5288	2,7182
1000	0,1	GAUSS	4	4	9,1718	3,0285	2,8296	3,0399
1000	0,1	GAUSS	4	5	6,5648	2,5624	2,4262	2,6612
1000	0,1	GAUSS	5	4	6,9147	2,6296	2,4767	2,6609
1000	0,1	GAUSS	5	5	8,0281	2,8334	2,6596	2,8576
1000	0,1	GAUSS	5	6	3,3092	1,8192	1,7087	1,8373
1000	0,1	GAUSS	6	5	3,3922	1,8418	1,6848	1,8106
1000	0,1	GAUSS	6	6	39,3889	6,2761	5,3324	5,7362

In the table 4.7.9, epochs, the step size remain constant as the 4.7.7 table, but change the type of membership function from a generalized bell to a Gaussian. The number of MF's for each input variable varies from 2 to 6, and the lower arithmetic errors are observed by the pair (3,4), that means the first input has 3 MF's and the second input has 4 MF's.

Table 4.7.10. Arithmetic errors for, epochs=1000, ss=0,1, Mf's type: Gaussian-2

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	0,1	GAUSS2	2	2	5,8361	2,4158	2,3052	2,4792
1000	0,1	GAUSS2	2	3	4,3921	2,0957	2,0417	2,1671
1000	0,1	GAUSS2	3	2	6,5868	2,5674	2,4363	2,6197
1000	0,1	GAUSS2	3	3	7,0626	2,6576	2,4736	2,6597
1000	0,1	GAUSS2	3	4	1,6876	1,2991	1,1669	1,2551
1000	0,1	GAUSS2	4	3	7,1455	2,6731	2,5665	2,7592
1000	0,1	GAUSS2	4	4	1,1875	1,0897	0,9271	0,9955
1000	0,1	GAUSS2	4	5	3,5764	1,8911	1,8088	1,945
1000	0,1	GAUSS2	5	4	3,8613	1,965	1,6573	1,779
1000	0,1	GAUSS2	5	5	1021300	1021,3	954,7875	1024,5
1000	0,1	GAUSS2	5	6	25,8938	5,0886	4,4165	4,7455
1000	0,1	GAUSS2	6	5	5,4762	2,3401	2,1844	2,3472
1000	0,1	GAUSS2	6	6	271.220,00	520,79	451,24	484,43

In the table 4.7.10, epochs, the step size remain constant, but change the type of membership function from a generalized bell to a Gaussian-2 membership function. The number of MF's for each input variable varies from 2 to 6. As concern from the evaluation results for the combination (5,5) and (6,6), the arithmetic errors are extremely high, but the lower arithmetic errors are given by the combination (4,4), that means the first input has 4 MF's and the second input has 4 MF's.

Table 4.7.11. Arithmetic errors for, epochs=1000, ss=0,1, Mf's type: Trapezoid

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	0,1	TRAP	2	2	4,409	2,0978	2,0015	2,1532
1000	0,1	TRAP	2	3	4,3638	2,089	1,9982	2,1499
1000	0,1	TRAP	3	2	6,5733	2,5639	2,4346	2,6179
1000	0,1	TRAP	3	3	7,5156	2,7415	2,5827	2,771

1000	0,1	TRAP	3	4	4,3563	2,0872	1,9813	2,1304
1000	0,1	TRAP	4	3	6,2168	2,4933	2,3813	2,5611
1000	0,1	TRAP	4	4	4,7241	2,1735	2,0765	2,2325
1000	0,1	TRAP	4	5	2,4481	1,5647	1,4581	1,5687
1000	0,1	TRAP	5	4	0,9043	0,951	0,8405	0,9044
1000	0,1	TRAP	5	5	3,5778	1,8915	1,7676	1,8995
1000	0,1	TRAP	5	6	1,1703	1,0818	0,8101	0,8674
1000	0,1	TRAP	6	5	0,8117	0,901	0,7896	0,8489
1000	0,1	TRAP	6	6	49,8838	7,0628	6,2474	6,7072

In the table 4.7.11, epochs, the step size and the type of membership function (trapezoid) remain constant but the number of MF's for each input variable varies from 2 to 6. The algorithm for the pair value (5,4) extract low arithmetic errors.

Table 4.7.12. Arithmetic errors for, epochs=1000, ss=0,1, Mf's type: π-shaped (PI)

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	0,1	PI	2	2	6,9675	2,6396	2,4697	2,6552
1000	0,1	PI	2	3	4,5989	2,1445	2,0452	2,1999
1000	0,1	PI	3	2	7,3616	2,7132	2,577	2,7707
1000	0,1	PI	3	3	5,4456	2,3336	2,2019	2,3682
1000	0,1	PI	3	4	3,532	1,8794	1,7035	1,8295
1000	0,1	PI	4	3	6,3532	2,5206	2,397	2,5778
1000	0,1	PI	4	4	11,4539	3,3844	3,2538	3,4896
1000	0,1	PI	4	5	2,1219	1,4567	1,3615	1,4647
1000	0,1	PI	5	4	12,1476	3,4853	3,2574	3,5
1000	0,1	PI	5	5	1,2934	1,1373	0,9927	1,0649
1000	0,1	PI	5	6	2,6383	1,6253	1,379	1,4794
1000	0,1	PI	6	5	0,8272	0,9095	0,8048	0,8631
1000	0,1	PI	6	6	46,5636	6,8238	6,1002	6,5514

In the table 4.7.12, the membership function is (π-shaped) remain constant with the number of MF's for each input variable varies from 2 to 6. The table 4.7.12 is the last, that epochs remain constant and equal to 1000, and step size constant and equal to 0,1 and the lower arithmetic errors are observed by the combination (5,5). The research continues with the following group of tables, where remain constant the number of epochs at 1000 and change the step size (ss) to 0,001.

Table 4.7.13. Arithmetic errors for, epochs=1000, ss=0,001, Mf's type: Triangular

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	0,001	TRIMF	2	2	2,3466	1,5319	1,4201	1,5285
1000	0,001	TRIMF	2	3	5,1504	2,2694	2,1694	2,3343
1000	0,001	TRIMF	3	2	4,976	2,2307	2,1177	2,2777
1000	0,001	TRIMF	3	3	3,7993	1,9942	1,7876	1,9232
1000	0,001	TRIMF	3	4	5,1175	2,2622	2,1401	2,3013
1000	0,001	TRIMF	4	3	4,2478	2,061	1,9738	2,1222
1000	0,001	TRIMF	4	4	1,0275	1,0137	0,8976	0,9654
1000	0,001	TRIMF	4	5	3,093	1,7587	1,4162	1,5167
1000	0,001	TRIMF	5	4	8,9763	2,9961	2,8511	3,0642
1000	0,001	TRIMF	5	5	22,0721	4,6981	4,3704	4,6942
1000	0,001	TRIMF	5	6	1,6479	1,2837	1,2158	1,3083
1000	0,001	TRIMF	6	5	56,7618	7,5340	6,6975	7,1895
1000	0,001	TRIMF	6	6	6,7413	2,5964	2,4165	2,5969

In the table 4.7.13, epochs, the step size (ss=0,1) and the type of membership function (triangular) remain constant but the number of MF's for each input variable changes from the value 2 to 6. Comparing the table 4.7.13 with table 4.7.7 (ss=0,1), it is observed that there are no significant differences mainly for the low values of input nodes and the lower arithmetic errors are given by the pair (4,4), that means the first input has 4 MF's and the second input has 4 MF's.

Table 4.7.14. Arithmetic errors for, epochs=1000, ss=0,001, Mf's type: Gaussian-Bell

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	0,001	GBELL	2	2	5,5907	2,3645	2,2760	2,4436
1000	0,001	GBELL	2	3	4,6976	2,1674	2,0745	2,2318
1000	0,001	GBELL	3	2	6,8873	2,6244	2,4709	2,6567
1000	0,001	GBELL	3	3	6,0594	2,4616	2,3233	2,4984
1000	0,001	GBELL	3	4	1,8534	1,3614	1,2464	1,3410
1000	0,001	GBELL	4	3	4,7131	2,1710	2,0458	2,2002
1000	0,001	GBELL	4	4	0,8444	0,9189	0,7850	0,8421

1000	0,001	GBELL	4	5	7,1149	2,6674	2,5451	2,7357
1000	0,001	GBELL	5	4	9,6645	3,1088	2,9489	3,1675
1000	0,001	GBELL	5	5	1,3030	1,1415	0,9463	1,0149
1000	0,001	GBELL	5	6	0,7307	0,8548	0,7529	0,8089
1000	0,001	GBELL	6	5	10,6660	3,2659	3,0066	3,2294
1000	0,001	GBELL	6	6	102,5603	10,1272	7,8565	8,4161

In the table 4.7.14, the epochs and the step size remain constant as the 4.7.13 table but is changing the type of membership function from triangular to a Generalized bell. The number of MF's for each input variable varies from 2 to 6. Low arithmetic errors are shown at the combination with 4 MF's for input1 and 4 MF's for input2, and for the combination with 5 MF's for input1 and 6 MF's for input2.

Table 4.7.15. Arithmetic errors for, epochs=1000, ss=0,001, Mf's type: Gaussian

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	0,001	GAUSS	2	2	5,6533	2,3777	2,2888	2,4619
1000	0,001	GAUSS	2	3	4,6219	2,1499	2,0566	2,2121
1000	0,001	GAUSS	3	2	6,8303	2,6135	2,4766	2,663
1000	0,001	GAUSS	3	3	5,1061	2,2597	2,161	2,3224
1000	0,001	GAUSS	3	4	9,3483	3,0575	2,8211	3,0327
1000	0,001	GAUSS	4	3	5,2355	2,2881	2,2012	2,3663
1000	0,001	GAUSS	4	4	1,0365	1,0181	0,897	0,9622
1000	0,001	GAUSS	4	5	7,4552	2,7304	2,6004	2,7943
1000	0,001	GAUSS	5	4	18,5629	4,3085	4,021	4,3178
1000	0,001	GAUSS	5	5	8,6416	2,9397	2,7913	2,9993
1000	0,001	GAUSS	5	6	6,3415	2,5182	2,3679	2,5451
1000	0,001	GAUSS	6	5	0,8019	0,8955	0,7625	0,8181
1000	0,001	GAUSS	6	6	162,6005	12,7515	11,9736	12,8597

In the table 4.7.15, epochs, the step size remain constant as the 4.7.14 table, but change the type of membership function from a generalized bell to a Gaussian. The number of MF's for each input variable varies from 2 to 6. Low arithmetic errors are shown only at the combination with 6 MF's for input1 and 4 MF's for input2.

Table 4.7.16. Arithmetic errors for, epochs=1000, ss=0,001, Mf's type: Gaussian-2

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	0,001	GAUSS2	2	2	5,3327	2,3095	2,2071	2,3734
1000	0,001	GAUSS2	2	3	4,3262	2,08	1,982	2,1323
1000	0,001	GAUSS2	3	2	8,3116	2,883	2,716	2,9202
1000	0,001	GAUSS2	3	3	5,8577	2,4203	2,2564	2,4264
1000	0,001	GAUSS2	3	4	1,6736	1,2937	1,1645	1,2528
1000	0,001	GAUSS2	4	3	7,8111	2,7948	2,6768	2,8779
1000	0,001	GAUSS2	4	4	5,0638	2,2503	2,1821	2,3452
1000	0,001	GAUSS2	4	5	6,0243	2,4545	2,3994	2,5797
1000	0,001	GAUSS2	5	4	13,6893	3,7011	3,2827	3,5244
1000	0,001	GAUSS2	5	5	251,4434	15,857	14,679	15,7512
1000	0,001	GAUSS2	5	6	21050	458,8463	432,3157	464,2863
1000	0,001	GAUSS2	6	5	2,9804	1,7264	1,5562	1,6711
1000	0,001	GAUSS2	6	6	32.180,00	567,27	511,37	548,81

In the table 4.7.16, epochs, the step size remain constant, but change the type of membership function from a generalized bell to a Gaussian-2 membership function. The number of MF's for each input variable varies from 2 to 6. As concern from the results for the combination (5,5) and (6,6), the arithmetic errors are extremely high, while the lower arithmetic errors are given by the combination (3,4).

Table 4.7.17. Arithmetic errors for, epochs=1000, ss=0,001, Mf's type: Trapezoidal

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF NODES FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	0,001	TRAP	2	2	4,3952	2,0965	2,009	2,1527
1000	0,001	TRAP	2	3	4,3596	2,088	1,997	2,1486
1000	0,001	TRAP	3	2	7,2695	2,6962	2,545	2,7363
1000	0,001	TRAP	3	3	6,339	2,5177	2,3778	2,5571
1000	0,001	TRAP	3	4	4,023	2,0058	1,9026	2,0461
1000	0,001	TRAP	4	3	5,8495	2,4186	2,3002	2,4738

1000	0,001	TRAP	4	4	9,8211	3,1339	2,954	3,1752
1000	0,001	TRAP	4	5	2,5526	1,5977	1,5026	1,6165
1000	0,001	TRAP	5	4	3,2179	1,7939	1,6791	1,8046
1000	0,001	TRAP	5	5	3,335	1,8262	1,7236	1,8529
1000	0,001	TRAP	5	6	16,9375	4,1155	3,7962	4,0773
1000	0,001	TRAP	6	5	0,7315	0,8553	0,7122	0,7654
1000	0,001	TRAP	6	6	6,8723	2,6215	2,3395	2,5136

In the table 4.7.17, epochs, the step size and the type of membership function (trapezoidal) remain constant but the number of MF's for each input variable varies from 2 to 6. The algorithm for the combination with 6 MF's for input1 and 5 MF's for input2 extract the lower arithmetic errors.

Table 4.7.18. Arithmetic errors for, epochs=1000, ss=0,001, Mf's type: π-shaped (PI)

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1000	0,001	PI	2	2	5,4168	2,3274	2,2006	2,3659
1000	0,001	PI	2	3	4,3837	2,0937	1,9945	2,1455
1000	0,001	PI	3	2	8,1493	2,8547	2,7014	2,9043
1000	0,001	PI	3	3	5,5257	2,3507	2,2362	2,4052
1000	0,001	PI	3	4	2,8392	1,685	1,5861	1,7054
1000	0,001	PI	4	3	5,313	2,305	2,194	2,3598
1000	0,001	PI	4	4	10,4613	3,2344	3,1013	3,3337
1000	0,001	PI	4	5	2,1572	1,4688	1,3753	1,4796
1000	0,001	PI	5	4	32,3566	5,6883	5,2869	5,6769
1000	0,001	PI	5	5	3,8996	1,9747	1,8624	2,0023
1000	0,001	PI	5	6	7,5783	2,7529	2,4543	2,6337
1000	0,001	PI	6	5	1,0181	1,009	0,9081	0,9767
1000	0,001	PI	6	6	92,8528	9,636	8,4945	9,1219

In the table 4.7.18, the membership function is (π-shaped) remain constant with the number of MF's for each input variable varies from 2 to 6. The table 4.7.18 is the last one, that epochs remain constant and equal to 1000, step size constant and equal to 0,001, in which table the lower arithmetic errors are given by the combination (6,5). The research continues with the following group of tables, where change the numbers of epoch and the number of step size.

In the next groups of tables, the number of iterations (epochs) increases to 1500, so that from the arithmetic errors that will occur, it will be seen whether the number of iterations (epochs) affects the model. With the new number of iterations (epochs) at 1500, it is tested with all types of participation functions and with step size (ss) at 1, 0.1 and 0.001.

Table 4.7.19. Arithmetic errors for, epochs=1500, ss=1, Mf's type: Triangular

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	1	TRIMF	2	2	4,2512	2,0618	1,9817	2,132
1500	1	TRIMF	2	3	5,042	2,2454	2,1437	2,3067
1500	1	TRIMF	3	2	5,1145	2,2615	1,8939	2,0403
1500	1	TRIMF	3	3	4,6978	2,1674	2,0701	2,2273
1500	1	TRIMF	3	4	11,7945	3,4343	3,2359	3,4806
1500	1	TRIMF	4	3	2,0413	1,4287	1,2766	1,3733
1500	1	TRIMF	4	4	1,0352	1,0174	0.8964	0.9641
1500	1	TRIMF	4	5	5,6992	2,3873	2,1681	2,3284
1500	1	TRIMF	5	4	-	-	-	-
1500	1	TRIMF	5	5	0.5555	0.7453	0.6559	0.7046
1500	1	TRIMF	5	6	168.395	41.036	38.760	41.633
1500	1	TRIMF	6	5	15.190	12.325	10.363	11.134
1500	1	TRIMF	6	6	36.655	19.146	17.058	18.350

In the table 4.7.19, epochs, the step size and the type of membership function (triangular) remain constant but the number of MF's for each input variable varies from 2 to 6. The algorithm for the pair (5,4) for each input node, doesn't extract any result. The algorithm for the combination with 5 MF's for input1 and 5 MF's for input2, extract the lowest arithmetic errors.

