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Estimation of a Multiple Equilibrium Game with Complete Information: Husband and Wife Labor Force Participation in Mexico

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Abstract

Econometric models under complete information environment with game theoretic foundations are used in this work to analyze husband and wife labor force participation in Mexico. A mechanism of equilibrium's selection was designed in the context of multiple equilibria, in order to identify the main parameters of the model, inclusive, interaction parameters a's in the context of non unique Nash-Equilibrium. It was used "Basal Survey of Savings, Credit and Rural Micro-Finances" in Mexico, made by BANSEFI in 2004. And it was found that married couples interact strategically. On average, wives decide not to participate in the labor market if their husbands participate.

Keywords: Strategic interaction, complete information, labor force participation, multiple equilibria.

Resumen

En este trabajo se utiliza un modelo econométrico basado en la teoría de juegos, en un contexto de información completa y con múltiples equilibrios, para analizar la participación en el mercado laboral de los esposos al interior de los hogares mexicanos. En otras palabras, se analiza la toma de decisiones de los esposos mexicanos en un juego con múltiples equilibrios, para lo cual se diseña un mecanismo de selección de dichos equilibrios, basado en la probabilidad de que el esposo participe en el mercado de trabajo. Se utiliza la Encuesta Basal sobre el ahorro, crédito y microfinanzas rurales. Se encuentra que los esposos interactúan estratégicamente y que, en promedio, las esposas deciden no participar en el mercado laboral como consecuencia de que sus esposos sí deciden hacerlo.

Palabras clave: interacción estratégica, información completa, mercado laboral, equilibrios múltiples.

Estimation of a Multiple Equilibrium Game with Complete Information: Husband and Wife Labor Force Participation in Mexico

Brasil Acosta-Peña[*]

October 24, 2011

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Econometric models under complete information environment with game theoretic foundations are used in this work to analyze husband and wife labor force participation in Mexico. A mechanism of equilibrium's selection was designed in the context of multiple equilibria, in order to identify the main parameters of the model, inclusive, interaction parameters α's in the context of non unique Nash-Equilibrium. It was used "Basal Survey of Savings, Credit and Rural Micro-Finances" in Mexico, made by BANSEFI in 2004. And it was found that married couples interact strategically. On average, wives decide not to participate in the labor market if their husbands participate.

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1 Introduction

In neoclassical analysis, household has been considered as homogeneous unit, then it has its own preferences and its own utility function; since 1980's, grow up another literature that have included preferences of each members of the household decisions. Accordingly with Vermelen (2002), we can say that Samuelson (1956) and Becker (1973) were pioneer works that taken account that each member of the household has its own preferences; but in the eighties Manser and Brown (1980), McElroy and Horney (1981), Apps and Ress (1988), Chiappori (1988a, 1992), and Kooreman and Kapteyn (1990), proposed that household members taken individual decisions, and these works have pointed out empirical and welfare implications.

Chiappori (1988a, 1992), considering that each member of the household has his or her own preferences, decision is Paretto efficient; nonetheless, there is not a unique solution, but a continuum of Pareto-efficient choices. In order to get a unique solution, the author proposes a decision "rule" that allows choosing one among the continuum of Pareto-efficient choices: Nash bargaining could be one of this rules. Manser and Brown (1980), characterizes the household decision rule under several options: dictatorial rule, Nash bargaining rule, and Kalai and Smorodinsky (1975) solution. McElory and Horney (1981) work with a two-person household, a "married couple", and their joint allocation of money-income and time. The model, however, is applicable to outcomes of any decisions that can be structured as a constrained, static, two-person, non-zero-sum game. They analyze only the outcome of a two-person cooperative game with a Nash Bargaining solution. Kooreman and Kapteyn (1990) focus on the collecting data process in order to capture strategic behavior which not necessary was captured by the database used. Then, if one wants to gain solid empirical ground, then one has to collect more specific data on each of the players in the household game. In other words, not only the theorist has to stop treating the household as a homogeneous unit, the data collector has to do the same. Apps and Rees (1988) pioneer work to analyze welfare between neoclassic versus unitary preferences works.

On the other hand, there is another literature that point out the household considering that spouses are players, that they have utility functions as well, but their decisions imply a strategic interaction behavior. That interaction has been modeled using no cooperative game theory, complete information and multiple equilibria. Pioneers of discrete games, that allow utility to also depends on the actions of the other player, were Bjorn and Vong (1984, 1985), as well as, Bresnahan and Reiss (1990, 1991), Berry (1992) and Kooreman (1994); but this framework has been studied too by Brock and Durlauf, (2001), Seim (2001), Ackerberg and Gowrisankaran (2002), Mazzeo (2002), Tamer (2003), Ciliberto and Tamer (2003), Aguirregabiria and Mira (2002), Berry, Ostrovsky and Pakes (2003), Pesendorfer and Schmith-Dengler (2003), Manuszak and Cohen (2004), Sweeting (2004) and Bajari and Krainer (2004), Aradillas-Lopez (2010).

This literature has treated both, complete and incomplete information. The second one is straightforward to estimate parameters; complete information framework represents more problems to deal with, because multiple equilibria can arise. Recently works have proposed methods of estimation: Bajari, Hong and Ryan (2004) proposes simulation-based estimatior for discrete games of complete information, they define a Method of Simulated Moments (MSM), exploiting recent algorithms that compute all of the equilibria to discrete games; on the other hand, Beresteanu, Molchanov and Molinari (2010) use random set theory because it can benefit partial identification analysis, obtaining a tractable characterization of the parameters' sharp identification region, and providing methods of identification it.

This paper deals with the estimation of complete information game theory with multiple equilibria, in the context of interaction strategy behavior of two by two games with two players. In this case, we applied the framework to husband and wife labor force participation in Mexico, and the main contribution derives of the use of selection mechanism of the equilibria in order to identify the parameters.

