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Is it possible to reduce income inequality in Mexico with the current fiscal formula for the allocation of shared revenues?

¿Es posible reducir la desigualdad de ingresos en México con la fórmula fiscal de asignación de participaciones actual?

Ignacio Ibarra López*

Tecnologico de Monterrey, México

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Abstract

In this paper, we analyze if the way in which the Federation grants resources to states in Mexico has an impact on income inequality, as measured by the Gini index. A model of artificial intelligence is used, which includes the following stylized facts: a) the criteria of efficiency and equity established in the Fiscal Coordination Law (LCF); b) the dynamics of oil prices and federal revenues; c) a model decision on public services and state tax, which takes up the approach of Tiebout (1956). The main result of the work is to prove that the Gini coefficient does not decrease over time. On the contrary, it tends to increase. It is concluded that the fiscal institutional design that uses the current Fiscal Formula to allocate resources represents a limit to the reduction of inequality in Mexico.

JEL Code: H21, H23, H77
Keywords: computational economy; fiscal federalism; inequality; public services; local governments

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* Corresponding author.
E-mail address: iibarral@tec.mx (I. Ibarra López).
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Resumen

En el presente trabajo se analiza si la forma en que la Federación otorga recursos a los estados en México tiene impacto en la desigualdad de ingresos, medida con el índice de Gini. Se utiliza un modelo de inteligencia artificial, que incluye los siguientes hechos estilizados: a) los criterios de eficiencia y equidad establecidos en la Ley de Coordinación Fiscal (LCF); b) la dinámica de los precios del petróleo y los ingresos federales; c) un modelo de decisión sobre servicios públicos e impuesto estatal, que retoma el planteamiento de Tiebout (1956). El principal resultado del trabajo, es probar que el coeficiente de Gini no disminuye en el tiempo. Por el contrario, tiende a aumentar. Se concluye entonces, que el diseño institucional fiscal que utiliza a la Fórmula Fiscal actual para asignar recursos representa un límite a la reducción de la desigualdad en México.

Código JEL: H21, H23, H77
Palabras clave: economía computacional; federalismo fiscal; desigualdad; servicios públicos; gobiernos subnacionales

Introduction

The decentralization process of public services that began in 1992 redefined how federal resources were allocated to the states. The change in the Fiscal Formula (FF) formulated in the Fiscal Coordination Law (Spanish: Ley de Coordinación Fiscal, LCF) sought to encourage states to raise their revenues (efficiency criterion) and to improve distributive equity (equity criterion). Contrary to expectations, almost thirty years later, there is a clear trend toward greater centralization of resources.[2] The dependence on the resources assigned by the FF is greater, particularly on shared revenues. Revenues generated by the states themselves represent a smaller percentage of total revenues.[3] Additionally, the conditions of inequality among states are more profound.

The literature documenting the impact of fiscal decentralization on inequality in a country is inconclusive. There are studies that recognize that fiscal decentralization has positive effects, as it helps to reduce inequality (Tselios et al., 2012; Sepúlveda & Martínez-Vázquez, 2011). However, there is also abundant evidence that fiscal decentralization has a negative impact and can increase inequality (e.g., West & Wong, 1995; Tanzi, 1996; Lessman, 2009, 2012).

This study aims to determine whether the current institutional arrangement (2018) leads to a decrease in inequality in Mexico, understood as the reduction of the Gini coefficient over time. The

[2] For example, while in 2016 the average percentage assigned to the states by the federation was 36.32%, in 2010 it increased to 38.18%.
[3] According to calculations, in 2006, 12.65% of the total incomes generated by the states were from their own collection efforts, while, by 2010, this percentage had decreased to 12.22%.

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hypothesis to which it belongs is: "the current combination of weighting factors of the Fiscal Coordination Formula does not contribute to a decrease in the level of inequality of Mexicans."

Institutional arrangement refers to the combination of parameters of the Fiscal Formula. One of the main contributions of this study is to identify whether a change in the Fiscal Formula parameters can impact the income inequality of a country in the long term. Another contribution is to identify whether an optimal combination of parameters in the Fiscal formula is possible. Of the specialized literature reviewed, no work has found this combination.

The methodology used is the so-called incentive fiscal approach (Oates, 2005, p. 362; Weingast, 2009; Ibarra-Salazar, 2018), where a fiscal system should be an institution capable of materializing the political advantages and economic gains of fiscal decentralization, avoiding distortions and destabilization, which can cause soft constraints on spending and revenue generation.

To operationalize this approach, a computational model is used to represent Mexico's fiscal institutional arrangement as a complex system. This model resorts to using optimization algorithms typical of artificial intelligence (e.g., Hill-Climbing, ranking systems, non-ergodic processes). Thus, there is a system of multiple agents interacting in a decentralized way. In this type of model, interaction generates aggregate patterns (i.e., equilibria or stages), which cannot be identified as a simple sum of representative agents' behaviors (Page, 2010). According to the literature review carried out, incorporating a model such as the one described in the analysis of the proposed topic implies the third contribution of this study to the literature.

The article comprises five sections. The first describes the theoretical elements of the fiscal decentralization model and the characteristics of the model. It analyzes the literature on inequality, growth and other variables, and the struggle between subnational governments (i.e., states and municipalities) and the federation. The second section discusses the stylized facts of the fiscal process in Mexico. In particular, the model's environmental modules are described: the dynamics of oil prices and the fiscal coordination formula. The third section presents the model and its usefulness for testing hypotheses on the FF's impact on income inequality. The fourth section outlines the results, the inferences, and the dynamics generated by the model. Finally, the last section is the conclusion.

