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ANALYSIS OF RICE FARMERS' ACCESS TO AGRICULTURAL CREDIT AND PROFITABILITY IN SOUTH TOGO

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Komlan Edem Agboklou[1], Burhan Ozkan[2]
[1]Akdeniz University, Faculty of Agriculture, Department of Agricultural Economics, Antalya, Turkiye.
tobeagboklou@gmail.com , ORCID: 0000-0001-8684-1473
[2]Akdeniz University, Faculty of Agriculture, Department of Agricultural Economics, Antalya, Turkiye.
bozkan@akdeniz.edu.tr , ORCID: 0000-0002-9799-654X

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ABSTRACT

Purpose- Access to suitable production means is required for producers to improve their profitability. As a result, agricultural financing appears to be a critical tool for attaining this goal. Various programs and donors have been attempting for decades to put together initiatives that would make it easier for the most disadvantaged populations, including the primarily agricultural rural world, to access sources of financing. Due to poor performance, the majority of these programs have failed. This study aims to investigate the determinants of credit access and how loans affect rice farm profitability.

Methodology - Data for this study were collected from 102 producers living in the two biggest paddy production zones in southern Togo. The treatment effect model was used to examine the data collected through the survey investigation.

Findings- Gender, asset type, producer experience, access to credit information, primary occupation, and land ownership status of the producer are all factors in determining rice growers' access to credit. Gender, producer experience, access to credit information, and land ownership status all have a beneficial impact on credit availability. However, asset type and the producer's main occupation have a negative impact. It also demonstrates that whether rice farms have access to loans has little bearing on their profitability. On the other hand, the average treatment impact of credit access is statistically significant. It also shows that the farmer's degree of education, expertise in the field, and lastly, the size of rice field farmed are the most important elements affecting the profitability of rice fields.

Conclusion- The findings have policy implications, increasing the channels for disseminating credible information about funding sources, access procedures and the institutions in charge of these funding sources. Integrating the enhancement of farmers' educational levels into rural support initiatives, and the extension of major agricultural landscaping works undertaken by the government to other areas suitable for rice cultivation.

Keywords: Agricultural credit, rice production, Probit-2SLS model, Togo.
JEL Codes: C26, D14, Q14

1. INTRODUCTION

As for most African countries, agriculture plays a very important role in development and the fight against extreme poverty. The economy of Togo is largely based on subsistence and commercial agriculture, with the agricultural sector accounting for over 54% of employment and about 40% of national income. The main agricultural products grown are coffee, cocoa, cotton, potatoes, cassava, maize, beans, millet, rice, and sorghum. Of these products, coffee, cocoa, and cotton are the country's major export items, and agricultural products account for more than 20% of export revenues (MAEP-FAO, 2013).

In developing countries, most agricultural producers are smallholders, usually depending on small-scale family land and labor. Most farmers in developing countries are smallholders, operating on a limited scale and often relying on family land and labor. Although there is no clear data available, in Togo, agriculture is mostly subsistence agriculture, but most of the time combined with cash crops (Djagni, 2002). According to (Adessou et al., 2017) smallholder producers in Togo refer to farmers who are unable,

on their own, to attract or secure the various benefits they need to improve the productivity of their production capital, i.e., production goods, agricultural advice, marketing facilities, and, of course, credit and savings facilities. The increase in loan access to small-scale producers will boost their capacity for appropriate farmland, labor, and technology acquisition to improve production and earn more profit (Sarfo, 2018).

In Togo, Finscoop, (2016) consumer survey result on financial inclusion results show that only 27% of Togolese have access to credit and most of the financially excluded are rural populations. Some sources reveal that, in Togo, the weak access to agricultural loans for producers impedes the development of the agricultural sector. These sources indicate that just about 12% of households benefit from agricultural loans, although credit is an instrument for the development of agricultural and rural activities, as are agricultural research and extension services. Due to the lack of adequate financial services, small-scale farmers had no alternative except to rely on usurious credit to acquire their inputs. Farmers are forced to borrow at usurious rates from businesswomen due to a lack of resources and difficult access to formal credit. These loans are used to cover expenses such as the purchase of inputs at the beginning of the season; remuneration of the workforce; the purchase of cereals during the lean season; and school fees. These loans, at interest rates approaching 100% over six months, usually mature during the harvest.

The need for cash at harvest time, combined with difficult access to credit, a lack of savings, and inadequate or no storage facilities, leads producers to discount their production at harvest time. This vicious circle of selling off production and low income, in which many Togolese producers find themselves, places them in a situation of great vulnerability. In addition, this severely impedes their ability to produce, innovate and invest and consequently greatly reduces their annual income (Mackiewicz-Houngue et al., 2014) Given the importance of access to agricultural credit for producers and the very important role that formal credit sources should play in the agricultural sector, this study proposes to first investigate the determinants of agricultural loan access in two rice-producing areas in Togo and the effect of access to credit on the profitability of rice farms.

Many studies have been conducted on the determinants of access to credit for agricultural producers in many countries (Abdul-Jalil, 2015; Akpan et al., 2013; Avocevou, 2003; Baiyegunhi, 2008; Diagne, 1999). Some have also sought to assess the impact of access to credit on the profitability of producers (Mghenyi, 2015; Nzomo & Muturi, 2014; Ogunleye, 2018; Rahman et al., 2014; Sarfo, 2018). In the case of Togo, empirical studies on producers' access to agricultural credit are minor (Adessou et al., 2017; Ali & Awade, 2019; Julien et al., 2021). According to the literature, no study has been conducted in Togo on the relationship between credit availability and farm profitability. It is; therefore, appropriate to take a look at these subjects which are of capital importance. Thus, the purpose of this work is to analyze access to agricultural credit and its effect on the profitability of rice producers. This paper is organized as follows. The next section is the literature review, and section 3 provides information about the methodology. Section 4 reports the empirical results, and the conclusion is given in section 5.

2. LITERATURE REVIEW

2.1. Empirical Evidence of Credit Accessibility Determinants

A lot of research has been done in all countries on the determinants of credit access among rural populations. According to these studies, access to credit is influenced by a number of factors that are or are not related to the characteristics of the borrowers. According to Tetteh Anang et al., (2015), gender, household income, farm capital, improved technology adoption, contact with extension agents, the location of the farm, and awareness of lending institutions in the area, are the main determinants of credit access in Northern Ghana. Mashile, (2014) finds that low levels of education, main occupation, group membership, and household income are significant and have encouraging effects on access to credit and financial services in Gauteng province (South Africa).

According to Kodjo et al., (2003) and Avocevou, (2003) diversification of activities and livestock ownership positively influence access to credit. Being a woman, being a member of a farmer's organization or structure, or having a material guarantee facilitates access to credit. Finally, the interest rate positively affects access to credit. For Phan, (2012) in the Mekong River Delta, Vietnam, the positive determinants of formal microcredit accessibility are: being a local government employee, having credit group membership and a poor certificate, educational attainment, working skills, and village road access. In their research on livestock farmers' credit access in Ebonyi State, Nigeria, Ume et al., (2018) find that off-farm income, level of education, farming experience, and membership in an organization are the determinants of producers' credit accessibility. According to Baiyegunhi, (2008) credit is supplied by lenders; in other words, credit access by households is largely determined by gender, monthly income, asset value, savings, dependency ratio, repayment capacity, and social capital, among other things. In Togo, Julien et al., (2021) found that gender, membership in a financial solidarity group, sown area, marital status, type of association, and interest rate are the determinants of agricultural credit demand. On their side, Ali & Awade, (2019) showed that farmers' age, membership in a

soybean organization, selling the soybeans to a recognized NGO or a private organization, and growing cotton or cashew are the main determinants of access to the full amount of credit.

2.2. Effect Of Credit Use on Farmers' Profitability

Credit is a very important input for any entrepreneurial activity. Therefore, like any business, agricultural activity also needs money. In farming, the importance of credit extends from soil preparation operations to harvesting and marketing (Sarfo, 2018). The capital shortage is one of the main problems impeding smallholder producers' activities. This situation prevents farmers from adopting new technologies and improving the efficiency of the agricultural sector. A well-structured credit market helps producers increase their consumption and input use, which in turn contributes to the improvement of their living conditions (Feder et al., 1990; Ayaz & Hussain, 2011).

According to Zeller, (2000) credit is a means of increasing income and consumption, future investment, and asset accumulation. Credit is naturally an instrument and a creator of value and growth. Investment and productivity cannot be developed without credit. The latter can be an instrument of equity if it is used in favor of the poor to "break down the walls of money" and reduce economic dualism and democracy (Bomda, 1998). According (Zeller et al., 1997), the availability of credit can significantly improve the ability of poor households lacking significant personal capital to purchase production inputs. According to Nzomo & Muturi, (2014), the efficient use of agricultural credit can increase income. Credit in terms of size serves a dual purpose: it expands economies of scale while also improving farm productivity from available resources.

3. METHOD

3.1. Source of Data

This study, as specified in its title, covers the southern Togo area. More specifically, it concerns two rice production areas, namely the Kovié and Agomé-Glozou areas located respectively in the Zio and Mono valleys, about 35 and 100 km from Lomé. These areas represent the two largest irrigated rice production zones in Togo (MAEP-FAO, 2013). Thus, only producers in the Kovié and Agomé-Glozou rice-producing areas were reached for data collection.

A multi-stage sampling method was used. In the first stage, the two largest paddy-producing regions in southern Togo were selected as research areas. Therefore, the Zio and Mono valleys have been selected. In the second stage, depending on the extent of the rice production area, the Kovié and Agomé-Glozou zones were targeted. Finally, producers were randomly selected for data collection. Since there is no data on paddy producers in our target zones, to compute the sample size, the following formula was employed (Anderson et al., 2013).

$$n = \frac{t^2 * p(1-p)}{e^2}$$

n: sample size,

t : confidence interval (generally 1.645 for 90% confidence interval),

p: the probability of the unit under study occurring in the population (p-value will be taken as 0.5),

e: degree of freedom (10%).

Using this formula, some 70 producers should be surveyed. At the end, a total of 102 producers were surveyed, 51 of whom had access to credit and 51 of whom did not, thus serving as a control group. The survey was conducted with Kobocollect.

3.2. Definition of Model Variables

This study aims to investigate the determinants of rice producers' credit access and assess the influence of accessing or not accessing credit on the profitability of their farms. Thus, access to credit (1=yes, and 0= otherwise) and farm profitability are the main dependent variables in this study.

The variables employed to specify the model are taken from the literature and take into account several assumptions. To investigate the determinants of credit access, many studies (Ankrah Twumasi et al., 2021; Baiyegunhi, 2008; Phan, 2012; Sossou et al., 2017) have used producers' socio-demographic characteristics, household characteristics, farm variables, financial structure variables as well as those of their products and other factors.

Phan, (2012) and Julien et al., (2021) used individual characteristics (age, gender, education level, main occupation) and household characteristics (size, agricultural land size, land ownership) to determine factors that influence microcredit access. In addition to the above factors, Baiyegunhi, (2008) also includes the variables "credit awareness" and the "assets" and other factors as those likely to determine credit access in the Eastern Cape Province, South Africa. Sossou et al., (2017) also included group membership (Social Capital) in addition to other variables to investigate credit access determinants in Benin. Farming experience, and extension services in addition to socio-demographic characteristics, were used by Oke et al., (2019); Akpan et al., (2013); Ankrah Twumasi et al., (2021) and Ume et al., (2018) to investigate the determinants of credit access. To assess the effect of access to microcredit on technical efficiency, Tijani *et al.*, (2009) and Ekwere and Edem, (2014) used age, family size, farming experience, educational status, and farmland size as control variables. Moreover, other variables were employed by Agbodji and Johnson, (2021); Awotide et al., (2015) ; Omolade and Adepoju, (2019); and Rahman *et al.*, (2014) to assess the effect of credit access on productivity. Finally, factors like age, household size, farming experience, educational status, and farm size were used (Rugube et al., 2019) to investigate the factors that influence the profitability of vegetable farmers in the Shiselweni Region, Kingdom of Eswatini, Swaziland. Thus, for our study, we retained variables such as age, gender, level of education, household size, and type of asset, membership in a farmer's organization, experience in agriculture, rice farm size, extension service access, credit awareness, the main occupation, land ownership, and other crop production. The detailed list of variables is presented in table 1.

Table 1: List of Variables

VARIABLE	SYMBOL	TYPE	A PRIORI EXPECTATION
Dependent Variable			
Credit Status: 1= Access to credit, 0= otherwise	ACCESS	Binary	
Profitability	PROF	Continuous	
Independent Variables			
Age (Age in years)	AGE	Continuous	Age is hypothesized to negatively affect the probability of having access to credit, so far that older clients may not be as active as younger ones in their enterprises.
Gender (Male=1,0 otherwise)	GENDER	Binary	The male is expected to have greater access to credit than the female; hence its expected sign is positive.
Scholar (level of education)	EDUC	Continuous	The coefficient is expected to be positive. Higher levels of education imply better technical knowledge and skills, and more information on markets and facilities provided by financial institutions.
Household size	HSİZE	Continuous	The coefficient of this variable is assumed to be indeterminate (+/-), insofar as, on the one hand, the size of the household could constitute a source of burden, hence the possibility of diverting the idea of using the credit and therefore difficulty in repayment. On the other hand, a large household size could be an asset in terms of labor and therefore the possibility of cultivating large areas and then having a lot of income and therefore ease of repayment.
Assets type	TASSET	Continuous	The type of asset that the producer has, could be a source of additional collateral and therefore could facilitate access to credit. We expect a positive sign for this variable.
Social Capital	APGRP	Binary	Belonging to a social network may be representative of the client's social relationships and may signal his ability to fulfill obligations. Its expected sign is positive.

Experience (Number of years of involvement in agriculture)	EXPER	Continuous	The number of years in agriculture is assumed to be positively correlated with access to credit. Indeed, the more the number of years increases, the more the producer is supposed to have experience and therefore has a good mastery of agricultural practices and presents less risk of failure.
Land size (for rice-producing)	SupRiz20	Continuous	The area of rice regularly produced by the producer is assumed to have a positive sign. The larger the area, the more likely it is that the producer will be considered a great producer, and thus more reassuring to financial services institutions.
Extension	EXTEN	Binary	Having access to extension services is assumed to improve the producer's farming practices and thus the probability of farm success. We, therefore, assume a positive sign for this variable.
Credit information (be informed about a credit source = 1, 0 otherwise)	INFCRED	Binary	Awareness may have a strong bearing on the accessibility of credit hence its sign is expected to be positive.
The practice of other crops	OCROP	Binary	Involvement in other crops is assumed to provide additional sources of income and thus more insurance in terms of repayment. A positive sign is therefore expected for this variable.
Main occupation	OCCUP	Continuous	The main occupation is supposed to have a positive influence on access to credit: a producer whose main activity is farming would be more reassuring and able to take good care of his farm.
Land ownership	OWNER	Continuous	Land ownership, as opposed to rental and other forms of access to land, is expected to increase the long-run investment incentives and the collateral value of the land to lenders. Its expected sign is positive.

Note: VARIABLE: Variables' full names; SYMBOL: Abbreviated names of variables; TYPE: The type of the variable; A PRIORI EXPECTATION: Variables explanation and its corresponding sign assumptions.

Tests of multicollinearity, heteroscedasticity, and normality analysis were performed. To identify any multicollinearity issues between variables, the variance inflation factor (VIF) is employed. According to Gujarati & Porter, (2009), the larger the value of VIF, the more "troublesome" or collinear the variable X. Generally, 10 is the threshold VIF's value, which, when exceeded shows that the variable is highly collinear. The test results indicate that the explanatory variables of our model do not suffer from any significant multicollinearity problem because none of the values exceeds 10 and the average is 1.587. To check for heteroscedasticity, the Breusch–Pagan test is used and the evidence shows no problem with heteroscedasticity (F =1.32 Prob = 0.2201). A normality test was performed, and the result indicated the residuals were normally distributed with a significance level of 5%. The Jacque Berra test was used, and the result is 2.93, which is less than 5.99, with a p-value equal to 0.231, which is more than 0.05, meaning that the null hypothesis could not be rejected. It was concluded that the residuals are normally distributed. Table 2 below presents the descriptive statistics of the study variables.

Table 2: Descriptive Statistics of the Variables

Variables	Description	Mean	Std. Dev.	Min	Max
Age	Age of the producer in years	40.96	10.048	20	75
Gender	Male=1,0 otherwise	0.68	0.470	0	1
Scholar	Level of education	1.26	1.024	0	4
Household size	The number of people in the household	4.42	2.23	0	12
TypeActif	The type of assets owned by the producer.	0.73	0.94	0	2

OP	Belonging to a social network	0.78	0.413	0	1
AnnAgri	Number of years of involvement in agriculture	20.03	10.47	2	45
SupRiz20	Sown rice area	1.03	0.73	0	4
Vulga	1=access to extension service, o= otherwise	0.93	0.25	0	1
Infocred	1=if access to credit information,0=otherwise	0.84	0.37	0	1
AutreCult	1=if involve in other crops production, 0= otherwise	0.85	0.37	0	1
Occup	1=agriculture, 2=Business, 3=Employed, 4=Artisan,5= Driver, 6=health staff, 7=Others	1.42	1.06	1	7
StatuFonc	1= owner of the land, 2=rental land	1.42	1.06	1	6

Note: Mean: Mean of the variables; Std.Dev: Standard deviation; Min: Minimum value of the variables; Max: Maximum value of the variables.

3.3. Model Specification

In our study, the selection equation's dependent variable is binary, and the research aims to analyze the influence of credit access or lack thereof on the profitability of rice farms. Based on the work of Hamilton & Nickerson, (2003) and Certo et al., (2016), two-stage least squares or treatment effects models would be more appropriate. Because the selection equation in our case was binary, the direct two-stage least squares regression could not be used.

As suggested by Cerulli, (2014), to exploit suitably the *binary* nature of the selection one can choose between the Probit-2SLS or the Probit-OLS model. Also, according to the same source, Probit-OLS compared to Probit-2SLS is less efficient and requires consistency that the Probit is "correctly" specified. Depending on this fact, the Probit-2SLS model will be used in this study.

In our study, access to credit will be considered as a "treatment" received by producers with access to credit. The treatment effect of accessing credit on the outcome variables (Z) represented here by the profitability of rice farmers is defined in the equation below.

$TE_i = y_{1i} - y_{0i}$

Where y_{1i} is the profitability of producer i in the case where he has access to credit, and y_{0i} is the profitability of producer i when he has no access to credit. According to Rosenbaum & Rubin, (1983), it's impossible to identify TEi because it refers to the same producer at the same moment. This means that only one of the two quantities is observable. The reason why one must rely on the estimation of average treatment effects (ATEs).

Average Treatment Effect = ATE = $E(y_1-y_0)$

In this study, the STATA command "ivtreatreg" developed by (Cerulli, 2014) is employed to compute the Probit-2sls model. Using the explanatory variable "X" and the instrumental variable "w" the predicted probability of getting credit is computed by the probit model.

$P_Y = E(Y|X,W) = Pr(Y=(1|X,W)$

Here, our instrument variable (w) is the variable "Credit information (INFCRED)". The structural system of (two) Equations is below:

$$y_i = \mu_0 + \boldsymbol{\omega_i} \mathrm{ATE} + x_i \boldsymbol{\beta} + \mu_{\mathbf{0i}}$$

$$\omega_i^* = \eta + q_i \delta + \varepsilon_i$$

$$\omega_i \begin{cases} 1 \text{ if } \omega_i^* \geq 0 \\ 0 \text{ if } \omega_i^* \leq 0 \end{cases}$$

$q_i = (xi, zi)$

Where equation (1) is the outcome equation, equations (2) and (3) are selection equations, and equation (4) is the exclusion restriction.

4. RESULTS

4.1. Determinants of Credit Access

Table 3 below presents the results of the probit-2sls model for the determinant of access to credit and its effect on rice farmers' profitability. The determinants of rice producers' credit access are gender (GENDER), type of assets owned by the producer (TASSET), the farmer's experience in agriculture (EXPER), access to information about credit sources (INFOCREDI), the farmer's main occupation (OCCUP), and the farmer's land ownership status (OWNER). Gender, experience, information access, and land tenure status also positively influence producers' credit access, as predicted by the study. Furthermore, asset type and main occupation negatively influence credit access, in contrast to the predicted trend.

In the process of granting credit access to the producers, the gender variable plays a positive role. The coefficient of the variable significant at 5% is positive, following its predicted sign. The reasons could be that women do not have easy access to production capital and, in addition, they rarely hold the role of household head, so they would not present sufficient collateral to financial institutions. Furthermore, since men are the natural owners of the land and the heads of the families in the community, they would have more credibility with the financial organizations. This result is consistent with those of Baiyegunhi, (2008); Sarfo, (2018); Zeller et al., (1994); Abdallah *et al.*, (2019); Siaw et al., (2021) and Agbodji and Johnson, (2021) according to whom this fact could mean the existence of discrimination against women. It can therefore be said that men are more privileged than women during credit access in the research zones. The result, on the other hand, contradicts those of Oke et al., (2019); Akpan et al., (2013), and Abdul-Jalil, (2015) according to whom being male negatively affects producers' chances to get access to credit.

The type of asset owned by the producer is negatively correlated with the probability of accessing credit, with a significant coefficient of 5%. Owing more non-productive assets than productive assets impede the chance of being granted credit. This result is consistent with that of Sekyi et al., (2017) who also found household asset type as one of the credit constraint factors. The result contrasts with that of Diagne, (1999), according to whom a household's asset composition influences more than the total value of the assets and the probability of accessing formal credit.

The experience of the producers in the agricultural field is likely to positively contribute to credit access. This finding is in line with those of Ume et al., (2018); Sarfo, (2018); Agyemang et al., (2020); and Ullah et al., (2020). According to Nwaru, (2004), more experienced producers are efficient in resource use and are likely to seek credit to increase their income by improving productivity. We can also assume that by being more experienced in the agricultural field, the producer would be more capable of exercising vigorously and would master the risks related to the profession, thus being more reassuring to financial institutions.

The easy accessibility of credit sources' information, according to its significant coefficient at 5%, positively contributes to the producers assess to credit. This finding is in line with those of (Chenaa et al., 2018; Lakhan et al., 2020; Rasheed et al., 2016; Ullah et al., 2020), who also came across the benefit of information access on credit accessibility. The probable explanation for this fact could be that a farmer with easy access to information on credit sources and procedures would be more likely to apply for credit and be granted it if possible. But a farmer without access to information will be less likely to apply.

The producer's main occupation is revealed to not be a credit accessibility support factor. With a negative coefficient significant at 10%, this variable negatively affects farmers' access to credit. Thus, a producer whose main activity is farming without any other activity would be less favored in terms of access to credit. This result conforms with Kiplimo et al., (2015); Ojo, (2003); Agbodji & Johnson, (2021); and Sekyi, (2017) who find that a farmer with extra income-generating activity has a greater chance of being granted a loan. Also, according to Zeller et al., (1998), this finding could be justified by the fact that many financial structures tend to give more credibility to business activities and therefore lend more easily to traders than to farmers. Farming is considered a high-risk activity. Commercial activity is considered more profitable in some respects and generates more frequent cash flows.

Farmers' land ownership status is found to be a supportive factor for credit access. It is what one can understand through its positive and significant coefficient. Working on your own farm area or having a legal right to it is likely to increase credit access. This finding is supported by Galang, (2020); and Knox *et al.*, (2021) who also found the beneficial importance of land ownership status on credit access. This result can be explained by the fact that many financial organizations employ land as collateral in their credit schemes, Hernando., (2000). The result is in contrast with Field & Torero, (2006) for whom property title is not significant in determining credit accessibility.