Table 4.7.20. Arithmetic errors for, epochs=1500, ss=1, Mf's type: Generalized-Bell

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	1	GBELL	2	2	5,0729	2,2523	2,1422	2,3038
1500	1	GBELL	2	3	5,2581	2,2931	2,1979	2,3637
1500	1	GBELL	3	2	4,993	2,2345	2,1355	2,2968
1500	1	GBELL	3	3	5,0942	2,257	2,1379	2,2994
1500	1	GBELL	3	4	1,276	1,1296	0.9987	1,0726

1500	1	GBELL	4	3	6,7035	2,5891	2,3992	2,5815
1500	1	GBELL	4	4	1,1403	1,0679	0.8902	0.9551
1500	1	GBELL	4	5	0.9994	0.9997	0.8257	0.8865
1500	1	GBELL	5	4	6,5077	2,551	2,3823	2,5607
1500	1	GBELL	5	5	1,6816	1,2968	1,1374	1,2224
1500	1	GBELL	5	6	7,3973	2,7198	2,5422	2,7307
1500	1	GBELL	6	5	7,1781	2,6792	2,3449	2,5178
1500	1	GBELL	6	6	10,7137	3,2732	2,8294	3,0349

In the table 4.7.20, the epochs and the step size remain constant as the 4.7.19 table but is changing the type of membership function from triangular to a Generalized bell. The number of MF's for each input variable varies from 2 to 6. Low arithmetic errors are shown only at the combination with 4 MF's for input1 and 5 MF's for input2.

Table 4.7.21. Arithmetic errors for, epochs=1500, ss=1, Mf's type: Gaussian

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	1	GAUSS	2	2	5,6533	2,3777	2,2888	2,4619
1500	1	GAUSS	2	3	4,6184	2,149	2,0559	2,2113
1500	1	GAUSS	3	2	6,8272	2,6129	2,476	2,6624
1500	1	GAUSS	3	3	5,1061	2,2597	2,161	2,3224
1500	1	GAUSS	3	4	8,8732	2,9788	2,7522	2,9587
1500	1	GAUSS	4	3	5,2355	2,2881	2,2012	2,3663
1500	1	GAUSS	4	4	2,4002	1,5492	1,4501	1,5589
1500	1	GAUSS	4	5	14,7767	3,8441	3,6042	3,871
1500	1	GAUSS	5	4	8,9431	2,9905	2,7959	3,0037
1500	1	GAUSS	5	5	4,9383	2,2222	2,0825	2,2376
1500	1	GAUSS	5	6	1,5298	1,2368	1,0878	1,1696
1500	1	GAUSS	6	5	79.305	282	181	195
1500	1	GAUSS	6	6	4,2453	2,0604	1,934	2,0777

In the table 4.7.21, epochs, the step size remain constant as the 4.7.20 table, but change the type of membership function from a generalized bell to a Gaussian. The number of MF's for each input variable varies from 2 to 6. The lower arithmetic errors are given by the number combination (5,6) of MF's for input1 and input2, respectively.

Table 4.7.22. Arithmetic errors for, epochs=1500, ss=1, Mf's type: Gaussian-2

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	1	GAUSS2	2	2	6,0037	2,4502	2,3329	2,5085
1500	1	GAUSS2	2	3	4,3857	2,0942	2,0133	2,1657
1500	1	GAUSS2	3	2	6,3713	2,5241	2,3976	2,5783
1500	1	GAUSS2	3	3	6,3327	2,5165	2,3836	2,5635
1500	1	GAUSS2	3	4	3,1722	1,7811	1,6656	1,7911
1500	1	GAUSS2	4	3	3,5167	1,8753	1,7456	1,878
1500	1	GAUSS2	4	4	3,4586	1,8597	1,7129	1,8415
1500	1	GAUSS2	4	5	0.5817	0.7627	0.6572	0.7049
1500	1	GAUSS2	5	4	5,6976	2,387	2,2185	2,3854
1500	1	GAUSS2	5	5	3,1777	1,7826	1,6554	1,7801
1500	1	GAUSS2	5	6	9,1673	3,0278	2,731	2,9337
1500	1	GAUSS2	6	5	1,4152	1,1896	1,0094	1,0837
1500	1	GAUSS2	6	6	1046700,0	10000,0	8.000,00	8.000,00

In the table 4.7.22, epochs, the step size and the type of membership function (Gaussian-2) remain constant but the number of nodes for each input variable varies from 2 to 6. The algorithm for the combination with 4 MF's for input1 and 5 MF's for input2, extract the lowest arithmetic errors.

Table 4.7.23. Arithmetic errors for, epochs=1500, ss=1, Mf's type: Trapezoidal

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	1	TRAP	2	2	4,4532	2,1103	2,0111	2,1634
1500	1	TRAP	2	3	4,9163	2,2173	2,1136	2,2734
1500	1	TRAP	3	2	6,5971	2,5685	2,4436	2,6275
1500	1	TRAP	3	3	7,1787	2,6793	2,5215	2,7113
1500	1	TRAP	3	4	6,6425	2,5773	2,4533	2,6365
1500	1	TRAP	4	3	5,8346	2,4155	2,3051	2,4791
1500	1	TRAP	4	4	6,2499	2,5	2,375	2,5538
1500	1	TRAP	4	5	-	-	-	-
1500	1	TRAP	5	4	-	-	-	-
1500	1	TRAP	5	5	-	-	-	-
1500	1	TRAP	5	6	-	-	-	-
1500	1	TRAP	6	5	-	-	-	-
1500	1	TRAP	6	6	7,0587	2,6568	2,496	2,6814

In the table 4.7.23, epochs, the step size and the type of membership function (trapezoidal) remain constant but the number of MF's for each input variable varies from 2 to 6. The algorithm for the combinations of pairs (4,5) to (6,5) for each input node number's, doesn't extract any result, while the lower arithmetic errors are given by the pair (2,2).

Table 4.7.24. Arithmetic errors for, epochs=1500, ss=1, Mf's type: π-shaped (PI)

Epochs	ss	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	1	PI	2	2	7,2435	2,6914	2,5177	2,7069
1500	1	PI	2	3	4,5988	2,1445	2,0452	2,1999
1500	1	PI	3	2	6,8842	2,6238	2,5092	2,6981
1500	1	PI	3	3	5,653	2,3776	2,241	2,4102
1500	1	PI	3	4	3,8937	1,9733	1,8111	1,945
1500	1	PI	4	3	5,3056	2,3034	2,218	2,3854
1500	1	PI	4	4	2,7019	1,6437	1,451	1,5577
1500	1	PI	4	5	2,3144	1,5213	1,4326	1,5407
1500	1	PI	5	4	5,3946	2,3226	2,1253	2,2831
1500	1	PI	5	5	1,7877	1,337	1,1543	1,2434
1500	1	PI	5	6	3,5785	1,8917	1,77	1,8957
1500	1	PI	6	5	3,5785	1,8917	1,77	1,8957
1500	1	PI	6	6	20,562	4,5345	3,812	4,0938

In the table 4.7.24, the membership function is (π-shaped) remain constant with the number of MF's for each input variable varies from 2 to 6 and the lower arithmetic errors are observed by the pair (5,5). The table 4.7.24 is the last one, that epochs remain constant and equal to 1500, and step size constant and equal to 1. The research continues, keeping the epochs constant at 1500 and changing the step size slightly to 0,1. The next group of tables lists all the arithmetic errors results that have been obtained.

Table 4.7.25. Arithmetic errors for, epochs=1500, ss=0.1, Mf's type: Triangular

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	0.1	TRIMF	2	2	2,3467	1,5319	1,4200	1,5284
1500	0.1	TRIMF	2	3	5,2562	2,2926	2,1916	2,3582
1500	0.1	TRIMF	3	2	11,8568	3,4434	3,1344	3,3718
1500	0.1	TRIMF	3	3	15,6792	3,9597	3,5931	3,8663
1500	0.1	TRIMF	3	4	1,5717	1,2537	1,1125	1,1962
1500	0.1	TRIMF	4	3	2,9806	1,7265	1,5960	1,7173
1500	0.1	TRIMF	4	4	1,0964	1,0471	0.9283	0.9985
1500	0.1	TRIMF	4	5	14,4310	3,7988	3,1278	3,3542
1500	0.1	TRIMF	5	4	17,2445	4,1526	3,9465	4,2392
1500	0.1	TRIMF	5	5	12,6705	3,5596	3,3180	3,5637
1500	0.1	TRIMF	5	6	1,4324	1,1968	1,1065	1,1910
1500	0.1	TRIMF	6	5	24,2532	4,9248	4,4679	4,7979
1500	0.1	TRIMF	6	6	11,7393	3,4263	3,1716	3,4067

In the table 4.7.25, epochs, the step size and the type of membership function (triangular) remain constant but the number of MF's for each input variable varies from 2 to 6. If compare this table with table 4.7.7 in which the number of epochs (1500) is the only difference in the model configuration , it is observed that the arithmetic errors are quite similar for every combination of the two input numbers of MF's. Also the lower arithmetic errors are observed by the combination (4,4) the same combination of number of Mf's inputs, as in the table 4.7.7.

Table 4.7.26. Arithmetic errors for, epochs=1500, ss=0.1, Mf's type: Generalized-Bell

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	0.1	GBELL	2	2	9,0323	3,0054	2,8380	3,0513
1500	0.1	GBELL	2	3	5,5437	2,3545	2,2169	2,3841
1500	0.1	GBELL	3	2	6,9025	2,6273	2,5054	2,6942
1500	0.1	GBELL	3	3	3,9820	1,9955	1,8999	2,0439
1500	0.1	GBELL	3	4	0.7993	0.8940	0.7224	0.7745
1500	0.1	GBELL	4	3	7,8716	2,8056	2,6157	2,8139

1500	0.1	GBELL	4	4	11358,0000	10657,0000	0.9632	10353,0000
1500	0.1	GBELL	4	5	8,4672	2,9098	2,7716	2,9789
1500	0.1	GBELL	5	4	10,8810	3,2986	3,1174	3,3485
1500	0.1	GBELL	5	5	3,2713	1,8087	1,6742	1,7982
1500	0.1	GBELL	5	6	1,5643	1,2507	0.9803	1,0528
1500	0.1	GBELL	6	5	0.8542	0.9242	0.7883	0.8463
1500	0.1	GBELL	6	6	38,3151	6,1899	5,6201	6,0268

In the table 4.7.26, the epochs and the step size remain constant as the 4.7.125 table but is changing the type of membership function from triangular to a Generalized bell. The number of MF's for each input variable varies from 2 to 6. Lower arithmetic errors are shown by the combination with 3 MF's for input1 and 4 MF's for input2, such as the combination (6,5) with low errors is also remarkable.

Table 4.7.27. Arithmetic errors for, epochs=1500, ss=0.1, Mf's type: Gaussian

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	0.1	GAUSS	2	2	5,6635	2,3798	2,2912	2,4645
1500	0.1	GAUSS	2	3	4,8566	2,2038	2,1137	2,2740
1500	0.1	GAUSS	3	2	7,3610	2,7131	2,5514	2,7433
1500	0.1	GAUSS	3	3	7,3214	2,7058	2,5362	2,7270
1500	0.1	GAUSS	3	4	1,3620	1,1671	1,0456	1,1256
1500	0.1	GAUSS	4	3	7,1366	2,6714	2,5288	2,7182
1500	0.1	GAUSS	4	4	9,1706	3,0283	2,8294	3,0397
1500	0.1	GAUSS	4	5	6,5645	2,5621	2,4261	2,6068
1500	0.1	GAUSS	5	4	6,9147	2,6296	2,4767	2,6609
1500	0.1	GAUSS	5	5	8,0281	2,8334	2,6596	2,8575
1500	0.1	GAUSS	5	6	3,3093	1,8192	1,7087	1,8373
1500	0.1	GAUSS	6	5	3,3922	1,8418	1,6847	1,8105
1500	0.1	GAUSS	6	6	39,3889	6,2761	5,3324	5,7362

In the table 4.7.27, epochs, the step size remain constant as the 4.7.26 table, but change the type of membership function from a generalized bell to a Gaussian. The number of MF's for each input variable varies from 2 to 6 and the lower arithmetic errors are given by the combination (3,4), that means the first input has 3 MF's and the second input has 4 MF's.

Table 4.7.28. Arithmetic errors for, epochs=1500, ss=0.1, Mf's type: Gaussian-2

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	0.1	GAUSS2	2	2	5,8363	2,4158	2,3052	2,4792
1500	0.1	GAUSS2	2	3	4,3900	2,0952	2,0141	2,1666
1500	0.1	GAUSS2	3	2	6,5840	2,5659	2,4352	2,6186
1500	0.1	GAUSS2	3	3	7,0626	2,6576	2,4736	2,6597
1500	0.1	GAUSS2	3	4	1,6876	1,2991	1,1669	1,2551
1500	0.1	GAUSS2	4	3	7,1455	2,6731	2,5665	2,7592
1500	0.1	GAUSS2	4	4	1,1885	1,0902	0.9275	0.9960
1500	0.1	GAUSS2	4	5	3,5764	1,8911	1,8088	1,9450
1500	0.1	GAUSS2	5	4	3,8613	1,9650	1,6573	1,7790
1500	0.1	GAUSS2	5	5	1043100,0000	1021,3000	954,7875	1024,5000
1500	0.1	GAUSS2	5	6	25,8938	5,0886	4,4165	4,7455
1500	0.1	GAUSS2	6	5	5,4762	2,3401	2,1844	2,3472
1500	0.1	GAUSS2	6	6	118540,0000	344,2987	296,1310	317,9441

In the table 4.7.28, epochs, the step size and the type of membership function (Gaussian-2) remain constant but the number of MF's for each input variable varies from 2 to 6. The algorithm for the combination with 5 MF's for input1 and 5 MF's for input2, and the model configuration with 6 MF's for each input, has extremely high arithmetic errors, in contrast to the combination (4,4) where the arithmetic errors are the lower.

Table 4.7.29. Arithmetic errors for, epochs=1500, ss=0.1, Mf's type: Trapezoid

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	0.1	TRAP	2	2	4,4009	2,0978	2,0015	2,1532
1500	0.1	TRAP	2	3	4,3638	2,0890	1,9982	2,1499
1500	0.1	TRAP	3	2	6,5733	2,5639	2,4346	2,6179
1500	0.1	TRAP	3	3	7,5156	2,7415	2,5827	2,7771
1500	0.1	TRAP	3	4	4,3563	2,0872	1,9813	2,1304
1500	0.1	TRAP	4	3	6,2168	2,4933	2,3813	2,5611
1500	0.1	TRAP	4	4	4,7463	2,1786	2,0812	2,2376
1500	0.1	TRAP	4	5	2,4481	1,5647	1,4581	1,5687
1500	0.1	TRAP	5	4	0.2681	0.5178	0.3505	0.3771
1500	0.1	TRAP	5	5	3,5778	1,8915	1,7676	1,8995

1500	0.1	TRAP	5	6	1,2076	1,0989	0.8276	0.8862
1500	0.1	TRAP	6	5	0.8117	0.9010	0.7896	0.8489
1500	0.1	TRAP	6	6	49,8838	7,0628	6,2474	6,7072

In the table 4.7.29, epochs (1500), the step size (0,1) and the type of membership function (trapezoidal) remain constant but the number of MF's for each input variable varies from 2 to 6. It is noticed, quite low arithmetic errors for the model configuration with 5 MF's first input and 4 MF's for second input, that will be analyzed in the next paragraph.

Table 4.7.30. Arithmetic errors for, epochs=1500, ss=0.1, Mf's type: π-shaped (PI)

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	0.1	PI	2	2	7,2233	2,6876	2,5139	2,7029
1500	0.1	PI	2	3	4,5989	2,1445	2,0452	2,1999
1500	0.1	PI	3	2	7,3616	2,7132	2,5770	2,7707
1500	0.1	PI	3	3	5,4448	2,3334	2,2018	2,3681
1500	0.1	PI	3	4	3,5320	1,8794	1,7035	1,8295
1500	0.1	PI	4	3	6,3532	2,5206	2,3970	2,5778
1500	0.1	PI	4	4	11,4539	3,3844	3,2538	3,4986
1500	0.1	PI	4	5	2,1219	1,4567	1,3615	1,4647
1500	0.1	PI	5	4	12,1476	3,4853	3,2574	3,5000
1500	0.1	PI	5	5	1,5133	1,2302	1,1111	1,1933
1500	0.1	PI	5	6	2,4728	1,5725	1,2903	1,3830
1500	0.1	PI	6	5	0.8272	0.9095	0.8048	0.8631
1500	0.1	PI	6	6	46,5636	6,8238	6,1002	6,5514

In the table 4.7.30, the membership function is (π-shaped) remain constant with the number of MF's for each input variable varies from 2 to 6. The lower arithmetic errors are given by the combination (6,5). The table 4.7.30 is the last one, that epochs remain constant and equal to 1500, and step size constant and equal to 0,1. The research continues, with the next group of tables where the number of epochs remains constant at 1500 and the step size (ss) decreases even more at the value ss=0.001, substantially increasing the sensitivity of the model in its operation.