Background and objectives

Government fiscal functions and inequality

The federal decentralization process can be described in terms of the fiscal functions of government: 1) the optimal provision of public goods; 2) macroeconomic stabilization; 3) income distribution—see

Musgrave and Musgrave (1989). Since its conception, there has been debate on the desirability of decentralization, without any conclusive evidence so far. On the one hand, it is assumed that transferring authority to subnational governments improves the provision of public goods. This, in turn, improves the government's efficiency as a whole (Bardhan, 2002). Subnational governments have a better understanding of the population's needs and can better determine the combinations of taxes and public services. However, it has also been recognized that in the allocation of public goods in a society, a central government's participation is indispensable (Oates, 1968).

Regarding the stabilization function, studies linking it to economic growth stand out. A recurrent argument is that decentralization increases competitiveness among regions and produces optimal allocations without resorting to the intermediation of a centralized government (see Careaga & Weingast, 2003).

Rodríguez-Pose & Krøijer (2009) demonstrate that shifting taxes to subnational governments can have positive effects in the long term. The authors think that a subnational government that controls its resources is more responsive to the population's demands, which increases economic performance in its territory. There is evidence for this argument—at least for OECD countries—in Rodríguez-Pose and Ezcurra (2010).

The literature on the fiscal function of income distribution is abundant, inconclusive, and with greater evidence that decentralization increases inequality. The strongest argument in favor of decentralization is that it decreases income inequality (Tselios et al., 2011). Studies on the dynamics of the decentralization-inequality relationship in Latin American countries (see Sepúlveda & Martínez-Vázquez, 2011) find mixed effects. On the one hand, poverty increases but at the same time (and under certain conditions), it is possible to decrease income inequality (e.g., only if the government represents 20% of GDP or more).

Decentralization processes also negatively affect income distribution, causing greater inequality (e.g., Tanzi, 1996; Zhang, 2006), among others, has reported the negative impact of decentralization on inequality and demonstrates that in China's decentralization process, the transaction costs associated with decentralization have contributed to excessive government, which translates into higher taxes.

Taxpayers in rural and poor areas pay the most. In contrast, taxpayers in wealthy areas enjoy subsidies and lower taxes. Thus, fiscal decentralization promotes regressive taxation and explains the regional divergence in economic growth. In China, the study concludes that the fiscal decentralization policy led to improving the conditions of the wealthiest territorial units, increasing the inequality gap with the poorest ones.

Prud'homme (1995) argues that a centralized government has a greater capacity to make trade-offs between territorial units than a decentralized government. Decentralization leads to a process of fiscal

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competition between territorial units, where the wealthiest regions attract more mobile factors of production (because they have better physical infrastructure, human capital, access to more developed markets, and, consequently, lower costs). The consequence of encouraging competition through decentralization is that the wealthiest territorial units will tend to become wealthier, and the poorer regions will tend to become poorer, leading to greater inequality.

In summary, the literature recognizes (without being conclusive) that decentralization can help to fiscally stabilize a country, improve the provision of public services, and, under certain circumstances, decrease income inequality (even in Latin American countries). However, it has also been found that the same decentralization process tends to generate greater income inequality. The following is a description of how fiscal resources are transferred in Mexico to subnational governments (particularly to the states).

Intergovernmental transfer system in Mexico

According to Blöchliger (2014), an intergovernmental transfer system must be an instrument designed to channel financial resources to subnational governments (i.e., states and municipalities). The aim is to offer their citizens similar levels of public services with similar levels of taxation. Therefore, for the case of Mexico, the Fiscal Coordination Law (LCF) has been created, with its latest amendments in 2018.[4] This law establishes two instruments: revenue sharing and contributions. The former is calculated on the General Revenue-Sharing Fund (Spanish: Fondo General de Participaciones, FGP), in which the allocation criteria are based on population and collection efficiency. Federal contributions are associated with resources that depend on specific projects that the states wish to carry out. This implies that each fund includes specific criteria both to obtain resources and to verify their use.

The formula used to know how much is allocated to each state has been analyzed in different works, which point out problems such as the creation of greater dependence on the federal government, the complexity of the calculation, the fact that it may favor opacity in the granting of resources, and the possible increase in inequality (Ibarra-Salazar et al., 1999; Chavez-Presa, 2004; Sobarzo, 2004; OECD, 2007; Hernández-Trillo, 2011; Figueroa, 2014; Rodríguez-Pueblita, 2017). In particular, the resources transferred by specific agreements between the federation and the states and the revenues that depend largely on oil activity have been identified as sources of income inequality.

However, conditional transfers from the federation to the states have also been found to be an advantage. For example, Carmona-Guerrero & Caamal-Olvera (2018) present evidence that

[4] See http://www.diputados.gob.mx/LeyesBiblio/pdf/31_300118.pdf

decentralization reduces wage inequality, particularly when considering allocation through earmarked resources.

Díaz-Cayeros (2004) provides one of the most concrete explanations of the origin and consequences of maintaining the fiscal formula and granting resources from the federation to Mexico's states. According to this author, in a democratic system, budgetary struggles are the expression of political agreements that seek to maintain the balance between paying taxes, generating public services, and the relationship between politicians and the governed.

In the Mexican federal arrangement, state governments do not need to spend according to a balance of revenues collected and goods and services provided. Rather, they budget according to what they can obtain from federal transfers in the present (through participations or transfers) or in the future (through debt).

To pressure the federation, the states use the elected federal deputies that comprise the Congress of the Union, which has the power to modify and, if necessary, authorize the budget proposed by the Federal Executive. Along the same lines, Rodríguez (2006) highlights that the dispute over the federal budget takes the proper form of negotiation, such as the National Association of Governors (Spanish: Asociación Nacional de Gobernadores, ANAGO), later known as the National Conference of Governors (Spanish: Conferencia Nacional de Gobernadores, CONAGO).

Public services and taxes

Understanding the endogenous relationship between the generation of public services and the taxes collected by the government is fundamental to understanding how an institutional arrangement for transferring resources modifies income inequality. Tiebout (1956) conceived that public services provision resulted from a model based on competition for taxpayers among territorial units.