Table 3: Probit-2SLS Model Results

Step 1. Probit Regression **Number of obs = 102**
LR chi2 (13) = 36.63
Prob > chi² = 0.0005
Log-likelihood = -52.37 **Pseudo R² = 0.2590**

AccesCredi	Coef.	Std.Err.	z	P>z	[95%Conf.]	Interval]
Age	-0.020	0.021	-0.920	0.358	-0.062	0.022
Gender	**0.889**	0.391	2.280	**0.023**	0.123	1.655
scholar	-0.046	0.181	-0.260	0.798	-0.401	0.308
Taillemen	-0.057	0.085	-0.660	0.508	-0.224	0.111
TypeActif	**-0.394**	0.174	-2.270	**0.023**	-0.735	-0.054
OP	0.214	0.459	0.470	0.642	-0.687	1.114
AnnAgri	**0.060**	0.022	2.730	**0.006**	0.017	0.104
SupRiz20	-0.375	0.287	-1.310	0.190	-0.937	0.186
Vulga	0.533	0.820	0.650	0.515	-1.073	2.140
InfoCredi	**0.915**	0.458	2.000	**0.046**	0.016	1.813
AutreCult	0.257	0.413	0.620	0.534	-0.553	1.066
Occup	**-0.291**	0.163	-1.780	**0.074**	-0.611	0.029
StatuFonc	**0.268**	0.140	1.910	**0.057**	-0.008	0.543
cons	**-1.885**	1.093	-1.720	**0.085**	-4.028	0.258

Step 2. Instrumental variables (2SLS) regression

Source	SS	df	MS
Model	8.97e+06	13	6.90e+05
Residual	8.87e+06	88	1.01e+05
Total	1.78e+07	101	1.77e+05

Number of obs =102
Prob > F = 0.000
R-squared = 0.540
Root MSE = 307.020

	Without Heterogeneous Effect			With Heterogeneous Effect		
RENTA5103	Coef.	Std.Err.	P>t	Coef.	Std.Err.	P>t
AccesCredi	-88.718	293.638	0.763	-228.624	295.043	0.441
_Ws_SupRiz20				**716.113**	**148.829**	**0.000*****
Age	-3.907	5.236	0.458	-4.483	5.080	0.380
Gender	-167.062	110.595	0.134	-134.206	108.685	0.220
scholar	57.658	38.335	0.136	**83.748**	**37.224**	**0.027****
Taillemen	-21.901	19.529	0.265	-17.424	18.815	0.357
TypeActif	-39.602	48.494	0.416	-73.944	48.874	0.134
OP	33.416	99.788	0.739	85.485	98.066	0.386
AnnAgri	8.982	6.693	0.183	**11.223**	**6.599**	**0.093***
SupRiz20	**471.182**	**64.819**	**0.000*****	**172.634**	**93.457**	**0.068***
Vulga	161.856	173.478	0.353	65.214	166.173	0.696
AutreCult	131.211	96.417	0.177	70.392	93.141	0.452
Occup	-24.580	36.058	0.497	-37.942	35.430	0.287
StatuFonc	55.628	41.912	0.188	47.804	40.203	0.238
Cons	-462.984	210.867	**0.031**	-14.302	227.795	0.950

Instrumented: AccesCredi _ws_SupRiz20
Instruments : Age Genre scholar Taillemen TypeActif OP AnnAgri SupRiz20 Vulga AutreCult Occup StatuFonc G_fv _z_SupRiz20

Note: Number of obs: Number of observations; LR chi2: Likelihood ratio chi-square test value; Prob > chi2: Probability of obtaining the chi-square statistic value; Pseudo R2: Pseudo R-squared; AccesCredi: The dependent variable credit accessibility; RENTA5103: The dependent variable profitability of Rice farmers. Coef.: Coefficients; Std.Err.: Standard error; SS: Sum of Squares; df: Degrees of freedom; MS: Mean Squared Errors; R-squared; Root MSE: Root Mean Squared Errors.
***: 1% significance; **: 5% significance; *: 10% significance.

The marginal effects of variables were computed and presented in Table 4 below. The analysis of the results indicates that the gender variable is affected by a positive coefficient. Being a man in the research zone increases by almost 25.9% the probability of being granted a loan. Also with positive coefficients, the "experience of the producer", "information access," and "land ownership status" variables showed a positive marginal effect on credit access. The chances of accessing credit increase respectively by around 1.8%, 26.6%, and 8% if the producer has been practicing agriculture for a long time, has easy access to information on credit sources and credit procedures, and is working on his land. Affected by negative coefficients, the variables "asset type" and "main occupation" have negative marginal effects on the probability of getting credit in the research area. In effect, according to the coefficient, the probability of accessing credit decreases by 11.5% as the producer owns more non-productive assets and by 8.5% as the producer has farming as the only occupation.

Table 4: Marginal Effects of the Variables

Variables	Coefficients	Std.Err.	z	P>z	[95%Conf.	Interval]
Age	-0.006	0.006	-0.930	0.351	-0.018	0.006
Gender	**0.259****	0.105	2.470	**0.014**	0.053	0.464
scholar	-0.013	0.053	-0.260	0.798	-0.117	0.090
Taillemen	-0.016	0.025	-0.670	0.506	-0.065	0.032
TypeActif	**-0.115****	0.047	-2.430	**0.015**	-0.207	-0.022
OP	0.062	0.133	0.470	0.641	-0.199	0.323
AnnAgri	**0.018***	0.006	3.080	**0.002**	0.006	0.029
SupRiz20	-0.109	0.082	-1.340	0.181	-0.269	0.051
Vulga	0.155	0.237	0.650	0.513	-0.310	0.620
InfoCredi	**0.266****	0.126	2.120	**0.034**	0.020	0.512
AutreCult	0.075	0.119	0.630	0.531	-0.159	0.308
Occup	**-0.085*****	0.045	-1.870	**0.062**	-0.174	0.004
StatuFonc	**0.078****	0.039	2.010	**0.044**	0.002	0.154

Note: Std.Err: Standart errors; Z: Z statistic value; P>z: Computed P value; 95% conf. Interval: 95% confidence interval
****: 1% significance; **: 5% significance; *: 10% significance.*

4.2. Determinants of Profitability

The 2SLS regression results show that access to credit is not a significant factor for rice farm profitability (neither without or with heterogeneous effect). Without a heterogeneous effect, the variation in farmers' profitability is explained by only the land size. With a heterogeneous effect, the variation in farmers' profitability is then explained by idiosyncratic factors such as the level of education, experience in the agricultural field, and land size (see table 2). The influence of the area cultivated can be explained by the fact that the yields and selling prices of rice in these production areas are generally acceptable so that as the area of land cultivated increases, the yield tends to increase, and therefore the profitability of the producer moves in the same direction. This result confirms that of Mwambi et al., (2014); Pradhan & Ranjan, (2016) and Rugube et al., (2019).

Ceteris paribus, the producer's level of education positively influences the producer's profitability. This can be explained by the fact that a well-educated producer tends to better understand and respect technical itineraries, has a better grasp of farm management techniques and risks, and is therefore likely to have a good yield and, in turn, be more profitable. This result is consistent with (Dong et al., 2010) and (Rahman et al., 2014). This result is contrasted with those of (Ogunleye, 2018) and (Rugube et al., 2019).

A producer with many years of experience in the agricultural field would be better able to master the different parameters of his operation and know-how to better use the resources available to him and thus be more profitable. This result is in line with that of Ogunleye, (2018) who finds that producer experience positively influences the level of technical efficiency and hence productivity of cassava producers with access to credit in Osun State, Nigeria. This finding contrasts with Rugube *et al.*, (2019)

who discovered a negative impact of producer experience on profitability in the Shiselweni Region, Kingdom of Eswatini (Swaziland).

4.3. The Average Treatment Effect of Access to Credit

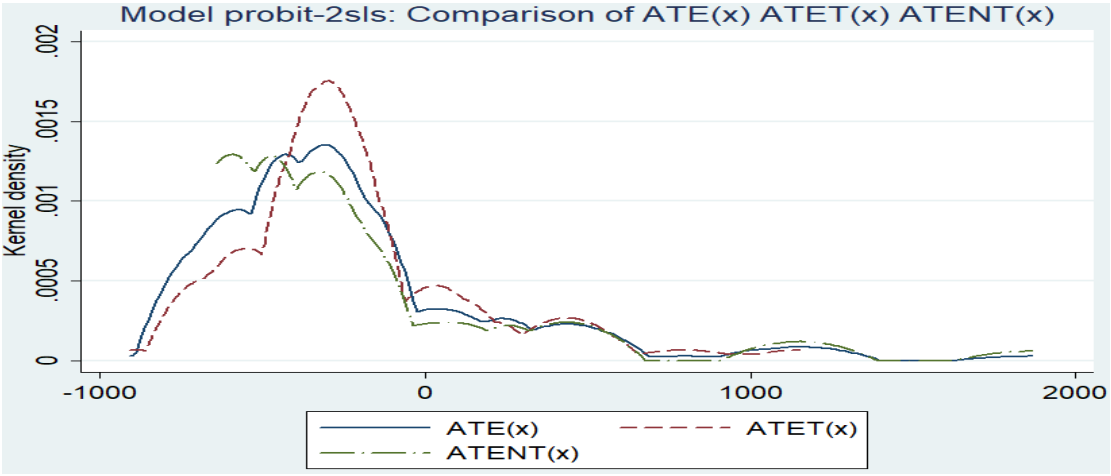
The results from the instrumental variables (2SLS) regression indicate that the ATET (average treatment effect on treated) of accessing credit is positive and statistically significant at 1% for the profitability of rice farmers (see table 5). Also, a comparison of the ATE, ATET, and ATENT was shown in Figure 1. The ATET values obtained without and with heterogeneous effects are the same and, are about $3.36. It means that farmers who have access to credit would have earned less profitability by $ 3.36 if they had not had access to credit. Between the two variables used to estimate the heterogeneous effects, only the coefficient of land size is positive and statistically significant at 1%. This means that farmers with a large area of rice would be more profitable. Thus, it can be argued that more than the variable access to credit, the area of rice cultivated has a greater impact on the profitability of rice farmers.

Table 5: Average Treatment Effects

	Without Heterogeneous Effect				With Heterogeneous Effect			
	Coef.	Bootstrap Std. Err.	z	P>|z|	Coef.	Bootstrap Std. Err.	z	P>|z|
ATET	1866.531	687.229	2.72	**0.007*****	1866.531	644.477	2.90	**0.004*****
ATENT	-639.863	396.846	-1.61	0.107	-639.863	311.480	-205	0.040**

Note: Coef: Coefficients; Bootstrap std.Err: computed standard error using bootstrapping.
***: 1% significance; **: 5% significance; *: 10% significance.

Figure 1: Probit 2SLS Model ATE, ATET, and ATENT Comparison



Note: ATE: Average Treatment effect; ATET: Average Treatment effect on Treated ATENT: Average Treatment effect on Non Treated.

5. CONCLUSION

The majorities of farmers in the Kovié and Agoméglozou zones are under 50 years old, have an average level of education, cultivate on government-developed land that they rent, own non-productive assets, are men, are members of farmers' organizations, practice mixed farming, have access to credit information, and have access to extension services, according to all these results.

Concerning the determinants of access to credit, demographic factors, and farm factors such as gender, asset type, producer' experience, access to credit information, principal occupation, and land ownership status of the producer are correlated with access to credit by rice farmers. Finally, only the results of the 2SLS model provided consistent estimators for the determinants of the profitability of producers with access to credit. Thus, the factor of interest, access to credit, taken exclusively, was found to

be insignificant for the profitability of farms, but its average effect on the treated group was statistically significant. Other factors, such as the amount of rice grown, the level of education, and the producer's experience, have been discovered to be determinants of credit-accessible producers' profitability.

Although access to credit is a very important factor for farming activities, according to the results of this study, it is not the only factor influencing farm profitability. Its effect appears to be less than that of the area of rice cultivated. This may imply the inadaptability of the credits made available to producers. Thus, as confirmed by the majority of producers, in addition to the fact that credit from formal and semi-formal sources is somewhat rare, it is also not adapted to agricultural activities. Either these credits are granted late compared to the agricultural calendar or they have high-interest rates with very restrictive repayment schedules.

Thus, the following recommendations could be made: (i) Financial institutions need to improve their agricultural financial services offerings to adapt them to the needs of rural populations. As a result, it is necessary to put on the market products that are better suited to the needs of producers, as well as more flexible terms that allow producers to feel secure. (ii) These institutions must also increase the number of channels for disseminating information on financial service offers to allow the rural world to obtain regular information from credible sources. (iii) The improvement of the education level of producers must be included in rural aid programs to significantly raise the literacy level of agricultural producers. (iv) This study, given the remarkable importance of the area of rice cultivated on the profitability of producers, strongly encourages policymakers to emphasize the development of large areas of rice in all areas suitable for rice production. This could allow more producers to have access to land and those who can plant larger areas could acquire them.

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ENVIRONMENTAL INFORMATION DISCLOSURE AND THE INVESTMENT-CASH FLOW SENSITIVITY

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Sheng Yao[1], Yuan Hong[2], Chen-Miao Lin[3]
[1]Shanghai University, Department of Accounting, School of Management, Shanghai, China.
Kj9704@126.com , ORCID: 0000-0002-8927-7983
[2]China University of Mining and Technology, School of Management, China.
1013514920@qq.com , ORCID: 0000-0003-2399-4178
[3]Clayton State University, Accounting, Economics, and Finance, Morrow, GA, USA.
Chen-MiaoLin@clayton.edu , ORCID: 0000-0002-4525-4405

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ABSTRACT

Purpose- In 2008 China issued the Measures for the Disclosure of Environmental Information. Using the introduction of this environmental policy, this paper examines how the environmental information disclosure quality affects a firm's access to capital markets. In particular, the relationship is investigated between the environmental disclosure quality and the investment-cash flow sensitivity, a measure of a firm's financial constraints, before and after the implementation of the policy.

Methodology- The content analysis is used to construct the measure of environmental disclosure quality. First of all, the contents of both qualitative and quantitative environmental disclosures are analyzed with respect to the following ten areas reported in firms' annual reports: (1) corporate investment in environmental protection, (2) government financial support related to environmental control, (3) tax reductions related to environmental programs, (4) lawsuits, settlements, penalties, and rewards related to environmental protection, (5) emissions and pollution reduction implementation, (6) certifications of environmental programs, (7) firm environmental protection missions and goals, (8) firm environmental protection plans and strategies, (9) bank loans related to environmental protection, and (10) other environmental-related information. And then, different points are assigned based on the disclosure quality for each of the ten disclosure areas and aggregated to obtain an overall disclosure score. Univariate and regression tests are used to examine the relationship between environmental information disclosures and investment-cash flow sensitivity.

Findings- A negative association is found between a firm's environmental disclosure quality and the investment-cash flow sensitivity after the policy was implemented, while no such association is found before the policy implementation. Furthermore, the observed reduction in investment-cash flow sensitivity tends to be stronger for firms in high-polluting industries.

Conclusion- Given the environmental policies in emerging markets are often viewed with great doubts, our findings suggest that government environmental policy plays an important role in firm's access to capital markets.

Keywords: Environmental information disclosure, investment-cash flow sensitivity, government policy, asymmetric information, financial constraints
JEL Codes: G18, G30, G32

1. INTRODUCTION

In 2008 the Ministry of Environmental Protection of the People's Republic of China issued the Measures for the Disclosure of Environmental Information (hereafter MDEI). Prior to the implementation of this policy, firms were encouraged to voluntarily disclose their environmental exposures to the public, but no mandatory public disclosure was required. The MDEI required mandatory disclosure for firms operating in the following sixteen high-polluting industries: thermal power, steel, cement, electrolytic aluminum, coal, metallurgy, chemistry, petrochemical, building materials, paper making, brewing, pharmaceuticals, fermentation, textiles, leather, and mining. The MDEI detailed the scope of disclosure requirements for pollutant discharges,

environmental emergency plans, environmental protection facilities and etc. as well as the methods of procedures. Although firms in low-polluting industries were not required to provide environmental disclosure, they were strongly encouraged to do so.

The introduction of MDEI allows us to examine how the environmental information disclosure quality affects a firm's access to capital markets. Particularly, what investigated is the investment-cash flow sensitivity, a measure of financial constraints, before and after the implementation of MDEI. Fazzari et al. (1988) argue that asymmetric information between the corporations and external fund providers makes it very costly or impossible for firms to have access to the capital markets. Accordingly, firms must finance their investment opportunities through their internal funds, and thus a greater investment-cash flow sensitivity for financial constrained firms. Empirically, they find a positive relation between investment and internal cash flows.

Both theory and empirical findings suggest that disclosure can increase a company's access to capital markets or lower the investment-cash flow sensitivity. Disclosure can enhance a firm's access to capital markets by reducing the "lemons market" problem in valuation discount (Myers and Majluf, 1984; Sanders and Boivie, 2004; Greenwald et al., 1984), and/or by reducing non-diversifiable estimation risk (Brown, 1979; Barry and Brown, 1984 and 1985; Coles and Loewenstein, 1988; Handa and Linn, 1993; Clarkson et al., 1996; Coles et al., 1995; Lambert et al., 2007). This reduction in information costs in turn leads to an increase in the liquidity of the company's securities and a reduction in the cost of raising outside capital (Botosan, 1997; Easley, Hvidkjaer and O'Hara, 2002; Bhattacharya, Daouk and Welker, 2003; Botosan and Plumlee, 2002; Francis et al., 2004; Botosan, Plumlee and Xie, 2004; Easley and O'Hara, 2004; Gietzmann and Ireland, 2005; Hughes et al., 2007; Sengupta, 1998; Baber and Gore, 2008; Hope et al., 2009).

In this study, no association is found between the disclosure quality and cash flow sensitivity of investment before MDEI was implemented for a sample of publicly traded companies in China. However, a negative relationship is found between environmental disclosure and the sensitivity of investment-cash flow after the issuance of MDEI. The results indicate that the environmental information disclosure quality has been increasing since MDEI was implemented and suggest that disclosures, by reducing the asymmetric information, increase a firm's access to the capital markets. Along this line, Surma (1992) states that "environmental issues can dramatically impact a company's short-term financial position and its chances for long-term success." Our finding is consistent with the notion that firm's superior corporate social responsibility performance is negatively associated with capital constraints as shown in several studies, for example, Cheng et al. (2014). Furthermore, the negative relation between the disclosure quality and investment-cash flow sensitivities is only significant for firms in high-polluting industries. This latter finding is consistent with the argument that since high-polluting firms face greater environmental issues and concerns, they are more inclined to provide more extensive disclosures to ease investors' concerns (Cho and Patten, 2007). Also, since the disclosure is mandatory for firms in high-polluting industries and voluntary for firms in low-polluting industries, our result suggest that the compulsory disclosure has a more pronounced impact on a firm's investment-cash flow sensitivities. Our results are robust to alternative measures of disclosure quality.

2. LITERATURE REVIEW

Literature has documented that environmental disclosure has an impact on firm value by either increasing a firm's future expected cash flows, or reducing its discount rate, or both. Richardson et al. (1999) argue that the disclosure quality affects firm value through the cash flow effects. Since the negligence of environmental issues possibly leads to regulatory interventions, fines, and penalties, the disclosure of company environmental risks and policies in annual reports provides important information for investors and other interested parties to estimate the impacts of regularly sanctions on future cash flows. Many empirical studies find evidence that environmental disclosure quality is positively associated with firm value (Hughes, 2000; Al-Tuwaijri et al., 2004; Rikhardsson and Holm, 2008; Ragothaman and Carr, 2008; Blacconiere and Patten, 1994; Iatridis, 2013, Clarkson et al., 2013; Plumlee et al., 2015). Plumlee et al. (2015) find that environmental disclosure increases firm value through the expected cash flow effects. Aerts et al. (2008) and Cormier and Magnan (2013) find supporting evidence showing that corporate environmental disclosure improves analysts' forecasts accuracy.

Richardson et al. (1999) also argue that the disclosure quality affects firm value through the discount rate effect or the cost of capital, which may in turn mitigate the firm's financial constraints. Lamont et al. (2001, page 529) define financial constraints as "this inability to obtain finance may be due to credit constraints or inability to borrow, inability to issue equity, dependence on bank loans, or illiquidity of assets". The issue of financial constraints arises as it has been well documented in the literature that capital markets are not perfect. One of the market frictionless that causes financial constraints is asymmetric information. The asymmetric information between insiders and outsiders causes financing costs to rise (Myers, 1984; Myers and Majluf, 1984; Sanders and Boivie, 2004) and investment opportunities may be constrained by the limited internal funds.

Prior studies (for example, Copeland and Galai, 1983; Demsetz, 1968; Amihud and Mendelson, 1986; Glosten and Milgrom, 1985) argue that extensive information disclosure can potentially reduce asymmetric information and in turn increase a firm's access to capital markets (or reduce financial constrains) by lowering the transaction costs or bid-ask spread. Another channel through which disclose is able to reduce asymmetric information is through reducing the non-diversifiable estimation risk (Coles and Loewenstein, 1988; Barry and Brown, 1985), and/or through increasing a company's trading liquidity (Diamond and Verrecchia, 1991). Several empirical studies report a negative association between corporate social responsibility and/or environmental disclosure and the cost of equity (Dhaliwal et al., 2011; Cormier and Magnan, 2007; Plumlee el al, 2015), while Richardson and Welker (2001) and Clarkson et al. (2013) fail to find the same relation. Transparent environmental information can also result in a reduction in the cost of debt by reducing monitoring and bonding costs and providing more flexible financing (Jones, 2010; Karolyi, 2012; Goss and Roberts, 2011).

Bewley and Li (2000) and Li et al. (1997) also argue that disclosing more environmental information can increase firm value by distinguishing good environmental performers from poor environmental performers. Since disclosures cannot be easily mimicked by poor environmental performers, by disclosing more information, good environmental performers signal their performance type, so they can potentially increase their firm value as investors infer expected environmental liabilities are lower for them.

In this study, it is focused on the discount rate effect and hypothesized that firms with greater disclosure quality, by reducing asymmetric information, will face lower financial constraints, measured by investment-cash flow sensitivity.

3. DATA AND METHODOLOGY

3.1. Data Description

Our sample covers publicly traded companies in the Chinese stock exchanges between 2004 and 2011. Since MDEI was implemented in 2008, information between 2004 and 2006 is defined as pre-MDEI time period and information between 2009 and 2011 is defined as post-MDEI time period. Observations are excluded for firms in the finance industry and for firms with missing financial data. Our final sample consists of 1,733 firm-year observations for the pre-MDEI period and 3,046 firm-year observations for the post-MDEI period.

3.2. Methodology

To examine the relationship between the environmental information disclosure quality and the investment-cash flow sensitivity, first of all, a firm's environmental information disclosure level is measured by using content analyses. Secondly, regression models are used to test our hypothesis. Finally, to ensure our results are robust, regression analysis is repeated by using alternative measure of environmental information disclosure quality. The details are provided in the following sections.

3.2.1. Measure of Environmental Information Disclosure Level

Following the approach in Wiseman (1982) and Al-Tuwaijri et al. (2004), the environmental information disclosure quality (hereafter EID) is constructed using content analysis. Environmental disclosures are usually found in company annual reports. Companies provide both qualitative and quantitative information about their environmental risks. The contents of corporate environmental disclosures are analyzed with respect to the following ten areas: (1) corporate investment in environmental protection, (2) government financial support related to environmental control, (3) tax reductions related to environmental programs, (4) lawsuits, settlements, penalties, and rewards related to environmental protection, (5) emissions and pollution reduction implementation, (6) certifications of environmental programs, (7) firm environmental protection missions and goals, (8) firm environmental protection plans and strategies, (9) bank loans related to environmental protection, and (10) other environmental-related information.

