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Analysis of coalitional stability among Mexican airlines within the air freight transport market before and during COVID-19

Análisis de estabilidad coalicional entre las aerolíneas mexicanas dentro del mercado de transporte aéreo de mercancías antes y durante la Covid-19

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Abstract

This work analyzes the stability of coalitions between Mexican airlines within the air freight transport market (AFTM) before and during Covid-19. Game theory and simulations in Scilab are applied to determine the elements of each game. There are a variety of ways that airlines can become part of a dominant group in the AFTM, where small airlines can be relevant. Furthermore, it is found that the stability of alliances depends on their strength and that, in the long run, not all minimally winning coalitions offer stability. This type of study can contribute to decision-making by companies within said market and by the government as a regulatory agent. It is important to know the possible alliances to have the advantages that this entails and reach new charging points in current and future airports.

JEL Code: C71, C88, D71, L22, L93
Keywords: Weighted Majority Game (WMG); Difference Game (DG); simulations in Scilab; air freight transport market (AFTM); Covid-19

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Resumen

En este trabajo se analiza la estabilidad de coaliciones entre aerolíneas mexicanas dentro del mercado de transporte aéreo de mercancías (MTAM) antes y durante la Covid-19. Se aplica teoría de juegos y simulaciones en Scilab para determinar los elementos de cada juego. Se halla una diversidad de maneras que las aerolíneas tienen para formar parte de un grupo dominante en el MTAM, donde las aerolíneas pequeñas pueden tener relevancia. Además, se encuentra que la estabilidad de las alianzas depende de su solidez y que, en el largo plazo, no todas las coaliciones ganadoras minimales ofrecen estabilidad. Este tipo de estudios puede coadyuvar a la toma de decisiones por parte de las empresas dentro de dicho mercado y por parte del gobierno como agente regulador. Es importante saber las posibles alianzas para tener las ventajas que ello conlleva y llegar a nuevos puntos de carga en los actuales y futuros aeropuertos.

Código JEL: C71, C88, D71, L22, L93
Palabras clave: Juego de Mayoría Ponderada (JMP); Juego en Diferencias (JD); simulaciones en Scilab; mercado de transporte aéreo de mercancías (MTAM); Covid-19

Introduction

This study analyzes the Mexican air freight transport market before and during COVID-19 using existing and self-developed theory in the area of game theory. Although the number of airlines dedicated to cargo transportation is not so large, the market can lend itself to making alliances among them or even associating with foreign companies within the same industry. Therefore, an analysis can be made using game theory to show companies the multiple ways in which they can dominate this market.

The formulation of this type of games can be approached with the theory of cooperative games, specifically with Weighted Majority Games (WGMs), which are a particular case of simple games. In the literature, these topics are usually placed within the analysis of coalition stability, which is approached from economic theory with the New Political Economy (NPE)[1]. In addition, it may be interesting to determine the number of periods in which a certain cluster of airlines can maintain control of this market; for this purpose, this paper will resort to what will be called Difference Games developed by the authors.

Regarding air transport in general, the International Air Transport Association (IATA), founded in April 1945, has lost authority over the years in its original role as a regulator of international fares. Today, the prices set by IATA have become "suggested" rather than mandatory fares, allowing government authorities to standardize the approval of airline tariff schedules. Each government reserves control of its airspace and sets traffic conditions and internal tariffs (Canseco González et al., 2015).

[1]Many of the authors of the NPE also subscribe to the Public Choice theory, which studies the behavior of government and voters with a positive character analysis.

Until the mid-1980s, the air transportation system in Mexico was heavily regulated by the government with unfair competition, where transportation services were carried out through concessions and permits (Joskow & Noll, 1999). Later, in the 1990s, this system changed due to the implementation of liberal economic measures, such as the privatization of service providers, the reduction of market entry barriers, and the deregulation of fares (Rico Galeana, 2010).

The most important consequence of liberalization and deregulation has been the sector's growth, which has been most visible in regions such as the United States and the European Union. Since the 1990s, these regions have strongly driven greater competitiveness among airlines and companies. During 2013, the global network carried 3.1 billion passengers via 33 million scheduled flights. Several studies suggest that these figures will almost double by 2030, which could lead to a very important role in the global economy (ICAO, 2014; AIRBUS, 2014; EUROCOTROL, 2014, as cited in Canseco González et al., 2015).

The Federal Economic Competition Commission (COFECE; Spanish: Comisión Federal de Competencia Económica) is one of the institutions in charge of overseeing and regulating the Mexican markets. This institution emerged as an autonomous body in charge of enforcing the Federal Law of Economic Competition (LFCE; Spanish: Ley Federal de Competencia Económica), enacted in June 1993. This regulating law of Article 28 of the Mexican Constitution on economic competition and monopolies aims to protect the process of competition, including free competition (Sánchez Ugarte et al., 2004). It was not until 2013, with the new LFCE, that COFECE became autonomous (Ambriz Villalpa, 2015).

According to COFECE (2018), making alliances can positively increase rivalry levels between competitors by reducing costs or increasing innovation. In other words, they encourage greater competition among economic agents. Cost reduction may be due to savings in resources by producing the same at lower costs, lower administrative expenses, technology transfer, and infrastructure expansion, among others.

According to Canseco González et al. (2015), the cost structure of any airline in Mexico is based on direct and indirect costs, representing approximately 80% and 20%, respectively. Fuel costs, rents, and salaries represent 60% of total costs. Figure 1 shows the average percentage covered by each airline's costs.

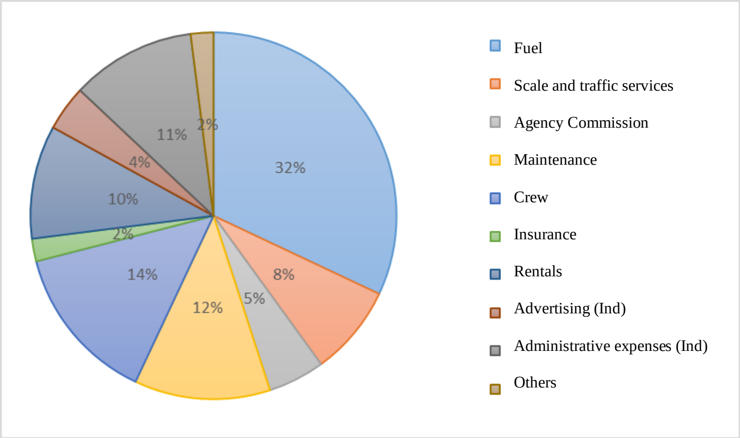

Figure 1. Cost structure of Mexican airlines
Source: Canseco González et al. (2015: 350)

As a result, over time there have been some low-cost carriers (LCC), especially in passenger services and recently in cargo services. The first concessions in air transportation were granted in 1921 to Mexicana de Transportación Aérea, S.A. and Mexicana de Aviación. Afterwards, Aeronaves de México did the same in 1932 (DGAC, 2010, as cited in Canseco González et al., 2015). Nevertheless, although Aeroméxico and Mexicana have been the traditional market leaders since the 1930s, as of 2005 their numbers began to decline from five to four million passengers per year. As has happened in other regions of the world, the traditional service model in Mexican airlines was affected by the arrival in 2005 of the new LCCs. Although cargo transportation is not a representative feature in the LCC business model, it has been practiced by some Mexican airlines, including Volaris and Interjet (DGAC, 2013, as cited in Canseco González et al., 2015).