The Tiebout arrangement works as follows: each territorial unit offers a set of public goods and services (service level) at different prices (taxes), which generates a diverse supply of public goods and services (i.e., the combinations of tax and the level of public services of each territorial unit are different).

Taxes and the level of public services are assumed to be positively related. The information on the level of public services and taxes allows taxpayers to make valuations of the cost and benefit they would obtain by settling in a particular territorial unit. With these valuations, taxpayers will tend to move from one place to another until they find the optimal combination concerning the level of public services and taxes they pay. Thus, they encourage a self-selection process that would reveal the individual preferences for public services and taxes, generating clusters of taxpayers with similar preferences. This is why the model is also known as "foot-voting."

The final result that Tiebout anticipates is Pareto superiority to any other allocation made because it allows each taxpayer to settle in the place that best suits their preferences, thus revealing information about the tax rate and the level of public services.

Many articles in the literature cite or analyze the main Tiebout hypotheses,[5] which even now face intense controversy regarding their validity (Hoyt, 1991; Orfield, 2002). Part of the criticism may originate from the challenge of replicating the logic of this model with conventional mathematical and statistical tools (i.e., econometrics, differential equations, or game theory).[6]

Alternatively, there are proposals for computational Tiebout models such as that of Kollman, Miller, & Page (1997). In this model, direct comparisons can be made between different types of political institutions (e.g., referendum and proportional representation) to analyze the relationship between political instability and the heterogeneity of voter preferences.

Penn (2004) uses a computational Tiebout model to explain fragmentation in cities. It models heterogeneity in income, political institutions, and the discretion that each city has to decide the tax rate.

The model seeks to explain how new territorial units are defined, considering that the secession of territories is possible (i.e., a city can cede territory to another existing or newly created city). An important conclusion is that increasing the tax rate also increases the number of territorial units, the heterogeneity in the mean income of their inhabitants, and social welfare (i.e., level of services). In other words, the Penn model computationally proves the Tiebout assumption: greater competition among territorial units improves the level of public services.

Nishida et al. (2011) use the Tiebout model to analyze migration phenomena. Their model includes two types of agents: 1) subnational governments (e.g., states of a federation, departments), which determine budgetary policies regarding the services they should provide; 2) citizens, who decide to migrate based on the level of services and taxes. Subnational governments have three strategies: 1) maintain a constant service; 2) follow the best government strategy that attracts the most citizens; 3) generate a level of services based on the citizens' preferences. The study's main conclusion is that when each subnational government has its own strategy, migration processes are favored. However, the convergence of strategies among subnational governments (i.e., all charging the same or generating the same level of public services) decreases migration. Therefore, Nishida et al. (2011) also test the validity of Tiebout's argument that greater competition generates a more diverse supply of public services.

This study adds to the Tiebout model the institutional transfer arrangement of resources from the federation discussed in section 1.2 and some stylized facts of the tax revenue process discussed below.

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[5] For example, Dowding, John & Biggs (1994) present an analysis of the findings of 200 works associated with the Tiebout model.
[6] For example, Sakashita (1999) proposes a system of dynamic equations with solution by numerical methods.

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Methods, materials used, and sources of information

Stylized facts of the intergovernmental transfer system in Mexico

The distribution of resources through the Fiscal Formula (FF)

According to Article 2 of the LCF, the General Revenue-Sharing Fund (Spanish: Fondo General de Participaciones, FGP) is distributed among the different states of the country (32), assigning to each one the fraction of $P_{i,t}$ calculated under the following rule:

$$P_{i,t} = P_{i,07} + \Delta FGP_{07,t}\left(0.6C1_{i,t} + 0.3C2_{i,t} + 0.1C3_{i,t}\right) \tag{1}$$

Where $P_{i,07}$ are the shared revenues of state i in the year 2007, $DFGP_{07,t}$ is the change in FGP resources from 2007 to year t, $C1_{i,t}$ is a coefficient that allocates resources to state i in period t, which depends on ratios of changes in Gross Domestic Product (GDP), as well as population size. Coefficients $C2_{i,t}$ and $C3_{i,t}$ are calculated using the information related to collecting taxes and duties received by state i in year t (using the data of the last official public account). Coefficient $C1_{i,t}$ represents the inequality criterion, while $C2_{i,t}$ and $C3_{i,t}$ are the efficient collection criteria.[7]

All the coefficients of the formula ($C1_{i,t}$, $C2_{i,t}$, and $C3_{i,t}$) include the population effect since the GDP and taxes generated for state i are positively related to population growth. Therefore, it is not surprising that states with greater economic activity (GDP and taxes) receive the most shared resources in Mexico.

Additionally, the "political effect" identified in Díaz-Cayeros (2004) must be considered. There is also a population effect since the number of federal deputies also depends on the number of inhabitants in a state of the country. The FF proposes specific weights, i.e., 0.6 for $C1_{i,t}$, 0.3 for $C2_{i,t}$, and 0.1 for $C3_{i,t}$, which demonstrate the importance of each criterion in allocating resources.

The other revenue source for the states is federal contributions, which depend on specific criteria for both allocation and verification. Including every condition outlined in the LCF for every contribution fund would be a much more complicated model. Therefore, the computational model omits the allocation of resources to the states in this manner. This omission is a limitation of the study and a possible future improvement of the model.

[7] For more details on components C1, C2, and C3 of the Fiscal Formula, please refer to the latest version of the LCF (30/01/2018).
Available at: http://www.diputados.gob.mx/LeyesBiblio/pdf/31_300118.pdf

Public revenues and oil prices

The oil price is a critical variable in the country's public finances that determines the resources available to the states. An analysis of the contribution of oil revenues to Mexican government revenues over time in the period from January 1990 to April 2011 (before the implementation of liberalization reforms in the energy sector) illustrated that oil revenues have represented between 25% and 33% of the total public revenues of the country (Figure 1).