Following prior studies (Patten, 1992; Wiseman, 1982), different points are assigned for disclosure level. For a typical environmental risk, if company annual report provides specific information and monetary impact of environmental risk it will score 3; if the report provides specific information about environmental risk but no monetary information provided it will score 2, if the disclosure is a generic statement of company's environmental exposure it will score 1, and if the report contains no discussion on environmental disclosure it will score 0. This is done for each of the ten disclosure areas and then aggregated to obtain an overall EID score.

3.2.2. Multivariate Framework

Investment to cash flow sensitivity equation is specified as follows:

$$Investment = \beta_0 + \beta_1 CF * EID + \beta_2 CF + \beta_3 EID + \sum \beta_i \, Controls \quad (1)$$

Investment is change in the ratio of investment in plant and equipment to total assets. Cash flow (CF) is the ratio of earnings before extraordinary items and depreciation to total assets. β_1 is expected to be negative if EID lowers the sensitivity of investment-cash flow and β_2 is expected to be positive, indicating a positive cash flow sensitivity of investment.

Control variables in equations (1) are described as follows. Size is measured as the natural log of total assets. Current ratio is computed as current assets over current liabilities. ROA is net income over total assets. Net cash flow from investing activities is net cash flow from investing activities scaled by total assets. Administration is assigned to a value of 1 for a company under the central administration of the Central People's Government, or a value of 2 for a stated-owned but not under the central administration company, or 3 for a non-state-owned company. Operation is a measure of the firm's operating environment which ranges from 1 to 5 with 1 poor and 5 the best. Interest coverage ratio is earnings before interest and taxes divided by interest expenses. Year dummies are also included to control for year effects. As shown in the descriptive statistics presented in Table 1, EID ranges from 0 to 18. EID has mean values of 2.32 for the pre-MDEI period and 5.04 for the post-MDEI period, while the median values are 1 and 4 for the pre-MDEI period and the post-MDEI period, respectively. Our results suggest an increase in environmental disclosure after the implementation of MDEI.

Table 1: Summary Statistics of Variables

	Variable	Mean	Median	Std Dev	Minimum	Maximum
Pre-MDEI	Investment	0.05	0.04	0.09	-0.16	0.24
	EID	2.32	1	2.69	0	18
	Cash Flow	0.06	0.06	0.06	-0.05	0.17
	Size	0.02	0.02	0	0.02	0.03
	Current Ratio	1.47	1.22	0.83	0.58	3.85
	ROA	0.03	0.03	0.07	-0.53	0.56
	Net Cash Flow from Investing Activities	-0.07	-0.06	0.06	-0.21	0.02
	Administration	2.08	2	0.72	1	3
	Operation	2.91	2.93	0.22	0	3.16
	Interest Coverage Ratio	0.01	0	0.01	-0.03	0.05
Post-MDEI	Investment	0.03	0.03	0.09	-0.24	0.19
	EID	5.04	4	4.24	0	18
	Cash Flow	0.04	0.04	0.07	-0.08	0.17
	Size	0.02	0.02	0	0.02	0.03
	Current Ratio	2.95	1.7	2.96	0.68	11.81
	ROA	0.07	0.07	0.04	0.01	0.17
	Net Cash Flow from Investing Activities	-0.07	-0.06	0.06	-0.23	0.02
	Administration	2.31	2	0.77	1	3
	Operation	3.1	3.09	0.2	0	3.38
	Interest Coverage Ratio	0.01	0.01	0.03	-0.02	0.11

Note: The sample consists of 1,733 firm-year observations for the pre-MDEI period and 3,046 firm-year observations for the post-MDEI period.

3.2.3 Alternative Measure of Environmental Information Disclosure

To ensure our environmental information disclosure measure is robust, the environmental information disclosure horizons (EID time) is used as an alternative measure (Darrell and Schwartz (1997)). If the disclosure reports only the present information, it receives 1 point; if its information is about the future environmental risk, it receives 2 points; if it compares the future and present environmental risk, it receives 3 points. The scores for all environmental disclosure are then aggregated to obtain a disclosure horizon score for each company.

4. FINDINGS AND DISCUSSIONS

Table 2 reports the regression results of investment-cash flow sensitivities before and after MDEI was implemented. As presented in table 2, the coefficient on EID*cash flow is insignificant in the pre-MDEI period. The findings suggest that before MDEI was implemented, disclosures about the environmental risks may be insufficient and unreliable and thus had no impact on the sensitivity of investment-cash flow. Next, the impact is examined of EID on investment-cash flow sensitivity in the post-MDEI period. As shown in Table 2, the coefficient on *EID**CF is -0.0132 and is statistically significant at the 5% level. Our results suggest that after MDEI was implemented, environmental disclosure lowers the sensitivity of investment to cash flows. Furthermore, the coefficient on cash flow is positive and significant at 1% level for the post-MDEI, which is consistent with evidence presented in Fazzari et al. (1988).

Table 2: Sensitivity of Investment to Cash Flow before and after the Implementation of MDEI

Independent Variables	**Pre-MDEI**	**Post-MDEI**
	Investment	**Investment**
EID*Cash Flow	-0.0200	-0.0132**
	(-1.60)	(-2.36)
Cash Flow	0.0617	0.1660***
	(1.37)	(4.39)
EID	0.0018*	0.0014***
	(1.69)	(3.13)
Size	11.0900***	10.6900***
	(5.35)	(7.02)
Current Ratio	-0.0259***	-0.0081***
	(-10.50)	(-14.28)
ROA	0.0790**	-0.0109
	(2.25)	(-0.26)
Net Cash Flow from Investing Activities	-0.3660***	-0.3270***
	(-11.57)	(-13.74)
Administration	-0.0050*	-0.0016
	(-1.89)	(-0.78)
Operation	0.0023	0.0044
	(0.28)	(0.57)
Interest Coverage Ratio	0.0883	-0.2680***
	(0.65)	(-4.82)
Intercept	-0.1790***	-0.2100***
	(-3.62)	(-5.14)
Year Dummies	Yes	Yes
Number of Observations	1,733	3,046
Adj R^2	0.2034	0.1885
F-value	41.18	65.23

*, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

The impact is further examined of EID on investment-cash flow sensitivity after the implementation of MDEI for firms in low-polluting and high-polluting industries. The regression analysis is repeated by breaking down our sample firms into high-polluting and low-polluting based on the CSRC (China Securities Regulatory Commission) industry classification and report our finding in Table 3.

Table 3 shows that the coefficient on EID*Cash Flow is -0.0075 and is insignificant for firms in low-polluting industries, while the coefficient on EID*Cash Flow is -0.0188 and is significant at the 1% level for firms in high-polluting industries. The findings suggest that only firms in high-polluting industries experience a decline in investment-cash flow sensitivity after the Implementation of MDEI. Also, the coefficients on cash flow are all positive and significant at 1% level for firms in the low-polluting and high-polluting industries. The results indicate greater sensitivities of investment-cash flow for firms in the high-polluting industries than for firms in low-polluting industries.

Table 3: Sensitivity of Investment to Cash Flow for Firms in Low-Polluting and High-polluting Industries after the Implementation of MDEI

Independent Variables	Low-Polluting	High-Polluting
	Investment	Investment
EID*Cash Flow	-0.0075	-0.0188***
	(-0.76)	(-2.57)
Cash Flow	0.1380***	0.2070***
	(2.58)	(3.75)
EID	0.0009	0.0016**
	(1.24)	(2.53)
Size	10.0700***	11.4100***
	(4.60)	(5.29)
Current Ratio	-0.0080***	-0.0083***
	(-9.52)	(-10.75)
ROA	-0.0658	0.0165
	(-0.98)	(0.30)
Net Cash Flow from Investing Activities	-0.3570***	-0.3010***
	(-9.57)	(-9.67)
Administration	-0.0048	0.0013
	(-1.57)	(0.43)
Operation	-0.0035	0.0081
	(-0.20)	(0.96)
Interest Coverage Ratio	-0.2680***	-0.2590***
	(-3.26)	(-3.41)
Intercept	-0.1580**	-0.2500***
	(-2.13)	(-4.68)
Year Dummies	Yes	Yes
Number of Observations	1,380	1,666
Adj R^2	0.1740	0.1900
F-value	27.41	36.50

*, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 4 reports the results of using EID_time as an alternative measure of environmental information disclosure quality. As shown in table 4, the coefficient on EID_time*Cash Flow is -0.0202 and is statistically significant at the 5% level in the post-MDEI period, which is consistent with the finding reported in Table 2. However, the coefficient on EID_time*Cash Flow is insignificant in the pre-MDEI period. The coefficient on cash flow is positive and significant in the post-MDEI period but not in the pre-MDEI period.

Table 4: Alternative Environmental Disclosure Quality Measure on Investment-Cash Flow Sensitivity before and after the Implementation of MDEI

Independent Variables	Pre-MDEI	Post-MDEI
	Investment	Investment
EID_time*Cash Flow	-0.0058	-0.0202**
	(-0.39)	(-2.43)
Cash Flow	0.0273	0.1670***
	(0.63)	(4.42)
EID_time	0.0006	0.0021***
	(0.38)	(3.18)
Size	10.9700***	10.8900***
	(5.28)	(7.24)
Current Ratio	-0.0260***	-0.0081***
	(-10.54)	(-14.27)

ROA	0.0817**	-0.0111
	(2.33)	(-0.26)
Net Cash Flow from Investing Activities	-0.3660***	-0.3290***
	(-11.54)	(-13.84)
Administration	-0.0052**	-0.0017
	(-1.96)	(-0.79)
Operation	0.0030	0.0042
	(0.35)	(0.55)
Interest Coverage Ratio	0.0775	-0.2680***
	(0.57)	(-4.83)
Intercept	-0.1750***	-0.2150***
	(-3.53)	(-5.27)
Year Dummies	Yes	Yes
Number of Observations	1,733	3,046
Adj R^2	0.2020	0.1886
F-value	40.84	65.28

The regression analysis is repeated for firms in low-polluting and high-polluting industries by using EID_time as a measure of disclosure quality. Table 5 reports the results. As shown in Table 5, the coefficient on EID_time*Cash Flow is negative and statistically significant at the 5% level for only high-polluting firms, which is consistent with the finding reported in Table 3.

Table 5: Alternative Environmental Disclosure Quality Measure on Investment-Cash Flow Sensitivity for Firms in Low- Polluting and High-polluting Industries

Independent Variables	**Low-Polluting**	**High-Polluting**
	Investment	**Investment**
EID_time*Cash Flow	-0.0130	-0.0271**
	(-0.89)	(-2.54)
Cash Flow	0.1430***	0.2020***
	(2.62)	(3.72)
EID_time	0.0015	0.0023***
	(1.32)	(2.60)
Size	10.0400***	11.8300***
	(4.59)	(5.64)
Current Ratio	-0.0081***	-0.0082***
	(-9.54)	(-10.69)
ROA	-0.0656	0.0156
	(-0.98)	(0.29)
Net Cash Flow from Investing Activities	-0.3570***	-0.3040***
	(-9.56)	(-9.75)
Administration	-0.0048	0.0012
	(-1.55)	(0.40)
Operation	-0.0032	0.0077
	(-0.18)	(0.91)
Interest Coverage Ratio	-0.2680***	-0.2560***
	(-3.27)	(-3.37)
Intercept	-0.1590**	-0.2580***
	(-2.14)	(-4.88)
Year Dummies	Yes	Yes
Number of Observations	1,380	1,666
Adj R^2	0.1741	0.1900
F-value	27.43	36.50

5. CONCLUSION

For many developing nations, like China, environmental protection and economic development are often conflicting goals. However, as economic continues to grow, environmental failure and ecological disaster start to catch the attention of the public and government. New environmental policies and regulations are issued to hope to improve corporate environmental disclosure and regulate polluting firms. As a result, nations in emerging markets start to put more effort enforcing environmental policies and put more resources in protecting natural resources. However, for developing nations, given that the tradeoff between economic growth and environmental protection seems to be inevitable, the effectiveness of environmental policies in emerging markets is often a question. It is, therefore, important for stakeholders to examine how companies react to the increasing disclosure requirement and its impact on a firm's access to capital markets.

As shown in this study, environmental regulation in emerging markets is not just a façade. Instead, it has increased the quantity and quality of environmental disclosure, resulting in a positive impact on firm's access to capital markets. In particular, a lower investment-cash flow sensitivity is found after the implementation of MDEI in China. Our results support the notion that the greater the level of environment disclosure, the lower is the level of asymmetric information, which leads to a reduction in a firm's financial constraints. Furthermore, high-polluting firms experience in the decline of investment-cash flow sensitivity more significantly than low-polluting firms in the post-MDEI period. Our findings support the notion of greater government regulation in emerging markets to improve environmental information disclosure.

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SECTORAL GROWTH DYNAMICS OF COUNTRY GROUPS: A COUNTRY GROUPING SUGGESTION

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Selcuk Alp[1], Elcin Aykac Alp[2], Tugba Kiral Ozkan[3], Mefule Findikci Erdogan[4]
[1]Yıldız Technical University, Faculty of Mechanical Engineering, Department of Industrial Engineering, Istanbul, Turkiye.
alp@yildiz.edu.tr , ORCID: 0000-0002-6545-4287
[2]Istanbul Ticaret University, Faculty of Business, Department of Economics, Istanbul, Turkiye.
ealp@ticaret.edu.tr , ORCID: 0000-0001-9076-2102
[3]Bahcesehir University, Faculty of Educational Sciences, Istanbul, Turkiye.
tugba.kiral@es.bau.edu.tr , ORCID: 0000-0002-7050-3805
[4]Istanbul Ticaret University, Institute of Finance, Istanbul, Turkiye.
mfindikci@ticaret.edu.tr , ORCID: 0000-0003-0150-0990

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ABSTRACT

Purpose- In the study, the effects of sectors on the growth of OECD member countries were determined by using the Fuzzy Goal Programming method. These findings may help policymakers see sector impacts that help countries in their growth targets. The study aims to contribute to the literature in two ways. The first of these analyses are based on long-term economic growth and primary sector analysis. The second contribution is to propose an alternative empirical methodology with clustering analysis which is not used to obtain the basic assumption of homogeneity in the application of panel data analysis.

Methodology- The effects of sectors on the growth of OECD member countries were determined by using the Fuzzy Goal Programming method. In the second step, countries were divided into groups using K-means clustering analysis according to these impact values. With the help of these weights, the growth dynamics of similar countries and the contributions of sectors to this dynamic were obtained.

Findings- Countries analyzed in terms of the contribution of sectoral growth rates to the growth rate of the country were divided into groups by cluster analysis. It is determined that the countries grouped in terms of the contribution of sectors to growth are divided into 5 groups. The first group has 10 member countries. The second group has 12 countries and the third group it has 7 countries, the fourth group has 4 countries and only 1 country belongs to the fifth group. The countries in group 1 are Estonia, Turkey, Greece, Italy, Poland, Portugal, Lithuania, Latvia, Slovakia, and Slovenia. The countries in group 2 are Australia, Belgium, Czech Republic, Germany, Denmark, Hungary, Ireland, Mexico, Netherlands, Norway, Sweden, and New Zealand. The countries in group 3 are Austria, Spain, Finland, France, the Republic of Korea, Luxembourg, Switzerland, the USA, Israel, Costa Rica, the United Kingdom, and Japan.

Conclusion- Countries that have similar sectoral structures can analyze growth with panel data analysis, but it is important to form homogeneous groups while doing this analysis. For this reason, another critical suggestion it is offered based on the study is the use of FGP methodology in the analysis method.

Keywords: Economic growth, sectoral growth, Fuzzy Goal Programming, Cluster Analysis, Panel VAR
JEL Codes: N10, C61, C38, C33

1. INTRODUCTION

The studies in the field of growth generally examine the relations between countries' growth rates and other economic and social indicators. Although there are many theoretical and applied studies investigating the dynamics of economic growth, some of these studies reveal the effect of the change and transformation of the sectoral structure on growth. The dynamics of the growth of countries go through certain stages and reveal the effects of the sectors on growth and development in these studies.

One of the most important studies conducted recently is the work of Zeira and Zoabi (2015). This study divides the sectors into traditional and modern sectors and highlights the importance of the increase in productivity in modern sectors.

While Fisher's (1939) study focused on production, the three-sector theories extended by Clark (1940) reveal the gradual development and support of the agriculture, industry, and services sectors. The discussion that continued with the study of Kuznets (1966), followed by Gershuny and Miles (1983), draws attention to the services sector development that started before the industrial sector growth was completed and that the two sectors grew together.

Due to the increase in the share of the knowledge economy in the countries and the importance of specialization, many sub-sectors that can form the engine of growth, accelerate and even prevent growth in the main sectors gain importance.

The issue of growth is related to many factors and takes place with different dynamics in different countries. However, it is known that countries have similar growth dynamics with each other. Based on this idea, it is seen that countries are analyzed together in the literature. In this study, an analysis structure is suggested based on the idea that countries with similar sectoral structures should be grouped before examining countries in terms of the contribution of sectors to growth.

In the second part of the study, literature review was made, in the third part, theoretical information about the analysis methods, and in the fourth part, the findings were reported.

2. LITERATURE REVIEW

From this perspective, there is literature that examines the effects of sectors on growth. It is specially tested that the industry and the manufacturing industry are engines of growth. This research question is based on Kaldor's "first law of growth" which puts forth a positive relationship between the output growth of the manufacturing sector and the GDP growth (Kaldor, 1966).

With this point of view Chakravarty, and Mitra, (2009) study aimed to examine if the manufacturing sector is still the engine of growth. They used the VAR model and especially variance decomposition analysis for testing their hypothesis. Variance decomposition analysis is used for the interrelation information between sectors. They examined that the manufacturing, construction, and services sectors are the three main drivers of Indian growth for the period they analyzed. In addition, two important studies are testing the impact of the difference between industry and agricultural growth. Those are Bhattacharya and Mitra (1989, 1990) studies. Bhattacharya and Mitra (1989) study analyse the pattern of growth of the tertiary sector and its implications on growth and distribution in India for the period 1950 to 1987. Bhattacharya and Mitra (1990) study also analyzed the period 1950 to 1987 and concluded that the services sector in India grew much faster than the commodity sector for this period.

Szirmai and Verspagen (2015) analyzed the relationship between manufacturing and economic growth in 88 countries for the period of 1950–2005. They used panel data models, and they tested if manufacturing acted as an engine of growth. They found that after 1990 manufacturing decreases the importance of being the engine of growth for intermediate levels of developing countries.

Su and Yao (2016) indicate that the manufacturing sector has the main role in economic growth for middle-income economies and if manufacturing sector production growth decreases it will negatively affect the growth of all other sectors.

Haraguchi, Cheng, and Smeets (2017) study also analyzed the importance of the manufacturing sector on growth and determined the decreasing effect of this sector on growth for developing countries. Their investigation takes into account the three sectors: manufacturing, agriculture, and service sectors. The analysis is also constructed for different periods. The hypotheses of this study are, "manufacturing is no longer the driver of economic growth in developing countries", and the second is "the share of manufacturing value-added relative to other sectors and employment has decreased significantly in developing countries".

Karami, Elahinia, and Karami (2019) studied 25 European economies for the period 1995-2016. They analyzed the effect of the manufacturing sector on economic growth and find a positive significant relationship between manufacturing, labor force and technology. They used panel data models for this sample.

In this context, it is important to examine the effects of countries' growth rates on total growth and thus reveal the dynamics of growth in countries. In this context, examining and grouping the sectoral sizes of countries that are at different levels in the stages of growth and development will also inform us about which sectors are in the foreground and the speed of growth increases.

This study analyses the effects of sectoral growth rates on total growth for each country and the sectoral structure of the growths of countries is revealed. In addition, countries are grouped according to these impact values.

The relationship between sectoral growth rates and total growth rate is based on historical data, and each sector has been included in the model in proportion to its share of the GDP. Using the Fuzzy Goal Programming (FGP) method, the impact of each sector on total growth was calculated. In the proposed model, the impact value of the growth rates in the sectors are

considered as decision variables, and the total growth rates of the countries are considered as target values. A separate mathematical model has been created for each country.

In the created models, the growth rates of countries in the sectors (for the period 2000-2017) were used as the coefficients of the decision variables. 10% of each target value was accepted as the tolerance value for the fuzzy model and the impact values of each sector growth rate to the total growth rate were calculated using the FGP method and the Hannan approach.

Using the obtained impact values, countries are divided into different groups by K-means cluster analysis. The growth structure of each group was examined with the Panel VAR model. As a result of the grouping, the structure of growth for each group is revealed, and the differences between the growth structures of OECD countries according to the sectors that affect growth are grouped.

In a study on this subject, the use of time series will undoubtedly create important information contributions, but it was decided to analyze the common structure countries together by applying the panel data model with both time and cross-section structure with the idea that it would be wrong to act on a single country model.

In the FGP method, the effects of the growth rates in the sectors on the GNP were determined for the OECD countries by using the Hannan approach. Countries were divided into groups by hierarchical cluster analysis using these impact values (effects of each sector on GNP growth rate). The structure of the growth is revealed for each group obtained as a result of grouping. In this way, the differences between the growth structures of OECD countries according to the sectors that affect growth are determined.

It is aimed to determine the common characteristics of the clusters in which countries are included and to reveal the structure of their growth dynamics. For this purpose, the groupings of countries whose sectors, which are the engines of growth, are similar provide important information about the growth dynamics of the countries. The information and findings to be obtained in line with this goal will contribute to the literature in two areas.

The first contribution is providing different types of prescriptions to policymakers by making different suggestions in decisions to be taken for the target of growth in different country groups and by choosing different growth engine sectors.

The second important contribution is a suggestion presented in terms of the empirical method. The applied analysis is a suggestion for the solution to the problem of not being able to form homogenous groups, which is one of the most important assumptions in panel data analysis. This suggestion is to incorporate the FGP method into the analyzing process, which enables cluster analysis to form homogenous groups in panel data analysis.

3. DATA AND METHODOLOGY

In the study, growth data belonging to 34 OECD countries are used. This data covers total and sectoral growth rates for those countries and the 18 years of OECD countries statistics between 2000-2017. This period is selected because this period allows analyzing the maximum time and country composition of OECD countries because of data availability.

The main objective of the study is to find the most significant sectors in the growth of the countries and to examine the effects of each sector on long-term growth. Since it would not be right to investigate this information from a single country, it is thought that similar countries should be examined together. For this reason, panel data analysis is planned to perform.

One of the basic assumptions of panel data analysis is the analysis of the homogeneity of groups. OECD countries can be analyzed to ensure the homogeneity assumption. However, since it is considered the growth structure will vary within OECD countries, it is decided to use clustering analysis for the country grouping process. To make cluster analysis, weights were calculated with fuzzy goal programming. After this step, Panel unit root and Panel VAR analyses were applied to the groups determined by clustering analysis.

3.1. Fuzzy Goal Programming

Goal Programming (GP) is based on the study of Charnes and Cooper (1961), Lee (1972), and Ignizio (1976). After these studies, many studies were carried out in different fields using GP. Some of the studies in different fields using GP can be exemplified as follows: Financial analysis (Charnes et al., 1963, El-Sheshai et al., 1977), media planning (Charnes et al., 1968), academic resources allocation (Lee and Clayton, 1972), location preferences (Courtney et al., 1972), product planning (Forsyth, 1969).

GP is one of the Multiple Criteria Decision-Making techniques used to solve multi-objective problems, minimizing deviations from the desired target for each target (Steuer, 1986). Objectives express the wishes of decision-makers. Targets are expressed as a numerical value of the objective to be achieved (Schnierdejans, 1984). GP is to achieve as much as possible a satisfying solution to the desired objectives in the problem. GP offers an efficient and mostly satisfactory solution rather than

the optimal solution to the problem. The main difference between Linear Programming (LP) and GP is that while LP maximizes or minimizes a single objective function, GP minimizes deviations from target values (Schnierdejans, 1984).