Furthermore, over time there have been certain alliances between airlines, both domestic and international. An example of this has been the SKYTEAM alliance formed in 2000 by the companies Aeroméxico, Air France, Delta Airlines, KLM, and Korean Air, and more recently, in 2019, the alliance between Interjet and Qatar Airways (Liligo, n.d. & Carrilo, 2019).

Many of these alliances have participated significantly in the air transportation of goods over time as permitted by Article 48 of the Civil Aviation Law, which states that air transportation service contracts may relate to passengers, cargo, or mail. For more information on cargo transportation, see this article and Article 55 in the document Civil Aviation Law (2021). Additionally, information on the issuance of tariffs and COFECE as the regulatory agent of such market is presented in this document (see Articles 42 and 43).

The literature identified no obstacles for the different Mexican airlines to merge. Nonetheless, according to the LFCE, there are certain legal limitations to buy companies or make a merger between them. Moreover, when the transaction between companies exceeds the defined thresholds, authorization must be requested from COFECE, which can be denied considering that it affects competition (Ambriz Villalpa, 2015).

Therefore, it is plausible that Mexican airlines may form alliances to gain power in this particular transportation market, not overlooking the fact that forming such alliances may involve some recoverable and non-recoverable costs.

Thus, this research aims to analyze the coalitional stability of Mexican airlines in the air freight transport market (AFTM) before and during COVID-19, using data from 2019 to 2021, special topics of cooperative game theory, and simulations performed in Scilab.

First, a study of the Mexican cargo airlines operating within the AFTM before and during COVID-19 is carried out to fulfill this aim. Then, specialized topics of cooperative game theory are presented, such as the Coalition Stability Analysis (AEC; Spanish: Análisis de Estabilidad de Coaliciones) theory and the theory developed for this article. Then, some results of the simulations made in Scilab are presented, giving some scenarios that airport groups can form to have a better position in the market and the stability of coalitions over a certain period. The main results and conclusions are presented at the end of the paper.

Distribution of Mexican airlines in the AFTM

According to information from the Federal Civil Aviation Agency (AFAC; Spanish: Agencia Federal de Aviación Civil) (2020, 2021), the participation of Mexican airlines within the AFTM has been carried out based on the information presented in Table 1.

Table 1
Distribution of airlines in the AFTM based on the amount of goods moved during 2019, 2020, and 2021

Airline	Distribution before COVID-19		Distribution during COVID-19			
	Company number by tonnage	Quantity of goods moved[1] during 2019	Company number by tonnage	Quantity of goods moved during 2020	Company number by tonnage	Quantity of goods moved during 20212
Mas Air	3	57.81 (14%)	2	79.46 (21%)	1	95.4 (22%)
Grupo Aeroméxico	1	124.88 (31%)	3	71.54 (19%)	2	92.13 (21%)
Aeronaves TSM	4	46.75 (12%)	4	50.56 (13%)	3	71.07 (16%)
Aerounión	2	73.67 (18%)	1	80.85 (21%)	4	65.45 (15%)

MCS Aerocarga de México	7	19.73 (5%)	5	44.74 (12%)	5	51.5 (12%)
Estafeta	6	30.36 (7%)	6	28.37 (7%)	6	31.87 (7%)
Volaris	8	19.3 (5%)	7	16.21 (4%)	7	18.91 (4%)
Viva Aerobus	10	0.08 (0.02%)	9	2.56 (0.7%)	8	6.16 (1%)
Others	9	0.83 (0.2%)	10	0.33 (0.1%)	9	0.33 (0.1%)
Interjet[3]	5	32.33 (8%)	8	7.08 (2%)	10	0 (0%)
Totals		405.74 (100%)		381.7 (100%)		432.82 (100%)

Notes: [1]Quantities in thousands of tons and in parentheses their percentage for the total for each year. [2]With data through November 2021. [3]Interjet suspended operations as of December 11, 2020.
Source: created by the authors with information from AFAC (2020, 2021)

According to Table 1, airline competition within the AFTM has been characterized by the dominance of the market by a different agent in each of the years before and during the COVID-19 pandemic. As expected, during 2020, there was a decrease in the total tons transported, although this total would rebound to levels even higher than the pre-pandemic figure for the following year.

These data will be used for the different scenarios among airline alliances, with the understanding that no unfair competition will be generated that would prevent other concessionaires or permit holders from remaining in the market and to promote healthy competition as stipulated by the Ministry of Communications and Transportation (SCT; Spanish: Secretaría de Comunicaciones y Transportes) (Ley de Aviación Civil, 2021: 20).[2]

Making strategic alliances will always be latent in the face of the threat of entry of new competitors and will prevent some companies in the air transportation industry from exiting the market due to economic losses (Canseco González et al., 2015: 16).

Coalition Stability Analysis (AEC)

The first part of this section presents the main concepts that game theory offers to analyze the dynamics of certain players and the relevance of being part of a particular group within the game. This type of topic is approached from the point of view of the AEC. First, cooperative games, one of the main indices of power used in the analysis of these topics, are studied; then, simple games and WMGs are introduced. Then, in the second part, the authors will introduce their own theory of what will be called Difference Games and their stability index, which will be defined based on a variant of the WMGs previously discussed.

[2]In passenger transportation, there is a record for 2013, where low-cost carriers in Asia and Australia accounted for 50% of the market, transporting 292 million passengers per year.

Existing simple games and stability indices

The formal definitions of a cooperative game and the most usual indices in this type of games are then presented: the Shapley index and the Shapley-Shubik index.

Definition 1 (Cooperative game (Carreras et al., 1992: 108)). A cooperative game is a pair $\Gamma \equiv (N, v)$, where N is a set of players (called a grand coalition) and $v: 2^N \to \mathbb{R}$ is a characteristic function (where 2^N denotes the power set of N) that assigns each coalition of players a payoff or value, with $v(\emptyset) = 0$.

In a cooperative game, some players team up through a binding agreement and receive a reward in the form of payment, which will depend on the rules of the game and the situation of each player, elements taken up in the characteristic function.

Definition 2 (Shapley's Index (SI) (Gilles, 2010: 75)). Let $\Gamma = (N, v)$ be a cooperative game, with $N = \{1, 2, \dots, n\}$ the set of players and v its characteristic function. Denote by $S = \{n_1, n_2, \dots, n_k\}$, $1 \leq n_j \leq n$, a coalition in N, with $n = |N|$ and $s = |S|$. The Shapley Index (SI) is defined as:

$$S_i \equiv S_i(v) = \sum_{i \epsilon S, S \subseteq N} \frac{(s-1)!\,(n-s)!}{n!}[v(S) - v(S \setminus \{i\})] = \frac{1}{n} \sum_{i \epsilon S, S \subseteq N} \frac{1}{{}_{n-1}C_{S-1}}[v(S) - v(S \setminus \{i\})], i = 1,2, \dots, n, \tag{1}$$

where ${}_{n-1}C_{s-1} = \binom{n-1}{s-1} = \frac{(n-1)!}{(n-s)!(s-1)!}$.

