Regional Science and Urban Economics 87 (2021) 103654

Contents lists available at ScienceDirect

Regional Science and Urban Economics

journal homepage: www.elsevier.com/locate/regec

On rational forward-looking behavior in economic geography: An experimental analysis

Iván Barreda-Tarrazona [a], Tapas Kundu [b], Stein Østbye [c,*]

[a] LEE & Economics Department, Universitat Jaume I, Castellón, Spain
[b] Oslo Business School, Oslo Metropolitan University, Oslo, Norway
[c] School of Business and Economics, UiT The Arctic University of Norway, Tromsø, Norway

ARTICLE INFO

JEL classification:
R1
C91
C73

Keywords:
New economic geography
Migration
Experiments

ABSTRACT

This paper adapts the canonical New Economic Geography model for experimental testing of the model's behavioral assumptions by developing a finite-player, finite-horizon dynamic game of migration. Our analysis gives distinctive predictions when migration is consistent with myopic behavior (MB) and when it is consistent with sequentially rational or perfect forward-looking behavior (FB). These alternatives are tested in an economic laboratory experiment with increasing number of agents in different treatments. Results show that perfect FB loses ground against MB as the number of agents and periods increases, and this number may be surprisingly small.

1. Introduction

The core-periphery (CP) model, which launched New Economic Geography (NEG) as a separate field, assumed that migrants made myopic adjustments and based their migration choices on the current real wage differences between locations (Krugman, 1991b). A major problem in relaxing the assumption of myopic behavior (MB) was that the original CP model was not analytically solvable. The assumption of MB was considered necessary for analytical tractability of the long-run equilibrium without compromising the richness of the CP model's findings (Baldwin, 2001).[1] Later, two important developments were made to incorporate forward-looking behavior (FB) in a model with agglomeration forces similar to those found in the CP model. In the first, Baldwin (2001) uses a numerical simulation technique to characterize the long-run transitional dynamics of the CP model. In the second, Ottaviano (2001) develops an analytically solvable version of the CP model with a minor modification of the production technology and analyzes stability properties of the long-run equilibria. Oyama (2009b,a), using the concepts of potential games, provides further insights into the question of global accessibility properties of the long-run equilibria. These developments lay the groundwork for the assumption of FB to replace MB as a default feature of the NEG models.

An assumption of MB or FB, however, deals with a positive, rather than a normative, aspect of human behavior. Our paper concerns the behavioral foundation of the assumption of FB and focuses on the equilibrium selection problem. Using an experimental framework, our primary objective is to investigate whether migration decisions are consistent with predictions from a model that assumes forward-looking adjustments by migrants. Further, since the long-run equilibrium outcome under MB always coincides with the outcome of one of the expectations-driven equilibria under FB, we study a related question of how good an approximation the assumption of MB is for the equilibrium selection problem.

We address these questions by developing a migration framework that can be tested in an experimental setting. Our static spatial framework is based on the much-used elaboration of the original CP model by Ottaviano (2001) and Forslid and Ottaviano (2003), allowing a closed-

* Corresponding author.
E-mail address: stein.ostbye@uit.no (S. Østbye).

[1] A set of models were also developed in parallel to focus on the problem of forward-looking adjustments. In these models, migration dynamics are characterized by linear differential equations, so the stability analysis of the long-run equilibrium is mathematically tractable. However, to achieve tractability, these models feature characteristics different from those of the original CP model, including non-pecuniary agglomeration forces (Krugman, 1991a) and indirect utility being modeled as linear in the share of skilled workers (Ottaviano, 1999).

https://doi.org/10.1016/j.regsciurbeco.2021.103654
Received 17 July 2020; Received in revised form 14 December 2020; Accepted 19 January 2021
Available online 5 February 2021

form solution for the inter-regional real wage differential. To adapt this model featuring an infinite number of agents to experimental testing with a finite number of subjects, we develop a finite-player, finite-horizon dynamic game of migration, in which one subject effectively represents a positive mass of population in the CP model. We model the migration dynamics as a sequence of games (instead of one sequential game), each lasting one period. Every subject gets one opportunity to move in the migration sequence, and only one subject moves in a given period. We allow subjects to accumulate payoff over periods. This arrangement allows us to distinguish between MB and FB in a precise way.

We study the equilibrium in Markov strategies, which assume players restrict their attention only to payoff-relevant past events (Maskin and Tirole, 2001). The migration game under FB shows multiple expectation-driven long-run equilibria. We focus on *Markov perfection*, which incorporates the concept of sequential rationality, as an equilibrium selection criterion. It requires the equilibrium strategy to be optimal in every possible continuation game. We characterize the conditions on initial states and payoff functions such that the long-run Markov perfect equilibrium (MPE) outcome under FB is different from the long-run equilibrium outcome under MB. This distinction allows us to test the behavioral foundation for *perfect* (or sequentially rational) FB.