In the GP model, there are positive (p_i) and/or negative (n_i) deviational variables for each objective. The value (n_i) represents an underachievement from (G_i: target values), while the value (p_i) represents an overachievement. For each target, at least one of (p_i) or (n_i) must be equal to zero.

The general GP model stated as:

$$\left.\begin{array}{ll} \textit{Objective Function} & \\ \min \sum_{k=1}^{r}\left(P_k\left(\sum_{t=1}^{s} w_{tk}^{+} p_t + \sum_{t=1}^{s} w_{tk}^{-} n_t \right)\right) & \\ \textit{subject to} & \\ \sum_{j=1}^{n} a_{ij}.x_j = b_i, & i = 1,2,...,m \\ \sum_{j=1}^{n} c_{ij}.x_j + n_t - p_t = G_t, & t = 1,2,...,s \\ x_j \geq 0, & \textit{for all } i \\ n_t, p_t \geq 0, & \textit{for all } t \\ n_t \times p_t = 0, & \textit{for all } t \end{array}\right\} \quad (1)$$

where

x_j : The *j*th decision variables,
a_{ij} : Coefficients of decision variables *j* of constraint *i*,
b_i : The right-hand side constant for constraint *i*,
c_{tj} : Coefficients of decision variables *j* of goal *t*,
G_t : The right-hand side constant for goal *t*,
n_i : Negative deviational variables,
p_i : Positive deviational variables,
P_k : Preemptive priority ($P_1>P_2>\ldots>P_r$ for k=1,2,…,r).
w^-_{ik} : The weight value of the t*th* negative deviation variable for the k*th* priority in the objective function,
w^+_{ik} : The weight value of the t*th* positive deviation variable for the k*th* priority in the objective function,

GP model consists of objective functions, target values, and crisp constraints. Determining these values is a difficult and subjective process. The subjectivity can be considered as fuzzy set theory. When the GP model is considered in the context of fuzzy set theory, expressions such as “approximately equal to” and “fairly large” can be used for target values. Such expressions are handled by membership functions in fuzzy sets theory.

When the fuzzy set theory is applied to the GP model, the target value and preference priorities of targets can be characterized by uncertain expressions (fuzzy). In such cases, it would be appropriate to use FGP (Venkatasubbaiah et al., 2011).

In the approach developed by Hannan, fuzzy targets are characterized by symmetrical triangular membership functions. In this approach, the FGP model is formulated as the LP Model with the theorem $\lambda^* = \max \lambda_j; j = 1,2,...,2^{m1}$. Where λ_j refers to the solution values of the sub-problems and λ^* is the highest member of the fuzzy decision set. (Hannan, 1981).

In Hannan approach, a tolerance value is determined for the target values. This value is taken as the coefficient of positive and/or negative deviation variables in target constraints. Constraints of performance level and deviation variables of less than one for each objective are added to the model. The objective function is set to maximize the performance level.

With the Hannan approach, the FGP model can be expressed as a LP problem as follows (Hannan, 1981);

$$\left.\begin{array}{l} \max \lambda \\ \text{constraints} \\ \dfrac{(Ax)_i}{d_i} + n_i - p_i = \dfrac{b_i}{d_i} \\ \lambda + n_i + p_i \le 1 \\ n_i \times p_i = 0 \\ x_i, \lambda, n_i, p_i \ge 0 \qquad i = 1,2,...,m \qquad j = 1,2,...,m \end{array}\right\} \tag{2}$$

$(Ax)_i$: Objective function,
b_i : Target value
n_i : Negative deviation variables,
p_i : Positive deviation variables,
λ : Performance level

3.2. Partition Based Clustering

Partition Based Clustering algorithms take the input parameter k and divide n objects into k sets. These techniques perform operations that find single-level clusters (Jain et al., 1999). All clustering techniques are based on the central point representing the cluster. Partition-based methods produce good results because their applicability is both easy and efficient.

One of the Partition Based Clustering Algorithms K-means was developed by J.B. MacQueen (1967). The assignment mechanism of K-means, one of the most commonly used unsupervised learning methods, allows each data to belong to only one cluster. Therefore, it is a sharp clustering algorithm (Han and Kamber, 2001).

In the evaluation of the K-means clustering method, the most common squared error criterion SSE is used. Clustering with the lowest SSE gives the best result. The sum of the squares of the distance of the objects to the center points of the cluster is calculated by equation (3) (Pang-Ning et al., 2006).

$$SSE = \sum_{i=1}^{K} \sum_{x \in C_i} dist^2(m_i, x) \tag{3}$$

As a result of this criterion, k clusters are as dense and separate from each other as possible. The algorithm tries to reduce the k part to determine by the squared-error function. The K-means algorithm divides the data set consisting of n data and n data by k parameter into k sets. Cluster similarity is measured by the average value of objects in the cluster, which is the center of gravity of the cluster (Xu and Wunsch, 2005).

3.3. Unit Root Tests for Panel Data

The panel data has two dimensions, those are cross-sectional dimension and time dimension. It is necessary to investigate the stationarity structure of the data before cointegration analysis like conventional time series analysis. To this end, many different panel unit root tests have been developed. Dickey Fuller (1979) and Augment Dickey-Fuller (ADF) test approaches were used to establish the hypotheses and to calculate the test statistics (Guris, 2018, 261; Breitung and Das, 2005).

In the literature, panel unit root tests are called the first generation if the data has cross-section independence. However, panel unit root tests are called the second generation if they are based on the horizontal cross-sectional dependency hypothesis.

First-generation panel unit root tests are applied if there is no correlation between cross-section units. Dickey Fuller (1979) and Augmented Dickey-Fuller (ADF) are based on the test approach. In this study, Levin, Lin and Chu (2002) test, Im, Peseran and Shin (2003) unit root test study and based on ADF Fisher and PP Fisher tests were applied. Panel unit root tests generally test the data for how the current period is affected by the previous periods. For a Y series, this can be examined using the following equation:

$$\Delta Y_{it} = \rho_i Y_{it-1} + \sum_{j=1}^{m_i} \beta_j \Delta Y_{it-j} + yZ_{it} + \varepsilon_{it} \tag{4}$$

m_i represents the optimal lag length, ρ_i unit root parameter, Z_{it} components such as constant term and trend that affect the stability of the Y series, and ε_{it} error terms.

The second-generation unit root tests are used in the panel data models if the cross-section dependency hypothesis is failed to reject. The main feature of the second-generation unit root tests is that it assumes a cross-sectional correlation. The main

second generation unit root tests are Bai and Ng (2002, 2004), Moon and Perron (2004), Phillips and Sul (2003), Choi (2002) and Pesaran(2007) (Hurlin and Mignon, 2007).

Pesaran (2007) CADF test, which is used in the study, is an extended version of ADF regression with the first differences of the individual series and the cross-sectional mean of the lag levels. In the test, both the individual results of each cross-section are obtained by CADF statistic and CIPS (Cross sectionally IPS) statistics are obtained by getting the average of cross-sections and the results are obtained for the whole panel. The CADF test provides very consistent results even when the horizontal cross-section (N) and time (T) dimensions are relatively small. In addition, this test can be used when both $T > N$ and N>T (Pesaran, 2007, 265-312).

3.4. Panel Vector Autoregression Analysis (Panel VAR)

One of the first studies in the literature on the Panel VAR model was by Holt-Eakin, Newey and Rosen (1988). This model was created by adding the horizontal cross-sectional dimension to the traditional VAR model introduced by Sims (1980). It consists of a set of equations instead of a single equation in the VAR system, which accepts all variables in the system as endogenous and independent. The panel VAR model also derives asymptotic results to be included in the model for unobservable cross-sectional effects. Under the assumption that all variables are endogenous, the panel VAR model with maximum p lag length, which is formed with panel data, is expressed as follows (Canova and Ciccarelli, 2013, Guris, 2018; Holtz-Eakin, Newey and Rosen, 1988).

$$y_{it} = \sum_{j=1}^{j} a_{11j} y_{it-j} + \sum_{j=1}^{j} a_{12j} x_{it-j} + \lambda_{1i0} + \lambda_{10t} + e_{1it} \quad (5)$$

$$x_{it} = \sum_{j=1}^{j} a_{21j} y_{it-j} + \sum_{j=1}^{j} a_{22j} x_{it-j} + \lambda_{2i0} + \lambda_{20t} + e_{2it}$$

In the equation, j represents the maximum lag length, λ_{1i0} and λ_{2i0} indicates unit effects, λ_{10t} and λ_{20t} shows the unobservable time effects (Guris, 2018).

Structural shocks which are analyzed by impulse-response and variance decomposition analysis can be examined with error terms in VAR models. The response of one variable to other variables is realized by analysis of coefficients in the impulse-response system which the short-term effects are estimated. The relationship between the variables in the PVAR models can also be interpreted by Variance Decomposition analysis. The variance decomposition analysis gives information about the effect of structural shocks on the total variance of each variable.

4. FINDINGS AND DISCUSSIONS

Abbreviations used in analysis are TOT; Total growth, AGR; Agriculture, CON; Construction, FIN; Finance, IND; Industry, INF; Information, MFG; Manufacturing, OTH; Other Services, PRO; Professional, Scientific, Support services, PUB; Public administration, defense, education, health, social work, REAL; Real estate sector, WHL; Wholesale, retail trade, repairs, transport.

As it's mentioned before in order to get homogenous groups for the analysis, firstly it is used fuzzy goal programming and gets the main growth equations weights for each country. The main findings of this analysis are given in the Appendix (App. 2). The weights found by the fuzzy goal programming method are used in k-means clustering for finding main groups of countries. Results for K-means clustering analysis are also given in the appendix (App. 3). Panel Cross-Section Dependency Test, Panel unit root and Panel VAR analysis results are given below. Table 1 gives the panel cross-section dependency test results for data.

Table 1: Panel Cross-Section Dependency Test

Pesaran (2004) CD test (N>T)				
OECD group	1.23	0.220	$h_0 = \rho_{ij} = \rho_{ji} = 0$ $h_a = \rho_{ij} = \rho_{ji} \neq 0$	$i \neq j$
Breusch-Pagan LM test of independence (T>N)				
	X^2	p		
Group 1	63.633	0.0350	$h_0 = \rho_{ij} = \rho_{ji} = 0$	$i \neq j$
Group 2	109.540	0.0006	$h_a = \rho_{ij} = \rho_{ji} \neq 0$	
Group 3	18.598	0.6109		

The results of the analysis show that the null hypothesis, which expresses cross-section independence, failed to reject the OECD countries' group and group 3 but rejected group 1 and group 2. Namely, there is no cross-sectional dependency for the OECD countries' group and group 3. Therefore, stationarity testing of variables in the data set should be performed with first-

generation unit root tests for these groups. However, there is a cross-sectional dependency between group 1 and group 2. Hence, stationarity testing of variables in the data set should be performed with second-generation unit root tests for those groups. Besides, these dependency results indicate that a shock in the total growth data (TOT) may be affected differently by other shocks for the countries in group 1 and group 2. This also means main research question may have different answers for different groups. This implication is also important because if it been had done the traditional panel data analysis, it would have taken all OECD countries as a single group, and this would prevent from recognition of different group types.

The results in Table 2 indicate that the data used in the analysis are stationarity for all groups. The variables are stationarity in the level form (I(0)). This result also gives signs of the appropriate analysis it can be used. The Panel VAR model is used for determining the relationship between variables. The appropriate lag length for the estimation of the Panel VAR model is chosen by using information criteria. The AIC, BIC, LR, and HQIC information criteria are used, and the results are given in the appendix (App. 4). The results indicate that, according to the information criteria, the appropriate lag length was determined as 3 for the first model which all countries were taken into consideration, 4 for the second model (Group 1), 1 for the third model (Group 2) and 2 for the last model (Group 3). For the stability analysis of the predicted Panel VAR model, the eigenvalues are less than one. As a result of the test of this condition, it is seen that the eigenvalues of all the characteristic roots of the Panel VAR model are below one. This result also can be seen according to the Inverse Roots Graphs given in the appendix.

Table 2: First Generation Unit Root Test Results

	OECD group			
	Levin, Lin & Chu t*	**Im, Pesaran and Shin W-stat**	**ADF - Fisher Chi-square**	**PP - Fisher Chi-square**
TOT	-9.534	-8.048	185.758	272.939
	0.000	0.000	0.000	0.000
AGR	-15.906	-15.107	335.854	1304.580
	0.000	0.000	0.000	0.000
CON	-6.938	-6.802	163.052	205.207
	0.000	0.000	0.000	0.000
FIN	-4.673	-6.696	168.564	332.487
	0.000	0.000	0.000	0.000
IND	-11.378	-9.952	225.214	406.544
	0.000	0.000	0.000	0.000
INF	-8.746	-9.204	211.575	565.807
	0.000	0.000	0.000	0.000
MFG	-12.804	-10.623	239.297	413.979
	0.000	0.000	0.000	0.000
OTH	-5.820	-8.248	191.279	403.984
	0.000	0.000	0.000	0.000
PRO	-9.868	-9.449	214.931	349.374
	0.000	0.000	0.000	0.000
PUB	-6.410	-5.850	144.408	247.468
	0.000	0.000	0.000	0.000
REAL	-7.471	-8.476	200.211	426.926
	0.000	0.000	0.000	0.000
WHL	-11.606	-9.819	222.204	371.552
	0.000	0.000	0.000	0.000
	Group 3			
	Levin, Lin & Chu t*	**Im, Pesaran and Shin W-stat**	**ADF - Fisher Chi-square**	**PP - Fisher Chi-square**
TOT	-5.369	-4.332	44.389	70.884
	0.000	0.000	0.000	0.000
AGR	-9.942	-9.375	94.362	446.940
	0.000	0.000	0.000	0.000
CON	-3.404	-3.502	37.991	50.333
	0.000	0.000	0.001	0.000
FIN	-1.607	-3.085	34.589	108.881
	0.054	0.001	0.002	0.000

IND	-6.473	-5.133	51.851	95.807
	0.000	0.000	0.000	0.000
INF	-4.495	-5.122	51.670	72.647
	0.000	0.000	0.000	0.000
MFG	-7.917	-6.248	62.915	114.670
	0.000	0.000	0.000	0.000
OTH	-0.226	-3.688	39.092	126.536
	0.411	0.000	0.000	0.000
PRO	-5.718	-4.172	42.727	77.254
	0.000	0.000	0.000	0.000
PUB	-3.620	-3.421	37.653	76.623
	0.000	0.000	0.001	0.000
REAL	-4.591	-4.646	48.014	84.601
	0.000	0.000	0.000	0.000
WHL	-4.392	-4.535	46.788	140.947
	0.000	0.000	0.000	0.000

The first raw for each variable indicates the critical test value and the second raw gives the probability values for this variable for individual unit root test.

Table 3: Second Generation Unit Root Test Results for Group 1 and Group 2

			Group 1			
	t-bar	**cv10**	**cv5**	**cv1**	**Z[t-bar]**	**P-value**
TOT	-2.939	-2.210	-2.340	-2.600	-3.712	0.000
AGR	-5.218	-2.210	-2.340	-2.600	-10.708	0.000
CON	-3.616	-2.210	-2.340	-2.600	-5.791	0.000
FIN	-3.789	-2.210	-2.340	-2.600	-6.320	0.000
IND	-3.004	-2.210	-2.340	-2.600	-3.911	0.000
INF	-4.236	-2.210	-2.340	-2.600	-7.693	0.000
MFG	-2.815	-2.210	-2.340	-2.600	-3.331	0.000
OTH	-3.992	-2.210	-2.340	-2.600	-6.944	0.000
PRO	-3.930	-2.210	-2.340	-2.600	-6.753	0.000
PUB	-3.166	-2.210	-2.340	-2.600	-4.408	0.000
REAL	-4.315	-2.210	-2.340	-2.600	-7.935	0.000
WHL	-3.424	-2.210	-2.340	-2.600	-5.199	0.000
			Group 2			
	t-bar	**cv10**	**cv5**	**cv1**	**Z[t-bar]**	**P-value**
TOT	-3.125	-2.140	-2.260	-2.470	-4.669	0.000
AGR	-4.779	-2.140	-2.260	-2.470	-10.287	0.000
CON	-3.419	-2.140	-2.260	-2.470	-5.669	0.000
FIN	-3.401	-2.140	-2.260	-2.470	-5.607	0.000
IND	-3.802	-2.140	-2.260	-2.470	-6.970	0.000
INF	-3.493	-2.140	-2.260	-2.470	-5.918	0.000
MFG	-3.438	-2.140	-2.260	-2.470	-5.733	0.000
OTH	-4.175	-2.140	-2.260	-2.470	-8.237	0.000
PRO	-3.928	-2.140	-2.260	-2.470	-7.396	0.000
PUB	-3.060	-2.140	-2.260	-2.470	-4.448	0.000
REAL	-3.457	-2.140	-2.260	-2.470	-5.796	0.000
WHL	-3.559	-2.140	-2.260	-2.470	-6.144	0.000

Fulfilling the conditions of stability analysis conditions is important in terms of using the Panel VAR model. Since the panel VAR model, which has been pre-tested, is examined the summary table of the four models showing the main model containing the growth variable is given below. Although the statistical significance of all coefficients is not expected for both

VAR and Panel VAR models, the coefficients are generally found statistically significant. Their interpretations were briefly given below.

For each group Panel VAR model has 13 endogenous variables and 13 models for each variable. Because the most important information in this study is the effect of each sub-sector on total growth and to save space, the main equation for total growth is given for each group.

From Table 4 it is seen that the agriculture sector has a negative effect on most of the groups and the effect is quite low in the OECD group. This is also valid in group 2 and 3, but it has a positive effect on group 1 countries. Although the 1st lag of the construction sector variable had a positive effect for all groups on the growth variable, it is determined that the greatest effect was in Group 1. The lag values of the construction sector indicate different effects for different groups. However, the Group 1 countries are positively affected by the relatively traditional production sectors.

The 1st lag of the finance and insurance sector variable has a positive effect on the Growth variable of the OECD group, Group 1 and Group 3, but has a negative effect on Group 2. The effect is the highest impact on Group 1. The effect of lags 2 and 3 of the finance and insurance sector variable is negative for all groups.

The 1st lag of the industry sector variable has a positive effect on growth for the OECD group and Group 1, whereas it has a negative effect on Group 2 and Group 3. The effect is positive in group 3 for the second lag.

The information sector has a positive effect on the Growth variable for the OECD group and Group 1, but a negative effect on Group 2 and Group 3 at the first lag of the Communication sector variable. The sector, like finance where the negative effect is similar to the past periods where the first lag has a positive and greater impact.

The 1st lag of the manufacturing sector has a negative effect on the OECD group, Group 1, and Group 2 on growth, but has a positive effect on group 3. For different lags, the sign of this effect varies in this sector.

While the effect of the 1st lag of the other services sector variable positive effect on the growth variable for all groups, the highest effect is in group 1. The effect of 2nd lag of the other services activities sector variable was negative for the OECD group and Group 1 but positive for Group 3. The effect is the highest for Group 3.

The effect of the 1st lag of the Professional, Scientific, and Support Services sector variable on the growth variable is positive for the OECD group and Group 1, but negative for Group 2 and Group 3. This effect turned negative to the 2nd and 3rd lags for the OECD group, but the positive effects persisted for lags 2 and 4 for group 1. The effect of this sector has a positive effect on Group 3 on the second lag.

The effect of the 1st lag of the sector "Public administration, defense, education, health, social work" on the growth variable was positive for the OECD group, Group 1, and Group 3, but negative for Group 2. The positive impact of this sector, which gives information about the institutional and social structures of the countries, is also an important finding.

The effect of the 1st lag of the real estate sector variable on the growth variable was positive for all models, but it was determined that Group 1 has the highest effect. The effect of this sector can be also analyzed based on groups, it is seen that it has a positive effect for the first lag, but this effect turns negative in the second and third lags for the countries in the OECD group and Group 1 countries.

Wholesale, retail trade, repairs, transport; the effect of the 1st lag of accommodation, food services sector variable on growth variable is positive for OECD group and Group 1, negative for Group 2 and group 3. The highest effect was determined for Group 1.

The analysis of dynamic relationships is carried out through impulse-response analysis and variance decomposition in VAR analysis. In this part of the study, graphs show the response of the total growth variable to the “one standard deviation” shock occurring in the variables of sector growth from the impulse-response functions for the 4 models examined are presented.