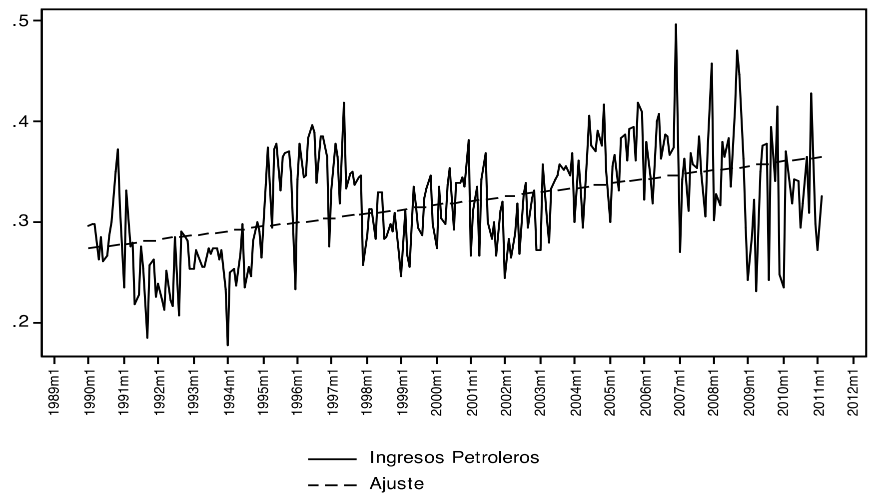

Figure 1. Contribution of oil revenues, January 1990 to April 2011.
Source: Created by the author with data from Public Finance and Public Debt Statistics. Budgetary Revenues from the Public Sector (Deputy Directorate General of Public Finance Statistics, Public Finance Economic Planning Unit, SHCP). Available at: https://tinyurl.com/yrdmh6mc

After the arrival of President Enrique Peña Nieto[8], the number of oil resources considered to calculate revenue sharing increased, even reaching 78.47% in 2018.

To investigate the sensitivity of the federal revenues to oil price variations and formally define this characteristic, a time series model is proposed that can explain the growth of federal revenues as a function of two variables: 1) the spot price of oil; 2) the Special Tax on Products and Services (STPS).

[8] According to the Fiscal Coordination Law (LCF), prior to the 2014 modification, the shared resources include all federal taxes, as well as duties on oil extraction and mining (LCF, Art. 2, amendment as of June 24, 2009). Since 2014, reforms on hydrocarbon revenues have been incorporated that set specific percentages for such revenues (e.g., in 2015 the proposal was 73.00%, in 2016 it was 74.82%, in 2017 it was 76.65%, and in 2018 it was 78.47%. In relation to the Fiscal Formula, no changes in the parameters were proposed.

The best-fitting model, which yields independent and identically distributed results, is an ARMA (12,1)-ARCH(1) process.[9] The results indicate that a 1% increase in the spot price of oil generates a statistically significant 16.5% increase in federal revenues on average. This finding is consistent with previous analyses such as Eifert et al. (2003).

Computational model structure

This study's computational model integrates modules that characterize two types of agents: states and taxpayers. Each of these has specific characteristics and obeys certain decision rules. Furthermore, environment modules are included that introduce the dynamics of oil prices and the allocation of resources through the fiscal formula. These modules are described below.[10]

Agents

States

The Mexican states are represented in the model as territorial units that agents can inhabit and are governed by an authority that decides the level of public services and the tax rate. A Cellular Automaton (CA) is used, which can be understood as a dynamic spatial system with the following components (Von Neumann & Burks, 1966): 1) a two-dimensional grid, in which each cell represents some type of agent; 2) a set of possible conditions in which each element of the grid is located; 3) evolution rules, which allow the transition from one condition to another, and which depend on the interaction with other agents as well as on conditions that previously existed; 4) a neighborhood defined for each agent; 5) a "clock" that indicates to each agent when to apply the evolution rules.

Each element of the CA grid represents a part of the state's total territory, where 3,200 cells comprise the 32 states of Mexico (i.e., each state has 100 units of territory). Individuals in each state face the same tax rate and public service level as defined by the authority. It is assumed that decisions made by a state government are fully complied with throughout the territory. Furthermore, the public service's

[9] Several ARMA(p,q) models with GARCH-type autoregressive conditional volatility (see Bollerslev, 1990) were estimated. The final order of the model was chosen based on the Akaike and Bayes Information Criteria. Detailed results of these estimations and decision criteria are available from the authors.

[10] The reader can access the program by contacting the author directly. Note that it is important to have Java version 7 or higher installed. It is preferable to use Mac OSX 10.7.5 for Safari users or Windows 7 for users of Google Chrome or Internet Explorer in its most recent version. The user can examine different scenarios such as the impact of changes in different variables on income inequality, as well as change the initial conditions, and observe population dynamics of taxpayers in the states of the Mexican Republic.

total cost in each state is calculated, as well as the state taxes collected, and the state GDP. These last two variables are used to determine the shared revenues allocated to each state i in periods t in which the simulation ($P_{i,t}$) is carried out.

Finally, the budget is determined for each state, including revenues (state revenues and shared revenues) and expenditures (cost of the supply of public services). The cost of the supply of public goods is obtained by multiplying the level of public service established in the state by the number of agents in its territory.

Taxpayers

Each state is inhabited by a number of taxpayers, which is initially determined by an exogenous population parameter (Pob). Each agent can occupy only one grid at a time. The CA can be densely populated (population close to 100%) or sparsely populated (population close to 0%).