Main question in this paper is: does a married couple interact strategically when they make their participation decisions to enter or not into the labor market in Mexico? Even though, most empirical evidence indicates that households make relatively long-term decisions regarding the earnings and labor force participation, in the context of relatively unstable labor market, as in Mexico, we are interested in show that spouses interact strategically when they make their participation decisions.

2 Games and econometrics

A strategic game is a model of interacting decision-makers: *players*. Each player has a set of possible *actions*. The model captures interaction between the players by allowing each player to be affected by the actions of *all* players. Each player has *preferences* about the action *profile* (the list of all players' actions). Following Osborne (2004, pg. 13-14) a *strategic game* (with ordinal preferences) consists of the following:

1. a set of *players*
2. for each player, a set of *actions*
3. for each player, *preferences* over the set of action profiles.

Given to the interaction between the agents, can they arrive to an equilibrium state? The answer was given by John Nash. Assuming that the players are rational, i.e., they choose the best available action; it is possible to reach an equilibrium (no player has incentives to change the status in which each player is in equilibrium). Nash equilibrium of strategic game with ordinal preferences is defined as follows:

Definition: The action profile a^* in a strategic game with ordinal preferences is a **Nash equilibrium**, if for every player i and every action a_i of a player i, a^* is at least as good according to player *i's* preferences as the action profile (a_i, a^*_{-i}) in which player i chooses a_i while every other player -i chooses a^*_{-i}. Equivalently, for every player i,

$$u_i(a^*) \geq u_i(a_i, a^*_{-i})$$

for every action a_i of player i, where u_i is a payoff function that represents player *i's* preferences[1] (Osborne 2004, pg. 23).

A generalization of Nash equilibrium can be made. We allow each player to choose a probability distribution over his set of actions rather than restricting him to choosing deterministic actions. Then, a *mixed strategy* can be defined as a probability distribution over the player's actions. It is important to note that a mixed strategy may assign probability 1 to a single action: by allowing a player to choose probability distributions, we do not prohibit the players from choosing deterministic actions. This kind of "mixed strategy" can be considered as a *pure strategy* (Osborne 2004, pg. 107-108).

There is another class of environment in which agents can interact strategically: *complete information* or *asymmetric information* contexts. Informational asymmetries can arise when individuals have different types and have private information about their own preferences only. In this sense, the asymmetry involves variables that affect each individual only (and not the others) but may affect how the game is played in equilibrium.

Asymmetric means that some parties are informed about variables that affect everyone, and some parties are not.

[1] a_{-i}, means actions of players different to player i.

2.1 Discrete Strategy Game

2.1.1 Complete Information

Let be a simultaneous 2×2 game in its normal representation,

Figure 1

A simple 2 x 2 game

		PLAYER 2 Y=1	Y=0
PLAYER 1	Y=1	$t_1 + \alpha_1, t_2 + \alpha_2$	$t_1, 0$
	Y=0	$0, t_2$	0,0

where, each player has two mutually exclusive actions: Y=0 or Y=1 (participate or not; to be aggressive or not; enter or not, etc.). Players' payoffs depend on their actions: players will receive $(t_1+\alpha_1, t_2+\alpha_2)$ if they choose $(Y = 1, Y = 1)$; $(0, 0)$ if they choose $(Y = 0, Y = 0)$; $(0, t_2)$ if they choose $(Y = 0, Y = 1)$, and $(t_1, 0)$ if they choose $(Y = 1, Y = 0)$. Notice that (α_1, α_2) appear only in the case in which each player chooses Y=1, separately or together. The $\alpha_p' s$ try to capture how the other players' actions affect player p for $p = \{1, 2\}$; they are known as "interaction coefficients".

Regardless of the signs of alpha's, based on the game in the Figure 1, it is true that:

If $t_1 + \alpha_1 \geq 0$ and $t_2 + \alpha_2 \geq 0$, players will choose (1,1)

If $t_1 < 0$ and $t_2 < 0$, players will choose (0,0)

If $t_1 \geq 0$ and $t_2 + \alpha_2 < 0$, players will choose (1,0)

If $t_1 + \alpha_1 < 0$ and $t_2 \geq 0$, players will choose (0,1)

Now, following McFadden (1974), payoffs can be treated as random decomposed into deterministic components and random components. Let $(X_1, \varepsilon_1) \in \mathbb{R}^k \times \mathbb{R}$ and $(X_2, \varepsilon_2) \in \mathbb{R}^k \times \mathbb{R}$. Assume that $(\varepsilon_1, \varepsilon_2) \simeq F(\cdot; \Omega)$, where $F(\cdot)$ is known and Ω (variance and covariance matrix), unknown. Let be:

$$t_1 \equiv X_1' \beta_1 - \varepsilon_1$$

$$t_2 \equiv X_2' \beta_2 - \varepsilon_2$$

Where $\mathbf{X} \equiv (X_1, X_2)$ is the characteristic vector[2]; $\boldsymbol{\beta} \equiv (\beta_1, \beta_2)$, unknown parameters (deterministic part), and $\boldsymbol{\varepsilon} \equiv (\varepsilon_1, \varepsilon_2)$ is an unknown (for the econometrician) error term (random part). If only *pure strategies* are considered, then the players' optimal actions are simply given by

$$Y_p = 1\{X_p' \beta_p + \alpha_p Y_{-p} - \varepsilon_p \geq 0\} \tag{1}$$

For $p = 1, 2$. Where Y_{-p} means the action taken by the p player's opponent, and $1\{A\}$ is the indicator function: $1\{A\} = 1$ if A is true, 0 otherwise. Here, the objective is to estimate the parameters:

$$\boldsymbol{\theta} = (\beta_1, \beta_2, \alpha_1, \alpha_2, \Omega)$$

This is a well-known model in econometrics studied by Heckman (1978), Schmidt (1982) and many others. The key issue is *Statistical Coherency*, which is a necessary and sufficient condition for the likelihood of the model to be well defined:

$$Pr[(1,1)|\mathbf{X}] + Pr[(0,0)|\mathbf{X}] + Pr[(0,1)|\mathbf{X}] + Pr[(1,0)|\mathbf{X}] = 1$$

$\Leftrightarrow \alpha_1 \times \alpha_2 = 0$. But this *coherency condition* especially eliminates simultaneity from the model (Kooreman, 1994).