Table 4.7.31. Arithmetic errors for, epochs=1500, ss=0.001, Mf's type: Trianglular

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	0,001	TRIMF	2	2	2,3525	1,5338	1,4221	1,5306
1500	0,001	TRIMF	2	3	5,2113	2,2828	2,1861	2,3521
1500	0,001	TRIMF	3	2	4,1712	2,0423	1,9462	2,0933
1500	0,001	TRIMF	3	3	3,8215	1,9549	1,7949	1,9310
1500	0,001	TRIMF	3	4	4,9416	2,2230	2,1029	2,2614
1500	0,001	TRIMF	4	3	4,9285	2,2200	2,1549	2,3167
1500	0,001	TRIMF	4	4	1,0543	1,0268	0.9139	0.9828
1500	0,001	TRIMF	4	5	1,2955	1,1382	1,0002	1,0754
1500	0,001	TRIMF	5	4	9,8958	3,1458	2,9651	3,1867
1500	0,001	TRIMF	5	5	25,1796	5,0179	4,5820	4,9216
1500	0,001	TRIMF	5	6	4,9422	2,2231	2,0533	2,2077
1500	0,001	TRIMF	6	5	36,1041	6,0087	5,3807	5,7766
1500	0,001	TRIMF	6	6	13,8308	3,7190	3,4266	3,6802

In the table 4.7.31, epochs, the step size and the type of membership function (triangular) remain constant but the number of MF's for each input variable varies from 2 to 6. If compare this table with table 4.7.25 in which the step size equal to 0,1 is the only difference in the model configuration , it is observed that the arithmetic errors are quite similar for every combination of the two input numbers of MF's. Also, the lower arithmetic errors are given by the same combination (4,4) of these two tables 4.7.31 and 4.7.25.

Table 4.7.32. Arithmetic errors for, epochs=1500, ss=0.001, Mf's type: Generalized-Bell

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	0,001	GBELL	2	2	5,5772	2,3616	2,2696	2,4410
1500	0,001	GBELL	2	3	4,7032	2,1687	2,0758	2,2332
1500	0,001	GBELL	3	2	6,9149	2,6296	2,4755	2,6616

1500	0,001	GBELL	3	3	6,0560	2,4609	2,3222	2,4972
1500	0,001	GBELL	3	4	1,8571	1,3627	1,2477	1,3424
1500	0,001	GBELL	4	3	4,7305	2,1750	2,0496	2,2044
1500	0,001	GBELL	4	4	0.8505	0.9222	0.7887	0.8461
1500	0,001	GBELL	4	5	7,2039	2,6840	2,5618	2,7537
1500	0,001	GBELL	5	4	9,6383	3,1046	2,9449	3,1632
1500	0,001	GBELL	5	5	1,4669	1,2112	1,0069	1,0802
1500	0,001	GBELL	5	6	0.6892	0.8302	0.7295	0.7837
1500	0,001	GBELL	6	5	345,2470	18,5808	13,1084	14,0308
1500	0,001	GBELL	6	6	102,5603	10,1272	7,8565	8,4161

In the table 4.7.32, the epochs and the step size remain constant as the 4.7.31 table but is changing the type of membership function from triangular to a Generalized bell. The number of MF's for each input variable varies from 2 to 6. The lower arithmetic errors for this group of results, are shown at the combination with 5 MF's for input1 and 6 MF's for input2.

Table 4.7.33. Arithmetic errors for, epochs=1500, ss=0.001, Mf's type: Gaussian

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	0,001	GAUSS	2	2	5,0648	2,2505	2,1671	2,3311
1500	0,001	GAUSS	2	3	4,8763	2,2082	2,1182	2,2788
1500	0,001	GAUSS	3	2	6,8831	2,6236	2,4609	2,6457
1500	0,001	GAUSS	3	3	7,8336	2,7989	2,6168	2,8135
1500	0,001	GAUSS	3	4	1,3107	1,1449	1,0244	1,1030
1500	0,001	GAUSS	4	3	4,3517	2,0861	1,9795	2,1287
1500	0,001	GAUSS	4	4	1,0258	1,0128	0.9018	0.9672
1500	0,001	GAUSS	4	5	5,4613	2,3370	2,2142	2,3798
1500	0,001	GAUSS	5	4	19,6165	4,4291	4,1294	4,4343
1500	0,001	GAUSS	5	5	8,7773	2,9626	2,8129	3,0224
1500	0,001	GAUSS	5	6	5,7627	2,4006	2,2595	2,4290
1500	0,001	GAUSS	6	5	0.7021	0.8379	0.6920	0.7425
1500	0,001	GAUSS	6	6	404,6682	20,1164	17,3480	18,6088

In the table 4.7.33, epochs, the step size remain constant as the 4.7.32 table, but change the type of membership function from a generalized bell to a Gaussian. The number of MF's for each input variable varies from 2 to 6. The lower arithmetic errors for this group of results, are shown at the combination with 6 MF's for input1 and 5 MF's for input2.

Table 4.7.34. Arithmetic errors for, epochs=1500, ss=0.001, Mf's type: Gaussian-2

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	0,001	GAUSS2	2	2	5,2754	2,2968	2,1983	2,3640
1500	0,001	GAUSS2	2	3	4,3073	2,0754	1,9775	2,1275
1500	0,001	GAUSS2	3	2	8,3112	2,8829	2,7164	2,9205
1500	0,001	GAUSS2	3	3	5,6491	2,3768	2,2177	2,3848
1500	0,001	GAUSS2	3	4	1,7467	1,3216	1,1935	1,2840
1500	0,001	GAUSS2	4	3	8,1268	2,8507	2,7286	2,9335
1500	0,001	GAUSS2	4	4	5,2128	2,2831	2,2136	2,3790
1500	0,001	GAUSS2	4	5	6,3796	2,5258	2,4695	2,6550
1500	0,001	GAUSS2	5	4	25,0313	5,0031	4,4987	4,8300
1500	0,001	GAUSS2	5	5	1.045,0000	32,3267	29,9218	32,1026
1500	0,001	GAUSS2	5	6	90,9797	9,5383	8,5301	9,1645
1500	0,001	GAUSS2	6	5	14291,0	11.955,0	10215,0	10.965,0
1500	0,001	GAUSS2	6	6	11269000,0	3.356,9	3042,6	3.265,0

In the table 4.7.34, epochs, the step size and the type of membership function (Gaussian-2) remain constant but the number of MF's for each input variable varies from 2 to 6. The algorithm for this model configuration has generally high errors. Especially, the combination with 5 MF's for input1 and 5 MF's for input2, and the combination with 6 MF's for each input, has extremely high arithmetic errors, in contrast with the combination 3 MF's for input1 and 4 MF's for input2 which has the lowest arithmetic errors of the table.

Table 4.7.35. Arithmetic errors for, epochs=1500, ss=0.001, Mf's type: Trapezoidal

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	0,001	TRAP	2	2	4,3952	2,0965	2,009	2,1527
1500	0,001	TRAP	2	3	4,3605	2,0882	1,9972	2,1488
1500	0,001	TRAP	3	2	7,2630	2,695	2,5437	2,7350
1500	0,001	TRAP	3	3	6,3378	2,5175	2,3775	2,5568
1500	0,001	TRAP	3	4	3,9779	1,9945	1,8917	2,0345
1500	0,001	TRAP	4	3	5,9016	2,4293	2,3106	2,4849
1500	0,001	TRAP	4	4	10,1987	3,1935	3,0067	3,2316
1500	0,001	TRAP	4	5	2,5643	1,6013	1,5065	1,6207
1500	0,001	TRAP	5	4	3,2179	1,7939	1,6791	1,8046
1500	0,001	TRAP	5	5	3,2640	1,8066	1,7062	1,8344
1500	0,001	TRAP	5	6	16,3830	4,0476	3,7337	4,0102
1500	0,001	TRAP	6	5	0.7315	0.8553	0.7122	0.7654
1500	0,001	TRAP	6	6	7,2748	2,6972	2,4124	2,5919

In the table 4.7.35, epochs (1500), the step size (0,001) and the type of membership function (trapezoidal) remain constant but the number of MF's for each input variable varies from 2 to 6. It is noticed quite low arithmetic errors, for the model configuration with 6 MF's first input and 5 MF's for second input.

Table 4.7.36. Arithmetic errors for, epochs=1500, ss=0.001, Mf's type: π-shaped (PI)

Epochs	SS	MF's TYPE	NUMBER OF MF's FOR INPUT1	NUMBER OF MF's FOR INPUT2	MSE	RMSE	MAE	MAPE
1500	0,001	PI	2	2	5,4881	2,3427	2,2112	2,3774
1500	0,001	PI	2	3	4,4708	2,1144	2,0151	2,1676
1500	0,001	PI	3	2	7,4596	2,7312	2,5942	2,7894
1500	0,001	PI	3	3	5,4513	2,3348	2,2237	2,3917
1500	0,001	PI	3	4	2,4264	1,5577	1,4589	1,5692
1500	0,001	PI	4	3	5,3173	2,3059	2,1942	2,3600
1500	0,001	PI	4	4	10,3939	3,2240	3,0920	3,3237
1500	0,001	PI	4	5	2,1607	1,4699	1,3766	1,4809
1500	0,001	PI	5	4	3,9313	1,9828	1,8122	1,9464
1500	0,001	PI	5	5	3,9778	1,9944	1,8807	2,0220
1500	0,001	PI	5	6	7,5550	2,7486	2,4505	2,6295
1500	0,001	PI	6	5	0.9954	0.9977	0.8957	0.9633
1500	0,001	PI	6	6	79,6146	8,9227	7,8417	8,4215

In the table 4.7.36, the membership function is (π-shaped) remain constant with the number of nodes for each input variable varies from 2 to 6. The table 4.7.36 is the last one, that epochs remain constant and equal to 1500, and step size constant and equal to 0,001. It is noticed that the lower arithmetic errors are given by the pair, 6 number of MF's for input1 and 5 number of MF's for input2. With this table, the research for all the possible different parameters that regulate the operation of the model is completed. Arithmetic errors will lead to useful conclusions for the optimal combination, that leads to the optimum results.

As emerged from all the previous tables (4.7.3 – 4.7.36), there are several different combinations of the model configuration regarding the type of membership function, the epochs, the step size, the number of rules, which extract low arithmetic errors and this is very important indication for the correct operation of this particular ANFIS algorithm.

To continue the research, it is necessary to select the lowest arithmetic errors that signal the optimum evaluation of the model. Therefore, from all the tables 4.7.1 to 4.7.36, in which all the arithmetic errors of the evaluations have been recorded for all the possible algorithm configurations, the lowest arithmetic errors are listed and numbered in order in the next table 4.7.37. In the table 4.7.37, are summarized in detail all the configuration values of the ANFIS Algorithm.

Table 4.7.37. The lowest arithmetic errors for all the combinations

No	Epochs	Step size	Membership function	Number of rules	Number of MF's for input1	Number of MF's for Input2	MSE	RMSE	MAE	MAPE
1	1500	0.1	Trapezoidal	20	5	4	0.2681	0.5178	0.3505	0.3771
2	1000 & 1500	1	Triangular	25	5	5	0.5555	0.7453	0.6559	0.7046
3	1000 & 1500	1	Gaussian2	20	4	5	0.5817	0.7627	0.6572	0.7049

The number 1 configuration of the table 4.7.37, refers to the model configuration with 1500 epochs, step size equal to 0.1, trapezoidal membership function with 20 rules (5 MF's for input1 (GDP growth rate) and 4 MF's for input 2 (General Government Expenditure)). It has the optimum evaluation with the lowest arithmetic errors than the other two (table 4.3.37), with MSE 0.2681, RMSE 0.5178, MAE 0,3505, MAPE 0.3771 and these are reported to the evaluation table 4.7.29. Each type of arithmetic errors of this configuration is lower that the next best configuration number 2, for MSE 0.2681<0.5555 for RMSE 0.5178<0.7453, for MAE 0.3505<0.6559 and for MAPE 0.3771<0.7046.

The next best evaluation, number 2 configuration, concern the model configuration with triangular membership function, step size equal to 1 and 25 rules with 5 MF's corresponding to each input. The arithmetic errors are, MSE 0.5555, RMSE 0.7453, MAE 0.6559, MAPE 0.7046 and is also necessary to note that with this number 2 model configuration, the arithmetic errors are exactly the same, whether the repetitions are 1000 or 1500. These results are emerged from the table 4.7.1 for epochs 1000 and from the table 4.7.19 for epochs 1500.

Similar low arithmetic errors as previous, has the number 3 model configuration, with Gaussian2 membership function, step size equal to 1, and 20 rules for fuzzy inference system with 4 MF's for GDP the input variable GDP growth rate and 5 MF's for the input variable General Government Expenditure. The arithmetic errors are MSE 0.5817, RMSE 0.7627, MAE 0.6572, MAPE 0.7049 and it is mentioned that the results are the same with either 1000 or 1500 epochs at this model configuration. These errors are reported in the table 4.7.4 for epochs 1000 and in the table 4.7.22 for epochs 1500.

4.8 Results Analysis

The optimum prediction results for the period from the third quarter of 2017 to fourth quarter of 2019, have emerged from three different configuration types of ANFIS algorithm.

The main criterion of the optimal evaluation of a model, is the lowest arithmetic errors. As concerned from the table 4.7.37 of the 4.7 paragraph, there are three different configuration of the algorithm, where they arise the optimum results. In the next paragraphs will proceed to the study of these results of the ANFIS algorithm for each optimum run.

4.8.1 First model application

For the first optimum application of ANFIS algorithm, the settings concern (table 4.7.37) the epoch number equal to 1.500, the step size equal to 0.1, the membership function is the trapezoidal (detailed presentation in 3.5.2.2) and 20 fuzzy logic rules are needed for the successfully operation of the algorithm. The basic structure of the forecasting algorithm is shown in the figure 4.8.1, according to the general model of fuzzy inference system (FIS) (Jang 2003), presented in 3.5.2.

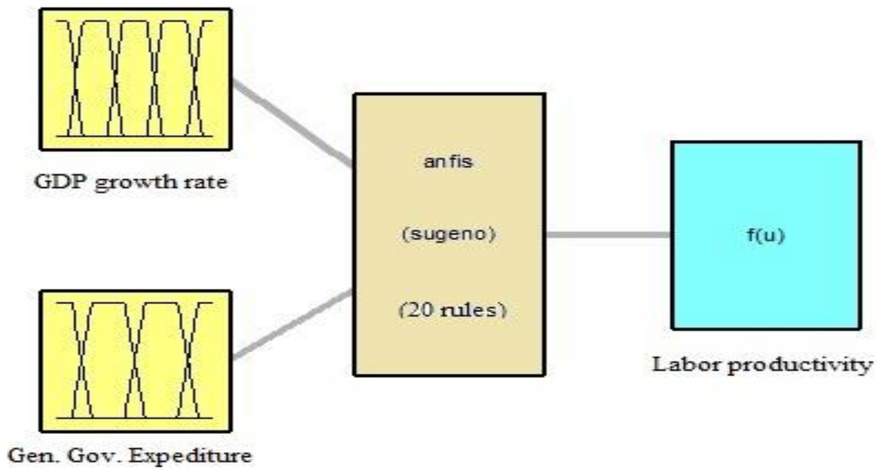

Figure 4.8.1. Basic structure of the ANFIS algorithm.

The data sets of two variables form the two inputs of the model, the adaptive system that uses a hybrid learning algorithm to identify parameters of Sugeno-type fuzzy inference system with respect to the rules is the core of the ANFIS model which create the output.

Table 4.8.1 Main features for the algorithm operation.

ANFIS Details	
FIS Type	Sugeno
Number of inputs	2
Name of 1st input	GDP growth of rate
Name of 2nd input	General Government Expenditure
Number of output	1
Name of output	Labor Productivity per hour worked
Number of input membership function	4 Trapezoid mfs
Number of rules	20
"And" method	Product
"Or" method	max
Implication method	min
Aggregation method	max
Defuzzification	wtaver
Number of nodes	60
Number of parameters	75
Number of linear parameters	60
Number of non linear parameters	15

During the operation of the algorithm, 20 nodes are created with a total number of 75 parameters which are adjusted based on the training data. There are 60 linear parameters and 15 non linear of the total of 75 parameters developed. To calculate the degree of activation of the rules "and", a part of the rules (hypothesis) is using the method of the "product" and for the degree of activation of the rules "or", a part of the rules (hypothesis) is using the method "max".

The method "product" is used, in order to find the output participation function based on each rule. In order to find the total participation function of the output of all rules, the method "max" is used. The weight average method "wtaver" is used to convert the output value to a crisp value (defuzzification). The main features of ANFIS model are shown in the table above 4.8.1.

In the following figure 4.8.2, is shown the architecture of the ANFIS algorithm as developed by Jang in 1993, and has been presented in detail in 3.7.1. Also in this figure is presented analytically the layers with all the types of nodes as has been developed in 3.7.1.1., (Jang 1993). The first layer (two black nodes) constitutes the input nodes of the model. The second layer (9 white nodes) has the role of adaptation, which produce membership grade of linguistic variable figure 4.8.3. In the third layer are presented the twenty rules (figure 4.8.4). The blue color of the nodes of the third layer that represent the rules means that all the rules are "and" type.