The empirical test is based on data generated through a laboratory experiment. In the experiment, subjects are exposed to all relevant payoff-related information, which enables all subjects to compare any path of decisions to all alternative paths and make decisions under perfect information. It would not be feasible to obtain the real wages expected by potential migrants under different agglomeration conditions in the future periods with field data, and this common knowledge of information is fundamental for our test of the behavioral assumption of FB. This fact has tilted the balance towards an experimental approach. Further, McKenzie (2015) argues that self-selection of migrants presents a methodological challenge to identify factors of migration in studies with field data. In the context of our model, self-selection of migrants would bring additional complexity to delineate the role of behavioral concerns - we would ideally require treatments to vary only in terms of the degree of forward-looking adjustments, but with homogeneous agents. Laboratory experiments also provide us with unprecedented control over transmission of payoff-relevant information and ensure internal validity that is critical for stringent tests of economic theories (Dhami, 2016, p. 11). It is also worth mentioning that several other internal validity shortcomings when a CP model is confronted with field data (see Combes et al., 2008) do not apply to our experimental data: 1) Homogeneous migrants: real migrants care about more than the real wage difference. While this is true, this variable is all that distinguishes different locations in the experimental setting. 2) Two regions: there are multiple regions real migrants can choose from. That may be so, but in the experiment, there are only two by design.

Our experimental design considers two heterogeneous regions, 0 and 1, such that individual payoff is lower when everyone is located in region 0 than when everyone is located in region 1. We test whether there exists a set of self-fulfilling expectations that leads the economy to region 1, starting from an initial state in which all subjects are located in region 0. The payoff functions are derived from our theoretical analysis so that the economy leads to full agglomeration in region 1 in the unique MPE under FB and remains fully agglomerated in region 0 under MB. Two potential migrants move sequentially in the baseline treatment. Our research strategy is to run two additional treatments. In these added treatments, complexity is marginally increased by first adding one potential migrant and period, then adding one more. We find that the outcome is consistent with perfect FB in the baseline treatment, as expected. This is also true when adding one potential migrant, but surprisingly, adding two is all it takes in terms of complexity to make a majority of subjects behave consistently with the predictions coming from the model under MB.

We are related to three strands of literature. First, we contribute to the small but growing literature on experimental studies on migration. Experimental techniques were suggested by a distinguished group of migration researchers within regional science more than 25 years ago (Greenwood et al., 1991). For some reason, the suggestion never caught on. The few exceptions include Greenwood et al. (1997) and Edwards and Huskey (2008, 2014). In recent years, researchers within development economics are using designed field experiments to study factors contributing to migration and migrants' behavior. Bryan et al. (2014) conduct experiments in Bangladesh to study constraints on seasonal migration and Ashraf et al. (2015) study migrants' incentives to remit; see McKenzie (2015) for a review of this literature. To the best our knowledge, there is no experimental study on migration testing forward-looking behavior of migrants. There are, however, experimental studies indirectly related to the game theoretic approach that we follow. These include experimental studies on backward induction failure in finite-horizon repeated games. See, e.g., Binmore et al. (2002) and the more recent paper by Dufwenberg and van Essen (2018).

Second, our study also relates to the quantitative economic geography literature studying spatial models; see a recent survey by Redding and Rossi-Hansberg (2017). While a dynamic spatial model is essential to understand evolution and growth of an economy over time, introducing dynamics in the spatial models presents a severe methodological challenge for tractability. This is because when the future events affect an agent's decision today, the agent must anticipate the future evolution of the game. Introducing all future possibilities in an agent's decision-making increases the dimensionality of the problem manyfold. To avoid the problem of increasing dimensionality, some studies consider short-lived agents in an otherwise dynamic spatial model (see, e.g., Delventhal, 2018; Allen and Donaldson, 2020). Not surprisingly, many empirical studies in economic geography and trade featuring structural estimation methodology involve static spatial models (Dekle et al., 2008; Costinot and Rodríguez-Clare, 2014). An important recent contribution is Caliendo et al. (2019), which extends the estimation methodology to a dynamic model with long-lived agents with perfect foresight. However, it is worth noting that the behavioral assumption of forward-looking agents with perfect foresight, especially in a complex environment, remains an open question. In this context, our findings may suggest that a dynamic model with bounded-rational agents may not necessarily be a compromise due to increasing complexities, but rather provide a better alternative in complex situations.

Finally, our theoretical findings share common features with those from the extant NEG literature. We contribute to the history versus expectation debate in the equilibrium selection problem (Krugman, 1991a; Fukao and Benabou, 1993; Oyama, 2009b). In our model, the long-run equilibrium under MB exhibits history dependency. The migration game under FB reveals the existence of multiple expectation-driven long-run equilibria. While the analysis of a NEG model under FB typically identifies the range of initial states for which multiple equilibria with self-fulfilling expectations may exist, it is usually uninformative about which expectation dominates in those states.[2] Since the equilibrium under MB coincides with the outcome of one of the expectations-driven equilibria under FB, we are able to test if the assumption of MB fits well for the equilibrium selection problem. Our findings further suggest that MB may be a better approximation from a behavioralal perspective in a world with more complexity and an even larger number of decision-makers. Although similar propositions have been put forth in the NEG literature (see, e.g., Fujita and Thisse, 2013, p. 311), we are not aware of any experimental studies in support of this proposition.