This stability index gives the same probability of occurrence to the formation of coalitions of size $s = |S|$, so S_i is the expected value of the marginal contribution of player i when all orders of coalition formation are equally probable. As can be seen, such an index depends on the combinations of the size of the different coalitions of which player i can form, but without counting itself (hence the term ${}_{n-1}C_{s-1}$).

The Shapley index is most appropriate when all players have a common value in judging a proposal.[3]

Definition 3 (Simple Cooperative Game (JS) (Peleg & Sudholter, 2007: 16-17)). A Simple Cooperative Game or Simple Game (JS) v is one where for any coalition $S \subseteq N$ it holds that: i) $v(S) = 0$ o $v(S) = 1$; ii) $v(N) = 1$; and iii) $v(S) \leq v(T)$ such that $S \subseteq T \subseteq N$.

Every JS is determined by the collection of winning coalitions (W), defined by the set $W = \{S \subseteq N : v(S) =\}$. Accordingly, it follows that: i) $N \in W$ and $\emptyset \notin W$ in every game v and ii) If $S \subseteq T$ and

[3]In this respect, there are alternative ways of representing the SI and SSI presented in works such as that of Felsenthal and Machover (1996). Likewise, there are other indexes such as the Banzhaf index, which is more adjusted when players have their own value when judging a given proposal (see Sanchez, 1994: 103).

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$S \in W \Rightarrow T \in W$. With the latter, the game v can be bounded to the collection of minimal winning coalitions (W^m) defined as follows: $W^m = \{S \subseteq W: T \in W \mid S \subseteq T\}$. The following definition presents a particular case of a JS.

Definition 4 (Weighted Majority Game (WMG) (Peleg & Sudholter, 2007: 17)). A Weighted Majority Game (WMG) is a particular case of a simple game. The game v is a weighted majority game if there exists a distribution of weights $w_1, w_2, \ldots, w_n$ among the players and a majority quantity or share (q) such that:

$$S \in W \Leftrightarrow w(S) \geq q \Leftrightarrow v(S) = 1, \text{ with: } w(S) = \sum_{i \in S} w_i, \forall\, S \in W \tag{2}$$

Usually, a WMG is represented as: $v \equiv [q;\ w_1, w_2, \ldots, w_n]$. In other words, a WMG is posed when a team of players is required to reach or exceed a proposed goal (translated into a quota); such a goal can be reached with a team where there are some players who are not needed to achieve the goal (in which case one has a winning coalition) or with players where all are needed to reach the proposed quota (in which case one has a minimum winning coalition). Next, the SI restricted to simple games is presented.

Definition 5 (Shapley-Shubik Index (ISS) (Carreras et al., 2003: 121)). The Shapley-Shubik Index (SSI) is the SI restricted to simple games for each player i, i.e., it is an index $SS_i = S_i|_{JS}$ with the following characteristics: i) Player i is null $\Leftrightarrow SS_i = 0 \Leftrightarrow i \notin S, \forall\, S \in W^m$; ii) Players i and j are equivalent $\Leftrightarrow SS_i = SS_j \Leftrightarrow$ appear symmetrically in W^m; and iii) There is efficiency $\Leftrightarrow \sum_{i=1}^{n} SS_i = 1$.

Difference game (DG) and its stability index

In this section, a Difference Game (DG) induced by a WMG is formulated in a general way. Then, its solution and the stability index derived from this type of games are presented. First, a WMG is defined in which some players, or part of them, are absent, giving rise to a new reconfiguration of the original game, modifying both its quota and its weight distribution.

Definition 6 (Game redefined by absenteeism in a WMG). Let $v = [q; w]$ be a WMG with $w = (w_1, \ldots, w_n)$ and where $w_s = w_1 + \cdots + w_n$. When some parts of some of the players $i, i = 1, \ldots, n$, decide not to enter the game, such "partial players" will be considered absent. The above leads to a new WMG as long as a quorum is present. Such a WMG will be called WMG redefined by absenteeism, which will have the following formula:

$$\bar{v} = [\bar{q}, \bar{w}], \text{ with } \bar{w} = w \setminus \{a_i w_i\}, 0 < a_i \leq 1, \tag{3}$$

http://dx.doi.org/10.22201/fca.24488410e.2023.4908

where $w \backslash \{a_i w_i\}$ means that the part of the weights of the absent players i is not considered. On its part, $\bar{q}$ is the corresponding share when considering the weights in $\bar{w}$; this share must represent the same percentage that q represents with respect to w_s of the original game. If $a_i = 1, \forall$ i is absent, the absenteeism will be considered to be group (or total); if $0 < a_i < 1, \forall$ i is absent, the absenteeism will be considered to be pure partial absenteeism.

It is not difficult to be convinced that if $\bar{v}$ inherits the properties of v, then $\bar{v}$ is also a WMG.

For more information about the above definition and other types of games, such as those redefined by abstentionism in a WMG and the same DG presented below, see Larios Ferrer (2022). Additionally, for the role of absenteeism and abstentionism within a WMG, see the propositions in Larios Ferrer and Ávila Pozos (2022), where it is shown that, under certain conditions, absenteeism plays in favor of the winning coalition (WC) and abstentionism plays against the winning coalition.

Formulation of the DG

For the formulation of the Difference Games (DGs), it is necessary to consider, apart from absenteeism (AU), the concept of betrayal among the different players. It is necessary to define the concept of betrayal because of its importance in the development of the different games, since without this concept, it would not be possible to connect some sets, such as those in favor (AF) of a certain alliance and against (EC) the same alliance. Let AU_AF be the set of absent players who are in favor, and let AU_EC be the set of absent players who are against.[4] It is intended to know up to which period t, $AF_t \in W$ in their respective redefined set.

Therefore, what will be referred to as the Difference Game induced by a WMG or simply as a DG is formally defined.

Definition 7 (Difference Game (DG)). Let $v = < N, q, w >$ be a WMG. A Difference Game v_{DG} induced by v, or simply Difference Game (DG), is a bin formed by $< S, v >$, where S is an autonomous linear system of Difference Equations (DEs) of the following form:

$$x(n) = Ax(n-1), n = 1, 2, \ldots, \tag{4}$$

where A is a non-singular square matrix and where the DG is won if the winning coalition in v is such that it remains winning until before a period p with $1 \leq p \leq p^*$ where p^* is a threshold or critical

[4]For a complete discussion of this concept, see Larios Ferrer (2022: 466-468).

http://dx.doi.org/10.22201/fca.24488410e.2023.4908

period.[5] If $p = 0$, the DG will be considered as null; otherwise, the DG will be referred to as non-null. When not specified, the DG will be assumed to be non-zero.

The definition of a DG redefined by absenteeism is shown below,[6] where some conditions related to the vector $x(n)$ are requested.

Definition 8 (DG redefined by absenteeism). Let $v =< N, q, w >$ be a WMG redefined by absenteeism. The DG v_{DG} induced by v will be called a non-zero absenteeism redefined DG or simply absenteeism redefined DG provided the following conditions are satisfied: (i) the win share q in each period p of the DG must not take into account the absent group players in vector $x(p)$; (ii) the set of non-absent players in $x(p)$ in each period p where the DG is won must exceed the quorum share of v, which will be the same for all periods of the DG; (iii) all entries in vector $x(p)$ must be non-negative in each period p of the DG; when this does not happen, the DG must terminate, no matter that WMG v has been won for that period.