Table 4: Panel VAR Model Summary Results of Four Groups

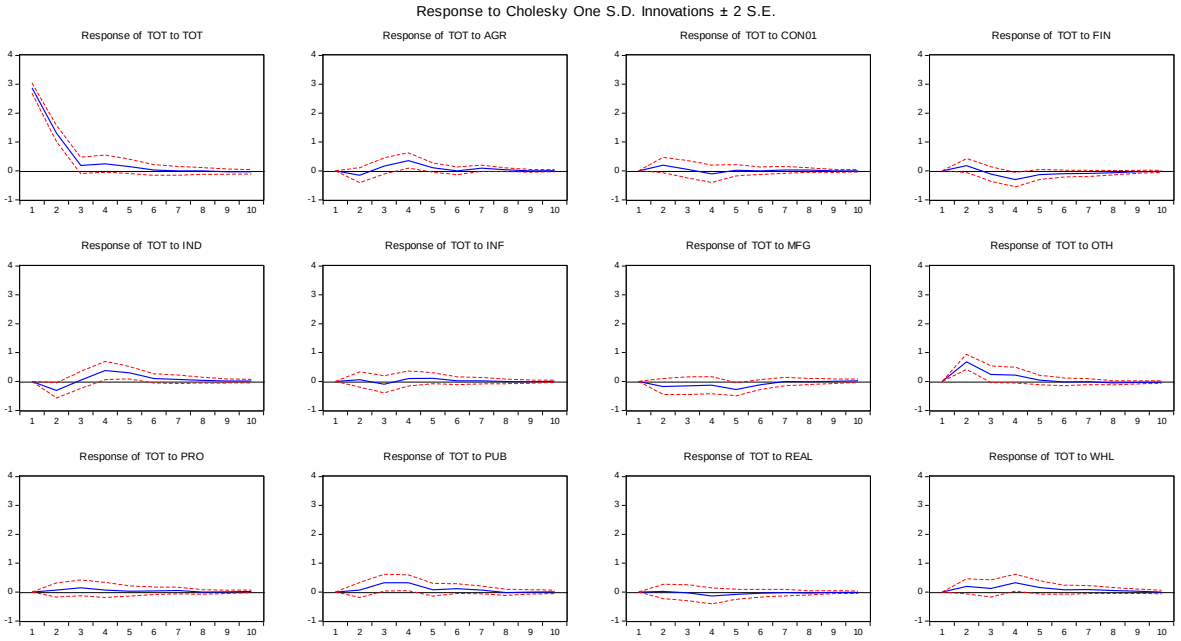
	OECD	**GROUP 1**	**GROUP 2**	**GROUP 3**
	TOT	TOT	TOT	TOT
TOT(-1)	-0.011	-2.43	0.64	0.198
	(0.27)	(0.866)	(0.53)	(0.465)
TOT(-2)	-0.33	-0.74		-0.549
	(0.283)	(0.929)		(0.462)
TOT(-3)	-0.522	0.536		

	(0.282)	(0.972)		
TOT(-4)		-1.118		
		(0.929)		
AGR(-1)	-0.003	0.028	-0.023	-0.062
	(0.016)	(0.058)	(0.023)	(0.021)
AGR(-2)	0.028	0.118		-0.001
	(0.017)	(0.061)		(0.023)
AGR(-3)	0.048	0.092		
	(0.017)	(0.07)		
AGR(-4)		0.048		
		(0.062)		
CON (-1)	0.042	0.153	0.059	0.065
	(0.026)	(0.074)	(0.047)	(0.048)
CON (-2)	-0.002	-0.012		-0.063
	(0.028)	(0.083)		(0.048)
CON (-3)	0.041	-0.108		
	(0.027)	(0.085)		
CON (-4)		0.034		
		(0.079)		
FIN(-1)	0.04	0.178	-0.032	0.14
	(0.023)	(0.066)	(0.038)	(0.056)
FIN(-2)	-0.015	-0.004		-0.004
	(0.023)	(0.058)		(0.055)
FIN(-3)	-0.005	0.005		
	(0.021)	(0.055)		
FIN(-4)		0.027		
		(0.05)		
IND(-1)	0.162	1.179	-0.017	-0.144
	(0.112)	(0.317)	(0.182)	(0.178)
IND(-2)	0.115	-0.253		0.435
	(0.112)	(0.323)		(0.182)
IND(-3)	0.24	0.158		
	(0.109)	(0.332)		
IND(-4)		0.815		
		(0.308)		
INF(-1)	0.026	0.083	-0.041	-0.05
	(0.031)	(0.088)	(0.048)	(0.06)
INF(-2)	-0.019	-0.056		-0.058
	(0.032)	(0.09)		(0.054)
INF(-3)	0.049	-0.111		
	(0.027)	(0.091)		
INF(-4)		-0.018		
		(0.069)		
MFG(-1)	-0.114	-0.565	-0.109	0.084
	(0.081)	(0.237)	(0.1)	(0.148)
MFG(-2)	-0.041	0.479		-0.363
	(0.082)	(0.244)		(0.158)
MFG(-3)	-0.036	-0.069		
	(0.078)	(0.241)		
MFG(-4)		-0.304		
		(0.212)		
OTH(-1)	0.167	0.187	0.106	0.085
	(0.032)	(0.055)	(0.077)	(0.067)
OTH(-2)	-0.029	-0.074		0.136
	(0.033)	(0.057)		(0.077)
OTH(-3)	0.031	0.017		
	(0.031)	(0.059)		

OTH(-4)		0.012		
		(0.049)		
PRO(-1)	0.037	0.147	-0.062	-0.058
	(0.04)	(0.108)	(0.065)	(0.08)
PRO(-2)	0.033	0.006		0.019
	(0.039)	(0.101)		(0.076)
PRO(-3)	0.007	-0.063		
	(0.036)	(0.091)		
PRO(-4)		0.07		
		(0.082)		
PUB(-1)	0.099	0.374	-0.228	0.124
	(0.1)	(0.217)	(0.176)	(0.178)
PUB(-2)	0.191	0.283		-0.05
	(0.103)	(0.244)		(0.17)
PUB(-3)	0.099	0.213		
	(0.094)	(0.222)		
PUB(-4)		0.314		
		(0.214)		
REAL(-1)	0.031	0.273	0.064	0.02
	(0.043)	(0.106)	(0.089)	(0.114)
REAL(-2)	-0.016	0.016		0.228
	(0.045)	(0.114)		(0.104)
REAL(-3)	-0.031	-0.16		
	(0.044)	(0.114)		
REAL(-4)		0.141		
		(0.126)		
WHL(-1)	0.116	1.022	-0.055	-0.028
	(0.076)	(0.262)	(0.125)	(0.124)
WHL(-2)	-0.044	-0.018		0.237
	(0.08)	(0.278)		(0.121)
WHL(-3)	0.131	-0.128		
	(0.083)	(0.293)		
WHL(-4)		0.267		
		(0.279)		
C	1.492	1.118	1.747	1.491
	(0.277)	(0.734)	(0.385)	(0.38)
R-squared	0.321	0.656	0.149	0.443
Adj. R-squared	0.269	0.474	0.095	0.289
Sum sq. resids	3899.784	1023.856	1418.362	245.0347
S.E. equation	2.871	3.354	2.725	1.678
F-statistic	6.204	3.611	2.782	2.877
Log likelihood	-1242.4	-337.93	-487.256	-202.764
Akaike AIC	5.017	5.528	4.904	4.067
Schwarz SC	5.324	6.557	5.116	4.674
Mean dependent	2.307	2.514	2.18	1.642
S.D. dependent	3.358	4.626	2.865	1.99

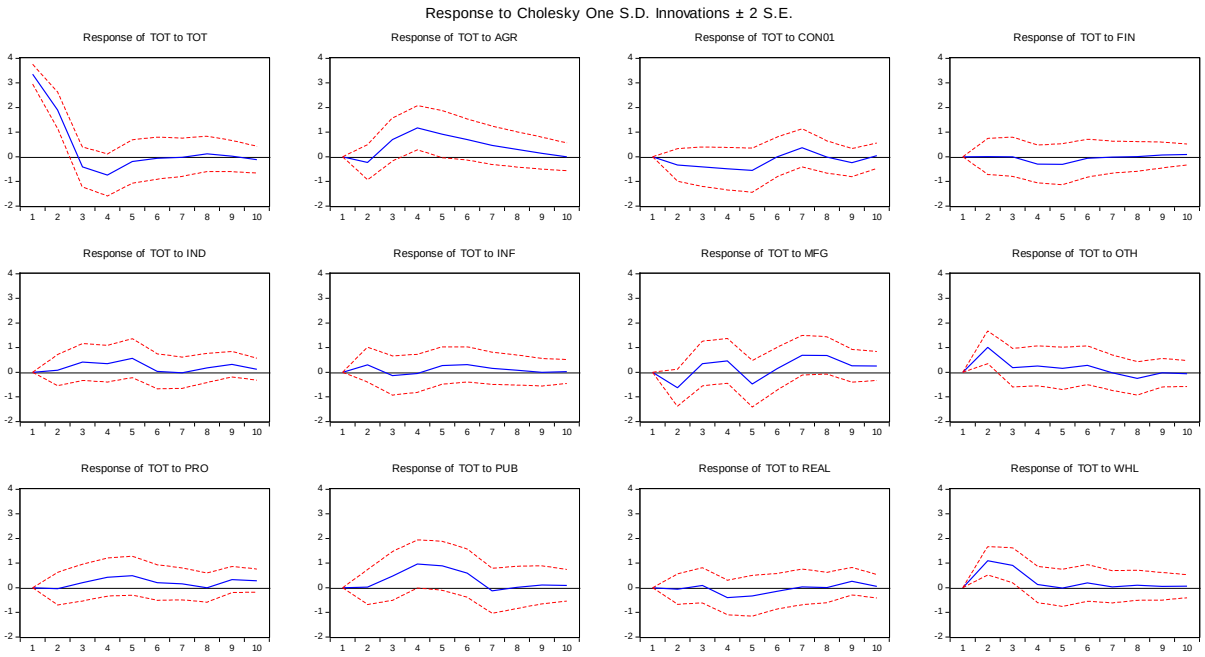
Figure 1 shows that one standard deviation shock to the sector growths of Construction, Finance, Information, Other Services, Professional, Scientific, Support services, public administration, defense, education, health, social work, Real estate sector and wholesale, retail trade, repairs, transport has a positive effect on total growth. On the other hand, the effect of Agriculture, Industry and Manufacturing sectors is negative.

Figure 1: Impulse Response Analysis Results Obtained for Panel VAR Model



The impulse-response graph results of the first group were examined; in terms of the countries in this group, one standard deviation shock to the sector growths of Finance, Information, Other Services, Industry, Professional, Scientific, Support services and Wholesale, retail trade, repairs, transport have a positive effect on total growth. Furthermore, the effect of Agriculture, Construction, Manufacturing, Professional, Scientific, Support services and Real estate sector sectors have negative effect.

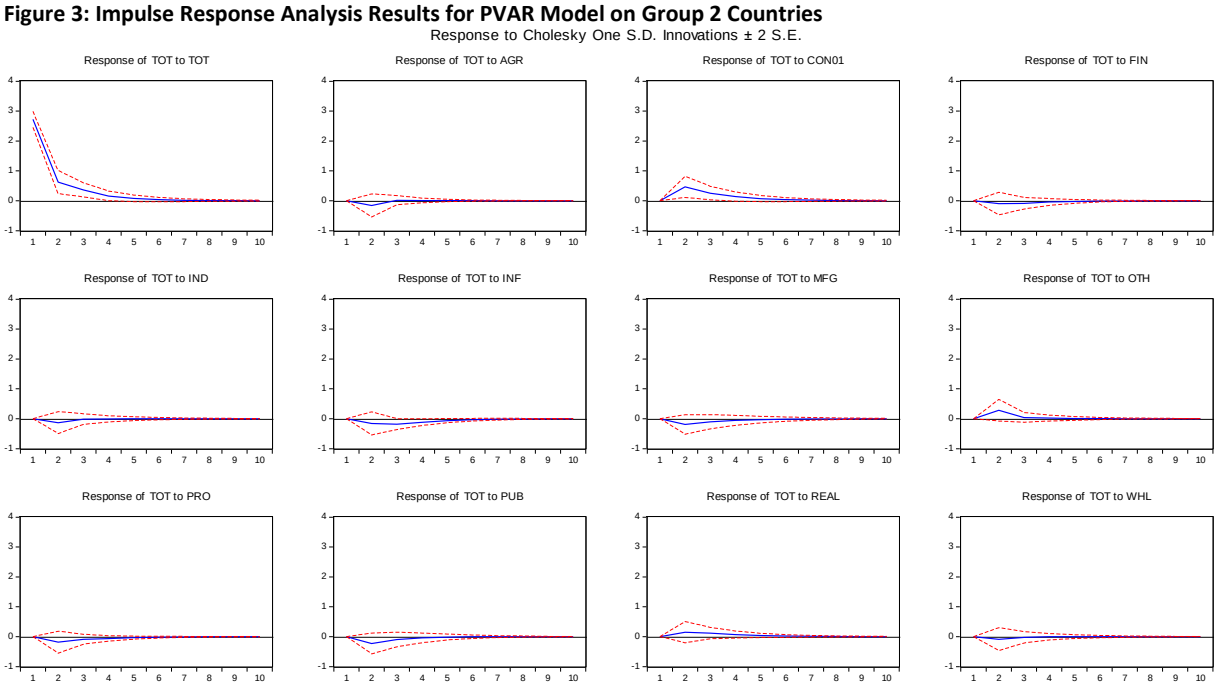
Figure 2: Impulse Response Analysis Results for PVAR Model on Group 1 Countries



The impulse-response analysis results of the Group 2 of the countries are examined, one standard deviation shock to the sector growths of Construction, Other Services and Real estate sector have a positive effect on total growth for the countries in this group. The effect of Agriculture, Finance, Industry, Information, Manufacturing, Professional, Scientific, Support

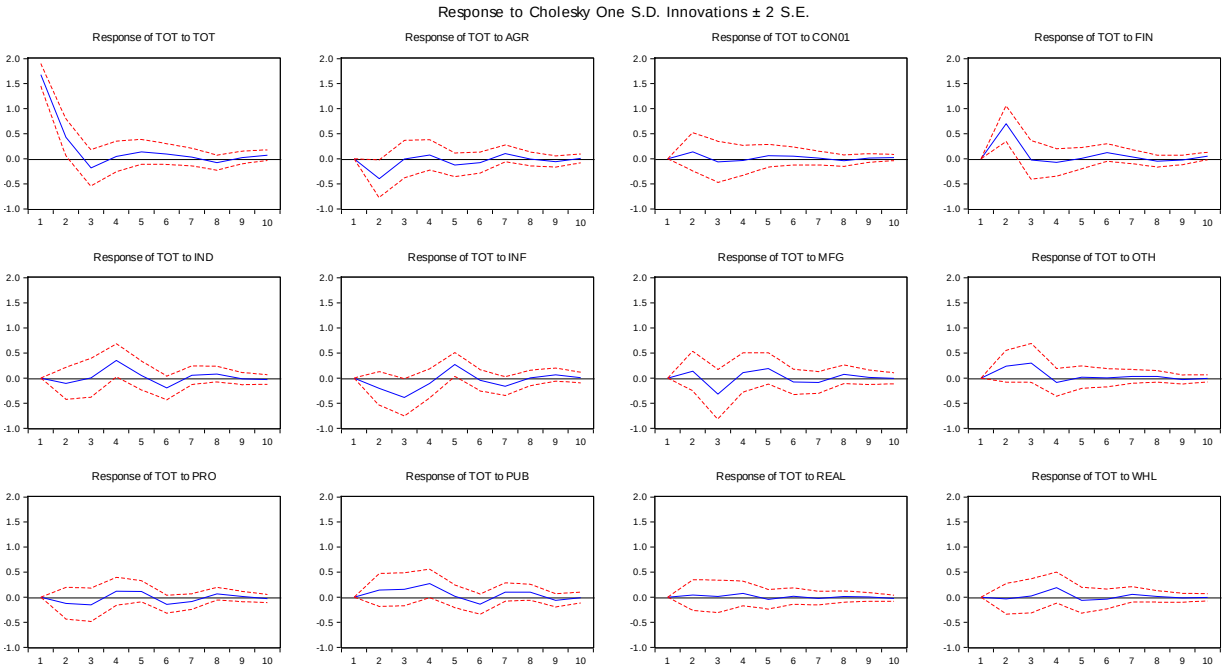
services, public administration, defense, education, health, social work and Wholesale, retail trade, repairs, transport sectors have negative effect.

Figure 3: Impulse Response Analysis Results for PVAR Model on Group 2 Countries



The impulse-response graph results for the group 3 countries, one standard deviation shock to the sector growths of Construction, Manufacturing, Other Services Public administration, defense, education, health, social work, and real estate sector have a positive effect on total growth. Also, the effect of Agriculture, Finance, Industry, Information, Professional, Scientific, Support services and Wholesale, retail trade, repairs, transport sectors have negative effect.

Figure 4: Impulse Response Analysis Results for PVAR Model on Group 3 Countries



According to the findings, the direction of the effect of sector growth on the total growth, the maximum value, the period when the maximum value was reached, and the period in which the effect changes sign is summarized in Table 5 and 6 for all models.

The change in direction of the response of total growth to shocks caused by sector growth was examined in terms of groups.

Impulse response analysis shows the effect of one standard deviation shock on each variable. The short-term impact of each sector's shock on total growth is shown in this analysis. To reveal the general structure of these effects, the above tables (5 and 6) is prepared. The table shows the direction, size, and periodic length of the impact of the shock in each sector on total growth.

For example, when the agricultural sector is analyzed in terms of both the OECD group and sub-groups, it is seen that the effect of a shock in the sector is negative on total growth. As of the period examined, this situation is within the expectation of the agricultural sector. When the other sectors are analyzed, it is determined that sector effects differ according to country groups.

For instance, the construction sector points to a positive impact on growth in the model in the OECD group. It is understood that for the countries in Group 2 and Group 3, the shock on the construction sector has a positive effect on those countries. Contrary it is seen that Group 1 countries will not be positively affected by an effect the construction sector like other countries. Another importance of this result is that such results can be obtained by using goal programming and clustering method.

Observing which sectors are affected in the short term for each group is possible. In Group 1, the impact of a shock in the Construction, Industry, Other Services and Public administration, defense, education, health, and social work sectors disappear completely after 7 periods. The effects of the shocks in these sectors are not easily absorbed by the system. Namely, they indicate that positive effects continue in the relatively long term. Consequently, the results in this table produce results that guide policymakers.

Table 5: Summary Table of Impulse-Response Analysis for "OECD Group and Group1"

	OECD GROUP				GROUP 1			
Period	**Sign of response**	**Max. value**	**Effect maximization occurs in period**	**Effect disappears**	**Sign of response**	**Max. value**	**Effect maximization occurs in period**	**Effect disappears**
AGR	-	-0.15	2	3	-	-0.23	2	3
CON	+	0.20	2	4	-	-0.55	5	7
FIN	+	0.18	2	3	+	0.01	2	3
IND	-	-0.31	2	3	+	0.57	5	7
INF	+	0.06	2	3	+	0.30	2	3
MFG	-	-0.27	5	9	-	-0.63	2	3
OTH	+	0.68	2	6	+	0.28	6	7
PRO	+	0.15	3	8	-	-0.05	2	3
PUB	+	0.32	3	8	+	0.96	4	7
REAL	+	0.02	2	3	-	-0.06	2	3
WHL	+	0.32	4	10	+	1.Eyl	2	5

Table 6: **Summary Table of Impulse-Response Analysis for "Group 2 and Group 3"**

	GROUP 2				GROUP 3			
Period	**Sign of response**	**Max. value**	**Effect maximization occurs in period**	**Effect disappears**	**Sign of response**	**Max. value**	**Effect maximization occurs in period**	**Effect disappears**
AGR	-	-0.16	2	3	-	-0.40	2	7
CON	+	0.46	2	4	+	0.14	2	3
FIN	-	-0.10	2	4	+	0.70	2	3
IND	-	-0.13	2	4	-	-0.11	2	3
INF	-	-0.18	3	6	-	-0.39	3	5
MFG	-	-0.19	2	5	+	0.14	2	3
OTH	+	0.28	2	4	+	0.30	3	4
PRO	-	-0.18	2	5	-	-0.15	3	4
PUB	-	-0.23	2	7	+	0.27	4	6
REAL	+	0.15	2	5	+	0.07	4	5
WHL	-	-0.08	2	4	-	-0.03	2	3

5. CONCLUSION AND POLICY IMPLICATIONS

The study examined the growth dynamics of 34 OECD member countries between 2000 and 2017. Eleven sector data for each country were taken into account to understand which sector originated the growth characteristics of the countries.

Countries analyzed in terms of the contribution of sectoral growth rates to the growth rate of the country were divided into groups by cluster analysis. It is determined that the countries grouped in terms of the contribution of sectors to growth are divided into 5 groups. The first group has 10 member countries. The second group has 12 countries, and the third group has 7 countries, the fourth group has 4 countries and only 1 country belongs to the fifth group. It is constructed that the third group of the 12 countries belongs to the third fourth and fifth groups.

The countries in group 1 are Estonia, Turkey, Greece, Italy, Poland, Portugal, Lithuania, Latvia, Slovakia, and Slovenia. The countries in group 2 are Australia, Belgium, the Czech Republic, Germany, Denmark, Hungary, Ireland, Mexico, Netherlands, Norway, Sweden, and New Zealand. The countries in group 3 are Austria, Spain, Finland, France, the Republic of Korea, Luxembourg, Switzerland, the USA, Israel, Costa Rica, the United Kingdom, and Japan.

Based on the factor sizes obtained for the first group of countries, it has been determined that the most important dynamics of growth with an average of 26% is the Wholesale, retail trade, repairs, and transport sector (WHL). The sectors that have an impact on growth after this sector are Industry (IND) with 20%, and public administration, defense, education, health, and social work (PUB) with 16%.

Based on the factor sizes obtained for the second group of countries, the most important dynamics of growth, with an average of 23%, were IND. The sectors that have an impact on growth after this sector are Wholesale, retail trade, repairs, and transport, with 16% Public administration, defense, education, health, and social work sectors.

The countries in the third group are mixed groups. Based on the factor sizes obtained, it has been determined that the most important dynamics of growth with an average of 18% are wholesale, retail trade, repairs, and transport. The sectors that have an impact on growth after this sector are public administration, defense, education, health, social work, and Industry with 13.5%.

The whole group of all OECD countries is investigated for this study, it is determined that the most important dynamics of growth with an average of 21%, based on factor sizes, are Wholesale, retail trade, repairs, and transport. Following this sector, the sectors that have an impact on growth are Industry with 19%, and Public administration, defense, education, health, and social work with 16%.

As can be seen from this study, the first three sectors of growth are the same for groups, but for 3 groups, the difference is in their order. This difference is also important for getting the correct information from the econometric analysis.

A similar situation was obtained from the Panel VAR model estimation results. As a result of this analysis, it was observed that the effects of shocks occurring in the sectors in each group differ.

The results of the panel cross-section dependency analysis show that the null hypothesis, which expresses cross-section independence, failed to reject for the OECD countries' group and group 3 but rejected for group 1 and group 2. Namely, there is no cross-sectional dependence between the OECD countries' group and group 3 which are the groups that it is hybrid.

As a result of the examination of these groups, the VAR analysis also provides information on how much each sector is affected by other sectors. From this point of view, it will be appropriate to make investment planning and resource allocation by using the impulse response analysis and variance decomposition analysis of the group which countries can take into consideration in terms of the interaction of the sector structures.

It can be also concluded that countries that have similar sectoral structures can analyze the growth, but it is important to form homogeneous groups while doing this analysis. For this reason, another essential suggestion offered based on the study is the use of the FGP methodology in the analysis method.