Now, following Aradillas-Lopez (2010), assuming that the *econometrician knows the signs* of the $\alpha's$, can be established the following assumptions:

[2]Theses variables will depend on the nature of the specific game.

Assumption A1 (**Information structure**)

i Realizations of (X_p, ε_p) are common knowledge. There is no source of private information.

ii In the context of *complete information*[3] players make decisions independently, no player being informed of the choice of any other player prior to making his own decision because of simultaneousness assumptions.

Assumption A2 (**Strategic behavior**)

i Under *complete informational* assumption, players could play pure or mixed strategies, then multiple equilibria can be allowed.

Assumption A3 (**Distributional properties of ε_1, ε_2, and η**)

i $(\varepsilon_1, \varepsilon_2)$ are jointly continuously distributed random variables with unbounded support. They are allowed to be correlated, but they are assumed to be independent of all other variables in the model, known as orthogonality condition. The conditional support $\mathbb{S}(\varepsilon_p|\varepsilon_{-p})$, is assumed to be unbounded for $p = 1, 2$, for any possible realization of ε_{-p}

ii $G_p(\epsilon_p)$ will denote the marginal distribution or ε_p, with density $g_p(\epsilon_p)$. The joint distribution of $(\varepsilon_1, \varepsilon_2)$ is given by $G_{1,2}(\varepsilon_1, \varepsilon_2; \rho)$, where $\rho \in [-1, 1]$ capture the entire dependence between ε_1 and ε_2; $G_{1,2}(\varepsilon_1, \varepsilon_2; \rho)$ represents unobserved (to the econometrician) distribution profits. For a given value of ϵ_1 and ϵ_2, the joint distribution of $G_{1,2}$ is an invertible function of ρ. This is true for all $(\epsilon_1, \epsilon_2) \in \mathbb{R}^2$.

[3]The existence of incomplete information means that the players are uncertain about the characteristics of the other players (see Rubinstein and Osborne, p.24).

2.1.2 Pure Equilibria

Now, assuming that the econometrist knows that $\alpha_1 \leq 0$, and $\alpha_2 \geq 0$ (parallel results arrive when $\alpha_1 \geq 0$, and $\alpha_2 \leq 0$), R^2 would be partitioned off as follows:

[Figure 2: see apendix]

In the blank square either outcome is likely.

2.1.3 Multiple Equilibria

Now, under the assumption that the econometrist knows that $\alpha_1 \leq 0$, and $\alpha_2 \leq 0$ (when $\alpha_1 \geq 0$ and $\alpha_2 \geq 0$, results are very similar). Let $\mathbb{S}(M)$ be the support of the random variable M; then, if $\mathbb{S}(\varepsilon_1, \varepsilon_2) \in \mathbb{R}^2$, the game with *complete information* will have *multiple equilibria* with positive probability for any realization of $\mathbf{X}$ unless: (a) $\alpha_1 \times \alpha_2 \leq 0$, if mixed-strategies are allowed (previous case), or (b) $\alpha_1 \times \alpha_2 = 0$, if mixed-strategies are ruled out (*coherency condition*). Now, we can do a partition of R^2, drawing the regions conformed by the solution of the game when $\alpha_1 \leq 0$, and $\alpha_2 \leq 0$, then:

[Figure 3: see apendix]

Then we have five regions. Pure strategy equilibrium, $\mathbf{R}_{(1,1)}$, $\mathbf{R}_{(0,0)}$, $\mathbf{R}_{(0,1)}$, and $\mathbf{R}_{(1,0)}$; mixed strategy equilibrium, $\mathbf{R}_{square}$.

In the middle box ($\mathbf{R}_{square}$) there are multiple Nash-equilibria: two pure, (0,1) and (1,0), and one mixed. By definition[4], mixed strategy equilibrium means that player 2 will choose $Y_2 = 1$ with probability Π_2, and player 1 will choose $Y_1 = 1$ with probability Π_1. But player 2 chooses Π_2 in order that player 1 is indifferent between $Y_1 = 1$ and $Y_1 = 0$; player 1, analogously, will choose Π_1 in order that player 2 would be indifferent

[4] See Osborne, pg. 137-142.

between $Y_2 = 1$ and $Y_2 = 0$. Equalizing expected utility of $Y_1 = 1$ and $Y_1 = 0$ we found that:

$$\Pi_2 = -\tfrac{t_1}{\alpha_1}, \text{ and } \Pi_1 = -\tfrac{t_2}{\alpha_2}$$

where $(\Pi_1, \Pi_2) \in [0,1] \times [0,1]$, $\forall\ t_1,\ t_2,\ \alpha_1$ and α_2 in the multiple equilibrium region $(\mathbf{R}_{square})$.

In this framework, statistical interdependence is allowed between ε_1 and ε_2. Then, each region will supply a certain amount of probability, according to the joint distribution of ε_1 and ε_2. This can be seen in Figure 4, in which it is assumed that $(\varepsilon_1, \varepsilon_2)$ follows a Farlie-Gumbel-Morgesten families of joint distributions (see Johnson, et. al. 1999).