Solution and stability of the DG

This section presents the solution of a DG with the help of Putzer's algorithm, which is extended to a DG redefined by absenteeism. At the end, this solution presents a stability index and its degree of stability.

Definition 9 (Solution of a general DG). Let v_{DG} be a (nonzero) DG induced by a WMG v. Let S be the self-contained linear DEs system of vDG with $_{n}0 = 0$, which has the following form:

$$x(n) = Ax(n-1), n = 1, 2, ...$$

The solution of the DG is given by: $x(n) = A^n x_0$, where x_0 is the initial state of the DG and A^n is determined based on Putzer's algorithm.[7]

The solution of the game redefined by absenteeism is shown below.

Definition 10 (Solution of a DG redefined by absenteeism). Let v_{DG} be a (non-zero) DG induced by a WMG redefined by absenteeism $v =< N, q, w >$. The solution of v_{DG} is given by Definition 9, where q and $x(p)$ satisfy the imposed conditions of the DG redefined by absenteeism (Definition 8) in each period p in which the DG is won.

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[5]The definition of such a critical period will depend on the context of each particular DG.
[6]A DG redefined by abstentionism, as well as its respective solution, is presented in the work of Larios Ferrer (2022) in an analogous manner.
[7]This algorithm uses the Cayley-Hamilton theorem, which states that a matrix satisfies its characteristic equation in an essential form, i.e., that every endomorphism of a finite-dimensional vector space over any body cancels its own characteristic polynomial. This theorem and Putzer's algorithm (discrete case) can be seen in detail in Elaydi (2010: 118-120).

With all the above, its own stability index is finally defined, derived from a DG induced by a particular WMG.

Definition 11 (Stability index derived from a DG). Let v_{DG} be a DG induced by a particular WMG v (redefined by absenteeism, for example). The DG-derived stability index is defined as follows:

$$\varepsilon(p) = \begin{cases} 1, & \text{si } p \geq p^* \\ p/p^*, & \text{si } p < p^*, \end{cases} \tag{5}$$

where p is the period where the DG is won consecutively and is such that it meets the conditions imposed by the particular WMG v and where p^* is the critical threshold of the DG, where $p^* \geq 1$.

To complement the above, the stability classification of this index is presented.

Definition 12 (Degree of stability of the DG). Let v_{DG} be a DG induced by a particular WMG v. Let p and p^* be as in Definition 11. The degree of stability of the DG will be given by its stability index ε as follows:

$$DG = \begin{cases} \text{is stable if } \varepsilon(p) = 1 \\ \text{is semi} - \text{stable, if } 0.5 < \varepsilon(p) < 1 \\ \text{is unstable, if } 0 \leq \varepsilon(p) < 0.5 \end{cases} \tag{6}$$

Moreover, one will speak of weak semi-stability as ε approaches 0.5 and strong semi-stability as ε approaches 1. The same applies for stability, where it will be strong if $p > p^*$ and weak if $p = p^*$.

The formal definition of DG, together with its solution and stability index (including its classification), will be used in the approach of some games in the following section.

Analysis of the stability of coalitions within the AFTM in Mexico

In this part of the paper, the decision-making power of the main Mexican airlines within the AFTM—the coalitions that could have control of the market and its stability during a certain period—is analyzed. The procedure is as follows: the information in Table 1 presented in the first section is used, where each of the 10 Mexican airlines is considered a player whose weight is the number of goods moved over the years 2019, 2020, and 2021;[8] as majority share it is proposed to use a simple majority of that market.[9] With the

[8]"Other" airlines are considered as one player.
[9]There is no consensus to date on a type or threshold level to define dominance in this market. The LFCE considers the "influence" (substantial power) of the agent according to its participation in the market and based on its power to fix prices and limit inputs, among others. In other words, it recognizes that market share is relevant although it does not

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theory presented in the second section and the use of Scilab simulations, the calculation of Winning Coalitions (GCs), Minimum Winning Coalitions (MWCs), and the power indexes of the airlines is carried out in the first part, and in the second part, some stability scenarios with the DGs are presented.

Analysis with SSI and with each WMG

With the information presented in Table 1, following the numbering of the Mexican airlines outlined in said table and with majority shares of 50%,[10] the WMGs for 2019, 2020, and 2021 are presented in Tables 2, 3, and 4, respectively.

These tables present the coalitions that Mexican airlines can form to have a better position in this particular transportation market. The coalitions that offer effective solutions to the game are specifically presented, that is, where the cases where MWCs exist are considered.

Concerning the MWCs results in the three tables, the following comments are made: the most "adjusted" MWCs, adjusted to include the smallest airlines, are shown in bold; the MWCs in which the main airlines are omitted are shaded in gray; and finally, the most adjusted MWCs, in which the main companies analyzed are omitted, are shown in bold and shaded in gray.

Following Table 2, the minimum size of a WC is three Mexican airlines, and its maximum size is 10 (the grand coalition). A large number of WCs (512 in total) was observed, where 10 are of size three and 154 are of size six. These WCs represent the different ways of obtaining some AFTM dominance by Mexican airlines, although not in a minimal way. Some airlines may still be excluded, and overtaking the market dominance share in cargo movement may exist.

Table 2
Summary of WMG simulations generated by Mexican airlines in the AFTM with 2019 data

WMG: $v = [202.87;\ 124.88, 73.67, 57.81, 46.75, 32.33, 30.36, 19.73, 19.30, 0.83, 0.08]$		
Coalition size	Number of WCs	Number of MWCs and minimal coalitions[1]
$s = 3$	10	10 in total. These are: $W^m = \begin{pmatrix} (1,2,3),(1,2,4),(1,2,5),(1,2,6),(1,2,7),(1,2,8),(1,3,4),(1,3,5), \\ (1,3,6),(1,4,5) \end{pmatrix}$
$s = 4$	56	9 in total. These are: $W^m = \begin{pmatrix} (1,3,7,8),(1,3,7,9),(1,4,6,7),(1,4,6,8),(1,4,7,8),(1,5,6,7), \\ (1,5,6,8),(2,3,4,5),(2,3,4,6) \end{pmatrix}$
$s = 5$	126	5 in total. These are: $W^m = ((1,3,8,9,10),(1,4,6,9,10),(2,3,4,7,8),(2,3,5,6,7),(2,3,5,6,8))$
$s = 6$	154	7 in total. These are: $W^m = \begin{pmatrix} (2,3,5,7,8,9),(2,3,5,7,8,10),(2,4,5,6,7,8),(2,4,5,6,7,9) \\ (2,4,5,6,7,10),(2,4,5,6,8,9),(3,4,5,6,7,8) \end{pmatrix}$

define a threshold, but must be assessed on a case-by-case basis. It is worth mentioning that, in the Telecommunications market, the Broadcasting and Telecommunications Law establishes a threshold of 50% to determine that an agent is a preponderant agent.
[10]Obtained as half of the goods transported by the airlines in the different years in Table 1.