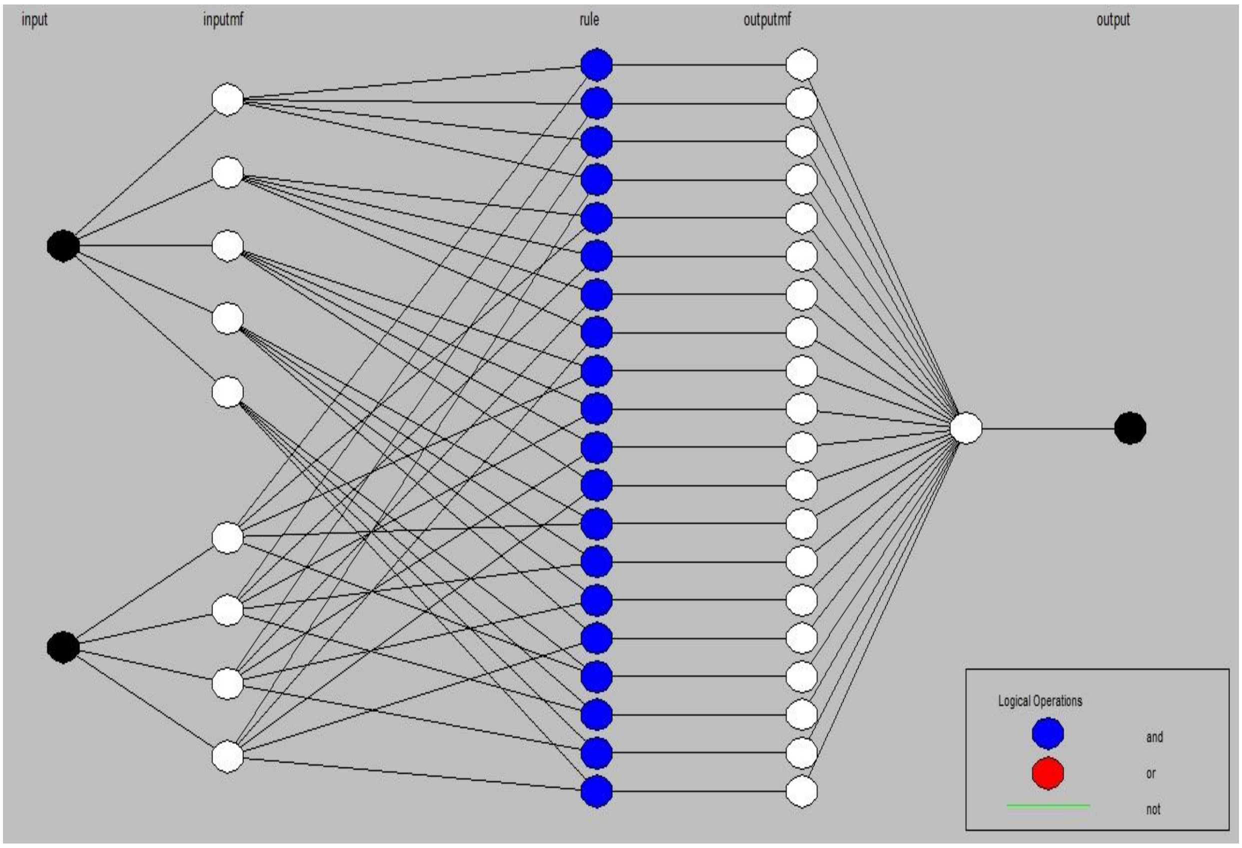

Figure 4.8.2. The architecture of the ANFIS algorithm.

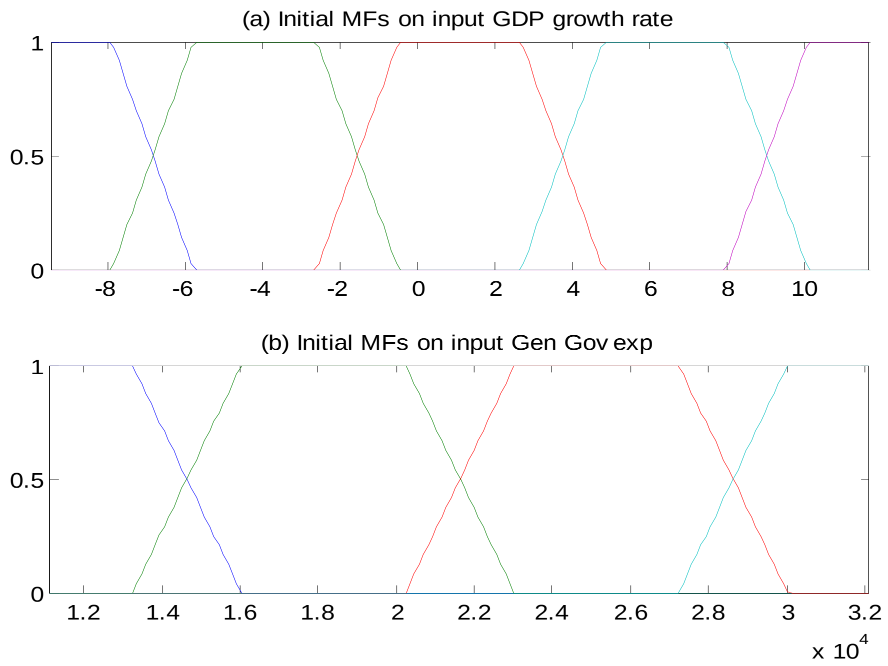

Figure 4.8.3. Membership grade of trapezoidal membership function on input variables.

The third layer (twenty blue nodes) consist the nodes that apply the rules of fuzzy logic and which are presented in detail below:

- 1. If GDP growth rate is too small and General Gov. Expenditure is too small then Labor productivity is O_1 (1)
- 2. If GDP growth rate is too small and General Gov. Expenditure is small then Labor productivity is O_2 (2)
- 3. If GDP growth rate is too small and General Gov. Expenditure is medium then Labor productivity is O_3 (3)
- 4. If GDP growth rate is too small and General Gov. Expenditure is large then Labor productivity is O_4 (4)
- 5. If GDP growth rate is small and General Gov. Expenditure is too small then Labor productivity is O_5 (5)
- 6. If GDP growth rate is small and General Gov. Expenditure is small then Labor productivity is O_6 (6)
- 7. If GDP growth rate is small and General Gov. Expenditure is medium then Labor productivity is O_7 (7)

- 8. If GDP growth rate is small and General Gov. Expenditure is large then Labor productivity is O_8 (8)
- 9. If GDP growth rate is medium and General Gov. Expenditure is too small then Labor productivity is O_9 (9)
- 10. If GDP growth rate is medium and General Gov. Expenditure is small then Labor productivity is O_{10} (10)
- 11. If GDP growth rate is medium and General Gov. Expenditure is medium then Labor productivity is O_{11} (11)
- 12. If GDP growth rate is medium and General Gov. Expenditure is large then Labor productivity is O_{12} (12)
- 13. If GDP growth rate is large and General Gov. Expenditure is too small then Labor productivity is O_{13} (13)
- 14. If GDP growth rate is large and General Gov. Expenditure is small then Labor productivity is O_{14} (14)
- 15. If GDP growth rate is large and General Gov. Expenditure is medium then Labor productivity is O_{15} (15)
- 16. If GDP growth rate is large and General Gov. Expenditure is large then Labor productivity is O_{16} (16)
- 17. If GDP growth rate is extra large and General Gov. Expenditure is too small then Labor productivity is O_{17} (17)
- 18. If GDP growth rate is extra large and General Gov. Expenditure is small then Labor productivity is O_{18} (18)
- 19. If GDP growth rate is extra large and General Gov. Expenditure is medium then Labor productivity is O_{19} (19)
- 20. If GDP growth rate is extra large and General Gov. Expenditure is large then Labor productivity is O_{20} (20)

The values O_1-O_{20} are the outputs of each rule, which are calculated by the formula (3.7.1.7), for i=1,2,3….,20.

The schematic representation of these twenty rules of fuzzy logic is presented in the figure 4.8.4, below. Each row refers to a rule. The first column represents the first input, the second column represents the second input and the third column represents the output. For example, in the first rule represented by the first row, it is stated that, when the value of the first input (GDP growth rate) is x and the value of the second input (General Government Expenditure) is y, then the output is O, which derived from the node function (3.7.1.7), $O_{4,i} = \overline{w}_i \cdot f_i = \overline{w}_i(p_1 \cdot x + q_i \cdot y + r_i)$

where is analyzed at the paragraph 3.7.1., while the parameters p_i, q_i, r_i, are determined by the training data.

The red vertical lines of the first and second columns diagrammatically indicate the point of activation of the rule, while the color range in which each rule has been activated is shown in yellow. There is a case depending on the values of the data that no rule is activated at all.

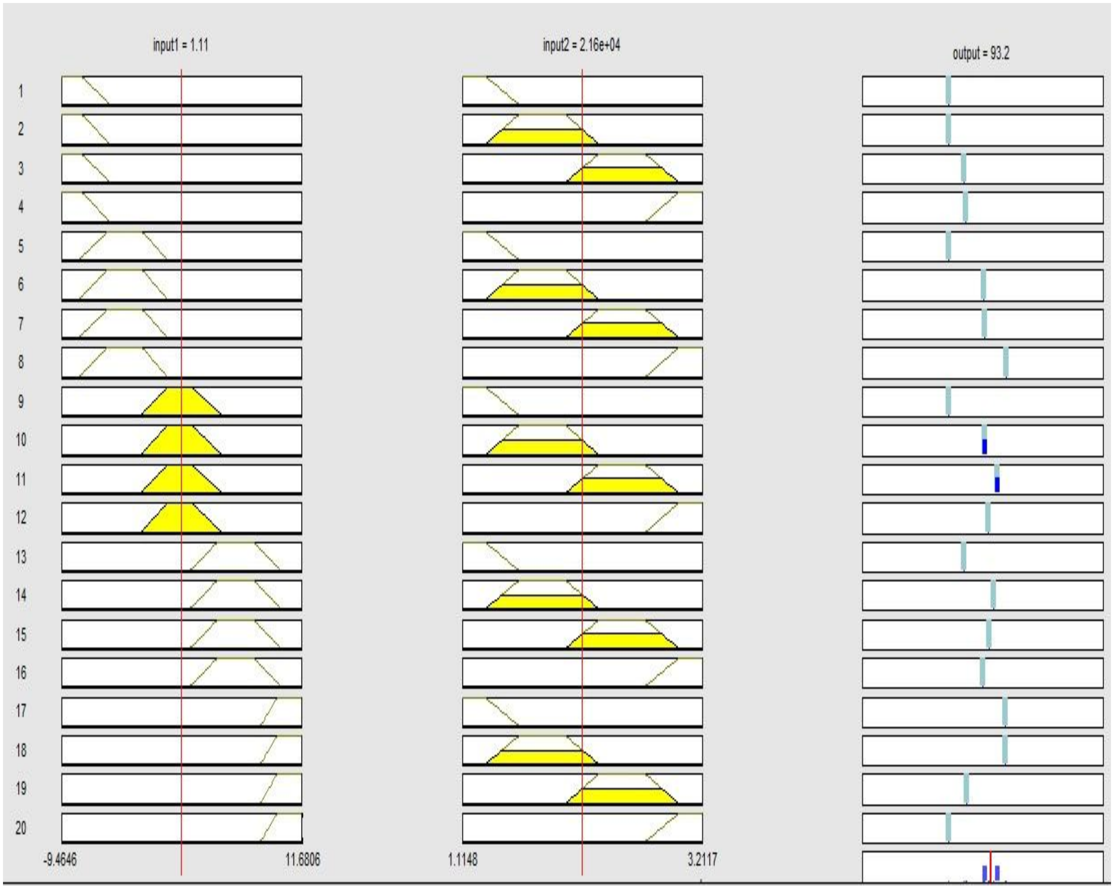

Figure 4.8.4. The schematic representation of the twenty rules, which shows the field of activation of each rule (yellow color) and the finding of the output value.

In the fourth layer the action of the membership function, represent fuzzy sets of respective input variables, (figure 4.8.5), and provides output values resulting from the inference of the rules. This output according to 3.5, is simply a product of normalized firing rule strength and first order polynomial. Weighted output of rule represented by node function as:

$$O_{4,i} = \overline{w}_i \cdot f_i = \overline{w}_i (p_1 \cdot x + q_i \cdot y + r_i)$$

where $\bar{w}_i$ is the output of layer 3 and $\{p_i, q_i, r_i\}$ is the parameter set. In the next table 4.8.2 is presented all the parameters $\{p_i, q_i, r_i\}$, for each rule. The value of the weight (w) is equal to one and as shown in the table, some rules are not activated as the parameters value is zero. The activation area for each rule is shown in yellow color at the first or the second column in figure 4.8.4.

Table 4.8.2. Presented the parameters for each rule.

RULES	Parameters (*p*, *q*, *r*)
Rule 1	[0 0 0]
Rule 2	[0 0 0]
Rule 3	[-1.471 0.0008315 59.94]
Rule 4	[5.248 0.003666 41]
Rule 5	[0 0 0]
Rule 6	[-4.58e-07 0.003975 1,758e-07]
Rule 7	[-0.4099 -0.001045 119.7]
Rule 8	[-0.544 0.0009331 69.74]
Rule 9	[0 0 0]
Rule 10	[56.32 -0.0005246 -30.1]
Rule 11	[-9.289 0.00393 30.94]
Rule 12	[0.5116 0.0006823 80.02]
Rule 13	[0.01097 -0.00631 176.8]
Rule 14	[0.2382 0.002094 52.39]
Rule 15	[1.91 0.0005336 77.07]
Rule 16	[1.011 0.002126 34.03]
Rule 17	[-0.2731 0.004467 29.67]
Rule 18	[-2.759 0.005809 2,717]
Rule 19	[6.333 0.00188 -5.479]
Rule 20	[0 0 0]

The fifth layer, which sums up all the inputs coming from the fourth layer and transforms fuzzy classification results into crisp values. The final membership function trapezoidal type of ANFIS model after the training, are presented at the next figure 4.8.5.

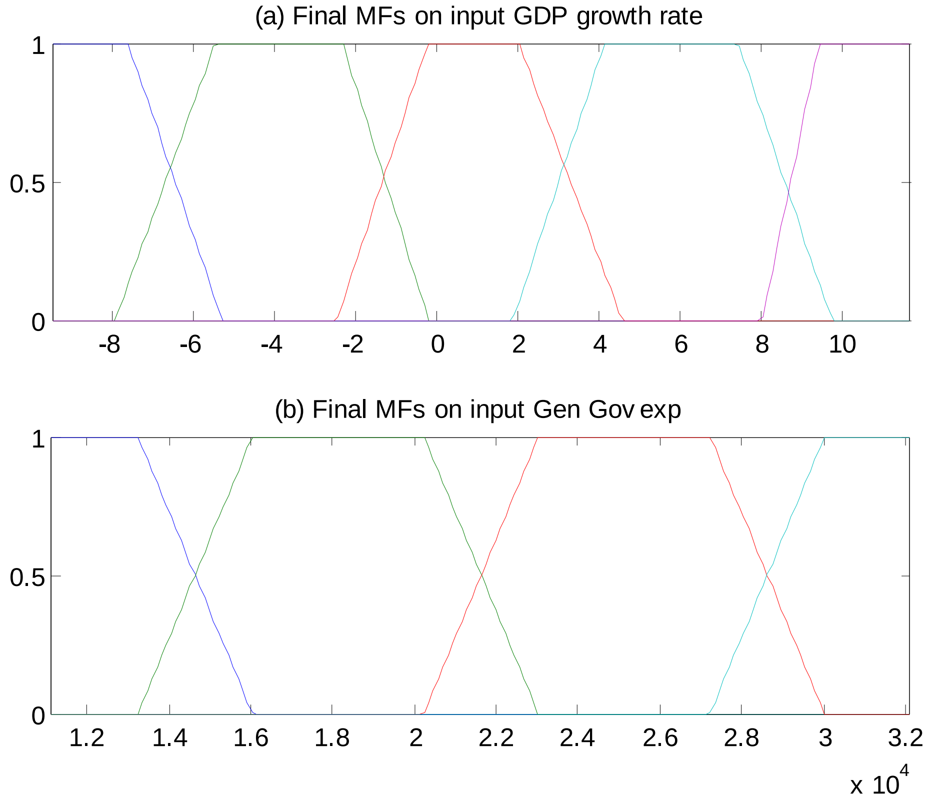

Figure 4.8.5. Act of Trapezoid Membership function in input variables.

Finally at the figure 4.8.6, a representation in the three-dimensional space of the output with respect to input1 and input2 is presented. The training data are distributed almost uniformly within the control area, without any significant abrupt changes of the surfaces. This means that the training data was quite satisfactory and the representation of the dynamic relationships between inputs and the output is also satisfactory as there are no significant abrupt changes in the edges of the surfaces.

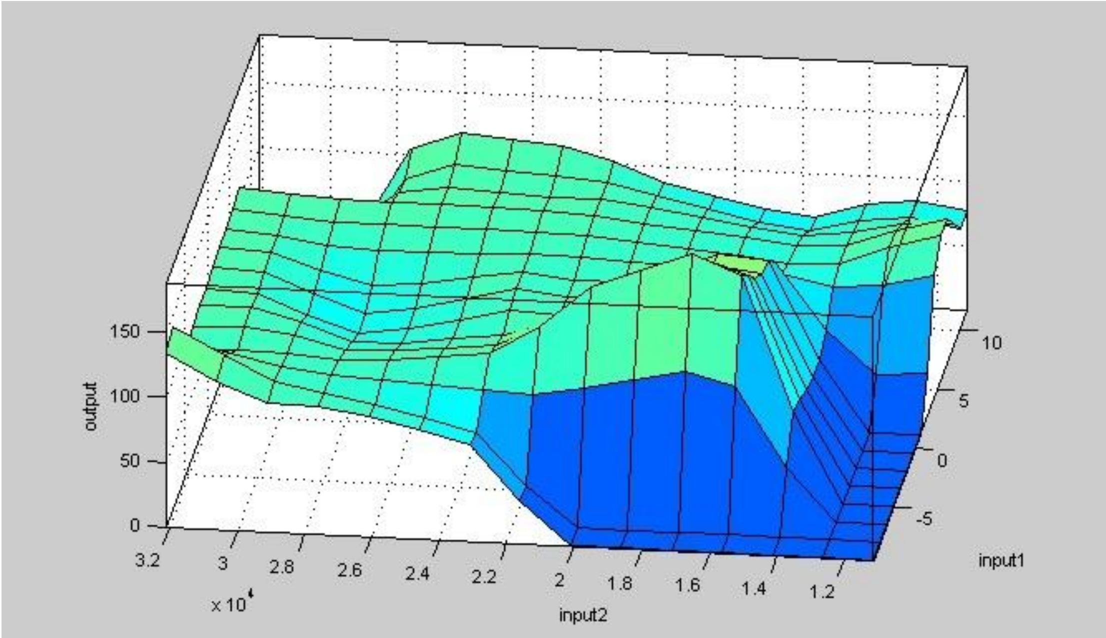

Figure 4.8.6. Input-output resulting area is presented.