[Figure 4: see apendix]

The main problem here is that:

$$Pr[(1,1)|\mathbf{X}] + Pr[(0,0)|\mathbf{X}] + Pr[(0,1)|\mathbf{X}] + Pr[(1,0)|\mathbf{X}] > 1$$

3 Labor Participation: Wife and Husband Decision Game

Let be player 1, *husband*; and player 2 *wife*, in a married couple which plays a game with *complete information* in order to decide their participation or not in the labor market. Using the game structure given in Figure 1, Y=1 means *participate* in the labor market, and Y=0, *don't participate*. As usual, upper-case will denote random variables and lower-case, particular realizations of these random variables. As mentioned, $\mathbb{S}(U)$ represents the support of the random variable U; and the subscript $p \in \{1, 2\}$ denotes a particular player, and $-p$ denotes the opponent. Strategic parameters will be represented as $(\alpha_1, \alpha_2) \in \mathbb{R}^2$. These parameters summarize the interaction effect between the players' actions.

Following Bjorn and Vuong (1984),[5] we assume that α_1 (husband's interaction coefficient) is negative. This means that the husband would be affected if his wife decides to work (because of social considerations, among others). At the same time, it is assumed that α_2 is negative. Could be reasonable to think that wife could not be affected by husband's decision to work; in terms of money there is not, because she needs that his husband work; but here we are included another social and psychological considerations: insecurity matters, loneliness, problems in the house or with the kids in which husband is important to be there in stead of working, among others. As a result, *multiple equilibria* is allowed in the context of *complete information* environment.

When multiple equilibrium is allowed, some authors have made *ad-hoc* assumptions: decision process is assumed to come from a "single equilibrium concept". As mentioned, pioneer work was carried out by Bjorn and Vuong (1984, 1985). Kooreman (1994), estimated and compared some microeconometric models for simultaneous discrete endogenous variables; he used data on the joint labor force participation decisions of husbands and wives in a sample of Dutch households, under the assumption that outcomes came from a Nash Equilibrium, Stackelberg Equilibrium and Pareto optimallity. Then, they made simplifying assumptions to respond to the nonuniqueness problem without invoking the coherency condition.

On the other hand, Tamer (2003), proposed a parametric and nonparametric estimator without invoking this coherency condition nor imposing *ad-hoc* assumptions to avoid multiplicity equilibria. Our model allows multiplicity equilibrium, but also designs an equilibrium selection mechanism which is the key for parameters' identification.

[5] This is the assumptions which indicate that econometrist knows the signs of $\alpha's$. Bjorn and Vuong (1984) found that interaction parameters in the U.S. were negative.

Bjorn and Vuong (1984, 1985) proposes an uniform probability mechanism selection of the equilibria; here, mechanism is based on husband's probability to work.

3.1 Equilibrium Selection Mechanism

As $\alpha_1 \leq 0$, and $\alpha_2 \leq 0$, we have multiple equilibria. Then, players should decide how to choose the optimal equilibrium. Equilibria will be ordered according to the husband's probability to work. In the square area in Figure 3, there are three equilibria: (0,1), mixed, and (1,0). In the first one, the husband will work with probability zero; in the second one he will work with probability $\Pi_1 = -\frac{t_2}{\alpha_2} \in [0,1]$; in the third one, he will work with probability one. Then, it will be considered an *ordered response approach* using a linear index.

Let be,

$$\mathbf{W}'\gamma + \eta \tag{2}$$

the linear index where $\mathbf{W}$ are observable characteristics using the *exclusion restriction*, which means that we should include some characteristics that are not included in $\mathbf{X}_1$ or $\mathbf{X}_2$. $\gamma \in \mathrm{R}^{k_2}$ is a vector of parameters and η is an unobservable vector. $k_2 \in \mathrm{Z}$.

It is well known that these simpler models cannot be identified without exclusion restrictions. That is, we must search for variables that influence one equation, but not the other: Bajari, Hong and Ryan (2004). On the other hand, . . . in a game with multiple equilibria, anything that tends to focus the players attention on one particular equilibrium, in a way that is commonly recognized, tends to make this the equilibrium that the players will expect and thus actually implement. The focal equilibrium could be determined by any of a wide range of possible factors, including environmental factors and cultural traditions (which fall beyond the scope of analysis in mathematical game theory), special mathematical properties of the various equilibria, and preplay statements made by the players or an outside arbitrator. . . (Myerson, Game Theory, pp. 371-2), that is why variable husband's age square, $AGEH^2$, was included because it is common recognized that labor experience[6] increases probability to participates in labor market.

Figure 6

Linear Index

where μ_a and μ_b are *threshold parameters*, such that $\mu_b \geq \mu_a$. If $\gamma_i > 0$ contributes husband to work. Finally, η is assumed independent of $(\varepsilon_1, \varepsilon_2)$[7].

According to Figure 3, regions have the following specific expressions:

$\mathbf{R}_{(sqr)}$: $0 \leq t_2 \leq -\alpha_2$ and $0 \leq t1 \leq -\alpha_1$

$\mathbf{R}_{(1,1)}$: $t_2 > -\alpha_2$ and $t1 > -\alpha_1$

$\mathbf{R}_{(0,0)}$: $t_2 < 0$ and $t_1 < 0$

$\mathbf{R}_{(0,1)}$: $t_2 > 0$ and $t_1 < 0$

$\bigcup$

$t_2 > -\alpha_2$ and $0 \leq t_1 \leq -\alpha_1$

$\mathbf{R}_{(1,0)}$: $t_2 < 0$ and $t_1 > 0$

$\bigcup$

$0 \leq t_2 \leq -\alpha_2$ and $t_1 > -\alpha_1$

Then, we need to construct specific expressions for Pr(1,1), Pr(0,0), Pr(0,1) and Pr(1,0).

[6] $AGEH^2$ is a proxy of labor experience.

[7] This could be relaxed.