The paper is organized as follows. Sections 2 and 3 develop our theoretical framework that can bridge the gap between existing CP models

[2] A notable exception is Oyama (2009b), who shows that the region, which maximizes the potential long-run gain if fully agglomerated, will always be reached from any initial state given a sufficiently small degree of friction.

and one that can be implemented in a laboratory The first presents the analytically solvable CP model with asymmetry and then the migration game. Sections 4 and 5 present the experimental design and findings, respectively. Section 6 concludes. Proofs and instructions for the experiment are given in Appendix A and Appendix B, respectively.

2. An analytically solvable CP model

We begin the theoretical analysis by presenting the analytically solvable CP model developed in Ottaviano (2001) and Forslid and Ottaviano (2003). We extend the model to allow inter-regional asymmetry in the production technology, the trading cost and the size of the unskilled labor force.[3]

2.1. Basic ingredients

There are two regions, 0 and 1. A continuum of mass 1 of skilled workers is distributed over the two regions and we let $s \in [0,1]$ denote the fraction of skilled workers in region 1. There are mass L of (immobile) unskilled workers, of which L_i are in region $i = 0, 1$, and $L_0 + L_1 = L$. Everyone gets utility from consumption of two goods, a differentiated modern good D and a homogeneous traditional good A. Preferences of the representative consumer involve CES preferences over the differentiated varieties of the modern good nested in a Cobb–Douglas upper-tier utility function

$$U_i(D_i, A_i) = \alpha \ln D_i + (1-\alpha)\ln A_i,\ \ i \in \{0,1\} \tag{1}$$

with

$$D_i = \left[\int_{q\in n_i} d_{ii}(q)^{\frac{\sigma-1}{\sigma}} dq + \int_{q\in n_j} d_{ji}(q)^{\frac{\sigma-1}{\sigma}} dq\right]^{\frac{\sigma}{\sigma-1}},\ \ \sigma > 1, \tag{2}$$

where D_i and A_i are consumptions in region i of the CES composite of modern varieties and the traditional good, respectively. $d_{ji}(q)$ is consumption in region i of a certain variety q that is produced in j, and n_i and n_j are the ranges of varieties produced in regions i and j and $i, j \in \{0,1\}$. And, $\sigma > 1$ is the elasticity of substitution between any two varieties. Let r_i and w_i denote the wages of skilled and unskilled workers in region i. Production of the modern good takes place in a monopolistic competition sector subject to increasing return. Production of a modern good variety in region i requires a fixed input of one skilled worker and a marginal input of β_i units of unskilled worker. With a fixed distribution of skilled workers, the ranges of varieties of modern goods are thus fixed at $n_0 = 1 - s$ and $n_1 = s$. A firm incurs a cost of $r_i + \beta_i w_i m$ to produce m units of a specific variety of the modern good. The traditional good is produced using a constant returns to scale technology in a perfectly competitive sector, and production requires a marginal input of 1 unit of unskilled worker.

Both goods are traded across regions. The traditional good is freely traded and so the wage of an unskilled worker is the same between the two regions.[4] Trading of a modern good is affected by frictional (iceberg) trading cost. Specifically, $\tau_{ji} > 1$ units must be shipped from region j to sell one unit in region i. Let $\rho_i = \tau_{ji}^{1-\sigma} \in (0,1)$ measure the degree of trade openness in region i.

2.2. Equilibrium of the CP model

The following proposition describes the indirect utility of a skilled worker in region i in equilibrium. A formal Proof is given in Appendix A.

Proposition 1. *For a given s, the indirect utility of a skilled worker in region i is*

$$v_i(s) = \alpha \ln\left(\alpha \frac{r_i}{P_i}\right) + (1-\alpha)\ln((1-\alpha) r_i), \tag{3}$$

where P_i is the CES-price index and r_i is the nominal wage of a skilled worker in region i, and they are given by

$$P_i = \frac{\sigma}{\sigma-1}\left[x_i\beta_i^{1-\sigma} + \rho_i x_j \beta_j^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \tag{4}$$

$$r_i = \frac{1}{\psi}\left[a_i L_i + b_i L_j - L_i x_j\left(a_i a_j - b_i b_j\right)\right], j \neq i, \tag{5}$$

where

$$x_1 = s,$$

$$x_0 = 1 - s,$$

$$a_i = \frac{\alpha \beta_i^{1-\sigma}}{\sigma\left[x_i\beta_i^{1-\sigma} + \rho_i x_j \beta_j^{1-\sigma}\right]},$$