In turn, every one of the taxpayers j possesses specific characteristics. This condition creates a heterogeneous population: 1) an income level; 2) the level of access (preference) to public services; 3) the utility that the agents derive ($U_{j,t}$). The latter is endogenous in character since it depends on the level of public services, income, and tax rate.

Decision modules

States

In each simulation period, states define the level of provision of public services ($S_{i,t}$) based on the citizens' preferences. In turn, the preferences and the individual demand of each citizen are obtained through a Cobb-Douglas utility function, as proposed by Penn (2004). The tax rate ($T_{i,t}$) depends on the income level of individual j. Once each state has established the level of provision of public services, all citizens can enjoy it within its area, as long as there is available space (i.e., the territory has not been fully occupied) in the state.

With the data on service provision and tax rate, the revenue of state i in period t is calculated. A public finance balance ($B_{i,t}$) is also calculated for each state. This variable is according to what is collected from taxpayers, the states' shared revenues from the Federation, and the cost of providing the level of services $S_{i,t}$. The states modify the level of provision of services and the tax rate according to changes experienced by this financial balance. If the value of $B_{i,t}$ allows the provision of the service, the states

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adopt the values of service $S_{i,t}$ and the tax rate $T_{i,t}$. If this is not possible, they maintain the previous period levels, i.e., $S_{i,t-1}$ and $T_{i,t-1}$.

Changes of residence

In each period, the agents can change their residence. This change results from a cost-benefit analysis between the current place of residence and another state with better tax rates. The algorithm that generates these changes is as follows: at the beginning of each period, it calculates the income $W_{j,t}$ of taxpayer j at time t, which is positively associated with the level of public service and negatively with the payment of state and federal taxes.

In each period, the income earned by the individual in the state where they reside is determined, and a cell is randomly chosen in another state where the tax rate is lower. If the potential income in the comparison state is higher than that in the state of residence, a movement of the agent to the selected cell is caused, provided that the cell is not occupied by another agent (to reflect the physical limits to the provision of the service).

The change of residence depends on a probability calculated from the 2010 Population and Housing Census of the National Institute of Statistics and Geography (Spanish: Instituto Nacional de Estadística y Geografía, INEGI). With this, it is sought to include idiosyncratic factors associated with residence changes in Mexico (e.g., it is of note that certain states are chosen to a greater extent) and relocation and transaction costs involved in a change of residence.[11]

Environment modules

In addition to the decision modules, some modules reflect the specific conditions of Mexico's public resource generation process, especially the movement of oil prices and the allocation of shared revenues using the FF described in the LCF. This includes all the shared revenues indicated in the LCF, using the aggregate data of the General Revenue-Sharing Fund (Spanish: Fondo General de Participaciones, FGP). However, it does not include federal contributions associated with resources to carry out specific programs and projects.

[11] These probabilities were estimated using information from INEGI: http://www.inegi.org.mx/est/contenidos/proyectos/ccpv/cpv2010/Default.aspx. The author can be consulted directly for further information.

Oil prices

To reflect the impact of oil price changes on federal revenues, the mean reversion model described in Schwartz (1997) is used, as well as the revenue-sharing allocation formula described in section 2.1 of this study.

State revenue-sharing allocation formula

The process of calculating the fiscal formula integrated into the model has some distinctive features:

1) $P_{i,07}$ equals $P_{i,t-1}$ in the model, i.e., the amount of revenues generated in the simulations in period t-1 for state i.
2) The General Revenue-Sharing Fund (FGP) represents 20% of total shareable resources in each period. The shareable resources contemplated in the model will be the total income tax revenues paid by taxpayers and oil revenues.
3) $DFGP_{07,t}$ equals $DFGP_t = FGP_t - FGP_{t-1}$ in the model, where FGP_t is the FGP in period t and FGP_{t-1} in the previous period.
4) The fiscal formula requires calculating the GDP of state i at different periods t ($PIB_{i,t}$). The sum of the income of all the inhabitants of state i results in the GDP estimate.
5) The collection level for each state in the different periods will be the revenue obtained by multiplying the tax rate by the taxpayer's income, i.e., $T_{i,t}W_{j,t}$.
6) INEGI presents information on the population of the states every five years (count) and ten years (census). In the model, the population is known for each period.
7) The initial values and parameters that accompany $C1_{i,t}$, $C2_{i,t}$, and $C3_{i,t}$ are pond1=0.6, pond2=0.3, and pond3=0.01. As illustrated in the next section, these are the model's choice variables, and the Gini coefficient will be the objective function. The variation of these parameters allows for the generation of counterfactual scenarios to assess the appropriateness of different resource allocation and inequality reduction schemes.

Development of the model

The model is designed to generate results for each period t, for a time horizon t, and has the following characteristics:

1) In period t=0 of each simulation, the initial environment parameters are defined (e.g., population, Fiscal Formula weights, among others). The characteristics of the agents in each state are also determined (i.e., their utility function parameters).
2) In the case of income, information from the National Survey of Household Income and Expenditure (Spanish: Encuesta Nacional de Ingresos y Gastos de los Hogares, ENIGH) 2010 is used. Due to the number of agents involved in the simulation, remarkably high-income values could be generated. To avoid this problem, a normalized income has been constructed for each decile, where the value that an individual in the lowest decile can take is 0.1602, and the value of the highest decile is 2.[12]
3) Regarding migration processes, information from the 2010 census by INEGI is used for two groups of variables: migration status and place of residence in 2000. In the censuses carried out by INEGI, there is also information on the migration of people in three categories: state migrant, international migrant, and unspecified. With these data, a probability that people in a state decide to change their residence is calculated using a Markov matrix.
4) Interstate migration only considers three main destinations for each taxpayer (i.e., the states with the highest probability of attraction).
5) Initial characteristics are defined for the 32 states in Mexico regarding initial budgets, public services level, and taxation defined by the authorities.
6) The oil price is updated each period, assuming a dynamic process as documented by Schwartz (1997). An initial price is used in each simulation, representing the mean of the period's prices analyzed in section 2.2 (i.e., from January 1990 to April 2011).
7) Subsequently, every state's budget is determined by period, integrating the federal resources allocated by the FF and the resources of state origin collected from taxpayers.
8) Based on its budget, each state determines the level of public service and taxes, using the decision rules described above.
9) Agents decide to stay or not in the state, given the level of public service, the states' taxes and using their utility function. If a higher utility is gained with the change, the agent changes residence.
10) Finally, the graphs and values for the different performance variables are generated.