These crisp values are shown in the next diagram, at figure 4.8.7 which are the prediction values for ANFIS model with the red color and can be schematically compared with the actual values with the blue color, where it is observed that they are very close to each other. These ten crisp values of the diagram 4.8.7 are essentially the values of the Labor productivity per hour, as calculated by Eurostat for the third quarter (Q3) of 2017 to the fourth quarter (Q4) of 2019.

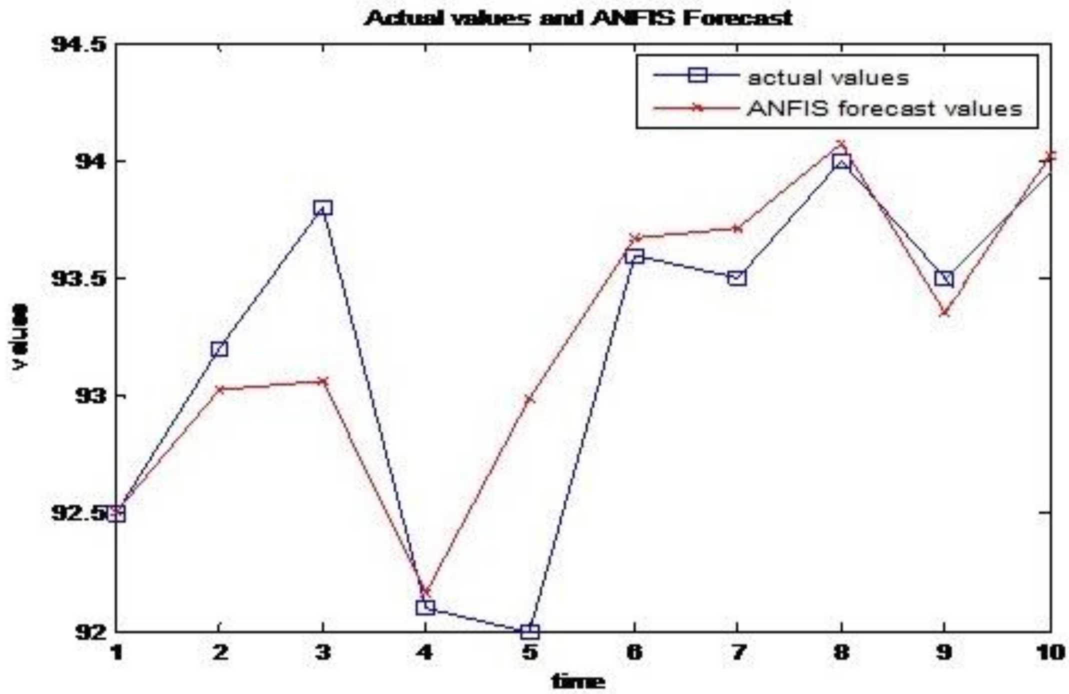

Figure 4.8.7. The ANFIS forecast values compared with the actual values of the output variable (Labor productivity).

Actually for the 3rd quarter of 2017, the 2nd quarter of 2018, the 4th quarter of 2018, and for the 2nd,3rd,4th quarter of 2019 the forecasting value of the Labor productivity per hour for Greece is the same as the actual values of the Greek Labor productivity per hour. For the remaining quarters between 2017-2019, the forecast values are very close to the actual values, so that the overall display of values can be confirmed with certainty the implementation of this ANFIS model to forecast the impact of interest groups on Greek economy.

The reliability of the ANFIS model in addition to the output values forecasted and are almost identical to the actual values, is also confirmed by the theory (3.8). The criterion for the reliability of the model is the arithmetic errors MSE, RMSE, MAE, MAPE which shown in the table 4.8.3.

Table 4.8.3. Arithmetic errors for the evaluation of the model

MSE	RMSE	MAE	MAPE
0.2681	0.5178	0.3505	0.3771

These are the lowest errors that have occurred, compared to any other application, even with the next two very satisfactory results. Therefore, it is emerged that this first application that analyzed above seems to be the best model configuration. Subsequently, two more model applications will be developed in detail, so that there is the possibility of comparison between them.

4.8.2 Second model application

For the second application of ANFIS algorithm, for the same time period as the first application, the settings concern: the epoch number equal to 1.500, the step size equal to 1, the membership function is the triangular (detailed presentation in 3.5.2.2) and 25 fuzzy logic rules are needed for the successfully operation of the algorithm. The basic structure of the prediction algorithm is shown in the figure 4.8.8, according to the general model of fuzzy inference system (FIS) (Jang 2003), presented in 3.5.2.

The data set of GDP growth rate and General Government Expenditure constitute the two inputs for the ANFIS model. The data sets after the procedure of fuzzification are processed from the fuzzy inference system Sugeno-type and with respect to the 25 rules, arise the output.

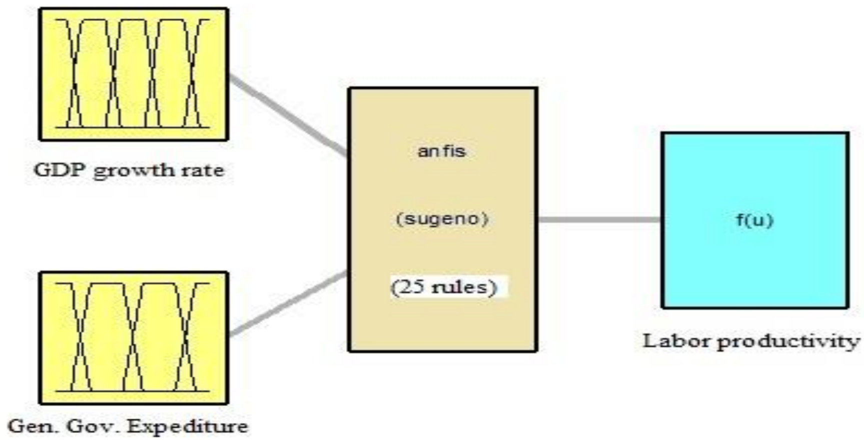

Figure 4.8.8. Basic structure of ANFIS algorithm. Two inputs, the fuzzy inference system Sugeno-type witch after the training method and the fuzzification procedure, emerges the output.

During the operation of the model, 25 nodes are created with a total number of 75 parameters which are adjusted based on the training data. There are 63 linear parameters and 12 non linear of the total of 75 parameters developed. To calculate the degree of activation of the rules "and", a part of the rules (hypothesis) is using the method of the "product" and for the degree of activation of the rules "or", a part of the rules (hypothesis) is using the method "max".

The method "product" is used, in order to find the output participation function based on each rule. In order to find the total participation function of the output of all rules, the method "max" is used. The weight average method "wtaver" is used to convert the output value to a crisp value (defuzzification). The main features of ANFIS model are shown in the next table 4.8.4.

Table 4.8.4 Details for the algorithm operation.

ANFIS Details	
FIS Type	Sugeno
Number of inputs	2
Name of 1st input	GDP growth of rate
Name of 2nd input	General Government Expenditure
Number of output	1
Name of output	Labor Productivity per hour worked
Number of input membership function	4 Triangle mfs
Number of rules	25
And method	Product
Or method	max
Implication method	min
Aggregation method	max
Defuzzification	wtaver
Number of nodes	60
Number of parameters	75
Number of linear parameters	63
Number of non linear parameters	12

In the following figure 4.8.9, is shown the architecture of the ANFIS algorithm as developed by Jang in 1993, and has been presented in detail in 3.9.1. Also in this figure is presented analytically the layers with all the types of nodes as has been developed in 3.7.1.1., (Jang 1993). The first layer (two black nodes) has the role of adaptation, which produce membership grade of linguistic variable.

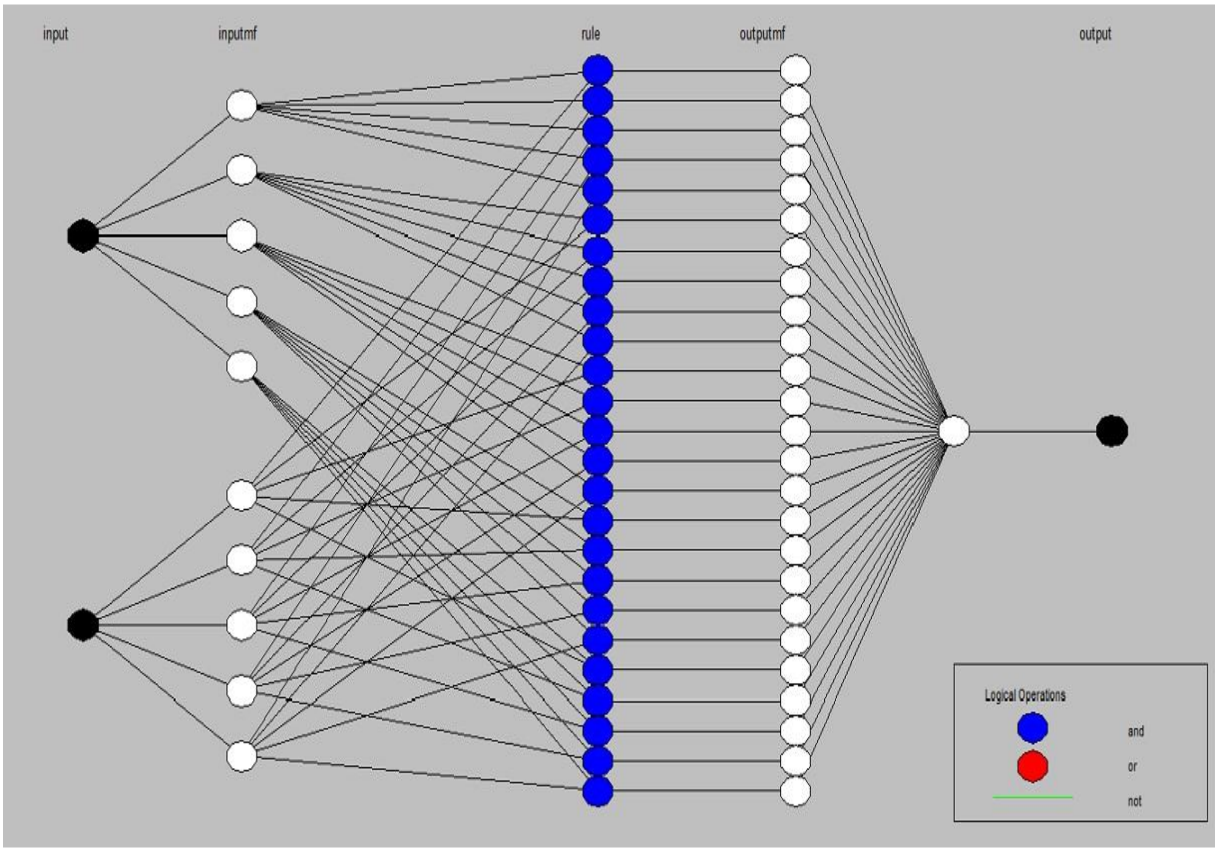

Figure 4.8.9. The architecture of ANFIS model.

The second layer (10 white nodes) checks the weights of each membership function, and act as a membership function to represent fuzzy sets of respective input variables, figure 4.8.10.

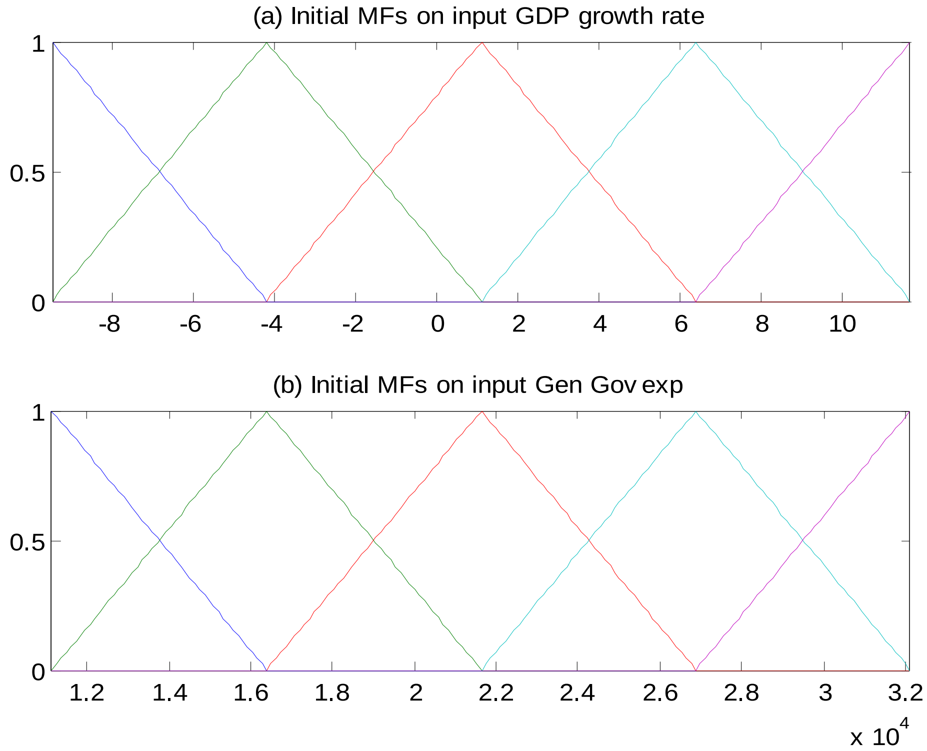

Figure 4.8.10. Triangle Membership function on input variables (Growth rate and General Government Expenditure).

The third layer (twenty five blue nodes) consist the nodes that apply the rules of fuzzy logic and which are presented in detail below:

- 1. If GDP growth rate is too small and General Gov. Expenditure is too small then Labor productivity is O_1 (1)
- 2. If GDP growth rate is too small and General Gov. Expenditure is small then Labor productivity is O_2 (2)
- 3. If GDP growth rate is too small and General Gov. Expenditure is medium then Labor productivity is O_3 (3)
- 4. If GDP growth rate is too small and General Gov. Expenditure is large then Labor productivity is O_4 (4)
- 5. If GDP growth rate is too small and General Gov. Expenditure is extra large then Labor productivity is O_5 (5)
- 6. If GDP growth rate is small and General Gov. Expenditure is too small then Labor productivity is O_6 (6)

- 7. If GDP growth rate is small and General Gov. Expenditure is small then Labor productivity is O_7 (7)
- 8. If GDP growth rate is small and General Gov. Expenditure is medium then Labor productivity is O_8 (8)
- 9. If GDP growth rate is small and General Gov. Expenditure is large then Labor productivity is O_9 (9)
- 10. If GDP growth rate is small and General Gov. Expenditure is extra large then Labor productivity is O_{10} (10)
- 11. If GDP growth rate is medium and General Gov. Expenditure is too small then Labor productivity is O_{11} (11)
- 12. If GDP growth rate is medium and General Gov. Expenditure is small then Labor productivity is O_{12} (12)
- 13. If GDP growth rate is medium and General Gov. Expenditure is medium then Labor productivity is O_{13} (13)
- 14. If GDP growth rate is medium and General Gov. Expenditure is large then Labor productivity is O_{14} (14)
- 15. If GDP growth rate is medium and General Gov. Expenditure is extra large then Labor productivity is O_{15} (15)
- 16. If GDP growth rate is large and General Gov. Expenditure is too small then Labor productivity is O_{16} (16)
- 17. If GDP growth rate is large and General Gov. Expenditure is small then Labor productivity is O_{14} (17)
- 18. If GDP growth rate is large and General Gov. Expenditure is medium then Labor productivity is O_{18} (18)
- 19. If GDP growth rate is large and General Gov. Expenditure is large then Labor productivity is O_{19} (19)
- 20. If GDP growth rate is large and General Gov. Expenditure is extra large then Labor productivity is O_{20} (20)
- 21. If GDP growth rate is extra large and General Gov. Expenditure is too small then Labor productivity is O_{21} (21)
- 22. If GDP growth rate is extra large and General Gov. Expenditure is small then Labor productivity is O_{22} (22)

- 23. If GDP growth rate is extra large and General Gov. Expenditure is medium then Labor productivity is O_{23} (23)
- 24. If GDP growth rate is extra large and General Gov. Expenditure is large then Labor productivity is O_{24} (24)
- 25. If GDP growth rate is extra large and General Gov. Expenditure is extra large then Labor productivity is O_{25} (25)

The values O_1 – O_{25} are the outputs of each rule, which are calculated by the formula (3.7.1.7), for i=1,2,3….,25.