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Appendix: FGP Problem Established with the Hannan Approach for Australia as an Example

$$Z_{\max} = \lambda$$

Subject to

$$3.8356x_1 - 14.2992x_2 + 1.3067x_3 + 3.4144x_4 + 3.6893x_5 + 2.1214x_6 + 5.0612x_7 + 9.8686x_8 + 3.0637x_9 + 2.4834x_{10} + 2.6112x_{11} + 0.2293n_{20000} - 0.2293p_{2000} = 2.2937$$
$$3.1543x_1 + 12.4538x_2 + 6.4553x_3 + 1.9964x_4 + 3.2541x_5 + 2.7470x_6 + 1.0043x_7 + 5.3092x_8 + 4.3994x_9 + 1.8632x_{10} + 3.5492x_{11} + 0.3982n_{2001} - 0.3982p_{2001} = 3.9827$$
$$-21.6022x_1 + 16.3570x_2 + 3.2945x_3 + 2.3293x_4 + 6.1478x_5 + 3.8547x_6 + 4.4586x_7 + 1.2508x_8 + 1.7590x_9 + 2.8641x_{10} + 4.7911x_{11} + 0.2789n_{2002} - 0.2789p_{2002} = 2.7898$$
$$25.5142x_1 + 8.2290x_2 + 6.5155x_3 - 0.0179x_4 + 4.2860x_5 + 1.2731x_6 + 5.2617x_7 + 3.1326x_8 + 2.8150x_9 + 2.3053x_{10} + 4.6558x_{11} + 0.4089n_{2003} - 0.4089p_{2003} = 4.0895$$
$$4.2838x_1 + 4.9107x_2 + 5.0847x_3 + 0.9163x_4 + 2.7916x_5 - 0.9844x_6 + 0.4215x_7 + 2.5663x_8 + 3.3837x_9 + 3.8417x_{10} + 4.8621x_{11} + 0.3314n_{2004} - 0.3314p_{2004} = 3.3144$$
$$2.8568x_1 + 6.4504x_2 + 4.5905x_3 + 0.3574x_4 + 3.9336x_5 - 0.6411x_6 + 0.1188x_7 + 4.7053x_8 + 2.7080x_9 + 3.3220x_{10} + 2.3977x_{11} + 0.2839n_{2005} - 0.2839p_{2005} = 2.8393$$
$$-15.0389x_1 + 5.7011x_2 + 10.0584x_3 + 4.4853x_4 + 6.5809x_5 + 2.0657x_6 + 3.9875x_7 + 3.8700x_8 + 3.8450x_9 + 0.0419x_{10} + 4.6830x_{11} + 0.3908n_{2006} - 0.3908p_{2006} = 3.9081$$
$$8.0938x_1 + 7.1979x_2 + 5.1602x_3 + 3.1634x_4 + 6.0903x_5 + 3.9784x_6 + 2.0639x_7 + 4.6670x_8 + 2.6602x_9 + 0.6004x_{10} + 4.4724x_{11} + 0.3848n_{2007} - 0.3848p_{2007} = 3.8482$$
$$17.0795x_1 + 4.4493x_2 + 0.1313x_3 - 0.5762x_4 + 1.3542x_5 - 5.1304x_6 + 4.5319x_7 + 1.2222x_8 + 5.4873x_9 + 3.2430x_{10} - 0.1109x_{11} + 0.2188n_{2008} - 0.2188p_{2008} = 2.1886$$
$$-0.7460x_1 + 0.5807x_2 + 0.4932x_3 + 3.9906x_4 + 1.9905x_5 + 0.3963x_6 + 0.1415x_7 + 4.1530x_8 + 2.9236x_9 + 0.7009x_{10} + 1.7118x_{11} + 0.2226n_{2009} - 0.2226p_{2009} = 2.2261$$
$$3.4663x_1 + 2.9531x_2 + 2.0220x_3 + 0.7257x_4 + 3.3297x_5 - 0.2535x_6 + 1.6870x_7 + 7.4626x_8 + 2.2326x_9 + 2.5119x_{10} + 1.6813x_{11} + 0.2510n_{2010} - 0.2510p_{2010} = 2.5108$$
$$0.9736x_1 + 11.3163x_2 + 5.0785x_3 + 3.8949x_4 + 1.1848x_5 + 0.9068x_6 + 3.9035x_7 + 2.9385x_8 + 2.6075x_9 + 2.7328x_{10} + 4.3774x_{11} + 0.4063n_{2011} - 0.4063p_{2011} = 4.0632$$
$$-0.7280x_1 + 3.5476x_2 + 3.2650x_3 + 3.4311x_4 - 0.1386x_5 - 3.2176x_6 - 2.1438x_7 + 2.7677x_8 + 2.5790x_9 + 2.7418x_{10} + 2.9435x_{11} + 0.2688n_{2012} - 0.2688p_{2012} = 2.6882$$
$$1.1444x_1 + 4.4825x_2 + 2.3945x_3 + 3.9155x_4 + 4.0982x_5 - 1.0780x_6 + 4.0388x_7 + 1.9056x_8 + 3.6771x_9 + 2.4672x_{10} + 0.2033x_{11} + 0.2719n_{2013} - 0.2719p_{2013} = 2.7192$$
$$1.4266x_1 - 2.5636x_2 + 4.7743x_3 + 3.2787x_4 + 7.2181x_5 - 1.5880x_6 + 1.9389x_7 + 2.1287x_8 + 2.9903x_9 + 1.4369x_{10} + 2.4298x_{11} + 0.2403n_{2014} - 0.2403p_{2014} = 2.4034$$
$$-7.9012x_1 - 1.2279x_2 + 4.9423x_3 + 2.0692x_4 + 7.2955x_5 - 2.2271x_6 + 1.8499x_7 + 3.1726x_8 + 3.5274x_9 + 3.6257x_{10} + 3.0233x_{11} + 0.2660n_{2015} - 0.2660p_{2015} = 2.6607$$
$$9.5979x_1 - 3.2326x_2 + 3.4074x_3 + 0.2720x_4 + 3.7840x_5 - 1.0337x_6 + 1.2529x_7 + 5.2286x_8 + 2.5977x_9 + 2.5178x_{10} + 3.1131x_{11} + 0.2345n_{2016} - 0.2345p_{2016} = 2.3454$$
$$-5.0514x_1 + 5.0970x_2 + 3.4323x_3 + 2.7887x_4 + 2.7300x_5 + 3.0492x_6 + 3.4388x_7 + 4.2430x_8 + 3.1680x_9 + 2.0194x_{10} + 1.7269x_{11} + 0.2778n_{2017} - 0.2778p_{2017} = 2.7786$$

$$\lambda + n_{2000} + p_{2000} \le 1 \qquad \lambda + n_{2006} + p_{2006} \le 1 \qquad \lambda + n_{2012} + p_{2012} \le 1$$
$$\lambda + n_{2001} + p_{2001} \le 1 \qquad \lambda + n_{2007} + p_{2007} \le 1 \qquad \lambda + n_{2013} + p_{2013} \le 1$$
$$\lambda + n_{2002} + p_{2002} \le 1 \qquad \lambda + n_{2008} + p_{2008} \le 1 \qquad \lambda + n_{2014} + p_{2014} \le 1$$
$$\lambda + n_{2003} + p_{2003} \le 1 \qquad \lambda + n_{2009} + p_{2009} \le 1 \qquad \lambda + n_{2015} + p_{2015} \le 1$$
$$\lambda + n_{2004} + p_{2004} \le 1 \qquad \lambda + n_{2010} + p_{2010} \le 1 \qquad \lambda + n_{2016} + p_{2016} \le 1$$
$$\lambda + n_{2005} + p_{2005} \le 1 \qquad \lambda + n_{2011} + p_{2011} \le 1 \qquad \lambda + n_{2017} + p_{2017} \le 1$$
$$x_i \ge 0 \qquad i = 1, 2, .., 11$$
$$n_j, p_j \ge 0 \qquad j = 2000, 2001, ..., 2017$$
$$\lambda \ge 0$$

Appendix 2: Impacts of Sectoral Growth Rates of Countries on Growth Rate

STATE	AGR	CON	FIN	IND	INF	MFG	OTH	PRO	PUB	REAL	WHL
AUS	0,0364	0,0715	0,1307	0,2311	0,0057	0,0000	0,0101	0,1161	0,1459	0,1179	0,1290
AUT	0,0230	0,0672	0,0537	0,2034	0,0235	0,0233	0,0000	0,1102	0,1200	0,0823	0,2037
BEL	0,0045	0,0555	0,0579	0,1936	0,0597	0,0000	0,0416	0,1159	0,1386	0,0805	0,1964
CHE	0,0066	0,0389	0,1191	0,1191	0,0448	0,0935	0,0228	0,0927	0,1335	0,0686	0,2174
CRI	0,1071	0,0284	0,0463	0,1376	0,0226	0,0000	0,0945	0,0701	0,1007	0,1331	0,2243
CZE	0,0256	0,0546	0,0380	0,2747	0,0489	0,0350	0,0221	0,0766	0,1158	0,0739	0,1830
DEU	0,0121	0,0494	0,0480	0,2279	0,0480	0,0193	0,0068	0,1160	0,1779	0,0879	0,1741
DNK	0,0127	0,0626	0,0587	0,1886	0,0326	0,0112	0,0691	0,0690	0,2170	0,1105	0,2066
ESP	0,0371	0,0791	0,0562	0,1616	0,0571	0,0265	0,0443	0,0731	0,1324	0,0791	0,2063
EST	0,0349	0,0745	0,0457	0,1945	0,0674	0,0000	0,0402	0,0480	0,2050	0,0856	0,2328
FIN	0,0165	0,0658	0,0277	0,2666	0,0568	0,0000	0,0000	0,1058	0,2982	0,0856	0,1391
FRA	0,0172	0,0590	0,0401	0,1563	0,0569	0,0000	0,0358	0,1373	0,2036	0,1073	0,1622
GBR	0,0165	0,0345	0,0900	0,1680	0,0503	0,0000	0,0416	0,1073	0,0733	0,1992	0,1926
GRC	0,0130	0,0692	0,0000	0,0895	0,0155	0,0000	0,0978	0,0203	0,1388	0,0996	0,3250
HUN	0,0457	0,0527	0,0307	0,2693	0,0440	0,0000	0,0108	0,0941	0,1667	0,0728	0,1624
IRL	0,0221	0,0403	0,0808	0,2519	0,0835	0,0000	0,0000	0,0747	0,1597	0,0994	0,1965
ISR	0,0070	0,0999	0,0700	0,1495	0,0562	0,0000	0,0473	0,0480	0,1525	0,2461	0,1166
ITA	0,0262	0,0481	0,0570	0,2022	0,0353	0,0000	0,0355	0,0950	0,1940	0,1112	0,2088
JPN	0,0148	0,0681	0,0585	0,0239	0,0785	0,2119	0,0328	0,0917	0,0000	0,0163	0,1550
KOR	0,0279	0,0578	0,0697	0,0644	0,0471	0,2183	0,0092	0,0352	0,1989	0,0916	0,1927
LTU	0,0403	0,0862	0,0153	0,1960	0,0627	0,0000	0,0153	0,0439	0,0909	0,0668	0,3096
LUX	0,0100	0,0705	0,2408	0,0995	0,0562	0,0000	0,0473	0,0823	0,1112	0,0960	0,1880
LVA	0,0581	0,0637	0,0530	0,1261	0,0290	0,0000	0,0573	0,0392	0,2364	0,0747	0,2707
MEX	0,0488	0,0657	0,0205	0,1914	0,0335	0,0000	0,0570	0,0551	0,1273	0,0094	0,3293
NLD	0,0153	0,0577	0,0908	0,1789	0,0509	0,0000	0,0000	0,1320	0,1712	0,0514	0,2011
NOR	0,0125	0,0619	0,0210	0,3792	0,0426	0,0019	0,0189	0,0494	0,2046	0,0749	0,1655
POL	0,0350	0,0897	0,0417	0,2485	0,0415	0,0000	0,0319	0,0448	0,1411	0,0525	0,2720
PRT	0,0192	0,0749	0,0448	0,1621	0,0369	0,0000	0,0431	0,0755	0,1697	0,0953	0,2329
SVK	0,0250	0,0671	0,0199	0,2597	0,0753	0,0000	0,0184	0,0715	0,0944	0,0827	0,2408
SVN	0,0305	0,0875	0,0192	0,2674	0,0396	0,0000	0,0300	0,0688	0,2084	0,1018	0,1906
SWE	0,0059	0,0851	0,0467	0,2083	0,0602	0,0000	0,0000	0,0596	0,1842	0,0983	0,2472
TUR	0,0783	0,0472	0,0239	0,2649	0,0268	0,0000	0,0000	0,0464	0,1852	0,0722	0,2670
USA	0,0129	0,0450	0,0778	0,0795	0,0760	0,0887	0,0469	0,1410	0,1699	0,0814	0,1327
NZL	0,0600	0,0512	0,0648	0,1955	0,0443	0,0000	0,0252	0,0934	0,1599	0,1115	0,1803

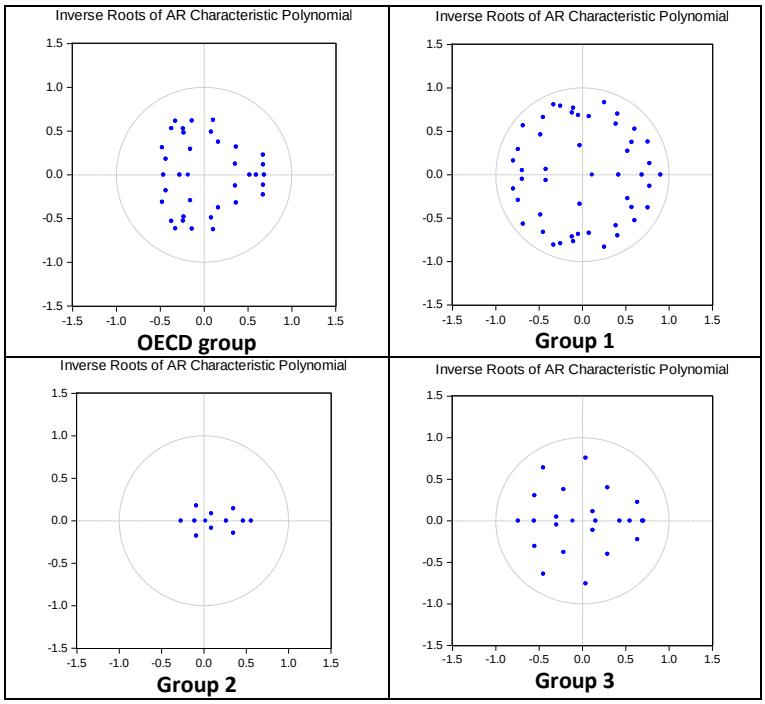
Appendix 3: Countries Grouped by Impact Values

Groups	Countries
Group 1	Estonia, Turkey, Greece, Italy, Poland, Portugal, Lithuania, Latvia, Slovakia, Slovenia
Group 2	Australia, Belgium, Czech Republic, Germany, Denmark, Hungary, Ireland, Mexico, Netherlands, Norway, Sweden, New Zealand,
Group 3	Austria, Spain, Finland, France, Republic of Korea, Luxembourg, Switzerland, USA, Israel, Costa Rica, United Kingdom, Japan

Appendix 4: Panel VAR Model Appropriate Lag Length

	Lag	LogL	LR	FPE	AIC	SC	HQ
OECD group	3	-13688.1	324.6247	9.63e+12*	63.94594*	68.05576	65.56697
Group 1	4	-3734.23	223.3443*	1.96e+14*	66.49585	79.46593	71.76603
Group 2	1	-4586.87	361.3713	4.17e+11*	60.80604*	63.8559	62.04476
Group 3	2	-2661.96	249.6739*	5.77e+09*	56.41825*	64.001	59.49093

Appendix 5: Inverse Roots Graphs



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HEDONIC COALITION FORMATION GAMES: NASH STABILITY UNDER DIFFERENT MEMBERSHIP RIGHTS

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Mehmet Karakaya[1], Seckin Ozbilen[2]
[1]Izmir Katip Celebi University, Department of Economics, Izmir, Turkiye.
mehmet.karakaya@ikcu.edu.tr, ORCID: 0000-0002-9495-2242
[2]Ozyegin University, Faculty of Business, Istanbul, Turkiye.
seckin.ozbilen@ozyegin.edu.tr, ORCID: 0000-0001-8230-9789

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ABSTRACT

Purpose - We study hedonic coalition formation games in which each agent has preferences over the coalitions she is a member of. Hedonic coalition formation games are used to model economic, social, and political instances in which people form coalitions. The outcome of a hedonic coalition formation game is a partition. We consider stability concepts of a partition that are based on a single-agent deviation under different membership rights, that is, we study Nash stability under different membership rights. We revisit the conditions that guarantee the existence of Nash stable partitions and provide examples of hedonic coalition formation games satisfying these conditions.

Methodology – While analyzing a stability notion for hedonic coalition formation games, two crucial points are considered: i) who can deviate from the given partition, ii) what are the allowed movements for the deviator(s), i.e., what deviators are entitled to do. For the first point, the deviation of a single agent is considered for Nash stabilities. For the second point, the allowed movements for deviators are determined by specifying membership rights, that is, membership rights describe whose approval is needed for a particular deviation. So, we reconsider stability concepts by using membership rights based on individual deviations, i.e., we consider Nash stability under different membership rights for hedonic coalition formation games.

Findings- A classification of stability concepts based on a single-agent deviation for hedonic coalition formation games are provided by employing membership rights. The conditions in the literature guaranteeing the existence of Nash stable partitions for all membership rights are revisited. For each condition, an example of a hedonic coalition formation game satisfying the condition is given. Hence, a complete analysis of sufficient conditions for all Nash stability concepts are provided.

Conclusion- To choose the correct stability notion one first should understand the membership rights in the environment that she studies. Then, for hedonic coalition formation problems, the appropriate Nash stability notion consistent with the ongoing membership rights should be chosen when single-agent deviation is considered.

Keywords: Coalition formation, Hedonic games, Nash stability, membership rights, separable preferences
JEL Codes: C71, C78, D71

1. INTRODUCTION

In many economic, social, and political instances people prefer to form groups (coalitions) rather than staying alone. For example, individuals form hobby groups, students form assignment groups in a course, researchers form research teams, and political parties form coalitions. Some of these instances of forming groups can be modeled as a hedonic coalition formation game.

A hedonic coalition formation game (shortly, a hedonic game) consists of a finite set of agents and a list of agents' preferences. A non-empty subset of the agents is called a coalition, and each agent's preferences depend only on the coalitions of which she is a member. That is, each agent only cares about which other agents are in her coalition and does not care how other agents who are not in her coalition behave. This is called the *hedonic aspect of preferences* by Drèze and Greenberg (1980). The formal model of hedonic coalition formation games was introduced by Banerjee et al. (2001) and Bogomolnaia and Jackson (2002). Marriage

problems and roommate problems (Gale and Shapley, 1962; Roth and Sotomayor, 1990) are special hedonic games in which the size of every coalition can be a maximum of two.

An outcome of a hedonic game is a partition (a coalition structure) that is a collection of pairwise disjoint coalitions such that their union is equal to the set of agents. The stability properties of partitions have been studied in the literature.[1] Stability notions concern individual as well as coalitional deviations from a given partition. One of the most studied stability concepts for hedonic coalition formation games is Nash stability.[2] A partition for a given hedonic game is Nash stable if there is no agent such that she gets strictly better off by leaving her current coalition and joining an existing coalition of the partition or she forms a singleton coalition by herself (in this case we say that she joins to the empty set). The agent who moves to another coalition of the partition does not consider whether the agents who are in the coalition she leaves, and joins are affected negatively, and hence she does not ask their permission for her movement.

As mentioned in Karakaya (2011), when a stability notion is analyzed, we consider agent(s) who can deviate and what are the allowed movements for the deviator(s), that is, what deviators are entitled to do. The allowed movements for deviators are determined by specifying membership rights, that is, membership rights describe whose approval is needed for a particular deviation. Sertel (1992) introduced four membership rights: Free Exit and Free Entry (FX-FE) membership rights, Free Exit and Approved Entry (FX-AE) membership rights, Approved Exit and Free Entry (AX-FE) membership rights, and Approved Exit and Approved Entry (AX-AE) membership rights.

Free Exit and Free Entry (FX-FE) membership rights describe situations in which an agent does not need the consent of anyone when leaving one coalition and joining another, that is, she asks permission from neither the remaining agents in the coalition she leaves nor the agents in the coalition she joins. For example, when a family moves from one neighborhood to another while changing houses, it does not need the permission of anyone (neither the families in the neighborhood they leave nor the families in the new neighborhood they move to).

Free Exit and Approved Entry (FX-AE) membership rights describe situations in which an agent does not need the consent of remaining agents in the coalition she leaves but she needs the consent of agents of the coalition she joins. For example, joining a new friendship group or a new hobby group, an agent must have the consent of everyone in the new group but does not need anyone's permission when leaving her old group.

Approved Exit and Free Entry (AX-FE) membership rights describe situations in which an agent does not need the consent of the agents of the coalition she joins but needs the consent of the remaining agents in the coalition she leaves. As an example, we can consider a person who would like to join a voluntary-based organization. Joining such an organization is usually easy and does not require permission. However, a person working in such an organization cannot leave her job without the consent of the people in the organization.

Approved Exit and Approved Entry (AX-AE) membership rights describe situations in which an agent needs the consent of both the remaining agents in the coalition she leaves and the agents in the coalition she joins. As an example, to quit a job and start another one, an agent must first terminate the contract with her current workplace and then start a contract with the new workplace, that is, the agent needs the permission of both workplaces.

In this study, we reconsider the stability properties of partitions regarding single-agent deviations under different membership rights together with conditions that guarantee the existence of such partitions. We revisit these sufficient conditions given in the literature by providing hedonic games satisfying them.

The Nash stability of a partition that we mentioned above is defined under FX-FE membership rights, and hence we call it FX-FE Nash stability. That is, a partition is **FX-FE Nash stable** if there does not exist an agent and an existing coalition of the partition (or, the empty set) such that she gets strictly better off by moving to this coalition (that is, she leaves her current coalition and joins the coalition of the partition) without asking the permission of anyone else.

[1]We refer the reader to Hajduková (2006) and Aziz and Savani (2016) for the survey of the hedonic coalition formation literature and Sung and Dimitrov (2007) for the taxonomy of stability concepts.

[2]The other one is core stability. A partition for a given hedonic game is core stable if there is no coalition such that each agent in the coalition prefers it to her coalition under the partition. That is, each agent in this coalition leaves her current coalition and then they form a new coalition among themselves. Note that when an agent in this coalition leaves her current coalition, she does not require any permission from members of her current coalition of the partition.

Nash stability under FX-AE membership rights is called *individual stability* in the literature (Bogomolnaia and Jackson, 2002). We call it FX-AE Nash stability. A partition is **FX-AE Nash stable** if there does not exist an agent and a coalition of the partition such that the agent gets strictly better off by moving to this coalition and each member of the coalition gets weakly better off (that is, all members of the coalition to which she moves approve her joining to their coalition).

Nash stability under AX-FE membership rights is called *contractual Nash stability* in the literature (Sung and Dimitrov, 2007). We call it AX-FE Nash stability. A partition is **AX-FE Nash stable** if there does not exist an agent and a coalition of the partition such that the agent gets strictly better off by moving to this coalition and all members of her coalition under the given partition she leaves get weakly better off (that is, all members of her coalition under the partition that she leaves approve her leaving).

Nash stability under AX-AE membership rights is called *contractual individual stability* in the literature (Bogomolnaia and Jackson, 2002). We call it AX-AE Nash stability. A partition is **AX-AE Nash stable** if there does not exist an agent and a coalition of the partition such that the agent gets strictly better off by moving to this coalition and all members of the coalition she leaves and joins gets weakly better off (that is, all members of coalitions that she leaves and joins approve her movement).

If a partition is Nash stable under some membership rights and when the membership rights are restricted, then it is also Nash stable under the restricted membership rights. That is, if a partition is FX-FE Nash stable, then it is also FX-AE Nash stable, AX-FE Nash stable, and AX-AE Nash stable. If a partition is FX-AE Nash stable, then it is also AX-AE Nash stable. In the same manner, if a partition is AX-FE Nash stable, then it is also AX-AE Nash stable. However, FX-AE Nash stability and AX-FE Nash stability are independent of each other.

The concepts of FX-FE Nash stability (or, Nash stability), FX-AE Nash stability (individual stability), and AX-AE Nash stability (contractual individual stability) were first introduced and studied by Bogomolnaia and Jackson (2002) without referring to membership rights. The concept of AX-FE Nash stability (contractual Nash stability) was first introduced by Sung and Dimitrov (2007) without referring to membership rights, but they introduced the taxonomy for stability concepts. Karakaya (2011) considered coalitional extension of Nash stability by employing membership rights in the context of hedonic games and introduced and analyzed the notion of *strong Nash stability* under different membership rights.[3]

Bogomolnaia and Jackson (2002) proved that if a hedonic game is *additively separable* and *symmetric*, then there exists an FX-FE Nash stable partition. They proved that the symmetry property is crucial and cannot be replaced by *mutuality*, otherwise, there would be no FX-FE Nash stable partition. Dimitrov and Sung (2004) and Dimitrov et al. (2006) introduced the properties of *appreciation of friends* and *aversion to enemies*. Dimitrov and Sung (2004) proved that if a hedonic game satisfies the properties of appreciation of friends and mutuality or the properties of aversion to enemies and mutuality, then there exists an FX-FE Nash stable partition. Dimitrov and Sung (2006) proved that if a hedonic game satisfies the *top responsiveness property* (Alcalde and Revilla, 2004) and *mutuality* (with respect to top responsiveness), then there exists an FX-FE Nash stable partition. Suksompong (2015) introduced the properties called *subset neutrality* and *neutral anonymity* and showed that if a hedonic game satisfies the subset neutrality property or the neutral anonymity property, then there exists an FX-FE Nash stable partition.