Figure 2 presents two images of the model incorporating the 32 states. States with higher taxes tend to be black, and states with lower taxes tend to be white. Each state is "populated" by agents (black or white dots).

[12] Due to space limitations, it was not possible to include the decile table. For detailed information on this calculation, please contact the author directly.

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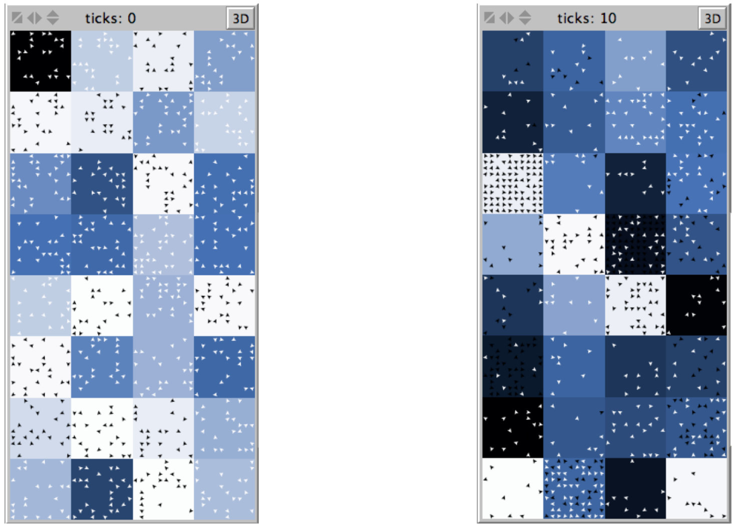

(a) Initial AC (b) Adapted AC

Figure 2. Graphic representation of the model
Source: created by the author with data from the model

Figure 2 (a) presents the states at time 0 (initial conditions of the model). Figure 2 (b) presents the model after an adaptation process has been generated over time, reflecting Mexico's population distribution. This second case is the result of the residence decisions of the agents.

Figure 2 (b) illustrates a change in the color of several states based on the adjustment of their tax policy. It also illustrates changes in the population concentration of certain states based on public service and taxes. In this case, the public service level is a dimensionless value representing the demand for any public service (e.g., number of police officers, the total number of streetlights, paved streets). The idea is to introduce a variable that allows for the reproduction of the Tiebout model's logic without this implying greater sophistication.

Study hypothesis

The hypothesis proposed is that: "the current combination of weighted factors of the Fiscal Coordination Formula does not contribute to reducing the level of inequality of Mexicans." To test this hypothesis and contrast results, the model incorporates the following performance values: 1) Gini coefficient based on the income of the citizens, which is a proxy variable of social welfare; 2) the percentage of citizens who decide to change their residence in relation to the total number of citizens; and 3) the mean state tax in all states.

The value of each of these performance variables is a result that depends on the set of initial parameters (i.e., the weights of the fiscal formula). Thus, the analysis focuses on finding the effect that different combinations of pond1, pond2, and pond3 have on these variables, particularly on the Gini index.

To test the hypotheses, the following experiment is proposed:

1) Current scenario: 100 simulations of 144 monthly periods (12 years) with pond1=0.6, pond2=0.3, and pond3=0.1 defined at t=0. Each simulation begins with the same initial conditions (see Table 1).
2) Optimized scenario: the objective is to find the value of the Gini coefficient that corresponds to a combination of optimal FF weights (pond1*, pond2*, and pond3*). Using the Hill-Climbing algorithm, 100 simulations are run, and the combination that minimizes the long-term Gini coefficient (at the end of period 144) is chosen. Each simulation starts from the same initial values of Table 1 but from different combinations in pond1, pond2, and pond3. The weights are the variables of choice.
3) Once the optimal combination of weights is found, another 100 simulations are generated, keeping the values of pond1*, pond2*, and pond3* constant. These values are then used to calculate the optimal mean value of the Gini coefficient.
4) Finally, the results of both models are compared, i.e., the optimal combination (pond1*, pond2*, and pond3*) and the institutional arrangement that currently exists in the FF (pond1=0.6, pond2=0.3, and pond3=0.1).

Table 1
Combination of parameters at initial conditions (t=0)

Parameter	Value at t=0
Initial oil price	$25.560
Federal tax rate	30.000%

Source: Created by the author with data from SHCP. For the case of the initial oil price, the value taken is of the constant of an autoregressive model built with data from https://www.eia.gov/. The data are for the Mayan mixture.

Results and discussion

The combination of weights that minimizes the long-term Gini coefficient is as follows: pond1*=0.21, pond2*=0.69, and pond3*=0.10. This implies that the fiscal formula should change in its original structure from Equation 1 (presented in section 2.1) to Equation 2, presented below:

$$P_{i,t} = P_{i,07} + \Delta FGP_{07,t}(0.21C1_{i,t} + 0.69C2_{i,t} + 0.100C3_{i,t}) \quad (2)$$

The finding of an optimal combination implies that to use the FF as a mechanism to reduce income inequality in Mexico, it would be necessary to reduce the current weight of the inequality criterion (pond1) by almost a third (from 0.6 to 0.21). It would also be necessary to increase the weight of state tax collection (pond2) by more than double (from 0.3 to 0.69) and maintain the $C3_{i,t}$ criterion with the same weight (pond3=pond3*=0.10).