The schematic representation of these twenty five rules of fuzzy logic is presented in the figure 4.8.11, below. Each row refers to a rule. The first column represents the first input, the second column represents the second input and the third column represents the output. For example, in the first rule represented by the first row, it is stated that, when the value of the first input (GDP growth rate) is x and the value of the second input (General Government Expenditure) is y, then the output is O, which derived from the node function (3.7.1.7),

$$O_{4,i} = \overline{w}_i \cdot f_i = \overline{w}_i(p_1 \cdot x + q_i \cdot y + r_i)$$

where is analyzed at the paragraph 3.7.1. while the parameters p_i, q_i, r_i, are determined by the training data.

The red vertical lines of the first and second columns diagrammatically indicate the point of activation of the rule, while the color range in which each rule has been activated is shown in yellow. There is a case depending on the values of the data that no rule is activated at all.

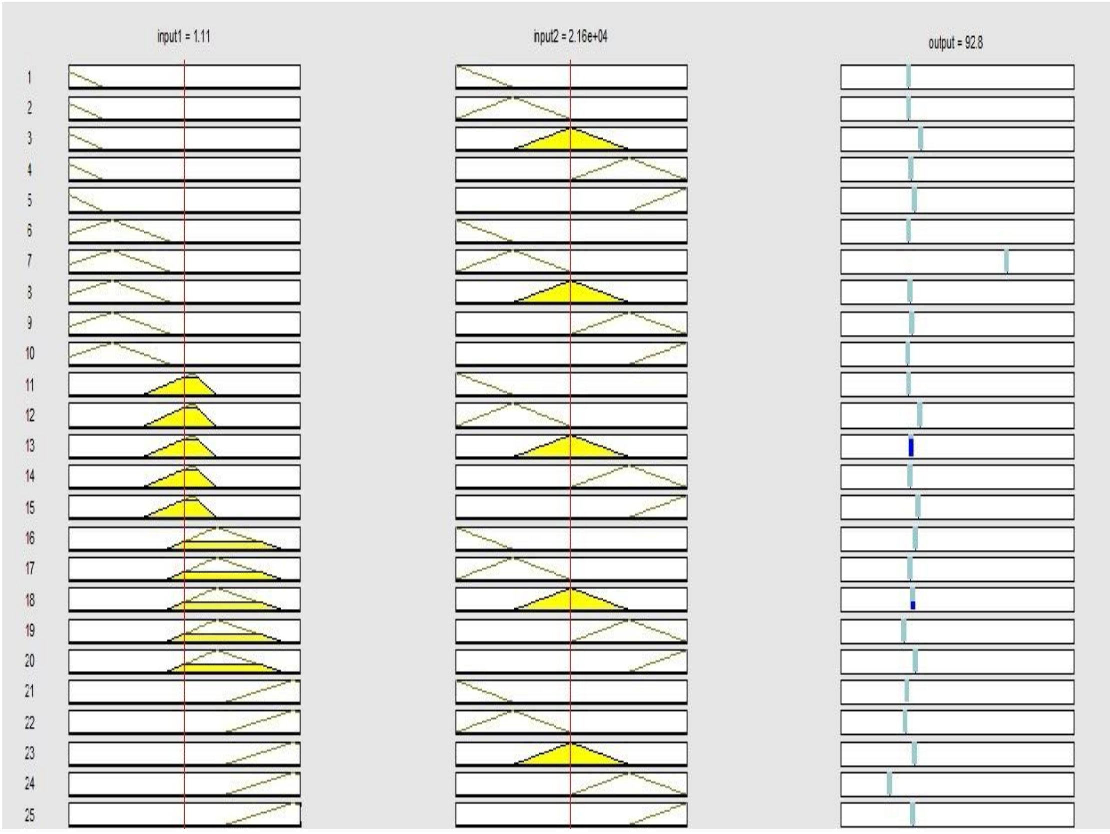

Figure 4.8.11. The schematic representation of the 25 rules, which shows the field of activation of each rule (yellow color) and the finding of the output value.

In the fourth layer the action of the membership function, represent fuzzy sets of respective input variables, (figure 4.8.12), and provides output values resulting from the inference of rules. This output according to 3.7, is simply a product of normalized firing rule strength and first order polynomial. Weighted output of rule represented by node function as:

$$O_{4,i} = \overline{w}_i \cdot f_i = \overline{w}_i (p_1 \cdot x + q_i \cdot y + r_i)$$

where $\bar{w}_i$ is the output of layer 3 and $\{p_i, q_i, r_i\}$ is the parameter set. In the next table 4.8.5 is presented all the parameters $\{p_i, q_i, r_i\}$, for each rule. The value of the weight (w) is equal to one and as shown in the table, some rules are not activated as the parameters value is zero.

Table 4.8.5. Presented the parameters for each rule.

RULES	Parameters (p,q,r)
Rule 1	[0 0 0]
Rule 2	[0 0 0]
Rule 3	[-5.079e-06 0.01574 5.864e-07]
Rule 4	[0.3272 0.004705 -22.75]
Rule 5	[12.76 0.006069 19.04]
Rule 6	[0 0 0]
Rule 7	[-3.976e-06 0.1266 5.873e-06
Rule 8	[-14.41 -0.01105 310.5]
Rule 9	[2.505 0.003561 12.81]
Rule 10	[-6.528 0.009419 -219.7]
Rule 11	[0 0 0]
Rule 12	[13.13 0.01339 1.172]
Rule 13	[-5.07 0.03691 -713.5]
Rule 14	[40.23 0.01264 -267.8]
Rule 15	[-23.63 -0.01962 703.9]
Rule 16	[3.007 0.01816 -209.1]
Rule 17	[15.52 0.004936 -67.3]
Rule 18	[-7.518 0.001825 92.02]
Rule 19	[70.87 -0.0002481 -227]
Rule 20	[-26.35 -0.0002997 237.6]
Rule 21	[-2.523 -0.01368 256.6]
Rule 22	[17.08 -0.0101 88.39]
Rule 23	[-7.288 -0.0072 329.6]
Rule 24	[75 -0.003843 -535.9]
Rule 25	[15.98 0.0003551 93.21]

The fifth layer which sums up all the inputs coming from the fourth layer and transforms fuzzy classification results into crisp values. The final membership function trapezoidal type of ANFIS model after the training, are presented at the next figure 4.8.12.

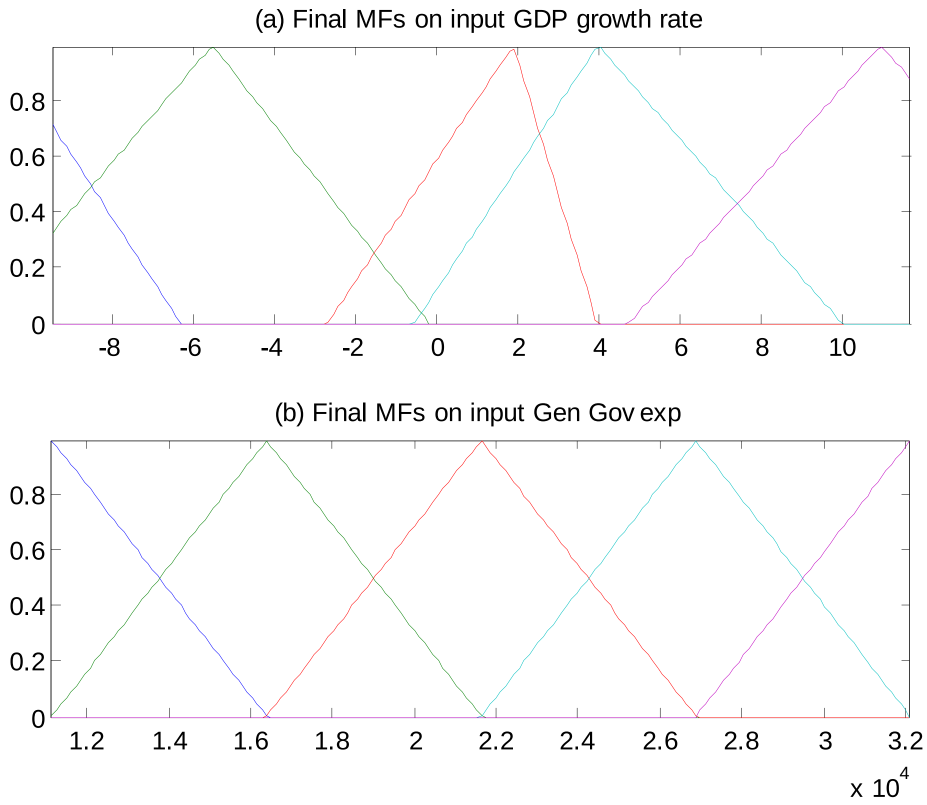

Figure 4.8.12. Act of Triangle Membership function in input variables.

Finally at the figure 4.8.13, a representation in the three-dimensional space of the output with respect to input1 and input2 is presented. The training data are distributed almost uniformly within the control area, without any significant abrupt changes of the surfaces. This means that the training data was quite satisfactory and the representation of the dynamic relationships between inputs and the output is also satisfactory as there are no significant abrupt changes in the edges of the surfaces.

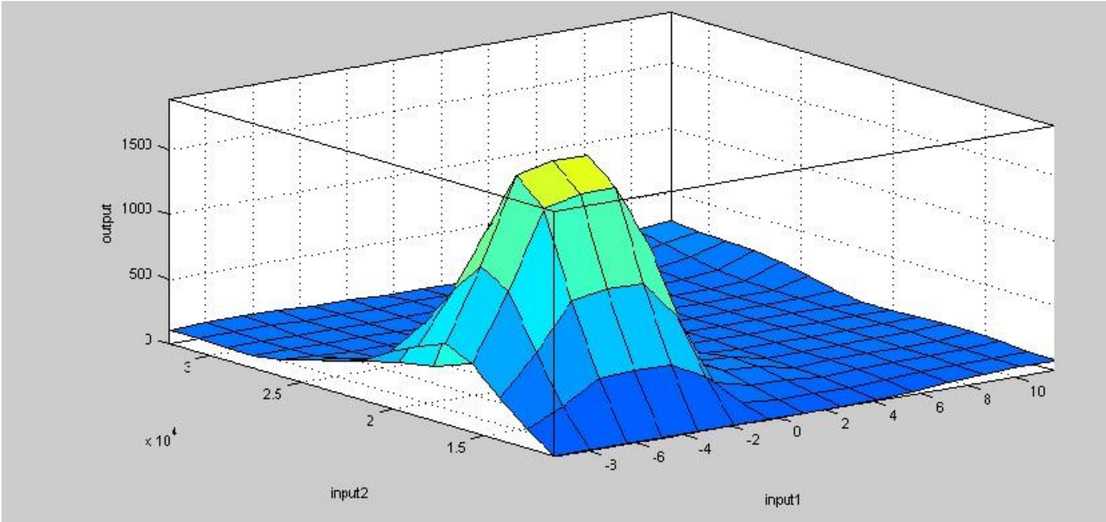

Figure 4.8.13. Input-output resulting area is presented.

These crisp values are shown in the next diagram, at figure 4.8.14 which are the prediction values for ANFIS model with the red color and can be schematically compared with the actual values with the blue color, where it is observed that they are very close to each other. These ten crisp values of the diagram 4.8.7 are essentially the values of the Labor productivity per hour, as calculated by Eurostat for the third quarter (Q3) of 2017 to the fourth quarter (Q4) of 2019.

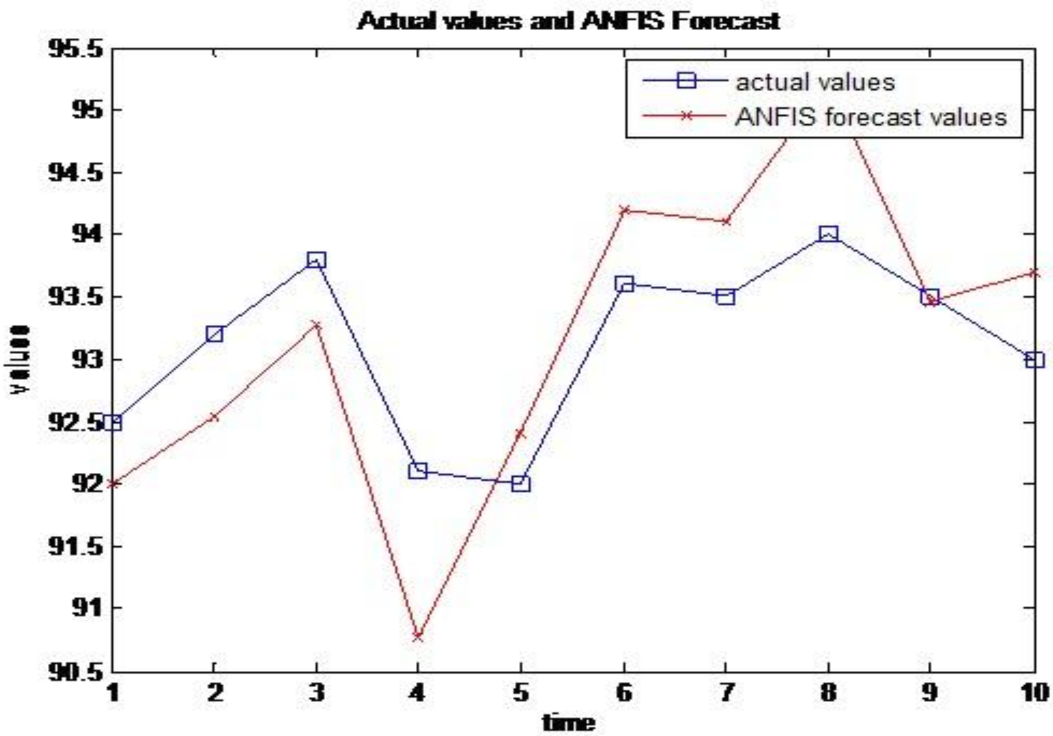

Figure 4.8.14 The ANFIS forecast values compared with the actual values of the output variable (Labor productivity).

Actually for the 4rd quarter of 2018, the 1nd quarter of 2019, the 3nd quarter of 2019, the forecasting value of the Labor productivity per hour for Greece is almost the same as the actual values of the Greek Labor productivity per hour. For the remaining quarters between 2017-2019, the forecast values are very close to the actual values, so that the overall display of values can be confirmed with certainty the implementation of this ANFIS model to forecast the impact of interest groups on Greek economy.

The reliability of the ANFIS model in addition to the output values forecasted and are almost identical to the actual values, is also confirmed by the theory (3.8). The criterion for the reliability of the model is the arithmetic errors MSE, RMSE, MAE, MAPE which shown in the table 4.8.6.

Table 4.8.6. Arithmetic errors for the evaluation of the second application of the ANFIS model

MSE	RMSE	MAE	MAPE
0.5555	0.7453	0.6559	0.7046

The arithmetic errors for the second application of the ANFIS model, as presented in the table 4.8.6 are quite low. These are slightly higher than the errors of the first application, but lower than any other application in the model. Thus the specific configuration of the ANFIS model is classified in the second best application of all the others, as presented in the tables 4.7.1 – 4.7.36.

4.8.3 Third model application

For the third run of ANFIS algorithm, for the same time period as the first and second run, the settings concern: the epoch number equal to 1.500, the step size equal to 1, the membership function is the Gaussian2 (detailed presentation in 3.5.2.2) and 20 fuzzy logic rules are needed for the successfully operation of the algorithm. The basic structure of the prediction algorithm is shown in the figure 4.8.15, according to the general model of fuzzy inference system (FIS) (Jang 2003), presented in 3.5.2.

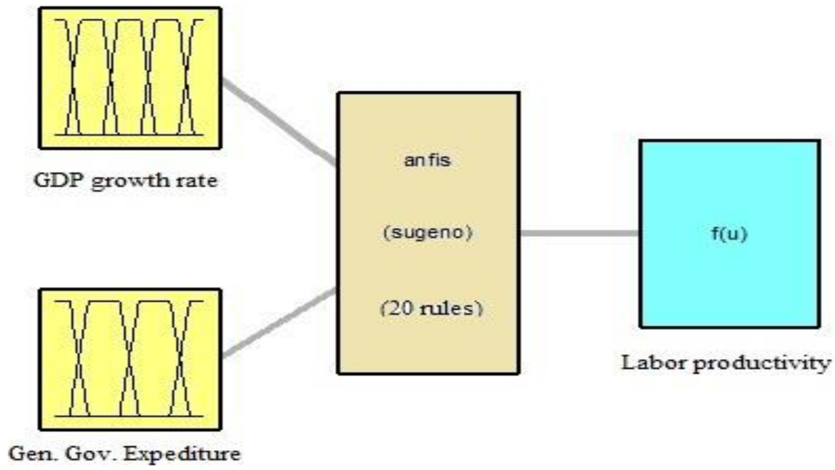

Figure 4.8.15. Basic structure of ANFIS algorithm.

The data sets of two variables form the two inputs of the model, the adaptive system that uses a hybrid learning algorithm to identify parameters of Sugeno-type fuzzy inference system with respect to the rules is the core of the ANFIS model which create the output.

During the operation of the model, 49 nodes are created with a total number of 60 parameters which are adjusted based on the training data. There are 60 linear parameters and zero non linear of the total of 60 parameters developed. To calculate the degree of activation of the rules "and", a part of the rules (hypothesis) is using the method of the "product" and for the degree of activation of the rules "or", a part of the rules (hypothesis) is using the method "max".