Total coalitions ($3 \leq s \leq 10$)[2]	512	31

Notes: [1]The player number corresponds to the 2019 information presented in Table 1, i.e., where the 10 players participating are: 1) Grupo Aeroméxico (with 124.88 tons), 2) Aerounión (with 73.67 tons), and so on until reaching 10) Viva Aerobus (with 0.08 tons). [2]In the case of WCs, the total includes coalitions of size greater than or equal to seven.
Source: created by the authors.

Concerning MWCs, it was found that the minimum size of MWCs is three Mexican airlines, which coincides with the 10 WCs of the same size; the maximum size of an MWC is six airlines. The total number of MWCs is 31, where both the largest and smallest airlines participate. With this type of coalition, it is possible to take the most effective solutions to dominate this market.[11] Due to the importance of this type of coalition, some comments are made on some MWCs presented in the third column of Table 2.

Of the MWCs of size three, all take the leading airline (Aeromexico), and only four of the 10 leave out the second leading carrier (Aerounion). The tightest coalitions are Grupo Aeromexico + Aerounion + MCS Aerocarga de Mexico and the top two airlines plus Volaris.

Regarding size four MWCs, there is a tighter coalition formed by Grupo Aeroméxico + Mas Air + MCS Aerocarga de México + Others, i.e., smaller airlines could participate and are represented by the latter companies. Moreover, with this size, there are two coalitions where the dominant company is disregarded; these alliances are: Aerounion + Mas Air + Aeronaves TSM + Interjet or Estafeta.

Finally, among the MWCs of size five and six, there are seven adjusted coalitions where players 9 (Others) or 10 (Viva Aerobus) appear. Additionally, there is a size six MWC formed by Mas Air + Aeronaves TSM + Interjet + Estafeta + MCS Aerocarga de México + Volaris, which leaves out the two main airlines analyzed.

On the other hand, during 2020, the first year of the COVID-19 pandemic, similar results to 2019 were obtained for WCs. Where there were noticeable changes was regarding MWCs. It was found that the size of the 18 MWCs can be three, four, and six, and that of these, two are adjusted, four dispense with the main airlines, and one more fulfills this dual role (adjusted and dispenses with the two dominant companies) and is formed by Grupo Aeromexico + Aeronaves TSM + MCS Aerocarga de Mexico + Volaris + Interjet + Viva Aerobus. This last MWC is the only one of size six and the only one of 160 WCs of the same size with this double characteristic (see Table 3).

[11]It is called dominance in the sense that at least 50% of the freight movement within the AFTM is reached and that with this there are the aforementioned advantages, including a possible reduction in operating costs. The above could go against what the regulatory institutions are proposing. Nonetheless, it should not be forgotten that only a part of the total air freight market is being studied, and the cases analyzed are precisely those where the group of airlines exceeds 50% of the submarket by a very small margin, since they work mainly with the MWCs.

Table 3
Summary of WMG simulations generated by Mexican airlines in the AFTM with 2020 data

WMG: $v = [190.85;\ 80.85, 79.46, 71.54, 50.56, 44.74, 28.37, 16.21, 7.08, 2.56, 0.33]$		
Coalition size	Number of WCs	Number of MWCs and minimal coalitions[1]
$s = 3$	7	7 in total. These are: $W^m = ((1,2,3), (1,2,4), (1,2,5), (1,3,4), (1,3,5), (2,3,4), (2,3,5))$
$s = 4$	50	10 in total. These are: $W^m = \begin{pmatrix} (1,2,6,7), (1,2,6,8), (1,2,6,9), (1,3,6,7), (1,4,5,6), (1,4,5,7) \\ (2,3,6,7), (2,4,5,6), (3,4,5,6), (3,4,5,7) \end{pmatrix}$
$s = 6$	160	1 in total. This is: $W^m = ((3,4,5,7,8,9))$
Total coalitions ($3 \leq s \leq 10$)[2]	512	18

Notes: [1]The player's number corresponds to the 2020 information presented in Table 1, i.e., where the 10 players participating are: 1) Aerounion (with 80.85 tons), 2) Mas Air (with 79.46 tons), and so on until reaching 10) Others (with 0.33 tons). [2]In the case of WCs, coalitions of size five and of size greater than or equal to seven are considered in the total.
Source: created by the authors.

On the other hand, during 2021, the second year of the COVID-19 pandemic, the number of WCs decreased by half compared to the previous two years. Due to the exit of Interjet from this market during that year, the number of WCs decreased from 512 to 256, distributed between sizes three and nine.

The number and type of MWCs were practically the same as that obtained for 2020. It was found that the size of the 19 MWCs can be three, four, and five, and that of these two are adjusted, two do without the main airlines, and two more meet this double objective, where the smallest size is formed by Grupo Aeroméxico + Aeronaves TSM + MCS Aerocarga de México + Viva Aerobus (see Table 4).

Table 4
Summary of WMG simulations generated by Mexican airlines in the AFTM with 2021 data

WMG: $v = [216.41;\ 95.40, 92.13, 71.07, 65.45, 51.50, 31.87, 18.91, 6.16, 0.33]$		
Coalition size	Number of WCs	Number of MWCs and minimal coalitions[1]
$s = 3$	7	7 in total. These are: $W^m = ((1,2,3), (1,2,4), (1,2,5), (1,2,6), (1,3,4), (1,3,5), (2,3,4))$
$s = 4$	42	10 in total. These are: $W^m = \begin{pmatrix} (1,3,6,7), (1,4,5,6), (1,4,5,7), (1,4,5,8), (2,3,5,6), (2,3,5,7), (2,3,5,8), \\ (2,4,5,6), (2,4,5,7), (3,4,5,6) \end{pmatrix}$
$s = 5$	84	2 in total. These are: $W^m = ((1,4,6,7,8), (2,3,6,7,8))$
Total coalitions ($3 \leq s \leq 9$)[2]	256	19

Notes: [1]The player number corresponds to the information for the year 2021 presented in Table 1, i.e., where the nine participating players are: 1) Mas Air (with 95.4 tons), 2) Grupo Aeroméxico (with 92.13 tons), and so on until reaching 9) Others (with 0.33 tons). [2]In the case of WCs, the total includes coalitions of size greater than or equal to six.
Source: created by the authors.

Concerning the SSI, Table 5 shows the decision-making power of each Mexican airline according to this index. In this table, the airlines with greater decision-making power in the AFTM in their respective years are shaded in gray, and in bold are the cases where the airlines have the same power despite having different load capacities. It can be observed that during 2019, Grupo Aeromexico had more than a third of such power by having 36.19% of the decision power and that during 2020, Mas Air and Aerounion shared the same market power with 22.06% of the power. Nevertheless, by 2021, Mas Air would be the first company to maintain such a position with 24.29%.

For the year 2020, there were cases where air carriers had different cargo capacity and had the same decision-making power: Aeronaves TSM and MCS Aerocarga de México, both with 13.25%, and the case of Viva Aerobus and Interjet with only 0.4%.