Table 2 presents a comparison of the performance variables in each scenario. In the scenario with the optimal combination (i.e., with the parameters of Equation 2), there is a mean Gini coefficient of 0.50, whereas, with the current combination of weights, the Gini coefficient is 0.52.

Table 2
Performance variables, optimal scenario, and current scenario

	Mean	Standard deviation	Variation coefficient	Minimum	Maximum	Observations
Optimal combination	0.502	0.232	0.463	0.316	0.988	14 500
Current combination	0.515	0.236	0.457	0.325	0.988	14 500
Total	0.508	0.234	0.460	0.316	0.988	29 000

Source: created by the author with data from the simulation
Note: the optimal combination is pond1*=0.212, pond2*=0.688, and pond3*=0.100, while the current combination is pond1*=0.600, pond2*=0.300, and pond3*=0.100

This implies that a change in FF can marginally reduce income inequality by two percentage points.[13] A test of means demonstrates the existence of this difference (see t-statistic in Table 3). The standard deviation in the two cases is high (just over 0.200, considering means of around 0.500). An argument could be made that the mean Gini coefficients in the two scenarios should not be statistically different.

[13] A standard mean difference test rejects H_0 at high confidence levels.

Table 3
Test of difference between means (assuming equal variances)

Sample	Observations	Mean	Standard error	Standard deviation	Interval (95% confidence)	
Group 1	14 500	0.502	0.002	0.232	0.498	0.505
Group 2	14 500	0.515	0.002	0.236	0.511	0.512
Combined	29 000	0.510	0.001	0.234	0.501	0.511
Difference		-0.013	0.003		-0.019	-0.008
						t=-4.879
						Degrees of freedom=28,998

Source: created by the author with data from the simulation
Note: Difference=Mean(Group 1)-Mean(Group 2). Group 1=Group with the optimal combination of weights in the FF, Group 2=Group with the current combination.

To be sure that a different combination of FF weights generates a different Gini coefficient, a Kolmogorov-Smirnov (KS) test is carried out. Given the null hypothesis that the distributions are equal, the D statistic's value associated with the test concludes that the distributions are different (Table 4).

Table 4
Kolmogorov-Smirnov test of the Gini value for the optimal combination and the current combination

Group	D	P-value	Corrected
1	0.065	0.000	
2	-0.022	0.001	
Combined	0.065	0.000	0.000

Source: created by the author with data from the simulation
Note: Equal values were found in both groups. For the combined statistic, there are 27,959 unique values out of a total of 29,000 observations.

Dynamics of the Gini Coefficient

Figure 3 presents the frequency distributions of the Gini variable for the current combination of weights and the optimized combination of weights. Both scenarios present bimodal distributions, suggesting that it is possible to achieve low inequality (i.e., between 0.30 and 0.45) and high inequality (i.e., between 0.90 and 1.00). However, scenarios with inequality of 0.30 to 0.45 are more likely in the model, assuming the optimal combination of parameters (the plot for the case of the optimized weights is higher).

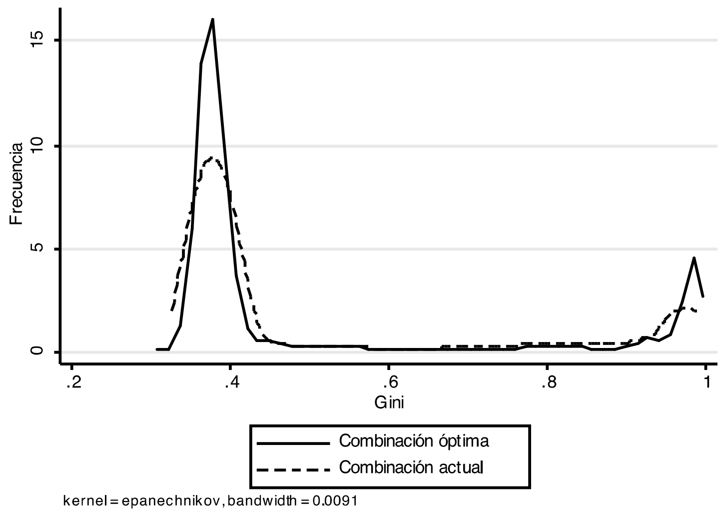

Figure 3. Frequency distribution of the Gini variable.
Source: created by the author with data from the simulation.

The situation in which it is possible to achieve lower inequality results from behavior that deserves an in-depth study. Intuitively, it can be associated with the capacity for interstate mobility of the agents (i.e., the citizens' change of residence).[14]

There is a relatively large area with low or no probability of occurrence in the interval values (0.45, 0.90) of the Gini variable in both cases. This implies that, over time, the behavior of the current allocation scheme can only have two outcomes: inequality close to 0.45, similar to the current one, or remarkably high inequality greater than 0.90 or close to 1.00.

Additionally, the Gini variable's mean value was calculated in each of the periods of the 100 simulations, both for the optimal combination and for the current combination. Thus, the mean trajectory of the Gini variable over time is now available for the two scenarios. Table 4 presents the results.

[14] It may be worthwhile to investigate what generates the bimodal behavior of inequality. Intuitively, this increase can be associated with the issue of mobility: when there is greater mobility, increases in inequality should be perceived.