4 Estimation

Assumption A4 (**Researcher**) The main assumption made here is that the distributions of $(\varepsilon_1, \varepsilon_2) \sim G_{1,2}(.,.;\rho)$, and $\eta \sim F(\bullet)$ are assumed to be known.

Here, the Farlie-Gumbel-Morgesten families of joint distributions (see Johnson, et. al. 1999), will be used, then $G_{1,2}(.,.;\rho)$ can be expressed as follows:

$$G_{1,2}(\epsilon_1, \epsilon_2; \rho) = G_1(\epsilon_1)G_2(\epsilon_2) \times \left[1 + \rho(1 - G_1(\epsilon_1))(1 - G_2(\epsilon_2))\right] \tag{3}$$

where

$$G(\epsilon_p) = \frac{e^{\epsilon_p}}{1 + e^{\epsilon_p}} \tag{4}$$

$G(\bullet)$ is the logistic cdf.

At the same time, we assume that η has a logistic cdf.

$$F(\eta) = \frac{e^{\eta}}{1 + e^{\eta}} \tag{5}$$

Assumption A5 (**Researcher**) The econometrician has in hand an iid sample of N games described by the assumptions (A1)-(A4). He observes $(Y_n, X_n, W_n)_{n=1}^{N}$, and uses the joint cdf $G_{1,2}(.,.;\rho)$ described above with $\rho \leq |1|$, and the logistical, $F(\bullet)$, for η, in order to identify all parameters.

4.1 Probabilities

Under the assumptions (A1)-(A5), probability functions for each pair of actions $\{(1,1),(0,0),(1,0),(0,1)\}$ are defined as follows.

4.1.1 Probability of (1,0)

Let be $1\{(1,0)\}$ the indicator function for the simultaneous actions: $Y_1 = 1$ and $Y_2 = 0$. From the Figure 3, and including the *selection mechanism*, we have:

$$
\begin{aligned}
1\{(1,0)\} = \quad & 1\{(t_1,t_2) \in \mathbf{R}_{(1,0)}\} + \\
& 1\{(t_1,t_2) \in \mathbf{R}_{(square)} \text{ and } W'\gamma + \eta > \mu_b\} + \\
& 1\{(t_1,t_2) \in \mathbf{R}_{(square)} \text{ and } \mu_a \leq W'\gamma + \eta \leq \mu_b\} \\
& 1\{U_2 \leq \Pi_2\}1\{U_1 > \Pi_1\}
\end{aligned} \tag{6}
$$

where U_1 and U_2 are uniform random variables in [0,1], independent from all random variables in the game and between them. $1\{U_2 \leq \Pi_2\}$, and $1\{U_1 > \Pi_1\}$ are called *randomization devices*. Notice that all possibilities have been considered, because regions are mutually exclusive from each other.

Now, the conditional probability of $\{(1,0)\}$ given X_1, X_2, W, ε_1, ε_2, and η is:

$$
\begin{aligned}
Pr[\{(1,0)\}|X_1,X_2,W,\varepsilon_1,\varepsilon_2,\eta] = \quad & 1\{(t_1,t_2) \in \mathbf{R}_{(1,0)}\} + \\
& 1\{(t_1,t_2) \in \mathbf{R}_{(square)} \text{ and } W'\gamma + \eta > \mu_b\} + \\
& 1\{(t_1,t_2) \in \mathbf{R}_{(square)} \text{ and } \mu_a \leq W'\gamma + \eta \leq \mu_b\} \\
& \Pi_2(1-\Pi_1)
\end{aligned} \tag{7}
$$

Finally, integrating over $\varepsilon_1, \varepsilon_2$,and η, we have:

$$_{(1,0)} = Pr(\{1,0\}|X_1, X_2, W) =$$

$$\int_{\varepsilon_1}\int_{\varepsilon_2}\int_{\eta} \Big[1\{(t_1,t_2) \in \mathbf{R}_{(1,0)}\} + 1\{(t_1,t_2) \in \mathbf{R}_{(square)} \text{ and } W'\gamma + \eta > \mu_b\} + 1\{(t_1,t_2) \in \mathbf{R}_{(square)} \text{ and } \mu_a \leq W'\gamma + \eta \leq \mu_b\} \Pi_2(1-\Pi_1)\Big]\ g_{1,2}(\epsilon_1,\epsilon_2;\rho)\ f(\eta)\ d\eta\ d\varepsilon_2\ d\varepsilon_1 \quad (8)$$

The parallel structure was used in order to find {(1,1)}, {(0,0)}, and {(0,1)} probabilities, so we get:

4.1.2 Probability of (1,1)

$$_{(1,1)} = Pr(\{1,1\}|X_1, X_2, W) =$$

$$\int_{\varepsilon_1}\int_{\varepsilon_2}\int_{\eta} \Big[1\{(t_1,t_2) \in \mathbf{R}_{(1,1)}\} + 1\{(t_1,t_2) \in \mathbf{R}_{(square)} \text{ and } \mu_a \leq W'\gamma + \eta \leq \mu_b\} \pi_2\pi_1\Big]\ g_{1,2}(\epsilon_1,\epsilon_2;\rho)\ f(\eta)\ d\eta\ d\varepsilon_2\ d\varepsilon_1 \quad (9)$$

4.1.3 Probability of (0,0)

$$_{(0,0)} = Pr(\{0,0\}|X_1, X_2, W) =$$

$$\int_{\varepsilon_1}\int_{\varepsilon_2}\int_{\eta} \Big[1\{(t_1,t_2) \in \mathbf{R}_{(0,0)}\} + 1\{(t_1,t_2) \in \mathbf{R}_{(square)} \text{ and } \mu_a \leq W'\gamma + \eta \leq \mu_b\} (1-\pi_2)(1-\pi_1)\Big]\ g_{1,2}(\epsilon_1,\epsilon_2;\rho)\ f(\eta)\ d\eta\ d\varepsilon_2\ d\varepsilon_1 \quad (10)$$