Table 5
Comparison of the SSI of Mexican airlines in the AFTM for 2019, 2020, and 2021

	Aviation company	SSI		
		2019	2020	2021
1.	Mas Air	0.1302	0.2206	0.2429
2.	Grupo Aeroméxico	0.3619	0.1992	0.2095
3.	Aeronaves TSM	0.1040	0.1325	0.1762
4.	Aerounión	0.1579	0.2206	0.1429
5.	MCS Aerocarga de México	0.0413	0.1325	0.1238
6.	Estafeta	0.0706	0.0540	0.0619
7.	Volaris	0.0373	0.0325	0.0286
8.	Viva Aerobus	0.0032	0.0040	0.0143
9.	Others	0.0071	0.0000	0.0000
10.	Interjet	0.0865	0.0040	DNP[2]
Total[1]		1	1	1

Note: [1]The total sum is 1 if all decimals are considered. [2]Does not participate in the game
Source: created by the authors.

Analysis of coalitional stability with the DG

Cases of application of the DGs are presented in this section, considering some assumptions for their development and where, for each DG proposed, a certain degree of stability of the initial coalitional structure is obtained. Three scenarios are presented: a non-cooperative, a semi-cooperative, and a cooperative one.[12]

The analysis with DGs is relevant to analyze the cargo capacity of airlines over a certain period. In these DGs, it is important to study absenteeism to consider the absence of some airlines for lack of market due to COVID-19, where the sets can be described as follows: AF as the alliance related to any particular MWC, which represents the alliance of airlines with market control; EC as the alliance where competing airlines are found and which seeks to take market control away from the MWC; AU_AF as the

[12]The number of scenarios is quite large. Representative cases are presented to show the application of the theory developed with respect to DGs and their corresponding stability indices.

group of absent airlines and which could contribute to the MWC; and AU_EC as the set of absent airlines and which could counterbalance the MWC.

In all cases, a 75% quorum, a 50% majority share, and a threshold period $p^* = 12$ are assumed, alluding to the desire to maintain the carrying capacity for at least one year (12 months) and thus maintain dominance in the AFTM. With these assumptions, some scenarios are presented below.[13]

Non-cooperative scenario

The AF set is treated based on the MWC (3,4,5,6) of 2021, i.e., with the alliance formed by Aeronaves TSM + Aerounión + MCS Aerocarga de México + Estafeta. On the other hand, the EC set is assumed to be represented by the remaining airlines that are not in the MWC above, where the absent groups are taken from the first COVID-19 pandemic year, i.e., 2020. Thus, based on the information in Table 1, the following initial conditions are found: $\pi_0 = (af_0, au_{AF0}, au_{EC0}, ec_0) = (204.52, 15.37, 35.75, 177.18)$ and $N_0 = 432.82$. These initial conditions will be used in the other scenarios for comparison purposes.

Thus, with the above coefficients and the transition rates derived from the information in Table 1, the diagram in Figure 2 was obtained.[14] A low rate of return was observed in the AF set and a higher rate of return in the EC set, as well as a high rate of absence in the MWC and a negligible rate in the opposition alliance.

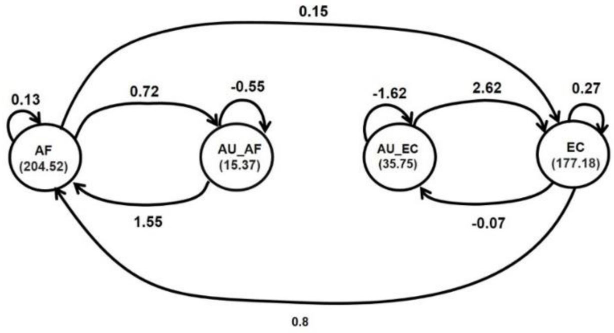

Figure 2. Transition diagram of a case of coalitional instability
Source: created by the authors with information from AFAC (2020, 2021)

With the parameters in Figure 2, the system (7) of the DG redefined by absenteeism is obtained:

[13]It was decided to use this periodicity since the reports made by the AFAC are on a monthly basis. These data are debatable and can be modified as much as required for a more detailed study.
[14]Some transitions are calculated based on previous years and others, due to lack of information, are proposed to discuss the corresponding scenarios.

$$af_{t+1} = 0.13af_t + 1.55au_{AFt} + 0.8ec_t$$

$$au_{AFt+1} = 0.72af_t - 0.55au_{AFt}$$

$$au_{ECt+1} = -0.07ec_t - 1.62au_{ECt}$$

$$ec_{t+1} = 0.15af_t + 0.27ec_t + 2.62au_{ECt}, t = 1, 2, \ldots, \tag{7}$$

Using Definition 10 about the solution for an absenteeism redefined DG, following Putzer's algorithm[15] and programming it all in Scilab, it was obtained that the number of consecutive periods in which the AF coalition is a winner in this DG is $p = 1$ and that its stability index is $\epsilon = 0.0833$ (by Definition 11). According to Definition 12, this means that this DG redefined by particular absenteeism is unstable.[16]

Semi-cooperative scenario

With the same initial conditions as in the previous scenario, assuming a higher rate of return in the AF set, a relatively zero rate from the AF to EC set, and the other transitions proposed in the diagram in Figure 3, one can arrive at a system of DG difference equations like the one formulated in system (1) of the first scenario.

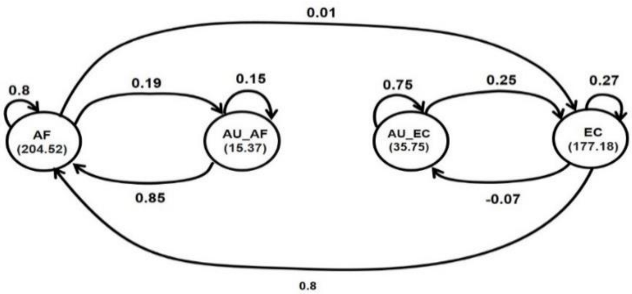

Figure 3. Transition diagram of a case of coalitional semi-stability
Source: created by the authors with information from AFAC (2020, 2021)

[15]For this and the other problems presented here, Putzer's algorithm is applicable since the matrices derived from the systems of equations in differences of each of the DGs, besides being real and square of order four (fulfilling the conditions of the Cayley-Hamilton Theorem) are non-singular matrices, that is to say, their determinant is different from zero. The above theoretically supports the results presented here.
[16]The stability of this index is not comparable to the SSI because now the stability of coalitions over several periods and not of a particular player during a single period is being considered.

It was found for this case that the number of consecutive periods in which the AF coalition is winning is six months, i.e., $p = 6$. This indicates that the stability index is $\epsilon = 0.5$. According to Definition 12, a semi-stable DG is obtained with this level of stability.

Cooperative scenario

For this last scenario, the same initial conditions of the first scenario and practically the same rates of return of the semi-cooperative scenario are used. Only a slightly higher rate is put from the EC set into the AU_{EC} set and a smaller rate from the first set into the AF state (see diagram in Figure 4). A DG system analogous to the one presented in the non-cooperative scenario can be obtained with the above.