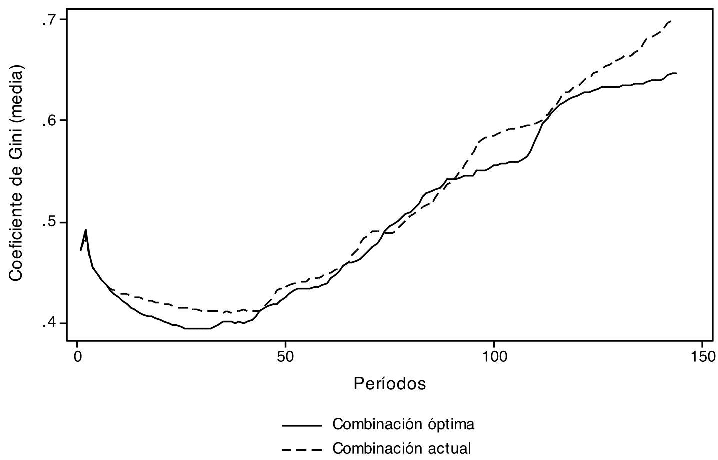

Figure 4. Comparison of the mean trajectory of the Gini variable for the optimal combination and the current combination.
Source: created by the author with data from the simulation.

There is a reduction in inequality for the first periods (a little more than three years) in both combinations (current and optimal), which implies that the adjustment of parameters leads to less inequality in the initial period.

The decay rate is higher in the optimal combination when it reaches the fastest minimum value (around period t=30), precisely when the gap between the two combinations is wider. A Kolmogorov-Smirnov test was also carried out to distribute the Gini variable in each combination of FF coefficients. Both distributions are statistically different (see Table 5), although Figure 4 presents a similar plot, in particular for periods less than 100.

This implies two issues: 1) in the short term (i.e., before period t=50), both combinations give rise to a similar effect on inequality; 2) in the long term (i.e., after period t=50), the current combination in the FF weights will tend to generate greater inequality than the combination of parameters in the FF identified as optimal.

Table 5
Kolmogorov-Smirnov test of the Gini value for the mean of the optimal combination and the current combination over time

Group	D	P-value	Corrected
Group 1	0.193	0.004	
Group 2	-0.028	0.896	
Combined	0.1931	0.009	0.001

Source: created by the author with data from the simulation

After the mean of each combination reaches its minimum value, there is a steep growth in income inequality in the following periods (approximately after period t=50). The optimal combination of weights always yields lower inequality except for a few periods around t=80.

Evidence that a reduction of the Gini coefficient is possible in the short term is found in the work of Cortés (2013) and Cortés & Vargas (2017). From 1989 to 2010 (i.e., 21 years), there was a gradual reduction in inequality as indicated in the computational model.

This tendency to an increase in the Gini coefficient in the long term highlights three disturbing situations: 1) the formula for the allocation of participations with the current coefficients will tend to generate greater inequality in the long term; 2) using the optimal coefficients of the formula's weights achieves reductions in inequality that unfortunately are not sustainable over time; 3) maintaining the current combination of weights in the fiscal formula results only in small reductions in inequality, which are not sustainable in the long term either. This leads to the conclusion that, in Mexico, income inequality will increase in the long term, regardless of the fiscal formula's institutional design. Therefore, any redesign (i.e., changes in the weights) will not be effective.

Conclusions

Over the last twenty-five years, institutional changes in fiscal federalism have sought a more efficient and egalitarian allocation of resources for the states. According to the computational model results, it is possible to reflect the behavior of inequality in Mexico. Regarding the working hypothesis: "the current combination of weights of the Fiscal Coordination Formula does not contribute to a reduction in the level of inequality of Mexicans", the computational model provides empirical arguments for not rejecting it.

Furthermore, maintaining this combination of weights will not reduce inequality in Mexico in the long term; on the contrary, it will increase considerably. The simulations presented a "J" effect (see Figure 4), where in less than 50 periods, a gradual reduction in inequality could be observed. In the best-case scenario, this reduction could place Mexico with a Gini slightly below 0.40. Using the optimal combination of parameters found in the model's optimization algorithms would result in a more significant reduction.

However, after the period of inequality reduction in Figure 4 (i.e., 50 periods), a considerable increase in inequality would be expected, regardless of maintaining the current combination of coefficients or using the optimal combination of coefficients estimated by the model. In addition to being discouraging, this result suggests that another institutional design that goes beyond the definition of weights should be considered. The current regulatory aspects of the Fiscal Coordination Law do not favor the reduction of inequality.

Part of the explanation for this phenomenon can be related to the fact that changes in the distribution of resources affect the states' growth. Any change in the amount of revenue of a state modifies state public spending and GDP. Due to the Fiscal Formula design, which integrates GDP as a variable for allocating resources, if GDP is positively or negatively affected through public spending, there will be repercussions in the allocation of shared revenues. This generates a positive feedback process.

Using a computational model helps provide evidence to support some arguments in the debate on fiscal decentralization and inequality. Specifically, it is shown that a change that privileges the collection efficiency criterion, i.e., that promotes the decentralization of resources, will improve citizens' welfare at the individual level. This improvement will also reduce inequality at the social level (at least in the short term). This is consistent with the argument of Tselios et al. (2011) and Sepúlveda & Martínez-Vázquez (2011), where fiscal decentralization was found to reduce inequality.

However, as previously mentioned, given the "J" effect in Figure 4, it cannot be indicated that the fiscal decentralization implied by the Tiebout model will generate a reduction in inequality in a sustainable way in the long term. Therefore, it is also proven that decentralization processes negatively affect income distribution, generating greater inequality, as proposed by Tanzi (1996) and Zhang (2006).

One of the by-products obtained from the model is analyzing specific scenarios related to the impact of movements in different variables; for example, the impact of inequality in the face of changes in oil prices (i.e., upward or downward trends), the definition of new taxes or the elimination of existing ones, or an increase in the mobility of people due to situations exogenous to the model (e.g., an increase in violence). Additionally, it would be of particular interest to explore the behavior of the states' economic growth in the face of changes in the weighting of the Fiscal Formula.

One of the main limitations of this study is that it does not include an analysis of the financing obtained by the states from the contribution funds. It would be desirable to incorporate the effect of this type of resource allocation mechanism in the future.

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