$$b_i = \frac{\alpha \rho_j \beta_i^{1-\sigma}}{\sigma\left[x_j\beta_j^{1-\sigma} + \rho_j x_i \beta_i^{1-\sigma}\right]},$$

$$\psi = 1 - a_0x_0 - a_1x_1 + x_0x_1\left(a_0a_1 - b_0b_1\right).$$

From (3), the inter-regional payoff difference is given by

$$v_1(s) - v_0(s) = \ln\left(\frac{a_1L_1 + b_1L_0 - L_1(1-s)(a_0a_1 - b_0b_1)}{a_0L_0 + b_0L_1 - L_0 s(a_0a_1 - b_0b_1)}\right) + \frac{\alpha}{\sigma-1}\ln\left(\frac{s\beta_1^{1-\sigma} + \rho_1(1-s)\beta_0^{1-\sigma}}{(1-s)\beta_0^{1-\sigma} + \rho_0 s \beta_1^{1-\sigma}}\right). \tag{6}$$

Eq. (6) is comparable to the utility-difference function Eq. (13) in Ottaviano (2001, p. 58).[5] Observe that $\beta_0 \neq \beta_1$ implies that $v_1(1) \neq v_0(0)$, i.e., the wage of a skilled worker under full agglomeration can be different between two regions. The following example plots the inter-regional payoff difference for various combination of parameter values.

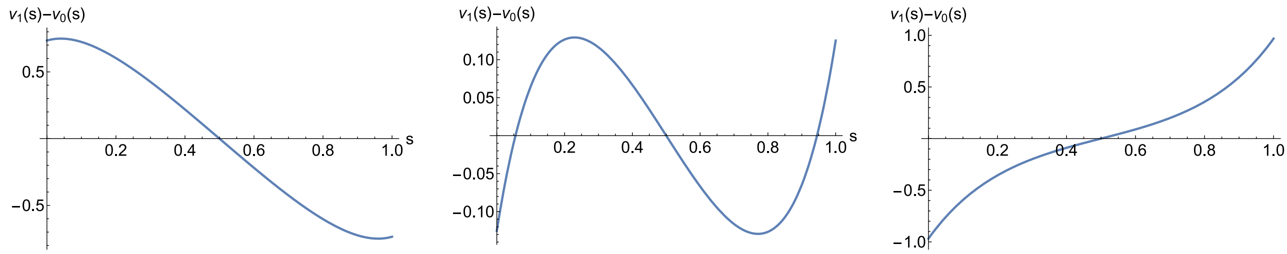
Example 1. (Regional asymmetry) The inter-regional payoff difference can take three alternative shapes (see Ottaviano, 2001, pp. 59, corollary 2, and Fig. 1). In Fig. 1a–c, we plot the payoff difference when the production technology is the same between regions. As discussed in Ottaviano (2001), the shape depicted in Fig. 1a arises for relatively large σ, small α and large τ. The shape depicted in Fig. 1c arises when the converse is true. The shape depicted in Fig. 1b arises for intermediate values of the parameters. The elasticity of substitution σ is different across the three plots. We use $\sigma = 2.66$, $\sigma = 2.58$ and $\sigma = 2.5$ in Fig. 1a–c respectively. Fig. 2 considers the same parametric specification as in Fig. 1, except that the production technologies are different between regions. Specifically, we allow $\beta_1 = 1 < \beta_0 = 1.01$, which implies that production of a variety of modern good requires relatively more unskilled workers in region 0 than in region 1.

The model exhibits agglomeration forces in certain situations. Of particular interest are the cases depicted in Figs. 1c and 2c, in which the inter-regional payoff difference increases monotonically with s, such

[3] Forslid and Ottaviano (2003) also provides an extension of the basic model allowing for the trading cost and the size of the unskilled labor force to vary between the two regions. The model, however, does not incorporate asymmetric production technology, which is necessary in order to create a real wage difference for skilled labor in one region compared to the other under full agglomeration.

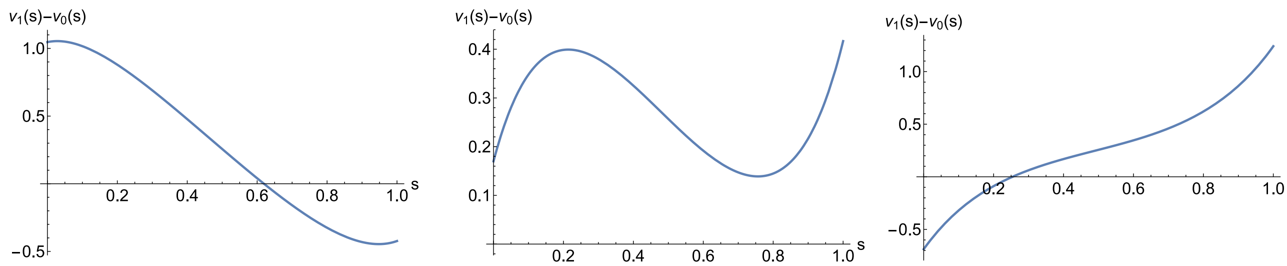
[4] We impose an additional parametric restriction to ensure that the traditional good is produced in both regions in positive quantities at equilibrium. This 'non-full-specialization' condition is given by $\max\left\{\frac{L_0}{L}, \frac{L_1}{L}\right\} < (1-\alpha)/\left[1 - \frac{\alpha}{\sigma}\right]$, see Ottaviano (2001, footnote 5) and Forslid and Ottaviano (2003, footnote 4).