4.1.4 Probability of (0,1)

$$_{(0,1)} = Pr(\{0,1\}|X_1, X_2, W) =$$

$$\int_{\varepsilon_1}\int_{\varepsilon_2}\int_{\eta} \Big[1\{(t_1,t_2) \in \mathbf{R}_{(0,1)}\} +$$
$$1\{(t_1,t_2) \in \mathbf{R}_{(square)} \text{ and } \mu_a \leq W'\gamma + \eta\} +$$
$$1\{(t_1,t_2) \in \mathbf{R}_{(square)} \text{ and } \mu_a \leq W'\gamma + \eta \leq \mu_b\}$$
$$(1-\pi_2)\pi_1\Big] \; g_{1,2}(\epsilon_1, \epsilon_2; \rho) \; f(\eta) \; d\eta \; d\varepsilon_2 \; d\varepsilon_1 \tag{11}$$

Under assumptions (A1)-(A5), it holds that

$$_{(1,1)} + _{(0,0)} + _{(1,0)} + _{(0,1)} = 1$$

without invoking the *coherency condition*.

4.2 Estimation of $\boldsymbol{\theta}$

All parameters are identified, then, using *maximum likelihood estimation*. We can construct the *likelihood function* as follows:

$$(Y,X,W,\theta) = \frac{1}{N}\sum_{i=1}^{N}\big[y_{i1}y_{i2} \; log(_{i\{1,1\}}) + (1-y_{i1})(1-y_{i2}) \; log(_{i\{0,0\}}) \quad +$$
$$+y_{i1}(1-y_{i2}) \; log(_{i\{1,0\}}) + (1-y_{i1})y_{i2} \; log(_{i\{0,1\}})\big] \tag{12}$$

where $_{i\{j,k\}}$ is the probability to play $\{j,k\} \in (\{1,1\},\{0,0\},\{1,0\},\{0,1\})$ of the $i-th$ married couple.

Matrix of variances and covariances can be found using maximum likelihood estimation techniques (see Amemiya, 1985). Then

$$\Omega_{MLE} = -\left[E\frac{\partial^2(\mathbf{Y,X,W},\theta)}{\partial\theta\partial\theta'}\right]^{-1} \tag{13}$$

Which is known as Cramer-Rao lower bound.

5 Application: Labor Force Participation in Mexico

5.1 Complete Information

As it was mentioned, we model husband and wife labor force participation decisions under complete informational framework, and multiple equilibria game. Each member of the household have his or her own preferences and utility payoffs.

5.2 Data base description

In order to characterize the strategic interaction and decisions of Mexican married couples, particularly those decisions which are related to participation in the labor market, it was used the "Encuesta Basal sobre el Ahorro, Crédito y Microfinanzas Rurales" (Basal Survey of Savings, Credit and Rural Micro-Finances), made by the "Banco del Ahorro Nacional y Servicios Financieros, Sociedad Nacional de Crédito, Institución de Banca de Desarrollo" (BANSEFI) and the "Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación" (SAGARPA), in 2004.

The entire survey attempts to capture changes and differences in social, economical and political terms, between those households in which at least one of its members belongs to one "Popular Credit and Savings Society" (SACP, by its acronym in Spanish).

In this study, 5767 randomly selected households were surveyed distributed in 3 regions: North, Center and South[8]. Additionally, the interviewed households were divided in rural and urban communities. We discarded those couples in which one of its

[8]Region=1 (North): Aguascalientes, Baja California, Baja California Sur, Chihuahua, Coahuila, Durango, Nuevo León, San Luis Potos, Sinaloa, Sonora, Tamaulipas and Zacatecas; Region=2 (Center): Colima, Distrito Federal, State of Mexico, Guanajuato, Hidalgo, Jalisco, Michoacán, Morelos, Nayarit and Querétaro; Region=3 (South): Campeche, Chiapas, Guerrero, Oaxaca, Puebla, Quintana Roo, Tabasco, Tlaxcala, Veracruz and Yucatán.

members was greater than 65 years old and those that there is no married couple, that is why N=3884.

Table 1

Couples	N	North	Center	South
Mexico	3884	19.44%	38.59%	41.97%

$$Y_p = \begin{cases} 0 & \text{If } p \text{ don't participate in the labor market} \\ \\ 1 & \text{If } p \text{ participate in the labor market} \end{cases}$$

where $p \in \{1, 2\}$. Then, $(Y_1, Y_2) \in \{(1,1), (1,0), (0,1), (0,0)\}$. Outcomes of the games can be seen in Figure 7:

Figure 7

Outcomes of the Games

		PLAYER 2 (Wife) Y=1	**PLAYER 2 (Wife)** Y=0
PLAYER 1 (Husband)	Y=1	907	2808
PLAYER 1 (Husband)	Y=0	42	127

Following Bjorn and Vuong (1985), I used social variables available in the survey which captures market participation decisions.

$$\mathbf{X}_1 = \{AGEH, EDUCH, KIDS13\}$$

$$\mathbf{X}_2 = \{AGEW, EDUCW, KIDS13\} \quad (14)$$

$$\mathbf{W} = \{AGEH^2, EDUCH\}$$

$\mathbf{X}_p$ is known of the married couple, which reinforces the *complete informational* assumption. Covariates of all variables were summarized in the Table 2. In W is included $AGEH^2$ which is an *excluded restriction* of X, and is a proxy to labor experience of husband. The more experience in labor market, the more probability to participate in the labor market and get a job.

[Table 2: see apendix]

As it can be seen, the male partner average age is about 41 years old, female partner is about 38 years old. Additionally, years of education is about 7 years in both cases. On average, Mexican couples have 1.55 kids less than 14 years old. The variable $AGEH^2$ was included as a proxy of the male experience. Without losses of generality, I assumed that couples "flip a coin" when they choose mixed strategies, so $\Pi_1 = 0.5$ and $\Pi_2 = 0.5$. Main results are presented in the next section.