The method "product" is used, in order to find the output participation function based on each rule. In order to find the total participation function of the output of all rules, the method "max" is used. The weight average method "wtaver" is used to convert the output value to a crisp value (defuzzification). The main features of ANFIS model are shown in the next table 4.8.7.

Table 4.8.7. Details for the algorithm operation

ANFIS Details	
FIS Type	Sugeno
Number of inputs	2
Name of 1st input	GDP growth of rate
Name of 2nd input	General Government Expenditure
Number of output	1
Name of output	Labor Productivity per hour worked
Number of input membership function	4 Gaussian mfs
Number of rules	20
And method	Product
Or method	max
Implication method	min
Aggregation method	max
Defuzzification	wtaver
Number of nodes	49
Number of parameters	60
Number of linear parameters	60
Number of non linear parameters	0

In the following figure 4.8.16, is shown the architecture of the ANFIS algorithm as developed by Jang in 1993, and has been presented in detail in 3.7.1. Also in this figure is presented analytically the layers with all the types of nodes as has been developed in 3.7.1.1., (Jang 1993). The first layer (two black nodes) has the role of adaptation, which produce membership grade of linguistic variable. The second layer (nine white nodes) checks the weights of each membership function, and act as a membership function to represent fuzzy sets of respective input variables, figure 4.8.17.

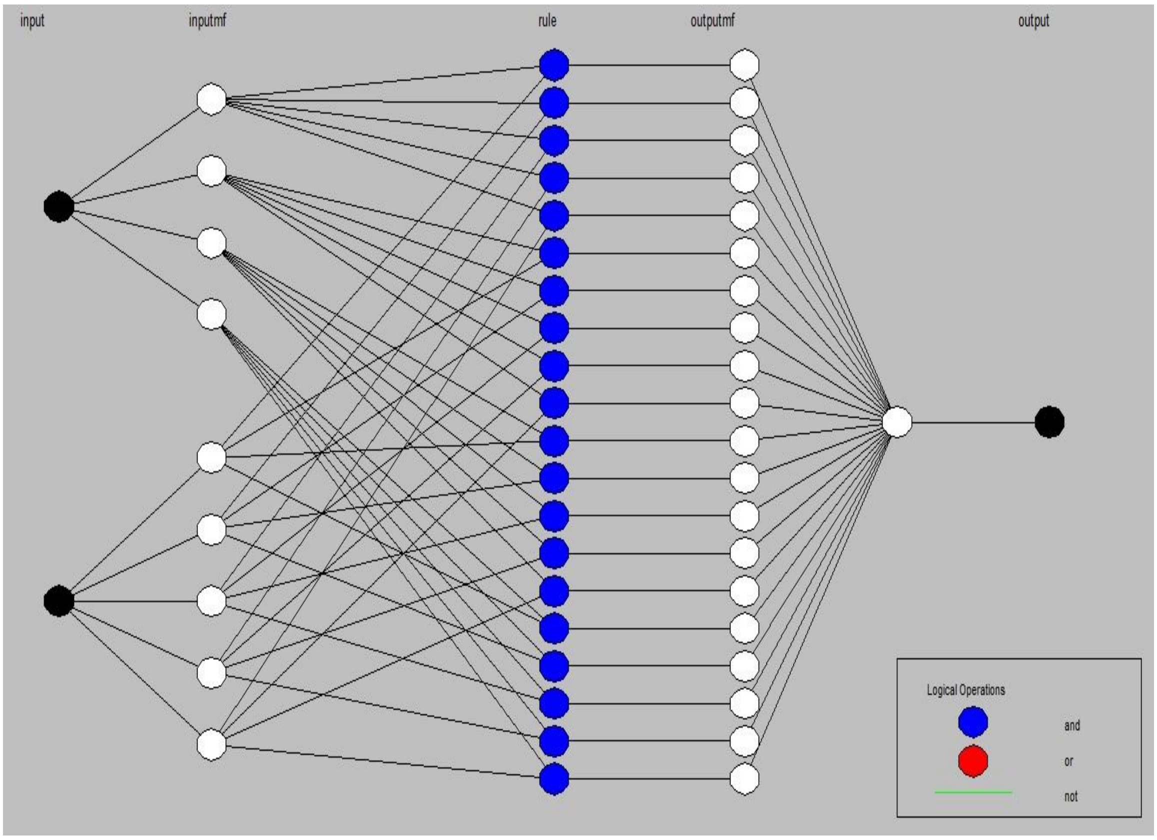

Figure 4.8.16 Architecture of ANFIS algorithm.

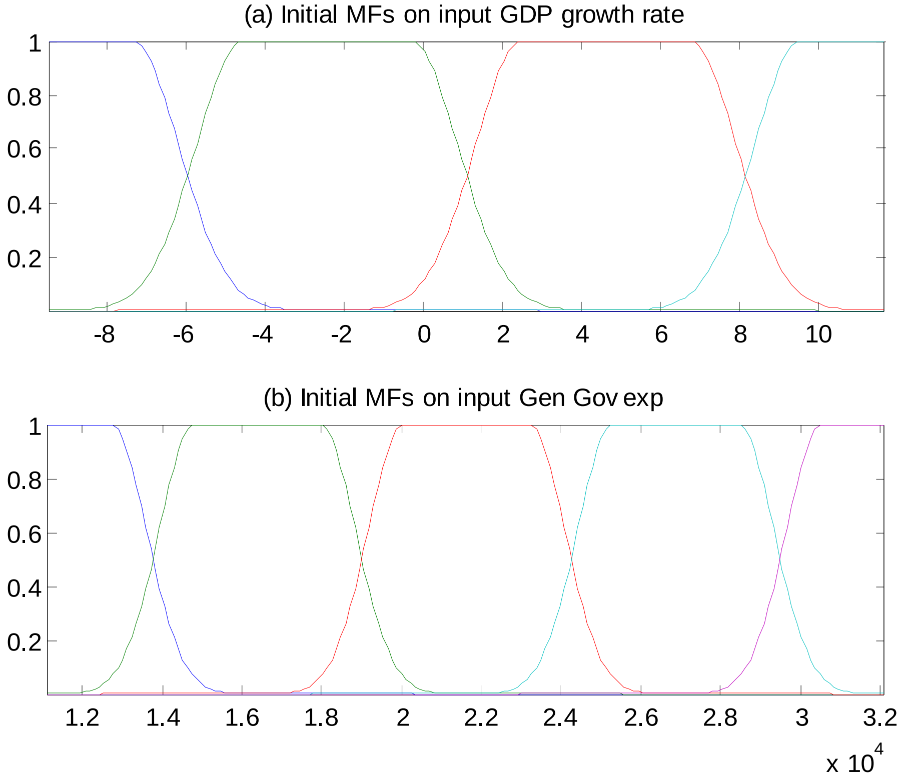

Figure 4.8.17. Gaussian membership functions act on input variables.

The third layer (twenty blue nodes) consist the nodes that apply the rules of fuzzy logic and which are presented in detail below:

- 1. If GDP growth rate is too small and General Gov. Expenditure is too small then Labor productivity is O_1 (1)
- 2. If GDP growth rate is too small and General Gov. Expenditure is small then Labor productivity is O_2 (2)
- 3. If GDP growth rate is too small and General Gov. Expenditure is medium then Labor productivity is O_3 (3)
- 4. If GDP growth rate is too small and General Gov. Expenditure is large then Labor productivity is O_4 (4)
- 5. If GDP growth rate is too small and General Gov. Expenditure is extra large then Labor productivity is O_5 (5)
- 6. If GDP growth rate is small and General Gov. Expenditure is too small then Labor productivity is O_6 (6)
- 7. If GDP growth rate is small and General Gov. Expenditure is small then Labor productivity is O_7 (7)
- 8. If GDP growth rate is small and General Gov. Expenditure is medium then Labor productivity is O_8 (8)
- 9. If GDP growth rate is small and General Gov. Expenditure is large then Labor productivity is O_9 (9)
- 10. If GDP growth rate is small and General Gov. Expenditure is extra large then Labor productivity is O_{10} (10)
- 11. If GDP growth rate is medium and General Gov. Expenditure is too small then Labor productivity is O_{11} (11)
- 12. If GDP growth rate is medium and General Gov. Expenditure is small then Labor productivity is O_{12} (12)
- 13. If GDP growth rate is medium and General Gov. Expenditure is medium then Labor productivity is O_{13} (13)
- 14. If GDP growth rate is medium and General Gov. Expenditure is large then Labor productivity is O_{14} (14)
- 15. If GDP growth rate is medium and General Gov. Expenditure is extra large then Labor productivity is O_{15} (15)

- 16. If GDP growth rate is large and General Gov. Expenditure is too small then Labor productivity is O_{16} (16)
- 17. If GDP growth rate is large and General Gov. Expenditure is small then Labor productivity is O_{14} (17)
- 18. If GDP growth rate is large and General Gov. Expenditure is medium then Labor productivity is O_{18} (18)
- 19. If GDP growth rate is large and General Gov. Expenditure is large then Labor productivity is O_{19} (19)
- 20. If GDP growth rate is large and General Gov. Expenditure is extra large then Labor productivity is O_{20} (20)

The values $O_1 – O_{20}$ are the outputs of each rule, which are calculated by the formula (3.7.1.7), for i=1,2,3….,20.

The schematic representation of these twenty rules of fuzzy logic is presented in the figure 4.8.18, below. Each row refers to a rule. The first column represents the first input, the second column represents the second input and the third column represents the output. For example, in the first rule represented by the first row, it is stated that, when the value of the first input (GDP growth rate) is x and the value of the second input (General Government Expenditure) is y, then the output is O, which derived from the node function (3.7.1.7),

$$O_{4,i} = \overline{w}_i \cdot f_i = \overline{w}_i (p_1 \cdot x + q_i \cdot y + r_i)$$

where is analyzed at the paragraph 3.7.1., while the parameters p_i, q_i, r_i, are determined by the training data.

The red vertical lines of the first and second columns diagrammatically indicate the point of activation of the rule, while the color range in which each rule has been activated is shown in yellow. There is a case depending on the values of the data that no rule is activated at all.

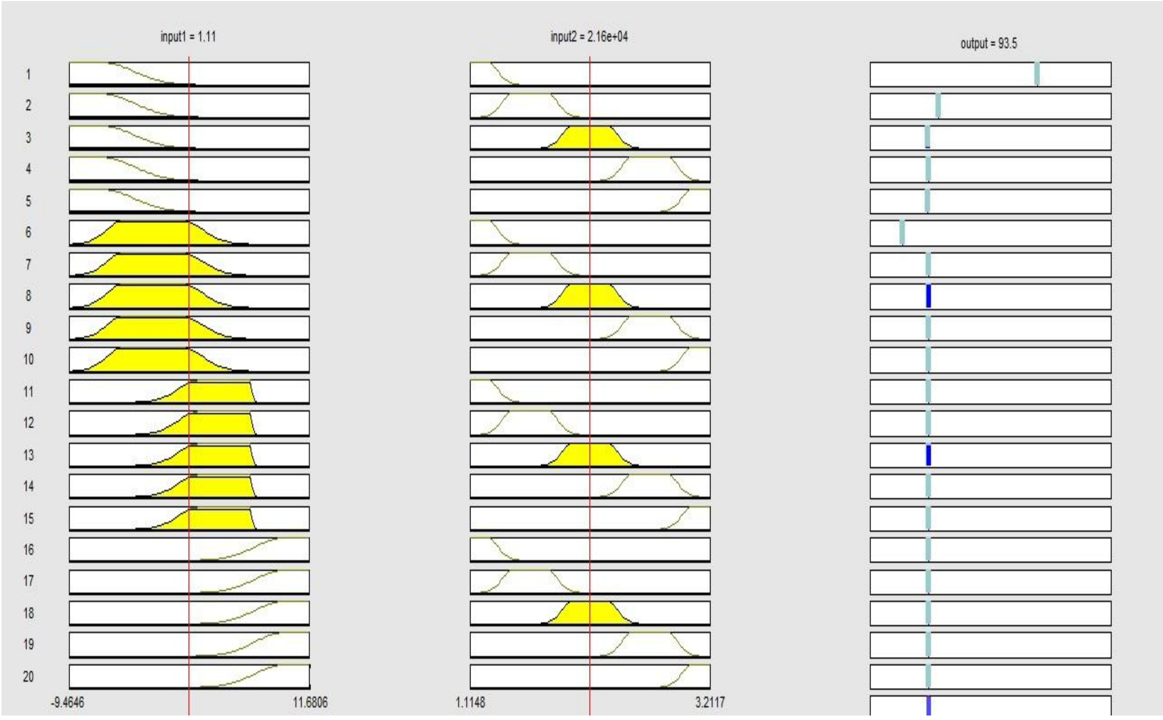

Figure 4.8.18. Schematic representation of these twenty rules of the ANFIS model, which shows the field of activation of each rule (yellow color) and the finding of the output value.

In the fourth layer of figure 4.8.16, the action of the membership function, represent fuzzy sets of respective input variables, (figure 4.8.19), and provides output values resulting from the inference of rules. This output according to 3.9, is simply a product of normalized firing rule strength and first order polynomial. Weighted output of rule represented by node function as:

$$O_{4,i} = \overline{w}_i \cdot f_i = \overline{w}_i (p_1 \cdot x + q_i \cdot y + r_i)$$

where $\bar{w}_i$ is the output of layer 3 and $\{p_i, q_i, r_i\}$ is the parameter set. In the next table 4.8.8 is presented all the parameters $\{p_i, q_i, r_i\}$, for each rule. The value of the weight (w) is equal to one and as shown in the table, some rules are not activated as the parameters value is zero.

Table 4.8.8. Presented the parameters for each rule.

RULES	Parameters (*p*, *q*, *r*)
Rule 1	[0.02796 14.47 0.001838]
Rule 2	[-5.767 1.347 -0.1038]
Rule 3	[-57.19 -0.04467 899.4]
Rule 4	[0.9049 0.002056 46.93]
Rule 5	[-14.15 0.01507 -447]
Rule 6	[12.84 -3.415 0.5234]
Rule 7	[-385.2 0.09935 -78.83]
Rule 8	[0.8741 0.004369 21.82]
Rule 9	[1.394 -0.003572 195.6]
Rule 10	[-19.22 0.001851 -9.486]
Rule 11	[-15 0.04266 7.596]
Rule 12	[-9.887 0.002952 104.7]
Rule 13	[5.139 0.003784 -14.91]
Rule 14	[22.03 -0.01124 269.1]
Rule 15	[-32.26 -0.01467 672.8]
Rule 16	[-1.384 0.006469 18.4]
Rule 17	[-5.404 0.002466 91.48]
Rule 18	[1.156 0.001542 54.23]
Rule 19	[2.102 0.003087 5.146]
Rule 20	[-102.7 0.03928 -290.8]

The fifth layer which sums up all the inputs coming from the fourth layer and transforms fuzzy classification results into crisp values. The final membership function trapezoidal type of ANFIS model after the training, are presented at the next figure 4.8.19.

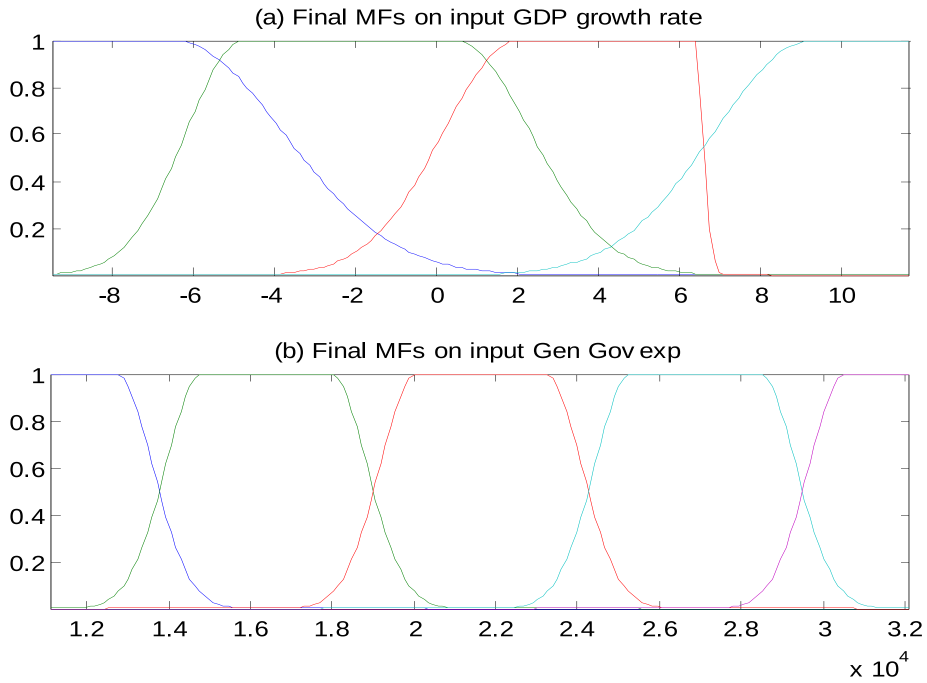

Figure 4.8.19 Act of Gaussian Membership function in input variables.

Finally at the figure 4.8.20, a representation in the three-dimensional space of the output with respect to input1 and input2 is presented. The training data are distributed almost uniformly within the control area, without any significant abrupt changes of the surfaces. This means that the training data was quite satisfactory and the representation of the dynamic relationships between inputs and the output is also satisfactory as there are no significant abrupt changes in the edges of the surfaces.