[5] The two functions coincide if two regions are symmetric, i.e., $\rho_0 = \rho_1$, $L_0 = L_1 = \frac{L}{2}$, and $\beta_0 = \beta_1$.



(a) $\sigma = 2.66$ (b) $\sigma = 2.58$ (c) $\sigma = 2.5$

Fig. 1. Indirect-utility functions and inter-regional difference in utility.



(a) $\sigma = 2.66$ (b) $\sigma = 2.58$ (c) $\sigma = 2.5$

Fig. 2. Inter-regional payoff difference, $v_1(s) - v_0(s)$, for different values of σ in the case of symmetric production technology ($\beta_0 = \beta_1 = 1$).
Note: The parameter specification: $L_0 = L_1 = 1, \alpha = 0.5, \beta_0 = \beta_1 = 1, \tau_{01} = \tau_{10} = 2$.

that the skilled workers' location decisions are mutually rewarding or complementary for every s. In these cases, the agglomeration forces exist for all s and the two agglomerated equilibria are potential stable steady states in the long run (see Ottaviano, 2001). To study the long run outcome of this model in presence of agglomeration forces, we therefore focus on the case when the inter-regional payoff difference increases monotonically with number of players migrated to region 1 and develop a dynamic game of migration that can be implemented in an experimental framework. The following assumption is a sufficient condition to ensure that the inter-regional payoff difference increases monotonically with s. In the remainder of the paper, we assume that Assumption 1 holds.

Assumption 1. $v_1(s)$ is strictly increasing in s and $v_0(s)$ is strictly decreasing in s.

3. The migration game

We now proceed by introducing a group-based migration process to address the mobility of skilled workers between regions. We first present the framework and then the analysis.

3.1. The framework

We develop a finite-player, finite-horizon dynamic game of migration to study the mobility of the skilled workforce. To differentiate MB from FB, we model the migration game as a sequence of games, each lasting one period, and allow the players to accumulate payoffs over periods. To see this, consider the population of the skilled workforce split in n groups of equal measure, referred to as players hereafter, and there are n periods.[6] Each player gets one opportunity to migrate and only one player migrates in any period. Unlike the previous literature, we assume a simple migration-cost structure.[7] In every period, one player has zero migration costs while other players have infinite migration costs. In effect, the player with zero migration cost has an opportunity to migrate. We consider an exogenous migration sequence. Without loss of generality, we label a player based on its position in the sequence.

The distribution of the skilled workforce is the common payoff-relevant variable across players and is, therefore, considered as the state variable. Let $s^t \in S := \left\{0, \frac{1}{n}, \ldots, 1\right\}$ denote the fraction of skilled workers in region 1 at the end of period t (or, at the beginning of period $t+1$, $t \in \{0, 1, 2, \ldots, n\}$. For analytical convenience, we consider migration games that start with full agglomeration in region 0, i.e., $s^0 = 0$. Each player has a common action space $A = \{0, 1\}$ such that action 1 refers to migrating to region 1 and action 0 refers to staying in region 0. Since only one player takes an action in each period, we denote the period-t action profile by $a^t \in A$, which is the action taken by player t in period t. Finally, the state-transition probabilities are

$$\Pr(s^t | s^{t-1}, a^t) = \begin{cases} 1 & \text{if } a^t = 1 \text{ and } s^t = s^{t-1} + \dfrac{1}{n} \\ 1 & \text{if } a^t = 0 \text{ and } s^t = s^{t-1} \\ 0 & \text{otherwise} \end{cases}, \tag{7}$$

and it gives the conditional probability that the state s^t is realized at the end of period t (or, beginning of period $t+1$), given the state s^{t-1} at the beginning of period t and an action a^t taken in period t.

A player's temporal utility depends on her location, action a^t and the state s^t in period t. Recall that $v_i(s)$, defined in (3), is the temporal indirect utility of a player in region $i \in \{0, 1\}$ at the state value s. We assume that players discount future payoffs at a common rate δ. For a given state-transition path $\underline{s} = (s^1, s^2, \ldots, s^n) \in S^n$ and a composite action profile $\underline{a} = (a^1, a^2, \ldots, a^n) \in A^n$, player i's aggregate payoff,

[6] To interpret the effect of having finitely many players in an otherwise model with infinite players, we assume that a player represents a strictly positive mass of population. We thus assume away the within-group coordination problem. In our experiment with finite players, a single player will represent a group, and so modeling within-group coordination is not relevant in our context.