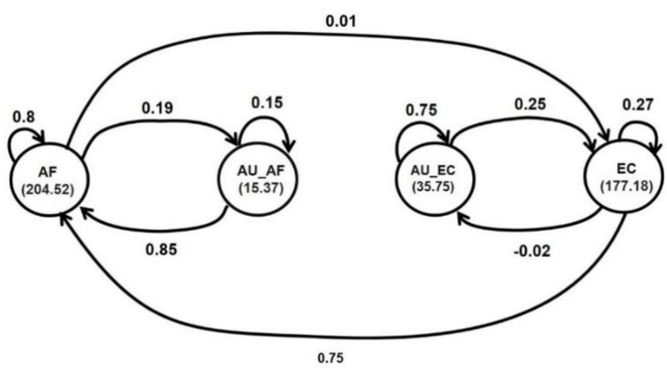

Figure 4. Transition diagram of a case of strong coalitional stability
Source: created by the authors with information from AFAC (2020, 2021)

For this case, it was found that the number of consecutive periods in which the AF coalition is winning is 14 months ($p = 14$). This indicates that the stability index is $\epsilon = 1$ and that a strong level of stability could be expected.

Finally, Table 6 presents a summary table with the ranking of the MWCs within the AFTM for the year 2021 using the parameters of this last scenario. It is worth mentioning that some MWCs were not stable because, among other reasons, although the coalition was a winner in 2021, it was a non-winner in 2020. This indicates an MWC that was not stable from the beginning, either because of the lack of airline participation in the MWC or because of its absence from the market.

Table 6
Classification of MWCs within the AFTM by 2021

MWC size	MWC			Total MWCs
	Not stable	Semi-stable	Stable	
3	(1,2,3), (1,2,5), (1,2,6), (1,3,5)	-	(1,2,4), (1,3,4), (2,3,4)	7
4	(1,3,6,7), (2,3,5,6), (2,3,5,7), (2,3,5,8)	-	(1,4,5,6), (1,4,5,7), (1,4,5,8), (2,4,5,6), (2,4,5,7), (3,4,5,6)	10
5	(2,3,6,7,8)	-	(1,4,6,7,8)	2
Total MWCs	9	0	10	19

Source: created by the authors.

Conclusions

This study analyzed the stability of coalitions of Mexican airlines operating in the AFTM before and during COVID-19—2019 and 2020-2021, respectively—using cooperative game theory and simulations implemented in Scilab.

It was found that there is a large number and diversity of ways for Mexican airlines to be part of a dominant group in the AFTM, where small groups can be relevant. Furthermore, it was found that the stability of alliances depends on the strength of the alliance and its initial conditions. There is a different configuration of this market before and after COVID-19 and this is reflected, although not directly, in the decision-making power given by the SSI of the companies in this line of business. In the long run, it was found that not all minimal winning coalitions offer stability in this market.

Tables 2, 3, and 4 presented data on WCs for 2019, 2020, and 2021, respectively. It was verified that there are many ways to reach or exceed the majority share: 512 WCs for 2019 and 2020 and only half of these coalitions for 2021 due to the exit of Interjet from this market. Nonetheless, for the purpose of effectiveness and to be as close as possible to what is required by government agencies, it is possible to focus only on MWCs.

The number of MWCs was 31, 18, and 19 for 2019, 2020, and 2021, respectively. Interestingly, despite the number of WCs halving for 2021 with respect to 2020, this reduction was not reflected in the MWCs. It can be seen from the tables already cited that the size of MWCs can range from three to six for the years 2019 and 2020 (with no coalitions of size five for 2020) and from three to five for the second pandemic year. This reflects the wide range of possible alliances to gain the advantages of being part of a dominant group of companies in such a market before or during the COVID-19 pandemic, for example, through partial control in the supply of such freight services, either via price or quantity. This type of alliance is plausible as long as the legal limitations are respected and the corresponding authorizations indicated by COFECE are carried out (Ambriz Villalpa, 2015).

Furthermore, Tables 2, 3, and 4 presented some very peculiar MWCs in their 2019, 2020, and 2021 structures, respectively. It was possible to observe the tightest MWCs where the smallest airlines are considered, the MWCs where the main airlines are dispensed with, and those that complied with these two characteristics. Regarding the latter coalitions, none were found for the pre-pandemic year (2019) and two in the COVID-19 pandemic years (one for 2020 and one for 2021).

This leads to the idea that it is possible for Mexican airlines with lower cargo capacity to form coalitions among themselves and gain partial control of the AFTM without having to consider the main Mexican airlines in that market. By being part of these MWCs, it is possible to have the advantages of economy of scale mentioned in COFECE (2018) while following what was suggested by the SCT in EFE (2008).

Regarding the SSI shown in Table 5, the results show a concentration of more than 63% of decision-making power among the three main AFTM airlines during the three years. The concentration was more pronounced in pre-pandemic times, where Grupo Aeromexico had just over 36% of decision-making power. Aerounion and Mas Air would be the main companies for the first pandemic year, with the same power of 22%. Moreover, for the second pandemic year, the latter airline would remain the main airline with more than 24% of decision-making power. A good market position is usually based on a good level of decision-making power, although not directly, as shown in the 2020 cases.

As for the stability index derived from the DGs developed, the importance of maintaining a united alliance among the different airlines and thus maintaining market dominance for several periods is noted. The scenarios presented in the paper show that a cooperative scenario between airlines leads to stability over several months, which would not be achieved with a semi-cooperative or non-cooperative scenario. The latter was precisely what happened during COVID-19, when some airlines were absent, perhaps due to a lack of market.

Finally, Table 6 presents the results of the simulations performed for all the MWCs obtained for the second year of the pandemic and where the calculation of the initial conditions considered the absences during the first year of COVID-19. Not all coalitions offered stability over time, as only 10 of the 19 MWCs managed to maintain market control for more than one year. This suggests thinking very carefully about who to form an alliance with, making sure that they are loyal to the coalition, that they do not repeatedly resort to absence in their services, and worse still, that they ally themselves with the competition from time to time.

Since no work was found in the literature that applied game theory to analyze this type of market, the following theoretical implications can be suggested: first, updates can be made in analyzing this market

http://dx.doi.org/10.22201/fca.24488410e.2023.4908

and in the case of the DG with more real data than those assumed. Second, this type of analysis can be performed for markets analogous to the one analyzed here. Third, other coalitional values can be incorporated into this type of study, such as Owen's Coalitional Value, which includes inter-coalitional decision-making power (Carreras et al., 1992). Fourth, the results presented here can be compared with other techniques used to analyze the stability of coalitions, such as the core (Gillies, 1953; Scarf, 1967), the nucleolus (Schmeidler, 1969), the alpha-core and beta-core (Aumann, 1961), or threat-related equilibria (Mohr, 1988; Moreno-Okuno, 2022), among others.

In practice, conducting this kind of study provides insight into possible scenarios where a coalition of Mexican airlines may partially control the AFTM. With a more robust analysis, this type of study could help entrepreneurs modify their status in the market, where they know the different ways they can be part of a dominant alliance and the possible duration of their dominance in the market. Moreover, it is important to know the possible alliances to have the advantages this entails and reach new cargo points in current and future airports inside and outside the country, such as the recent AIFA.[17]

On the other hand, it can provide the government with information so that, at any given time, it can prevent a group of airlines from taking control of the AFTM. Based on the combined load capacity of a coalition of airlines and the analysis of other coalitions, the government—through its various agencies such as the SCT and the COFECE—can make decisions on merger or acquisition quotas or simply deny permits to such alliances.