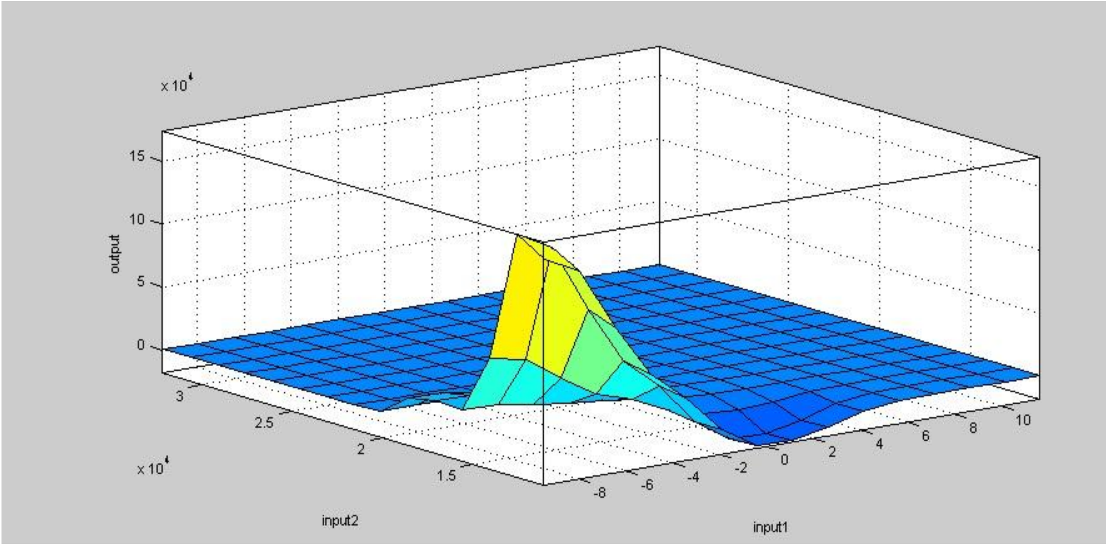

Figure 4.8.20 Input-output resulting area is presented.

These crisp values are shown in the next diagram, at figure 4.8.21 which are the prediction values for ANFIS model with the red color and can be schematically compared with the actual values with the blue color, where it is observed that they are very close to each other. These ten crisp values of the diagram 4.8.7 are essentially the values of the Labor productivity per hour, as calculated by Eurostat for the third quarter (Q3) of 2017 to the fourth quarter (Q4) of 2019.

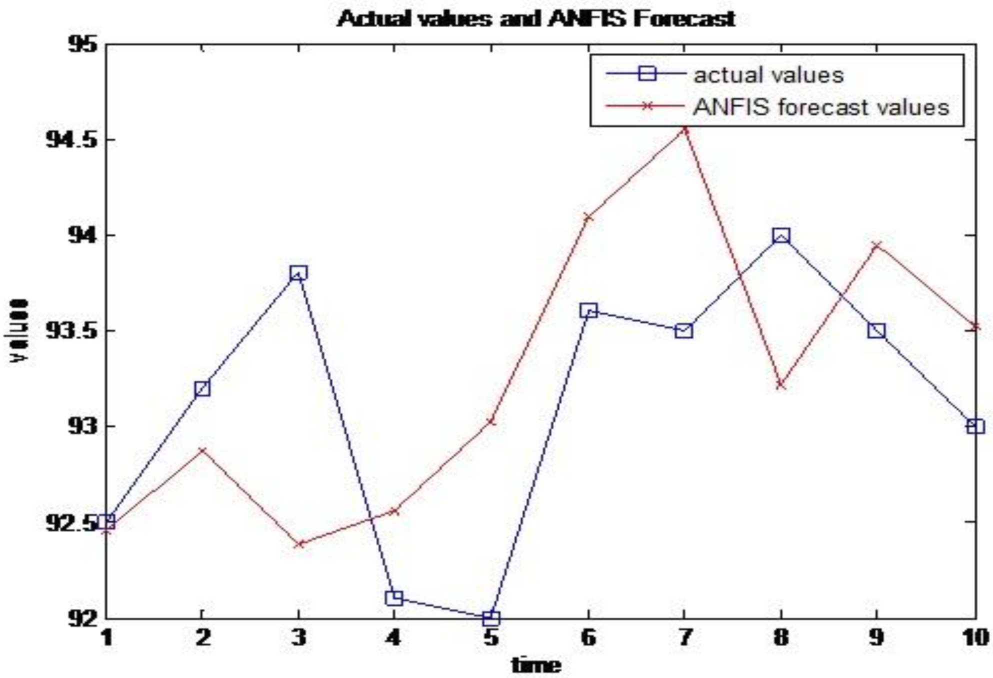

Figure 4.8.21. The ANFIS forecast values compared with the actual values of the output variable (Labor productivity).

Actually for the 3rd and 4th quarter of 2017, the 2nd quarter of 2018, the 4th quarter of 2018, and for the 3rd quarter of 2019 the forecasting value of the Labor productivity per hour for Greece are very close to the actual values of the Greek Labor productivity per hour. For the remaining quarters between 2017-2019, the forecast values are enough close to the actual values, so that the overall display of values can be confirmed with certainty the implementation of this ANFIS model to forecast the impact of interest groups on Greek economy.

The reliability of the ANFIS model in addition to the output values forecasted and are almost identical to the actual values, is also confirmed by the theory (3.8). The criterion for the reliability of the model is the arithmetic errors MSE, RMSE, MAE, MAPE which shown in the table 4.8.9.

Table 4.8.9. Arithmetic errors for the evaluation of the model.

MSE	RMSE	MAE	MAPE
0.5817	0.7627	0.6572	0.7049

These evaluation errors are quite low and acceptable, as a very good representation of the forecast points gives the corresponding diagram in figure 4.8.21. These are the third lowest arithmetic errors of all the rest that emerged from application of all possible configurations of ANFIS model.

Summarizing, in this paragraph were presented in detail the model's configuration that gave the optimum evaluation results from all the runs of the 4.7 paragraph. These optimum results were emerged, as they have the smaller arithmetical errors and this is the main evaluation criterion. The configuration of the models with the lower errors are shown in the next table 4.8.10.

Table 4.8.10. The lowest arithmetic errors from all the different model's configurations

Number of Application	Epochs	Step size	Membership function	Number of rules	MSE	RMSE	MAE	MAPE
1st	1500	0.1	Trapezoidal	20	0.2681	0.5178	0.3505	0.3771
2nd	1000 & 1500	1	Triangular	25	0.5555	0.7453	0.6559	0.7046
3rd	1000 & 1500	1	Gaussian2	20	0.5817	0.7627	0.6572	0.7049

The first application of the above table 4.8.10 has the lowest errors from all the others runs of the ANFIS model as presented to tables 4.7.1 – 4.7.36. More analytically, this model configuration operate with 1500 epochs (repetitions), step size equal to 0,1 (training step), trapezoidal membership function and has a Suggeno type of Fuzzy Inference System (FIS), therefore this is the best model. The excellent performance of this model is also confirmed by the diagram in figure 4.8.7, in which the forecast values are very close to actual values.

4.9 Discussion

The results of this research confirm the implications of the influence of special interest groups on the Greek economy, as developed by Olson's theory. Olson uses the exclusive interest group model developed in the Logic of Collective Action (1965) to account for differences in national incomes, growth rates, inequality, unemployment, and susceptibility to business cycles. Also, in his pionner study The Rise and Decline of Nations (1982) develops nine (9) specific implications on the country's economy by the action of special interest groups. In this research, three main implications were studied, the second (2nd), the fourth (4th) and the seventh (7th), which were developed in paragraph 1.4..

The successful forecasting with the ANFIS model of labor productivity for the period Q3 2017 to Q4 2019, which model was trained with quarterly data for the period 1999 to 2017, confirms the action of interest groups in Greece and by extension it confirms the Olson's second implication. The modern researchers for the action of interest groups in Greece, refers to their role from the 1974 onwards, after the falling of dictatorship, (Mavrogordatos 1988; Mavrogordatos 2009; Pelagidis and Mitsopoulos 2006, Lavdas 2007, Atsalakis et al. 2016).This report by researchers is not accidental. Greece after the end of the Second World War, had the misfortune to start a civil war (1946-1949), where it gave the gratuitous shot to its economy. When the rest of the European countries closed their wounds and proceeded with the industrialization and development of entrepreneurship and trade, even the great losers of the war, in Greece there was a civil war and this resulted the delay in the beginning of economic development. It had to deal with the destruction of the productive fabric, foreign borrowing, high public debt and the political crisis due to weak governments. Despite these problems, after 1955 there was a high rate of growth in the country's GDP, but in 1967 the country experienced another political instability, the imposition of the colonel's coup, which lasted eight (8) years, until 1974. After the fall of the dictatorship in 1974, Greece had a stable democratic political system until today.

Essentially, it is the application of the second impact of Olson's theory in Greece, where in countries with political stability and immovable borders, the development of interest groups is favored. Thus, with evidence, the researchers' references to the work of the interest groups in Greece are fully confirmed by the second implication of Olson in Greece.

Further, the results confirm the seventh implication, which states that, distributional coalitions due to interest groups, slow down a society's capacity to adopt new technologies and to reallocate resources in response to changing conditions and thereby reduce the rate of economic growth. Special interest groups slow down growth by reducing the rate at which resources are distributed from one activity or sector to another in response to new technologies or conditions. An obvious way to do this is by demanding government guarantees on debt redemption for businesses in recession, delaying or preventing the transfer of resources to areas where they would have higher productivity rates (Hicks, 1983). Increasing productivity means that resources should be reallocated if they are to maintain economic efficiency, and society should fully exploit the rise in productivity.

Required resource reallocations will be prevented or they will be delayed by entry barriers. Even if there is no accumulation of special interest groups over time, barriers for reallocation of resources that are created by such groups would reduce the growth rate and the absolute level of income (Atsalakis et al. 2016).

Also, the successfully forecasting of the labor productivity for the period between the third quarter of 2017 to the fourth quarter of 2019, confirm the correctness of choosing the specific variable as an output variable, given that the input variables are GDP growth rate and the General Government Expenditure. In the paragraph 4.5 were fully developed the factors as they emerged from the literature and led to the choice of labor productivity as an output variable.

As emerged from the results of the paragraph 4.8, it is confirmed the 4th implication which refers "*On balance, special interest organizations and collusions reduce efficiency and aggregate income of the societies in which they operate and make political life more divisive*", as far as the economic side of the implication is concerned. Besides, this doctoral thesis only studies the economic effects of the action of interest groups in the Greek economy and not the political effects.

Consequently, it is fully confirmed that special interest organizations and collusions reduce efficiency and aggregate income of the societies but the effect it has on the political landscape of the country has not been studied.

CHAPTER V

CONCLUSIONS – PROPOSALS

5.1 Conclusions

Neuro-fuzzy modeling is an evolving approach to compute the combination of human mind's ability to explain and learn in an uncertain environment and inaccuracy. It was created by the realization that to solve realistic problems requires the usage of smart systems which combine knowledge, methodologies and techniques from different fields. These intelligent systems need to posses specialized human knowledge, adapt and learn in a changing environment and explain how they make decisions or how they act.

The combination of neural networks and fuzzy logic, as methodologies, compose the hybrid systems. The usage of hybrid systems is growing rapidly with successful applications in areas such as stock market analysis and prediction, engineering design, process control, forecasting methods, credit card analysis, medical diagnosis, and many more cognitive simulations (Sivanandam and Deepa 2007).

The present research uses an advanced hybrid model, the ANFIS, a neuro fuzzy system that determines its parameters by processing data samples with the usage of a learning algorithm derived from the neural network theory (Sivanandam and Deepa 2007). Fuzzy systems and neural networks are combined in order to join their advantages and to cure their individual disadvantages.

The aim of this doctoral dissertation is to use an advanced model of soft computing in order to study the impact of interest groups on the Greek economy. As presented in detail in the first chapter of the dissertation, special interest groups act in the modern economies of countries with stable borders and democratically elected governments, according to Olson's theory. Based on the implications of the special interest group's action, as Mancur Olson mentions in his pioneering book "Rise and Decline of Nations", there are strong indications of a similar action of interest groups in Greece especially after 1974. Therefore, the research concerns the period from 1998 to 2019, where it was possible to find all the required data for the variables as they emerged from the literature.

As there was no other study in this field of research, it was necessary to determine the appropriate economic parameters affected by the action of interest groups. An extensive bibliographic research on the action of interest groups in all the countries was necessary to find out the variables that reflect this action of the interest groups in the economy of a country. From a large set of variables and despite the difficulty to find out data for all the variables, using the appropriate methodology and tools such as the Principal Component Analysis, it is emerged that two variables are capable to express the effect of interest groups in the Greek economy. Therefore, the variables GDP growth rate and the Final Consumption Expenditure (government spending) have been used as input variables in ANFIS model and the variable Labor Productivity per hour worked, as the output variable.

With quarterly data from 1999 to 2019 for the input and output variables, the model of ANFIS algorithm, does the required training and then predicts the values of the output variable while calculating the arithmetic errors for the evaluation of the model. All the results obtained from the runs of the algorithm were recorded, taking into account all the possible values of the model configuration. The results are all presented in the dissertation and it is observed that many results generally have small arithmetical errors which is significant for the research as it is the main evaluation criterion of the model.

The three applications with the lowest arithmetic errors stood out, for which the operation of the model and its configuration were presented in detail, the rules of fuzzy logic that were created, as well as the diagrams of the prediction of the output variables values. The diagram image which reliably predicts the last ten time values of the output variable, as well as the trend of change of these values confirm the choice of the forecast model, as well as that the specific input and output variables have been selected correctly.

The successful ANFIS model results confirm the theory of Mancur Olson and more specifically the three main implications (the second (2nd), the fourth (4th) and the seventh (7th)), that he mentions in his pioneer work The Rise and Decline of Nations (1982) and has been presented in detail in the previous paragraph (4.9).

5.2 Future research

This doctoral thesis opens a new window at the research field of the interest groups implications in an economy. Following the methodology that developed in this dissertation can be studied the impact of the interest groups action in an economy of any European country or any other country out of the European borders.

It will be interesting to study the variables that affect the economy for another country, because of the action of interest groups. In the begging, is necessary to test the correlation of all the variables and then by the methodology of Principal Component Analysis to find out the most significant variables. For some countries maybe the same variables as emerged from this dissertation GDP growth rate, General Government Expenditure and Labor productivity, will also arise, but for other countries some others will arise. It is important that for the first time a group of variables has been developed which is related to the action of interest groups and has emerged from the literature search (Papadakis and Atsalakis 2019). This group of variables can be the starting point of any future research in this field.

A modern and reliable prediction model was used in this dissertation, the ANFIS model. Nowadays many other models have been developed and it would be interesting to do the corresponding study of the specific variables and data with another model.

A Fuzzy model that capture the knowledge of experts can be developed, or another future research could be the development of empirical research that shows the effect of the action of interest groups in the economic sector of the countries.

Finally, with the use of the variables that emerged from the specific research and with the use of an appropriate model, a classification of the countries could be made, based on the level of influence of the interest groups, in the economy of each country.

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ANNEX – Abbreviations

ANFIS	Adaptive Neural Fuzzy Inference System
ANN	Artificial Neural Networks
ARDL	Auto Regressive Distributed Lag
B.A.	Bachelor of Art
CEIC	Global Economic Data Company
CPI	Consumer Price Index
DmEFuNN	Dynamic Evolving Fuzzy Neural Network
EEC	European Economic Community
FDI	Foreign Direct Investment
FIS	Fuzzy Inference System
GDM	Geometric Direct Minimization
GDP	Gross Domestic Product
GINI coefficient	Measure of statistical dispersion
GNP	Gross National Product
GSEE	General Confederation of Greek Workers
GSP	Gross State Product
EFuNN	Evolving Fuzzy Neural Network
EMU	Economic and Monetary Union
EU	European Union
FALCON	Fuzzy Adaptive Learning Control Network
FINEST	Fuzzy Inference and Neural Network in Fuzzy Inference Software
FIS	Fuzzy Inference System
FUN	Fuzzy Net
GARIC	Generalized Approximate Reasoning based Intelligence Control
Gen. Gov. Exp.	General Government Expenditure
H.S.A.	Hellenic Statistical Authority (EL.STAT.)
IMF	International Monetary Fund
LSM	Least Squares Method
MAE	Mean Absolute Error
MAPE	Mean Absolute Percentage Error
MF	Membership Function
MoU	Memorandum of Understanding
MSE	Mean Square Error
NFC	Neuronal Fuzzy Controller
NFN	Fuzzy Neural Network
NFS	Neuro-Fuzzy System
NN	Neural Networks
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
PCA	Principal Component Analysis
PCs	Principal Components
PRLC	Political Rights and Civil Liberties Values
RMSE	Root Mean Square Error
RSA	Rent Seeking Activity

SEK	Socialist Worker's Party
SIG's	Special Interest Groups
SONFIN	Self Constructing Neural Fuzzy Inference Network
SPSS	Statistical Package for the Social Sciences
SS	Step Size
US	United States
USA	United States of America
USD	United States Dollar
VAR model	Vector Autoregressive model
WVS	World Values Surveys