5.3 Main Results

[Table 3: see apendix]

As an additional assumption, ρ was picked up at 0.5, which means that there is a positive relationship between $(\varepsilon_1, \varepsilon_2)$. There were no significant changes with other values of ρ.

[Table 4: see apendix]

5.4 Analysis of results

In both cases, AGE_p's parameters were significant; nonetheless, the husband's age was negative, which means that the greater the husband's age is, the lesser his participation will be, which is reasonable. On the other hand, the female parameter is positive, which means that wives have more incentives to participate in the labor market as they become older. Social and economic considerations can lead wives to participate in the labor market; for example, the older they become, the more "independent" their children are, setting them free to work if they wish so.

Education is not significant in the husband's case, but in the wife's case it is, and positive. This means that the more years of education, the more incentives to participate in the labor market. In recent years, Mexican women have had an active role in the labor market, specifically in those cases in which women are more prepared academically and are, thus, better positioned to get better jobs.

In the spouses decision to participate or not in the labor market, only wives care about children. $KIDS13_p$ has negative coefficient, as predicted (Bjorn and Vuong (1984), obtained the same qualitative result in the female case). This means that children are an objective restriction when couples make their decisions to participate or not in the labor market. In Mexico, men are traditionally less worry about children in general, which is directly related to gender culture in this country.

Interaction strategic parameter is very important in this analysis. As we can see in Table 2, this coefficient was significant only in the wives' case. This sign was negative, and it means that they care about their husbands decisions. Moreover, she will not participate in the labor market if her husband decides to participate (on average). The fact that husband's parameter was not significant means that they don't care about their wives decisions (on average) to participate in the labor market.

All the parameters of the selection mechanism were not significant, which means that they assign uniform probability to each equilibria. Nonetheless, it is interesting that even though parameters of $EDUC_1$ were not significant, they both were negative (See Table 2 and 3).

6 Concluding remarks

Decisions to participate in the labor market can be modeled in the context of the game theory, and here it is presented in the Mexican labor market. In the context a *complete information* and multiple equilibrium game, it was modeled a specific mechanism of equilibrium selection. Results reveal that participation decisions in the labor market that come from this game structure have more influence over the wife than over the husband. Husband's decisions are not essentially affected by wife's decisions; but, wife's decisions are directly affected by her husband's decisions ($\alpha_2 < 0$ and significant). Husband participation decisions are only affected by his age; the wife participation is affected by age, education and number of kids less than 14 years old. Finally, all variables from selection mechanism were not significant.

These results are very significant, but there is still more to do about it. For example, selection mechanism could be analyzed in the context of other games with characteristics described here.

7 Apendix

Figure 2

(R^2 **Partition Pure Equilibrium**)

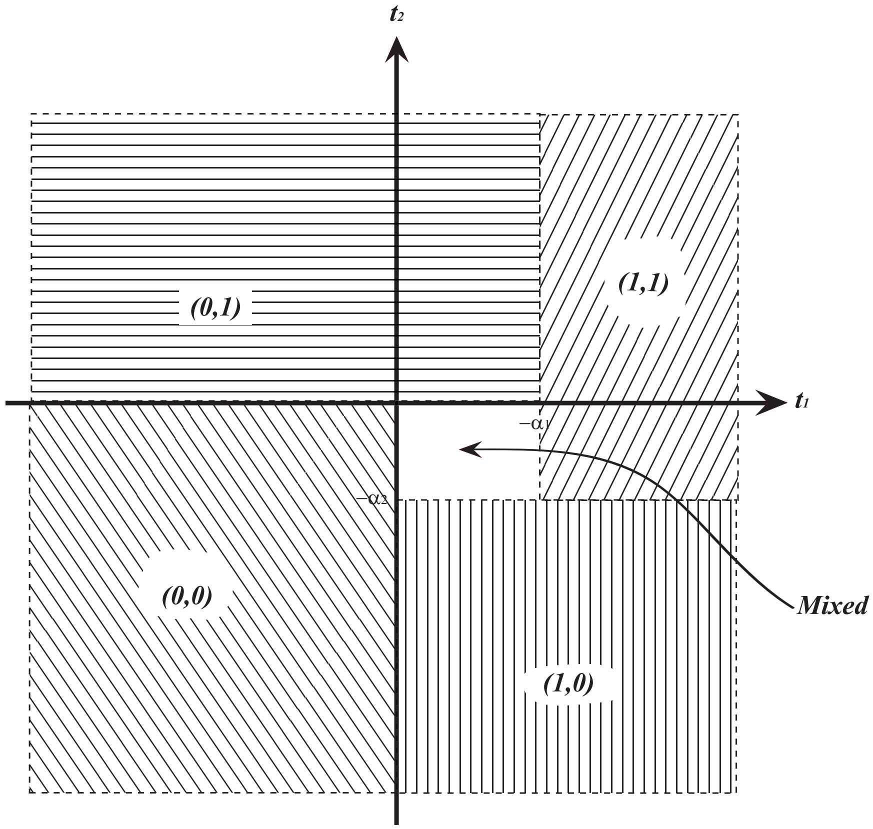

Figure 3

(R^2 **Partition Multiple Equilibrium**)