Burani and Zwicker (2003) introduced *descending separable preferences* and showed that they guarantee the existence of a partition that is both FX-FE Nash stable and core stable. Karakaya (2011) showed that descending separable preferences are indeed sufficient for the existence of an FX-FE strongly Nash stable partition. He also introduced a sufficient condition called *weak top-choice property* (by using the weak top-coalition notion of Banerjee et al. (2001)) and proved that if a hedonic game satisfies the weak top-choice property, then there exists an FX-FE strongly Nash stable partition. Aziz and Brandl (2012) proved that if a hedonic game satisfies the *top responsiveness property* and *mutuality* (with respect to top responsiveness) or *bottom responsiveness property* (Suzuki and Sung, 2010) and *mutuality* (with respect to bottom responsiveness), then there exists an FX-FE stronly Nash stable partition.[4]

[3]A partition is FX-FE strongly Nash stable if there exists no subset of agents who reach a new partition via movements among the coalitions of the given partition (e.g., these movements include but not restricted to forming a new coalition, joining existing coalitions individually or as a group, exchanging their current coalitions, or shuffling their coalitions, etc.) such that these agents strictly prefer the new partition to the initial one. This definition uses the reachability approach that we also adopt to define Nash stabilities under different membership rights. We also note that FX-FE strong Nash stability is stronger than core stability and FX-FE Nash stability.

[4]In this study, we do not provide the definitions of *descending separable preferences*, *weak top-choice property*, *top responsiveness property*, and *bottom responsiveness property* since these conditions guarantee the existence of an FX-FE strongly Nash stable partition. For these properties, we refer readers to Burani and Zwicker (2003), Karakaya (2011), Dimitrov and Sung (2006), Suzuki and Sung (2010), and Aziz and Brandl (2012).

Bogomolnaia and Jackson (2002) also studied FX-AE Nash stability and showed that if a hedonic game satisfies the *ordered characteristics property,* then there exists an FX-AE Nash stable partition. Suksompong (2015) also proved that if a hedonic game satisfies the *common ranking property* (Farrell and Scotchmer, 1988), then there exists an FX-AE Nash stable partition.

Sung and Dimitrov (2007) showed that if a hedonic game satisfies the *separability* and *weak mutuality*, then there exists an AX-FE Nash stable partition.

Bogomolnaia and Jackson (2002) proved that every hedonic game has an AX-AE Nash stable partition and introduced an algorithm that brings an AX-AE Nash stable partition which is also Pareto optimal and individually rational when preferences of each agent are strict. Ballester (2004) showed that every hedonic game has an AX-AE Nash stable partition.

In the field of electrical and electronics engineering, the problem of allocating different and complex tasks to a swarm of autonomous robots is a well-known problem. That problem is a hedonic game and the Nash stability of partitions of the given swarm is analyzed via experimental and computational methods. For such studies, we refer the reader to Czarnecki and Dutta (2021), Jang et al. (2018), and Xiong and Xie (2023). In the field of computer science, Nash stability under different membership rights is also studied. In these studies, the computational complexity analysis of the problem for finding a Nash stable partition is investigated for different domains of hedonic games, and algorithms that yield Nash stable partitions are studied. For such studies, we refer the reader to Aziz et al. (2011), Ballester (2004), Bilò et al. (2018), Kerkmann and Rothe (2019), Olsen (2009), and Sung and Dimitrov (2010).

The paper is organized as follows. In Chapter 2, we introduce the model of hedonic coalition formation games. In Chapter 3, we study FX-FE Nash stability and conditions (symmetric and additively separable preferences, appreciation of friends and aversion to enemies, subset neutrality and neutral anonymity) that guarantee its existence by providing examples for each of them. In Chapter 4, we study FX-AE Nash stability with common ranking and ordered characteristics properties each of which suffices for the existence of an FX-AE Nash stable partition. We also provide hedonic games that satisfy these properties. In Chapter 5, we study AX-FE Nash stability with separability and weak mutuality. We provide an example that is separable and weakly mutual and hence has an AX-FE Nash stable partition. In Chapter 6, we study AX-AE Nash stability and provide the proof ideas for the existence of such partitions for every hedonic game by Bogomolnaia and Jackson (2002) and Ballester (2004). In the concluding chapter (Chapter 7), the entire study is summarized and further comments on Nash stability are included.

2. HEDONIC COALITION FORMATION

Let $N = \{1,2, \dots, n\}$ be a finite set of agents with $n \geq 2$. A nonempty subset S of N is called a *coalition of* N. For each agent $i \in N$, let $\mathcal{C}_i^N = \{S \subseteq N \mid i \in S\}$ denote the set of all coalitions of N containing agent i.

Each agent $i \in N$ has complete and transitive preferences (*weak preferences*) $\succcurlyeq_i$ over $\mathcal{C}_i^N$.[5] For each $i \in N$ and each $S, T \in \mathcal{C}_i^N$ with $S \neq T$, $S \succ_i T$ if and only if $S \succcurlyeq_i T$ but not $T \succcurlyeq_i S$, that is, agent i *strictly prefers* S *to* T; and $S \sim_i T$ if and only if both $S \succcurlyeq_i T$ and $T \succcurlyeq_i S$ hold, that is, agent i *is indifferent between* S *and* T. For instance, let $i \in N$ and $S, T, U, V \in \mathcal{C}_i^N$, then $[\succcurlyeq_i : S \succ_i T \sim_i U \succ_i V \sim_i \{i\} \succ_i \dots]$ means that the best coalition for agent i is S (that is, S is strictly preferred to any other coalition that contains i), agent i is indifferent between coalitions T and U, and these are strictly preferred to coalition V, and agent i is indifferent between coalition V and being single ($\{i\}$), etc.

For each $i \in N$, let $\mathcal{R}_i$ denote the set of all preferences of agent i over $\mathcal{C}_i^N$, and let $\mathcal{R}^N = \prod_{i \in N} \mathcal{R}_i$ denote the set of all preference profiles of agents in N.

A ***hedonic coalition formation game***, or simply a ***hedonic game***, consists of a finite set of agents N and their preferences $\succcurlyeq = (\succcurlyeq_1, \succcurlyeq_2, \dots, \succcurlyeq_n) \in \mathcal{R}^N$ and is denoted by $(N, \succcurlyeq)$.

A ***partition*** for a hedonic game $(N, \succcurlyeq)$ is a set $\pi = \{S_1, S_2, \dots, S_K\}$ ($K \leq |N|$ is a positive integer) such that (i) for any $k \in \{1, \dots, K\}$, $S_k \neq \emptyset$, (ii) $\bigcup_{k=1}^{K} S_k = N$, and (iii) for any $k, l \in \{1, \dots, K\}$ with $k \neq l$, $S_k \cap S_l = \emptyset$.

[5] A preference relation $\hat{\succcurlyeq}$ over $\mathcal{C}_i^N$ satisfies *completeness* if for all $S, T \in \mathcal{C}_i^N$, $S \hat{\succcurlyeq} T$ or $T \hat{\succcurlyeq} S$, and it satisfies *transitivity* if for all $S, T, U \in \mathcal{C}_i^N$, if $S \hat{\succcurlyeq} T$ and $T \hat{\succcurlyeq} U$, then $S \hat{\succcurlyeq} U$.

Given any partition π and any $i \in N$, we let $\pi(i)$ denote the unique coalition in π that contains agent i. We denote the set of all partitions for hedonic game $(N, \succcurlyeq)$ by $\Pi(N, \succcurlyeq)$. Since agents only care about their own coalitions, preferences over coalitions are extended to over partitions as follows: for each $i \in N$ and partitions $\pi, \pi' \in \Pi(N, \succcurlyeq)$, $\pi \succcurlyeq_i \pi'$ if and only if $\pi(i) \succcurlyeq_i \pi'(i)$.

Next, we introduce the classic voluntary participation concept, individual rationality, and the most common efficiency concept, Pareto optimality.

A partition π is ***individually rational*** for hedonic game $(N, \succcurlyeq)$ if for all $i \in N$, $\pi(i) \succcurlyeq_i \{i\}$.

A partition π is ***Pareto optimal*** for hedonic game $(N, \succcurlyeq)$ if there does not exist another partition $\pi' \in (\Pi(N, \succcurlyeq) \backslash \{\pi\})$ such that for all $i \in N$, $\pi'(i) \succcurlyeq_i \pi(i)$ and for some $j \in N$, $\pi'(j) \succ_j \pi(j)$.

Given a partition $\pi \in \Pi(N, \succcurlyeq)$ and an agent $i \in N$, when agent i deviates from π, she leaves her current coalition $\pi(i)$ and moves to another coalition $S \in (\pi \cup \{\emptyset\})$ of the partition π (or to the empty set). With this deviation of agent i from π, another partition $\pi' \in (\Pi(N, \succcurlyeq) \backslash \{\pi\})$ is obtained. Following Karakaya (2011), we call this case as π' ***is reachable from*** π ***via agent*** i (denoted by $\pi \xrightarrow{i} \pi'$), that is,

- $\pi'(i) = S \cup \{i\}$,
- for each $j \in S$, $\pi'(j) = S \cup \{i\}$,
- for each $k \in \pi(i)$, $\pi'(k) = \pi(i) \backslash \{i\}$, and
- for each $h \in N$ such that $h \notin \pi(i)$ and $h \notin S$, $\pi'(h) = \pi(h)$.

In the following sections, we introduce Nash stability under different membership rights and revisit the sufficient conditions that guarantee the existence of such stable partitions.

3. FREE EXIT - FREE ENTRY (FX-FE) NASH STABILITY

In this section, we introduce the definition of Nash stability under Free Exit and Free Entry membership rights, Free Exit - Free Entry (FX-FE) Nash stability and consider the sufficient conditions that guarantee the existence of such partitions.

Definition 1. FX-FE Nash Stability

*Let $(N, \succcurlyeq)$ be a hedonic game. A partition $\pi \in \Pi(N, \succcurlyeq)$ is **FX-FE Nash stable** if there does not exist a pair (i, S), where $i \in N$ and $S \in (\pi \cup \{\emptyset\})$, such that $S \cup \{i\} \succ_i \pi(i)$. If such a pair (i, S) exists, we say that agent i **FX-FE Nash blocks** π (by joining coalition S).*

We can redefine FX-FE Nash stability by using the reachability notion as follows:

A partition $\pi \in \Pi(N, \succcurlyeq)$ is ***FX-FE Nash stable*** if there does not exist a pair (i, π'), consisting of an agent $i \in N$ and another partition $\pi' \in (\Pi(N, \succcurlyeq) \backslash \{\pi\})$, such that $\pi \xrightarrow{i} \pi'$ (π' is reachable from π via agent i) and $\pi'(i) \succ_i \pi(i)$. If such a pair (i, π') exists, we say that agent i **FX-FE Nash blocks** π (by inducing π').

3.1. Symmetric and Additively Separable Preferences

The notion of *additive separability* was introduced by Banerjee et al. (2001) and Bogomolnaia and Jackson (2002). Bogomolnaia and Jackson (2002) showed that if a hedonic game is additively separable and symmetric, then there exists an FX-FE Nash stable partition.

A hedonic game is additively separable if each agent's preferences are representable by an additively separable utility function.

Definition 2. Additive Separability

*A hedonic game $(N, \succcurlyeq)$ is **additively separable** if for any $i \in N$, there exists a function $v_i: N \to \mathbb{R}$ such that for any $S, T \in \mathcal{C}_i^N$,*

$$S \succcurlyeq_i T \Leftrightarrow \sum_{j \in S} v_i(j) \geq \sum_{j \in T} v_i(j), \text{ where } v_i(j) = 0 \text{ for } i = j.$$

*An additively separable hedonic game $(N, \succcurlyeq)$ satisfies **symmetry** if for any $i, j \in N$, we have $v_i(j) = v_j(i)$, and satisfies **mutuality** if for any $i, j \in N$, we have $v_i(j) \geq 0 \Leftrightarrow v_j(i) \geq 0$.*

For each agent i, v_i denotes her utility function that assigns a cardinal utility for every agent in N, where she assigns zero value to herself. For any coalition $S \in \mathcal{C}_i^N$, the total payoff that agent i obtains from being a member of this coalition is the sum of the utilities that she assigns to each agent in S, that is, $\sum_{j \in S} v_i(j)$. Then, any two coalitions containing agent i are compared according to the total payoffs that she obtains from these coalitions, that is, for any $S, T \in \mathcal{C}_i^N$, agent i prefers S to T if and only if the total payoff that i obtains from S is as big as the total payoff that she obtains from T.

Additively separable preferences are symmetric if every two agents assign the same utilities to each other, that is, for every agent i and j, $v_i(j) = v_j(i)$. Additively separable preferences are mutual if it holds for every two agents i and j that i assigns a positive (negative or zero, respectively) value to j if and only if j assigns a positive (negative or zero, respectively) value to i. Note that symmetry implies mutuality.

The hedonic game given in the following example is additively separable and symmetric and hence it has an FX-FE Nash stable partition.

Example 1. Symmetric and Additively Separable Hedonic Game

Let $(N, \succcurlyeq)$ be a hedonic game with $N = \{1,2,3\}$ and additively separable and symmetric preferences are represented by following functions: $v_1(2) = v_2(1) = 2$, $v_1(3) = v_3(1) = -1$, $v_2(3) = v_3(2) = 1$. That is, we have following preferences:

$\succcurlyeq_1$: $\{1,2\} \succ_1 \{1,2,3\} \succ_1 \{1\} \succ_1 \{1,3\}$,

$\succcurlyeq_2$: $\{1,2,3\} \succ_2 \{1,2\} \succ_2 \{2,3\} \succ_2 \{2\}$,

$\succcurlyeq_3$: $\{2,3\} \succ_3 \{1,2,3\} \sim_3 \{3\} \succ_3 \{1,3\}$.

The partitions $\pi^1 = \{\{1,2\},\{3\}\}$ and $\pi^2 = \{\{1,2,3\}\}$ are FX-FE Nash stable. □

Bogomolnaia and Jackson (2002) mentioned that a hedonic game with mutual and additively separable preferences may not have an FX-FE Nash stable partition, so symmetry is a critical property, and it cannot be weakened to mutuality for the existence of FX-FE Nash stable partitions.

3.2. Appreciation of Friends and Aversion to Enemies

Dimitrov and Sung (2004) and Dimitrov et al. (2006) introduced the *appreciation of friends* and the *aversion to enemies* properties. These properties are based on the cardinality of friends and the cardinality of enemies in each coalition.

Let $(N, \succcurlyeq)$ be a hedonic game. For each $i \in N$, we say that $F_i = \{j \in N \mid \{i,j\} \succcurlyeq_i \{i\}\}$ is the ***set of friends of agent*** i, and $E_i = \{j \in N \mid \{i\} \succ_i \{i,j\}\} = N \backslash F_i$ is the ***set of enemies of agent*** i. Note that for each $i \in N$, $i \in F_i$.

Definition 3. Appreciation of Friends

Let $(N, \succcurlyeq)$ be a hedonic game. We say that $(N, \succcurlyeq)$ satisfies the ***appreciation of friends property*** if, for each $i \in N$ and each $S, T \in \mathcal{C}_i^N$, $S \succcurlyeq_i T$ if and only if

- $|S \cap F_i| > |T \cap F_i|$ or,
- $|S \cap F_i| = |T \cap F_i|$ and $|S \cap E_i| \leq |T \cap E_i|$.

A hedonic game $(N, \succcurlyeq)$ having the *appreciation of friends property* also satisfies ***mutuality*** (with respect to appreciation of friends) if for each $i, j \in N$ with $i \neq j$, $i \in F_j$ if and only if $j \in F_i$.[6]

The appreciation of friends property means that: For an agent, when comparing two coalitions containing her, she first looks at the number of friends in these coalitions and that she prefers the one with more friends. If the two coalitions have the same number of friends, then she looks at the number of enemies in these coalitions and prefers the one with fewer enemies. If the numbers of friends and enemies are equal in these two coalitions then she is indifferent between these two coalitions.

[6] This is equivalent to that $i \in E_j$ if and only if $j \in E_i$, since if $i \notin F_j$ we then have $i \in E_j$.

Definition 4. Aversion to Enemies

Let $(N, \succcurlyeq)$ be a hedonic game. We say that $(N, \succcurlyeq)$ satisfies the ***aversion to enemies property*** if, for each $i \in N$ and each $S, T \in C_i^N$, $S \succcurlyeq_i T$ if and only if

- $|S \cap E_i| < |T \cap E_i|$ or,
- $|S \cap E_i| = |T \cap E_i|$ and $|S \cap F_i| \geq |T \cap F_i|$.

A hedonic game $(N, \succcurlyeq)$ having the *aversion to enemies' property* also satisfies ***mutuality*** (with respect to aversion to enemies property) if for each $i, j \in N$ with $i \neq j$, $i \in E_j$ if and only if $j \in E_i$.[7]

The aversion to enemies' property means that: For an agent, when comparing two coalitions containing her, she first looks at the number of enemies in these coalitions and that she prefers the one with fewer enemies. If the two coalitions have the same number of enemies, then she looks at the number of friends in these coalitions and prefers the one with more friends. If the numbers of enemies and friends are equal in these two coalitions then she is indifferent between these two coalitions.

When appreciation of friends or aversion to enemies' property is satisfied for a hedonic game $(N, \succcurlyeq)$, then for any agent $i \in N$, the best coalition is F_i and the worst coalition is $E_i \cup \{i\}$ according to her preferences. Moreover, the domain of preferences at which appreciation of friends or aversion to enemies property is satisfied is a proper sub-domain of additively separable preference profiles.[8] If a hedonic game $(N, \succcurlyeq)$ satisfies the appreciation of friends property then it is additively separable where for each $i \in N$ the function $v_i: N \to \mathbb{R}$ is defined as follows: for each $j \in N \backslash \{i\}$, $v_i(j) = n$ if $j \in F_i$, $v_i(j) = -1$ if $j \in E_i$, and $v_i(i) = 0$. If a hedonic game $(N, \succcurlyeq)$ satisfies the aversion to enemies property then it is additively separable where for each $i \in N$ the function $v_i: N \to \mathbb{R}$ is defined as follows: for each $j \in N \backslash \{i\}$, $v_i(j) = 1$ if $j \in F_i$, $v_i(j) = -n$ if $j \in E_i$, and $v_i(i) = 0$.

Dimitrov and Sung (2004) showed that if a hedonic game satisfies the appreciation of friends' property and mutuality (with respect to appreciation of friends) then it has an FX-FE Nash stable partition, and similarly, if a hedonic game satisfies the aversion to enemies' property and mutuality (with respect to aversion to enemies) then it has an FX-FE Nash stable partition.[9]

We now provide a hedonic game that satisfies the appreciation of friends' property and mutuality (with respect to appreciation of friends), and hence it has an FX-FE Nash stable partition.

Example 2. A Hedonic Game Satisfying Appreciation of Friends and Mutuality

Let $(N, \succcurlyeq)$ be a hedonic game with $N = \{1,2,3,4\}$. Let $F_1 = \{1,2,3\}$, $F_2 = \{1,2\}$, $F_3 = \{1,3\}$, and $F_4 = \{4\}$. Then, agents' preferences satisfying the appreciation of friends' property are as follows:

$\succcurlyeq_1: \{1,2,3\} \succ_1 \{1,2,3,4\} \succ_1 \{1,2\} \sim_1 \{1,3\} \succ_1 \{1,2,4\} \sim_1 \{1,3,4\} \succ_1 \{1\} \succ_1 \{1,4\}.$

$\succcurlyeq_2: \{1,2\} \succ_2 \{1,2,3\} \sim_2 \{1,2,4\} \succ_2 \{1,2,3,4\} \succ_2 \{2\} \succ_2 \{2,3\} \sim_2 \{2,4\} \succ_2 \{2,3,4\},$

$\succcurlyeq_3: \{1,3\} \succ_3 \{1,2,3\} \sim_3 \{1,3,4\} \succ_3 \{1,2,3,4\} \succ_3 \{3\} \succ_3 \{2,3\} \sim_3 \{3,4\} \succ_3 \{2,3,4\},$

$\succcurlyeq_4: \{4\} \succ_4 \{1,4\} \sim_4 \{2,4\} \sim_4 \{3,4\} \succ_4 \{1,2,4\} \sim_4 \{1,3,4\} \sim_4 \{2,3,4\} \succ_4 \{1,2,3,4\}.$

We note that this hedonic game also satisfies mutuality (with respect to appreciation of friends): $2 \in F_1$ and $1 \in F_2$, $3 \in F_1$ and $1 \in F_3$, $4 \notin F_1$ and $1 \notin F_4$, $3 \notin F_2$ and $2 \notin F_3$, $4 \notin F_2$ and $2 \notin F_4$, and $4 \notin F_3$ and $3 \notin F_4$.

The partition $\pi = \{\{1,2,3\}, \{4\}\}$ is FX-FE Nash stable. □

[7] This is equivalent to that $i \in F_j$ if and only if $j \in F_i$, since if $i \notin E_j$ we then have $i \in F_j$.

[8] See Definition 2 for additively separable preferences.

[9] Suzuki and Sung (2010) showed that hedonic games that satisfy the appreciation of friends' property also satisfy the top responsiveness property, and hedonic games that satisfy the aversion to enemies' property also satisfy the bottom responsiveness property. Therefore, the results in Aziz and Brandl (2012) also hold for the appreciation of friends and aversion to enemies' properties. If a hedonic game satisfies the appreciation of friends and mutuality (with respect to appreciation of friends), then there exists an FX-FE strongly Nash stable partition and likewise if a hedonic game satisfies the aversion to enemies and mutuality (with respect to aversion to enemies), then there exists an FX-FE strongly Nash stable partition.

We now provide a hedonic game that satisfies the aversion to enemies' property and mutuality (with respect to aversion to enemies), and hence it has an FX-FE Nash stable partition.

Example 3. A Hedonic Game Satisfying Aversion to Enemies and Mutuality

Let $(N, \succcurlyeq)$ be a hedonic game with $N = \{1,2,3,4\}$. Let $F_1 = \{1,2,3\}$, $F_2 = \{1,2\}$, $F_3 = \{1,3\}$, and $F_4 = \{4\}$. Then, agents' preferences satisfying the aversion to enemies' property are as follows:

$\succcurlyeq_1$: $\{1,2,3\} \succ_1 \{1,2\} \sim_1 \{1,3\} \succ_1 \{1\} \succ_1 \{1,2,3,4\} \succ_1 \{1,2,4\} \sim_1 \{1,3,4\} \succ_1 \{1,4\}$.

$\succcurlyeq_2$: $\{1,2\} \succ_2 \{2\} \succ_2 \{1,2,3\} \sim_2 \{1,2,4\} \succ_2 \{2,3\} \sim_2 \{2,4\} \succ_2 \{1,2,3,4\} \succ_2 \{2,3,4\}$,

$\succcurlyeq_3$: $\{1,3\} \succ_3 \{3\} \succ_3 \{1,2,3\} \sim_3 \{1,3,4\} \succ_3 \{2,3\} \sim_3 \{3,4\} \succ_3 \{1,2,3,4\} \succ_3 \{2,3,4\}$,

$\succcurlyeq_4$: $\{4\} \succ_4 \{1,4\} \sim_4 \{2,4\} \sim_4 \{3,4\} \succ_4 \{1,2,4\} \sim_4 \{1,3,4\} \sim_4 \{2,3,4\} \succ_4 \{1,2,3,4\}$.

This hedonic game also satisfies mutuality (with respect to aversion to enemies): $2 \notin E_1$ and $1 \notin E_2$, $3 \notin E_1$ and $1 \notin E_3$, $4 \in E_1$ and $1 \in E_4$, $3 \in E_2$ and $2 \in E_3$, $4 \in E_2$ and $2 \in E_4$, and $4 \in E_3$ and $3 \in E_4$.

The partitions $\pi^1 = \{\{1,2\},\{3\},\{4\}\}$ and $\pi^2 = \{\{1,3\},\{2\},\{4\}\}$ are both FX-FE Nash stable. □

3.3. Subset Neutrality and Neutral Anonymity

Suksompong (2015) introduced conditions called *subset neutrality* and *neutral anonymity*. He showed that if a hedonic game satisfies the subset neutrality property or the neutral anonymity property, then there always exists an FX-FE Nash stable partition.