[7] Observe, however, that both in our case as well as in the cases considered in previous literature, the cost structure essentially prevents workers from moving all together. See, e.g., Fujita and Thisse (2013, p. 311).

computed at time $t = 1$, is the discounted sum of utilities and can be written as

$$\pi_{i,1}(\underline{s}, \underline{a}) = \sum_{t=1}^{i-1} \delta^{t-1} v_0\left(s^t\right) + \mathbb{1}_{\{a^i=0\}} \sum_{t=i}^{n} \delta^{t-1} v_0\left(s^t\right) + \mathbb{1}_{\{a^i=1\}} \sum_{t=i}^{n} \delta^{t-1} v_1\left(s^t\right), \tag{8}$$

where $\mathbb{1}_{\mathbf{E}}$ takes value 1 if the event **E** occurs, and zero otherwise. Observe that player i moves only in period i, and effects of actions taken in the previous periods are entirely captured in the state-transition path. However, player i's continuation payoff from period i is location-specific and depends on her action in period i. Precisely, for a given state-transition path $\underline{s} \in S^n$ and an action profile $\underline{a} \in A^n$, player i's continuation payoff from period i is

$$\pi_{i,i}(\underline{s}, \underline{a}) = \mathbb{1}_{\{a^i=0\}} \sum_{t=i}^{n} \delta^{t-i} v_0\left(s^t\right) + \mathbb{1}_{\{a^i=1\}} \sum_{t=i}^{n} \delta^{t-i} v_1\left(s^t\right). \tag{9}$$

In general, strategies in a dynamic game can consider a player's action as a complicated function of the preceding history. It is, however, common to restrict attention to Markov strategies in which the past influences the current play only through its effect on the payoff-relevant state variable.[8] A (pure) Markov strategy for player i is a function $\sigma_i : S \to A$. A strategy profile $\underline{\sigma} = (\sigma_1, \ldots, \sigma_n)$ is a Markov perfect equilibrium (MPE) when σ_is are Markov strategies and the strategy profile constitutes a subgame-perfect equilibrium of this finite-horizon dynamic game (Fudenberg and Tirole, 1991).[9] We consider MPE in pure strategies as the solution concept of the game. It is worth pointed out that the requirement of perfection in MPE is intimately linked to the idea of sequential rationality. It requires that the equilibrium strategies must reflect optimal behavior in the continuation game at any state even if that state may not necessarily be realized along the equilibrium path. Consequently, the set of MPE can be smaller than the set of all equilibria of the dynamic game.

3.2. Analysis

We study the equilibrium outcomes in two different cases:

1. MB – the migration decision is based on one-period utility gain from migration. Specifically, every player considers $\delta = 0$ and it is common knowledge.
2. FB – the migration decision is based on the accumulated utility flows over all the remaining periods and under the belief that all other groups are forward-looking. Specifically, every player considers $\delta = 1$ and it is common knowledge.

3.2.1. MB

Since every player only cares about the current period payoff and only one player moves in each period, players' behaviors are non-strategic in MB and the analysis is trivial. Given a state value s, player i's payoff from migrating is $v_1(s + \frac{1}{n})$ and from not migrating is $v_0(s)$. The optimal strategy is straightforward and given by[10]

$$\sigma_i(s) = \sigma(s) = \begin{cases} 1 & \text{if } v_1\left(s + \frac{1}{n}\right) > v_0(s) \\ 0 & \text{otherwise} \end{cases}. \tag{10}$$

The strategy profile $(\sigma(s), \ldots, \sigma(s))$ constitutes the unique equilibrium of the n–player game. If $v_0(0) < v_1(\frac{1}{n})$, then player 1 migrates to region 1. Given Assumption 1, all the following players migrate. On the other hand, If $v_1(\frac{1}{n}) \le v_0(0)$, none of the players find incentive to migrate. Therefore, there are only two possible outcomes – every player either stays in region 0 or migrates to region 1, depending on whether or not the following condition holds:

$$v_1\left(\frac{1}{n}\right) \le v_0(0). \tag{MB0}$$

The following proposition documents this finding. The Proof is straightforward and skipped.

Proposition 2. *Consider the migration game with n myopic players. In the unique equilibrium, there will be full agglomeration either in region 0 or in region 1. If (MB_0) holds, no player migrates and $s^n = 0$. If (MB_0) does not hold, every player migrates and $s^n = 1$.*

The above proposition points out history dependency in the migration game with myopic players. To see this, suppose that $v_1(0) < v_0(0)$. Then, condition (MB_0) holds for sufficiently large n. Therefore, if the population is partitioned in sufficiently fine groups, the economy will remain at the initial agglomerated state. Suppose instead that $v_1(0) > v_0(0)$. Then, condition (MB_0) is violated for any n and the whole population of skilled workers move to region 1 in any n–player migration game. Therefore, an inter-regional real wage difference at the initial state drives the outcome of the migration game.