The main limitation of this work is the number of airlines studied. The fact that only the Mexican airlines of the AFTM were analyzed was due, in part, to the large amount of calculations necessary and therefore, the time required to run the simulations in Scilab. Likewise, there is a lack of real data in some transitions of the states involved in the DGs proposed, but in a more robust study, they can be obtained with greater precision.

References

Ambriz Villalpa, J. L. (2015). Guía para la notificación de Concentraciones. Disponible en: https://www.cofece.mx/wp-content/uploads/2017/12/guia-0042015_not_concentraciones.pdf. Consultado: 25/05/2022

[17]Aeropuerto Internacional Felipe Angeles, which began operations in March 2022. This airport is located in the metropolitan area of the Valley of Mexico and its cargo terminal is expected to be a "strategic hub" in the medium term.

Agencia Federal de Aviación Civil-AFAC. (2020). Indicadores de la Aviación Mexicana. Disponible en: https://www.gob.mx/cms/uploads/attachment/file/652032/ind_ene_dic_2020-18022021.pdf. Consultado: 20/06/2022

Agencia Federal de Aviación Civil-AFAC. (2021). Indicadores de la Aviación Mexicana. Disponible en: https://www.gob.mx/cms/uploads/attachment/file/691339/ind-aviacion-aereo-nov-040122.pdf. Consultado: 20/06/2022

Larios Ferrer, J. L. (2022). Estabilidad e inestabilidad políticas en las LXII y LXIV Legislaturas mexicanas, desde la perspectiva de la teoría de juegos. Revista Mexicana de Ciencias Políticas y Sociales, 67(244), 457-495. https://doi.org/10.22201/fcpys.2448492xe.2022.244.72754

Larios Ferrer, J. L. y Ávila Pozos, R. (2022). Juegos de mayoría ponderada redefinidos por ausentismo y abstencionismo: definición y su aplicación a la LXII y LXIV legislaturas mexicanas. Pädi Boletín Científico De Ciencias Básicas E Ingenierías Del ICBI, 10(Especial), 117-126. https://doi.org/10.29057/icbi.v10iEspecial.8350

Aumann, R. J. (1961). The core of a cooperative game without side payments. Transactions of the American Mathematical Society, 98(3), 539-552. https://doi.org/10.1090/s0002-9947-1961-0127437-2

Canseco González, A. D., Zúñiga Alcaraz, C. y Blanco Martínez, L. (2015). Análisis estratégico sobre el desarrollo de las líneas aéreas de bajo costo en México. Revista Electrónica Nova Scientia, 17(15), 343-363. https://doi.org/10.21640/ns.v7i15.311

Carreras, F., Amer, R. y Magaña, A. (2003). Juegos simples e índice de poder de Shapley-Shubik. Revista de estudios políticos (Nueva Época), julio-septiembre (121), 107-136. Disponible en: https://dialnet.unirioja.es/servlet/articulo?codigo=740725. Consultado: 11/01/2022

Carreras, F., García-Jurado, I. y Pacios, M. A. (1992). Estudio coalicional de los parlamentos autonómicos españoles de régimen común. Documento de Trabajo 92-13 (Serie de Economía 08), 1-21. Disponible en: https://www.cepc.gob.es/sites/default/files/2021-12/16838repne082160.pdf. Consultado: 12/01/2022

Carrilo, J. (21 de mayo de 2019). Interjet firma nueva alianza, ahora con Qatar Airways. Recuperado el 01 de noviembre de 2022 de: https://www.revistaneo.com/articles/2019/05/21/interjet-firmanueva-alianza-ahora-con-qatar-airways

Comisión Federal de Competencia Económica-COFECE. (2018). El procedimiento de concentraciones. Disponible en: https://www.cofece.mx/wpcontent/uploads/2018/05/2elprocedconcentaciones.pdf. Consultado: 28/05/2022

EFE (31 de julio de 2008). Gobierno plantea fusión de aerolíneas mexicanas. La República. Recuperado el 30 de noviembre de 2022 de https://www.larepublica.net/noticia/gobierno-plantea-fusion-deaerolineas-mexicanas

Elaydi, S. (2010). An Introduction to Difference Equations (3rd Ed.). San Antonio: Springer.

Felsenthal, D. S. y Machover, M. (1996). Alternative Forms of the Shapley Value and the Shapley-Shubik Index. Springer, 87(3), 315-318. https://doi.org/10.1007/bf00118651

Gillies, D. B. (1953). Some Theorems on n-Person Games. Princeton: Princeton University.

Gilles, R. P. (2010). The Cooperative Game Theory of Networks and Hierarchies. Nueva York: Springer.

Joskow, P. L. y Noll, R. G. (1999). Regulación económica. Desregulación y reforma regulatoria durante la década de los ochenta. Working Paper 175, Departamento de Economía - Pontificia Universidad Católica del Perú. Disponible en: http://files.pucp.edu.pe/departamento/economia/DDD175.pdf. Consultado: 30/05/2022

Ley de aviación civil (2021). Diario Oficial de la Federación. Disponible en: https://www.diputados.gob.mx/LeyesBiblio/pdf/25_200521.pdf. Consultado: 07/06/2022

Liligo (s.f.). Alianzas aéreas: fundada por 4 de las compañías más grandes del mundo, Aeroméxico, Air France, Delta Airlines, KLM y Korean Air. Recuperado el 29 de octubre de 2022 de https://www.liligo.es/magazine-viajes/alianzas-aereas

Mohr, E. (1988). On the Incredibility of Perfect Threats in Repeated Games: Note. International Economic Review, 29(3), 551–555. https://doi.org/10.2307/2526798

Moreno-Okuno, A. T. (2022). A note on fair threats and promises. Estudios Económicos, 37(1), 171-198. https://doi.org/10.24201/ee.v37i1.429

Peleg, B. y Sudholter, P. (2007). Introduction to the Theory of Cooperative Games (2nd Ed.). Berlin: Springer.

Rico Galeana, O. (2010). Potencial de la distancia de viaje como distribución espacial del transporte mexicano. Revista Transporte y Territorio, enero-junio (2), 6-17. Disponible en: https://www.redalyc.org/articulo.oa?id=333027080002. Consultado: 15/08/2022

Sánchez, S. F. (1994). Introducción a la matemática de los juegos. México: Siglo XXI Editores.

Sánchez Ugarte, F., Kate Thielen, A. T., Alba Iduñate, P. G., Heftye Etienne, F., Alberro Semerena, J. L., Yépez García, R. A., García Rocha, A., Meléndez Barrón, J., Negrín Muñoz, J. L., O’Dogherty Madrazo, P., González Pier, E., González Hernández, A., Peña Baca, H., Tovar Landa, R. y Estrada González, E. (2004). Competencia Económica. Disponible en: http://dx.doi.org/10.22201/fca.24488410e.2023.4908 286 https://www.cofece.mx/wp-content/uploads/2018/05/COMPETENCIA-ECONOMICA-ENMEXICO.pdf. Consultado: 03/06/2022

Scarf, H. E. (1967). The Core of an N Person Game. Econometrica, 35(1), 50–69. https://doi.org/10.2307/1909383

Schmeidler, D. (1969). The Nucleolus of a characteristic function game. Siam Journal of Applied Mathematics, 17(6), 1163- 1170. https://doi.org/10.1137/0117107