Definition 5. Subset Neutrality

A hedonic game $(N, \succcurlyeq)$ is ***subset neutral*** if there exists a function $\omega: 2^N \setminus \{\emptyset\} \to \mathbb{R}$ such that for each $i \in N$ and each $S, T \in \mathcal{C}_i^N$,

$$S \succcurlyeq_i T \Leftrightarrow \sum_{i \in \bar{S} \subseteq S} \omega(\bar{S}) \geq \sum_{i \in \bar{T} \subseteq T} \omega(\bar{T})$$

The function ω is defined on the set of all coalitions, and it assigns a numerical value to each coalition. For an agent, when comparing two coalitions containing her, she compares the sums of the numerical values of all sub-coalitions that contain her assigned by ω for the two coalitions and prefers the coalition with the larger sum.

We note that a hedonic game that is additively separable and symmetric satisfies subset neutrality, when we define the ω as follows: for each coalition $|S| > 2$ we let $\omega(S) = 0$. However, a hedonic game satisfying subset neutrality might not be additively separable.

A hedonic game $(N, \succcurlyeq)$ satisfies ***anonymity*** if for each $i \in N$ and each $S, T \in \mathcal{C}_i^N$ with $|H| = |T|$ we have $H \sim_i T$.

Definition 6. Neutral Anonymity

A hedonic game $(N, \succcurlyeq)$ satisfies ***neutral anonymity*** if there exists a function such that for each $i \in N$ and each $S, T \in \mathcal{C}_i^N$,

$$S \underset{i}{\succcurlyeq} T \text{ if and only if } f(|S|) \geq f(|T|).$$

Neutral anonymity means that: There exists a function that assigns a numerical value for each coalition size, and when an agent compares two coalitions containing her, she prefers the coalition whose size is assigned a larger numerical value than the other one. We note that a neutrally anonymous hedonic game is also subset neutral.

We now continue with a hedonic game that satisfies the subset neutrality and neutral anonymity properties, and hence it has an FX-FE Nash stable partition.

Example 4. A Hedonic Game Satisfying Subset Neutrality and Neutral Anonymity

Let $(N, \succcurlyeq)$ be a hedonic game with $N = \{1,2,3\}$ and a function $\omega: 2^N \setminus \{\emptyset\} \to \mathbb{R}$ is as follows: for each $i \in N$, $\omega((i)) = 0$, for each $i, j \in N$ with $i \neq j$, $\omega(\{i,j\}) = 2$, and $\omega(\{1,2,3\}) = 4$. Then, players' preferences derived from the function ω satisfying the subset neutrality property are as follows:

$\succcurlyeq_1$: $\{1,2,3\} \succ_1 \{1,2\} \sim_1 \{1,3\} \succ_1 \{1\}$,

$\succcurlyeq_2$: $\{1,2,3\} \succ_2 \{1,2\} \sim_2 \{2,3\} \succ_2 \{2\}$,

$\succcurlyeq_3$: $\{1,2,3\} \succ_3 \{1,3\} \sim_3 \{2,3\} \succ_3 \{3\}$.

This hedonic game also satisfies the neutral anonymity property. We define a function $f: \{1,2,3\} \to \mathbb{R}$ for each coalition size $t \in \{1,2,3\}$ as $f(t) = 2t - 2$, that is, $f(1) = 0,\ f(2) = 2$, and $f(3) = 4$. Now, for each $i \in N$ and each $S, T \in \mathcal{C}_i^N$ we have that $S \succcurlyeq_i T$ if and only if $f(|S|) \geq f(|T|)$, e.g., for agent 1, $\{1,2,3\} \succ_1 \{1,2\}$ since $f|\{1,2,3\}| = f(3) = 4$, $f|\{1,2\}| = f(2) = 2$ and $4 > 2$.

The partition $\pi^1 = \{\{1,2,3\}\}$ is FX-FE Nash stable. □

4. FREE EXIT - APPROVED ENTRY (FX-AE) NASH STABILITY (INDIVIDUAL STABILITY)

In this section, we introduce Nash stability under Free Exit and Approved Entry membership rights, Free Exit - Approved Entry (FX-AE) Nash stability and consider the sufficient conditions that guarantee the existence of FX-AE Nash stable partitions.

Definition 7. FX-AE Nash Stability

*Let $(N, \succcurlyeq)$ be a hedonic game. A partition $\pi \in \Pi(N, \succcurlyeq)$ is **FX-AE Nash stable** if there does not exist a pair (i, S), where $i \in N$ and $S \in (\pi \cup \{\emptyset\})$, such that*

(i) $S \cup \{i\} \succ_i \pi(i)$ *and*

(ii) *for all* $j \in S,\ S \cup \{i\} \succcurlyeq_j S$.

*If such a pair (i, S) exists, we say that agent i **FX-AE Nash blocks** π (by joining coalition S).*

We can redefine FX-AE Nash Stability by using the reachability notion as follows:

A partition $\pi \in \Pi(N, \succcurlyeq)$ is ***FX-AE Nash stable*** if there does not exist a pair (i, π'), consisting of an agent $i \in N$ and another partition $\pi' \in (\Pi(N, \succcurlyeq) \backslash \{\pi\})$, such that $\pi \overset{i}{\to} \pi'$ (π' is reachable from π via agent i), $\pi'(i) \succ_i \pi(i)$, and for all $j \in (\pi'(i) \backslash \{i\})$, $\pi'(j) \succcurlyeq_j \pi(j)$. If such a pair (i, π') exists, we say that agent i **FX-AE Nash blocks** π (by inducing π').

4.1. Common Ranking Property

The *common ranking property* was introduced by Farrell and Scotchmer (1988). The common ranking property requires that there is a linear order on the set of all coalitions which coincides with any agent's preference ordering over her coalitions. Suksompong (2015) proved that when a hedonic game satisfies the common ranking property, there exists an FX-AE Nash stable partition.

Definition 8. Common Ranking Property

A hedonic game $(N, \succcurlyeq)$ satisfies the ***common ranking property*** if there exists an ordering $\succcurlyeq$ over $2^N \backslash \{\emptyset\}$ such that for each $i \in N$ and each $S, T \in \mathcal{C}_i^N$, we have

$$S \underset{i}{\succcurlyeq} T \text{ if and only if } S \succcurlyeq T.$$

We now give an example of a hedonic game that satisfies the common ranking property and has an FX-AE Nash stable partition.

Example 5. A Hedonic Game Satisfying the Common Ranking Property

Let $(N, \succcurlyeq)$ where $N = \{1,2,3\}$ and the preferences of agents are as follows:

$\succcurlyeq_1$: $\{1,2\} \succ_1 \{1\} \sim_1 \{1,2,3\} \succ_1 \{1,3\}$,

$\succcurlyeq_2$: $\{1,2\} \succ_2 \{2\} \sim_2 \{1,2,3\} \succ_2 \{2,3\}$,

$\succcurlyeq_3$: $\{1,2,3\} \succ_3 \{1,3\} \sim_3 \{2,3\} \succ_3 \{3\}$.

This hedonic game satisfies the common ranking property with respect to the ordering $\succcurlyeq$, where [$\succcurlyeq$: $\{1,2\} \succ \{1\} \sim \{2\} \sim \{1,2,3\} \succ \{1,3\} \sim \{2,3\} \succ \{3\}$].

The partition $\pi = \{\{1,2\},\{3\}\}$ is FX-AE Nash stable. □

4.2. Ordered Characteristics

Bogomolnaia and Jackson (2002) showed that if a hedonic game satisfies the *ordered characteristics* property, then there exists an FX-AE Nash stable partition. We will follow Bogomolnaia and Jackson (2002) to define the ordered characteristics property.

Let each coalition $S \subseteq N$ be described by a *characteristic* $c(S)$ that lies in $\{0,1,\dots,|S|\}$. Let each agent $i \in N$ has single-peaked preferences on $\{0,1,\dots,n\}$ with peaks denoted by p_i such that $p_i \geq 1$. Agents' preferences over coalitions correspond to the preference ranking of $c(S)$, that is, for all $i \in N$, all $S, T \in \mathcal{C}_i^N$, $S \succcurlyeq_i T$ if and only if $c(S) \succcurlyeq_i c(T)$.

Definition 9. Ordered Characteristics

A hedonic game $(N, \succcurlyeq)$ has ***ordered characteristics*** if agents' preferences over coalitions depend on single-peaked preferences over characteristics $c(S)$ where:

(i) If $c(S) < |S|$ then $c(S) = p_j$ for some $j \in S$, and

(ii) If $i \notin S$, $j \notin S$, and $p_i \geq p_j$, then $c(S \cup \{i\}) \geq c(S \cup \{j\})$. Moreover, if $c(S \cup \{i\}) > p_i$, then $c(S \cup \{i\}) = c(S \cup \{j\})$.

The first condition states that if a characteristic of a coalition is smaller than the size of that coalition, then the characteristic is the peak of some agent in that coalition. The first part of the second condition states that when comparing any two coalitions which differ by only one agent, the characteristics of these coalitions are ordered by the peaks of the agents who differ. The second part states that if the peak of the agent who has a higher peak than other agent is smaller than the characteristic of the coalition that contains her, then the characteristics of these two coalitions that differ by one agent are equal.

Bogomolnaia and Jackson (2002) noted that if in a hedonic game, agents' preferences are anonymous and single-peaked on the sizes of the coalitions to which they belong, then this hedonic game satisfies the ordered characteristics property.

The following hedonic game is taken from Bogomolnaia and Jackson (2002). It satisfies the ordered characteristics property and hence has an FX-AE Nash stable partition.

Example 6. A Hedonic Game Satisfying Ordered Characteristics Property

Let $(N, \succcurlyeq)$ be a hedonic game with $N = \{1,2,3,4\}$. Agents' preferences are anonymous and single-peaked over the sizes of coalition that they belong. For each coalition $S \subseteq N$ we have $c(S) = |S|$ and the peaks of the agents are as follows: $p_1 = 4$, $p_2 = 3$, and $p_3 = p_4 = 2$. Moreover, agents' preferences over sizes of coalitions are $[4 \succ_1 3 \succ_1 2 \succ_1 1]$, $[3 \succ_2 2 \succ_2 1 \succ_2 4]$, $[2 \succ_3 3 \succ_3 1 \succ_3 4]$, and $[2 \succ_4 3 \succ_4 1 \succ_4 4]$.

This hedonic game satisfies the ordered characteristics property, and the preferences of agents are as follows:

$\succcurlyeq_1$: $\{1,2,3,4\} \succ_1 \{1,2,3\} \sim_1 \{1,2,4\} \sim_1 \{1,3,4\} \succ_1 \{1,2\} \sim_1 \{1,3\} \sim_1 \{1,4\} \succ_1 \{1\}$,

$\succcurlyeq_2$: $\{1,2,3\} \sim_2 \{1,2,4\} \sim_2 \{2,3,4\} \succ_2 \{1,2\} \sim_2 \{2,3\} \sim_2 \{2,4\} \succ_2 \{2\} \succ_2 \{1,2,3,4\}$,

$\succcurlyeq_3$: $\{1,3\} \sim_3 \{2,3\} \sim_3 \{3,4\} \succ_3 \{1,2,3\} \sim_3 \{1,3,4\} \sim_3 \{2,3,4\} \succ_3 \{3\} \succ_3 \{1,2,3,4\}$,

$\succcurlyeq_4$: $\{1,4\} \sim_4 \{2,4\} \sim_4 \{3,4\} \succ_4 \{1,2,4\} \sim_4 \{1,3,4\} \sim_4 \{2,3,4\} \succ_4 \{4\} \succ_4 \{1,2,3,4\}$.

The partition $\pi = \{\{1,2\}), \{3,4\}\}$ is FX-AE Nash stable. □

5. APPROVED EXIT - FREE ENTRY (AX-FE) NASH STABILITY (CONTRACTUAL NASH STABILITY)

We now introduce Nash stability under Approved Exit and Free Entry membership rights, Approved Exit - Free Entry (AX-FE) Nash stability and consider the sufficient condition that guarantee the existence of AX-FE Nash stable partitions.

Definition 10. AX-FE Nash Stability

*Let $(N, \succcurlyeq)$ be a hedonic game. A partition $\pi \in \Pi(N, \succcurlyeq)$ is **AX-FE Nash stable** if there does not exist a pair (i, S), where $i \in N$ and $S \in (\pi \cup \{\emptyset\})$, such that*

(i) $S \cup \{i\} \succ_i \pi(i)$ *and*

(ii) *for all* $k \in (\pi(i) \backslash \{i\})$, $\pi(i) \backslash \{i\} \succcurlyeq_k \pi(i)$.

*If such a pair (i, S) exists, we say that agent i **AX-FE Nash blocks** π (by joining coalition S).*

We can redefine AX-FE Nash Stability by using the reachability notion as follows:

A partition $\pi \in \Pi(N, \succcurlyeq)$ is ***AX-FE Nash stable*** if there does not exist a pair (i, π'), consisting of an agent $i \in N$ and another partition $\pi' \in (\Pi(N, \succcurlyeq) \backslash \{\pi\})$, such that $\pi \xrightarrow{i} \pi'$ (π' is reachable from π via agent i), $\pi'(i) \succ_i \pi(i)$, and for all $k \in (\pi(i) \backslash \{i\})$, $\pi'(k) \succcurlyeq_k \pi(k)$. If such a pair (i, π') exists, we say that agent i **AX-FE Nash blocks** π (by inducing π').

5.1. Separable Preferences

The notion of *separable preferences* was introduced by Banerjee et al. (2001) and Bogomolnaia and Jackson (2002) in the context of hedonic games. Sung and Dimitrov (2007) proved that when a hedonic game satisfies separability and weak mutuality, then there exists an AX-FE Nash stable partition.

Definition 11. Separability

A hedonic game $(N, \succcurlyeq)$ is ***separable*** if for each $i \in N$, each $S \in \mathcal{C}_i^N$ and each $j \notin S$, we have $[S \cup \{j\} \succcurlyeq_i S \Leftrightarrow \{i, j\} \succcurlyeq_i \{i\}]$ *and* $[S \succcurlyeq_i S \cup \{j\} \Leftrightarrow \{i\} \succcurlyeq_i \{i, j\}]$.

A separable hedonic game $(N, \succcurlyeq)$ satisfies ***mutuality*** if for each $i, j \in N$, we have $[\{i, j\} \succcurlyeq_i \{i\} \Leftrightarrow \{i, j\} \succcurlyeq_j \{j\}]$ *and* $[\{i\} \succcurlyeq_i \{i, j\} \Leftrightarrow \{j\} \preccurlyeq_j \{i, j\}]$.

A separable hedonic game $(N, \succcurlyeq)$ satisfies ***weak mutuality*** if for each $i \in N$, if there exists $j \in N \backslash \{i\}$ such that $\{i, j\} \succcurlyeq_i \{i\}$, then there exists $k \in N \backslash \{i\}$ such that $\{i, k\} \succcurlyeq_k \{k\}$.

Separability means that for any agent $i \in N$, any coalition S containing agent i, and any other agent j not in S, i prefers to cooperate with j rather than staying alone if and only if i prefers $S \cup \{j\}$ to S. In the same way, i prefers to stay alone rather than cooperating with j if and only if i prefers S to $S \cup \{j\}$. A separable hedonic game satisfies mutuality if, for each pair of agents, one agent prefers to cooperate with the other to stay alone if and only if the other behaves in the same way, and one agent prefers to be alone to cooperate with the other if and only if the other behaves in the same way. A separable hedonic game satisfies weak mutuality if, for each agent, there exists an agent with whom she prefers to stay together rather than to be alone, then there exists another agent who prefers staying with her rather than being alone.

The following hedonic game satisfies separability and weak mutuality, and it has an AX-FE Nash stable partition.

Example 7. A Hedonic Game Satisfying the Separability and Weak Mutuality

Let $(N, \succcurlyeq)$ where $N = \{1,2,3\}$ and the preferences of agents are as follows:

$\succcurlyeq_1$: $\{1,2\} \succ_1 \{1,2,3\} \succ_1 \{1\} \succ_1 \{1,3\}$,

$\succcurlyeq_2$: $\{2,3\} \succ_2 \{1,2,3\} \succ_2 \{2\} \succ_2 \{1,2\}$,

$\succcurlyeq_3$: $\{1,3\} \succ_3 \{1,2,3\} \succ_3 \{3\} \succ_3 \{2,3\}$.

For agent 1, we have that $[\{1,2\} \succ_1 \{1\}$ and $\{1,2,3\} \succ_1 \{1,3\}]$, $[\{1\} \succ_1 \{1,3\}$ and $\{1,2\} \succ_1 \{1,2,3\}]$. For agent 2, we have that $[\{2,3\} \succ_2 \{2\}$ and $\{1,2,3\} \succ_2 \{1,2\}]$, $[\{2\} \succ_2 \{1,2\}$ and $\{2,3\} \succ_2 \{1,2,3\}]$. For agent 3, we have $[\{1,3\} \succ_3 \{3\}$ and $\{1,2,3\} \succ_3 \{2,3\}]$, $[\{3\} \succ_3 \{2,3\}$ and $\{1,3\} \succ_3 \{1,2,3\}]$. So, this hedonic game satisfies separability.

This hedonic game also satisfies weak mutuality since we have that $\{1,2\} \succ_1 \{1\}$, $\{1,3\} \succ_3 \{3\}$, and $\{2,3\} \succ_2 \{2\}$.

The partition $\pi = \{\{1,2,3\}\}$ is AX-FE Nash stable. □

6. APPROVED EXIT - APPROVED ENTRY (AX-AE) NASH STABILITY (CONTRACTUAL INDIVIDUAL STABILITY)

In this section, we introduce Nash stability under Approved Exit and Approved Entry membership rights, Approved Exit - Approved Entry (AX-AE) Nash stability. We describe the proof techniques offered by Bogomolnaia and Jackson (2002) and Ballester (2004) to show the existence of an AX-AE Nash stable partition for every hedonic game.

Definition 12. AX-AE Nash Stability

*Let $(N, \succcurlyeq)$ be a hedonic game. A partition $\pi \in \Pi(N, \succcurlyeq)$ is **AX-AE Nash stable** if there does not exist a pair (i, S), where $i \in N$ and $S \in (\pi \cup \{\emptyset\})$, such that*

(i) $S \cup \{i\} \succ_i \pi(i)$ *and*

(ii) $for\ all\ j\ \in S,\ S\ \cup \{i\}\ \succcurlyeq_j\ S$, and

(iii) *for all* $k\ \in (\pi(i)\backslash\{i\}),\ \pi(i)\backslash\{i\}\ \succcurlyeq_k\ \pi(i)$.

If such a pair (i,S) *exists, we say that agent* i ***AX-AE Nash blocks*** π *(by joining coalition* S*).*

We can redefine AX-AE Nash Stability by using the reachability notion as follows:

A partition $\pi \in \Pi(N,\succcurlyeq)$ is ***AX-AE Nash stable*** if there does not exist a pair (i,π'), consisting of an agent $i \in N$ and another partition $\pi' \in (\Pi(N,\succcurlyeq)\backslash\{\pi\})$, such that $\pi \xrightarrow{i} \pi'$ (π' is reachable from π via agent i), $\pi'(i) \succ_i \pi(i)$, and for all $l \in (N\backslash\{i\})$, $\pi'(l) \succcurlyeq_l \pi(l)$. If such a pair (i,π') exists, we say that agent i **AX-AE Nash blocks** π (by inducing π').

Bogomolnaia and Jackson (2002) proved that every hedonic game has an AX-AE Nash stable partition by showing that any Pareto optimal partition is AX-AE Nash stable. They also constructed an algorithm and showed that for every hedonic game with agents having strict preferences, the result of the algorithm is an AX-AE Nash stable partition which is also Pareto optimal and individually rational.

The algorithm works as follows: Let $(N,\succ)$ be a hedonic game such that $N = \{1,2,\dots,n\}$ and each agent has strict preferences. Consider the first agent, that is, agent 1, and call her i_1. We choose the coalition that agent i_1 prefers the most out of all the individually rational coalitions of N, that is, the best coalition for agent i_1 in the set $\{S \subseteq N \mid i_1 \in S \text{ and for each } j \in S, S \succcurlyeq_j \{j\}\}$ is chosen, and we call it S_1. If $N\backslash S_1 \neq \emptyset$, we continue with $N_2 = N\backslash S_1$. Consider the first agent in N_2 and call her i_2. We choose the coalition that agent i_2 prefers the most out of all the individually rational coalitions of N_2, that is, the best coalition for agent i_2 among the coalitions of the set $\{S \subseteq N_2 \mid i_2 \in S \text{ and for each } j \in S, S \succcurlyeq_j \{j\}\}$ is chosen, and we call it S_2. If $N\backslash(S_1 \cup S_2) \neq \emptyset$, we continue with $N_3 = N\backslash(S_1 \cup S_2)$. The algorithm continues like this and since we have a finite set of agents, there exists a positive integer K such that $N\backslash(S_1 \cup \dots \cup S_K) = \emptyset$. That is, the algorithm terminates, and the resulting partition is $\pi^* = \{S_1, S_2, \dots, S_K\}$ that consists of all coalitions that are chosen in the algorithm. It is clear that π^* is individually rational, and Bogomolnaia and Jackson (2002) showed that π^* is Pareto optimal and AX-AE Nash stable.

Ballester (2004) also proved that every hedonic game has an AX-AE Nash stable partition by introducing a different approach. Ballester's approach is as follows: Choose a partition randomly. If it is AX-AE Nash stable, then we are done. If not, then there exists an agent who AX-AE Nash blocks the partition by inducing another partition. If the induced partition is AX-AE Nash stable, then we are done. If not, then there exists an agent who AX-AE Nash blocks the partition by inducing a new partition, and so on. Since the preferences are transitive, this procedure will never be cyclic, that is, an already induced partition will not be reached again. When passing from one partition to another by an AX-AE Nash blocking of an agent, at least one agent is made strictly better off without hurting other agents. Since the set of agents for a hedonic game is finite, we have a finite number of coalitions and of partitions. So, an agent can be made finite times strictly better off. Hence, this process stops, and an AX-AE Nash stable partition is obtained.

7. CONCLUSION AND FURTHER COMMENTS

In this study, we focused on hedonic coalition formation games. Hedonic coalition formation games are used to model and analyze economic, social, and political instances where agents form coalitions. A hedonic coalition formation game consists of a finite set of agents and a preference list of agents such that each agent has preferences over all coalitions that contain her. An outcome of a hedonic coalition formation game is a collection of coalitions that are pairwise disjoint, and their union is equal to the set of agents, and it is called a partition. We considered Nash stable partitions under different membership rights. We revisited the (sufficient) conditions that guarantee the existence of a Nash stable partition for each membership rights and provided examples of hedonic coalition formation games satisfying these sufficient conditions.

We note that there are sufficient conditions in the literature for the existence of a Nash stable partition under different membership rights. The existence of a necessary and sufficient condition for the existence of a Nash stable partition under different membership rights is not yet known and it is still an open research question.

Conditions that we reconsidered in this survey are imposed either on the preferences of the agents or on the preference profiles. Pápai (2007) studied hedonic coalition formation models with preferences over permissible coalitions and presented sufficient conditions that guarantee the existence of an FX-FE Nash stable and an FX-AE Nash stable partitions in these models. The existence of an AX-FE Nash stable partition or the existence of an AX-AE Nash stable partition in hedonic coalition formation models with preferences over permissible coalitions has yet to be investigated and this is still an open research question.

In the hedonic coalition formation model that we considered in this study, the agents are myopic, they are not farsighted, that is they are unable to look many steps ahead and consider credible outcomes. We refer readers to Diamantoudi and Xue (2003) about how stability notions are analyzed in the hedonic coalition formation models where agents are endowed with foresight.

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