3.2.2. FB - perfect equilibrium in markov strategies

We next analyze the migration game with forward-looking players (i.e., $\delta = 1$). In a finite-horizon dynamic game with perfect information, there always exists a pure-strategy MPE (see Fudenberg and Tirole, 1991, Chapter 13.2.2). The following lemma shows that in any MPE, players' optimal strategies are threshold strategies and the thresholds are increasing in the player's position in the migration sequence. We prove the lemma by backward induction and the Proof is included in Appendix A.

Lemma 1. *There exist thresholds $\bar{s}_i$, $i \in \{1, 2, \ldots, n\}$ with $\bar{s}_i - \frac{1}{n} \le \bar{s}_{i-1} < \bar{s}_i$ such that in any MPE, the optimal strategy of player i is given by*[11]

$$\sigma_i(s) = \begin{cases} 1 & \text{if } s > \bar{s}_i \\ 0 & \text{if } s \le \bar{s}_i \end{cases}. \tag{11}$$

Further, the threshold $\bar{s}_i$, $i \in \{i, \ldots, n\}$ uniquely solves[12]

$$v_0(s) = \frac{1}{n - i + 1} \sum_{t=1}^{n-i+1} v_1\left(s + \frac{t}{n}\right). \tag{12}$$

For player n, the threshold $\bar{s}_n$ solves $v_0(s) = v_1(s + \frac{1}{n})$ and it coincides with the corresponding threshold derived in MB; see (10). However, the preceding players have weaker thresholds – they are willing to migrate at lower state values. This is because their incentives to migrate are driven by the expectation that future players would follow suit and all would benefit from increased migration to region 1. In particular,

[8] The restriction of strategy space is also suitable for our experimental analysis, in which subjects receive only payoff-related information.

[9] Observe that only players $t+1, \ldots, n$ take actions period $(t+1)$ onward. Therefore, a strategy profile $\underline{\sigma} = (\sigma_1, \ldots, \sigma_n)$ is a subgame-perfect equilibrium of the n–periods game if, for any history of play $h_t = (a^1, \ldots, a^t)$, $t \in \{1, 2, \ldots, n\}$ ending in a state $s \in S$, the continuation strategy profile $\underline{\sigma}|_{h_t} = (\sigma_{t+1}, \ldots, \sigma_n)$ is a Nash equilibrium of the $(n-t)$–periods continuation game starting at the state s.

[10] We use the tie-breaking rule that players do not migrate if they are indifferent between migration and no migration.

[11] Similar to MB, here we consider the tie-breaking rule that players do not migrate if they are indifferent between migration and no migration.

[12] Although we solve the problem in case of no future discounting ($\delta = 1$), the results are quite similar in the general problem with a discount factor of $\delta \in [0, 1]$. The corresponding threshold $\bar{s}_i$ satisfies $v_0(s) \sum_{t=1}^{n-i+1} \delta^{t-1} = \sum_{t=1}^{n-i+1} \delta^{t-1} v_1(s + \frac{t}{n})$.

player 1 has the least demanding migration threshold $\bar{s}_1$, which solves $v_0(s) = \frac{1}{n}\sum_{t=1}^{n} v_1(s + \frac{t}{n})$. Building on Lemma (1), the following lemma shows that any pair of consecutive players must take the same action in any MPE. The Proof is included in Appendix A.

Lemma 2. *In any MPE, player $i+1$ migrates if and only if player i migrates for any $i \in \{1, \dots, n-1\}$.*

The above lemma implies that only two action profiles can occur in a MPE – one in which every player migrates and the other in which no player migrates. The action of the first player determines which action profile we observe in equilibrium. Player 1 migrates if and only if $\bar{s}_1 < s^0 = 0$, which is, given Assumption 1, equivalent to the following condition:

$$v_0(0) < \frac{1}{n}\sum_{t=1}^{n} v_1\left(\frac{t}{n}\right). \tag{MPE1}$$

The following proposition characterizes the unique MPE of the game. The Proof directly follows from the above discussion and is skipped.

Proposition 3. *Consider the migration game with n forward-looking players. In the unique MPE, there will be full agglomeration either in region 0 or in region 1. If (MPE_1) holds, every player migrates and $s^n = 1$. If (MPE_1) does not hold, no player migrates and $s^n = 0$.*

3.2.3. FB - non-perfect equilibrium in markov strategies

The requirement of perfection and the assumptions of strict monotonicity of the indirect utility functions result in a unique MPE. There can be other equilibria in Markov strategies that do not satisfy the requirement of perfection in all possible continuation games. The following lemma shows that similar to the case of MPE, only two possible action profiles can be sustained in any non-perfect equilibrium in Markov strategy – either every players migrates or no one does. The key to proving this result is showing that whenever there is a pair of consecutive players taking different actions, a unilateral deviation by one of the pair is profitable. The technical Proof is included in Appendix 7.