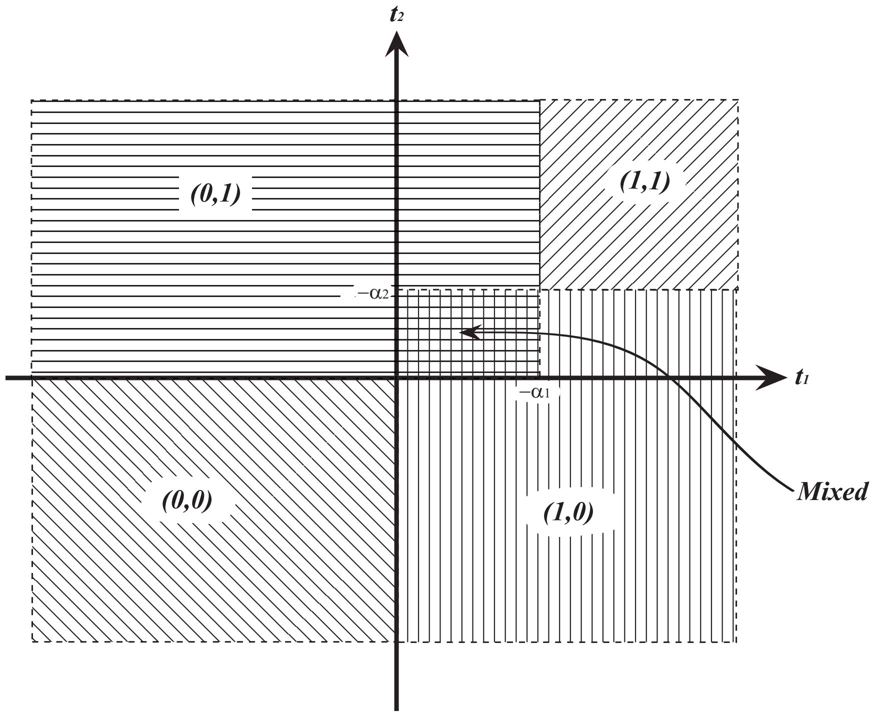

Figure 4

($\varepsilon_1, \varepsilon_2$) Joint Density Function

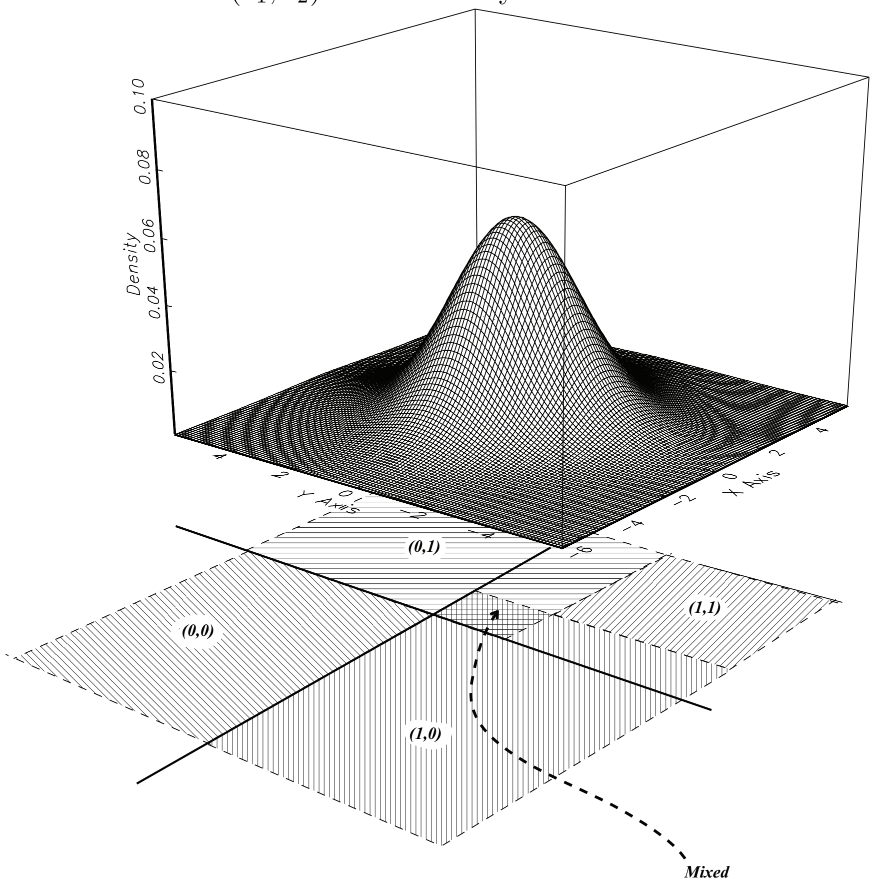

Table 2

Covariates of the Model

Variable	Description	Mean	Std. Dev.	Min	Max
AGEH	Age of the male partner	41.83	11.32	17	65
AGEW	Age of the female partner	38.62	10.89	14	65
EDUCH	Years of education (male partner)	7.16	4.52	0	17
EDUCW	Years of education (female partner)	6.81	4.28	0	17
KIDS13	Number of kids less than 14 years old	1.55	1.31	0	7
$AGEH^2$	Age Square of male partner (Experience proxy variable)	1878.49	976.075	289	4225

Table 3

(Standard Errors in parentheses)

Variable	**Player 1** (Husband)	**Player 2** (Wife)
$CONS_p$	4.6126*	-1.6807*
	(0.4985)	(0.2776)
AGE_p	-0.0385*	0.0125*
	(0.0083)	(0.0045)
$EDUC_p$	-0.0125	0.1894*
	(0.0172)	(0.0101)
$KIDS13_P$	0.0572	-0.1386*
	(0.0644)	(0.0378)
α_p	13.5730	-1.2276*
	(27.6374)	(0.1324)
ρ	0.5	

(*) Statistically significant at a 5% level.

Table 4

Linear Index

(Standard Errors in parentheses)

Variable	$\boldsymbol{W}$
AGE_p^2	-0.1000
	(0.2169)
$EDUC_p$	-0.0100
	(0.0344)
μ_a	-0.0054
	(0.0102)
μ_b	-0.0048
	(0.0342)

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