Lemma 3. *In any Markov equilibrium, either $a^i = 0$ for all $i \in \{1, \dots, n\}$, or, $a^i = 1$ for all $i \in \{1, \dots, n\}$.*

Let us first consider the action profile $a^i = 0$ for all $i \in \{1, \dots, n\}$. In period i, player i has a continuation payoff of $(n - i + 1)v_0(0)$ by playing $a^i = 0$, and a unilateral deviation gives her a continuation payoff of $(n - i + 1)v_1(\frac{1}{n})$. Therefore, the condition for no unilateral deviation is

$$v_1\left(\frac{1}{n}\right) \leq v_0(0), \tag{NPE0}$$

which is same as the condition under which we observe $s^n = 0$ in MB. The strategy profile that sustains the above action profile in a non-perfect equilibrium is not necessarily unique. One specific strategy profile of interest, because of symmetry and extremity, is the Markov strategy profile $(\sigma(s), \dots, \sigma(s))$ such that $\sigma(s) = 0$ for all $s \in [0, 1]$. This strategy profile constitutes an equilibrium if (NPE_0) holds.[13] However, the strategy profile violates subgame perfection.[14]

Next, consider the action profile $a^i = 1$ for all $i \in \{1, \dots, n\}$. Player i gets a continuation payoff of $\sum_{t=i}^{n} v_1(\frac{t}{n})$ by playing $a^i = 1$, and a unilateral deviation gives her a continuation payoff of $\sum_{t=i}^{n} v_0(\frac{t-1}{n})$. A unilateral deviation is not beneficial to player t if $\sum_{t=i}^{n} v_0(\frac{t-1}{n}) < \sum_{t=i}^{n} v_1(\frac{t}{n})$. From Assumption 1, it follows that if the no-unilateral-deviation condition holds for player i, it must hold for player $i+1$. Therefore, we can express the condition for no unilateral deviation by any player as

$$\frac{1}{n}\sum_{t=1}^{n} v_0\left(\frac{t-1}{n}\right) < \frac{1}{n}\sum_{t=1}^{n} v_1\left(\frac{t}{n}\right). \tag{NPE1}$$

As with the previous case, the strategy profile sustaining the above action profile in a non-perfect equilibrium is not unique. One specific profile of interest is an extreme strategy profile, in which every player decides to migrate in every possible state, i.e., $\sigma(s) = 1$ for all $s \in [0, 1]$. This strategy profile constitutes an equilibrium if (NPE_1) holds.

The two conditions (NPE_0) and (NPE_1) are collectively exhaustive but not mutually exclusive – for any parameter specification of the model, we will have at least one, and sometime both, of the two types of non-perfect equilibria present.[15] The following proposition documents the findings. The Proof follows from the above discussion and is skipped.

Proposition 4. *There always exists a non-perfect equilibrium in Markov strategies in the migration game with n forward-looking players. If (NPE_0) holds, there always exists a non-perfect equilibrium such that no player migrates and $s^n = 0$. If (NPE_1) holds, there always exists a non-perfect equilibrium such that every player migrates and $s^n = 1$.*

The action profile in any perfect or non-perfect equilibrium under FB is associated with a set of self-fulfilling expectations, since a player's migration decision depends on expectations of future utilities, which depend on actions of other players. If the conditions (NPE_0) and (NPE_1) are simultaneously satisfied, there exist multiple expectation-driven equilibria (in Markov strategies), which differ in the final outcome.

Of particular interest to our experimental design is the case when (NPE_0) and (MPE_1) are simultaneously satisfied:

$$v_1\left(\frac{1}{n}\right) < v_0(0) < \frac{1}{n}\sum_{t=1}^{n} v_1\left(\frac{t}{n}\right). \tag{13}$$

There are several reasons for it. First, by Assumption 1, (MPE_1) implies (NPE_1). Therefore, when (13) holds, we continue to have multiple expectation-driven equilibria and we can test whether the expectation consistent with perfect FB plays a dominant role in determining the final outcome. Secondly, (MB_0), which coincides with (NPE_0), holds given (13). Therefore, the prediction under MB is distinctly different from that under perfect FB. It allows us to investigate whether MB is a good approximation against perfect FB for predicting the long run outcome. It is worth pointing out that there always exists a non-perfect equilibrium of FB, the outcome of which coincides with the outcome of the unique MPE.[16] It is, therefore, not feasible to distinguish perfect and non-perfect behaviors from observing the outcome of the migration game.

For our experiment, we construct indirect utility functions $v_1(s)$ and $v_0(s)$, satisfying (13), such that the unique prediction under MB is complete agglomeration in region 0 and the unique prediction under perfect FB is full agglomeration in region 1. We vary the number of players or, equivalently, the partitioning of the population, and study the outcome of the migration game.

4. Experimental study

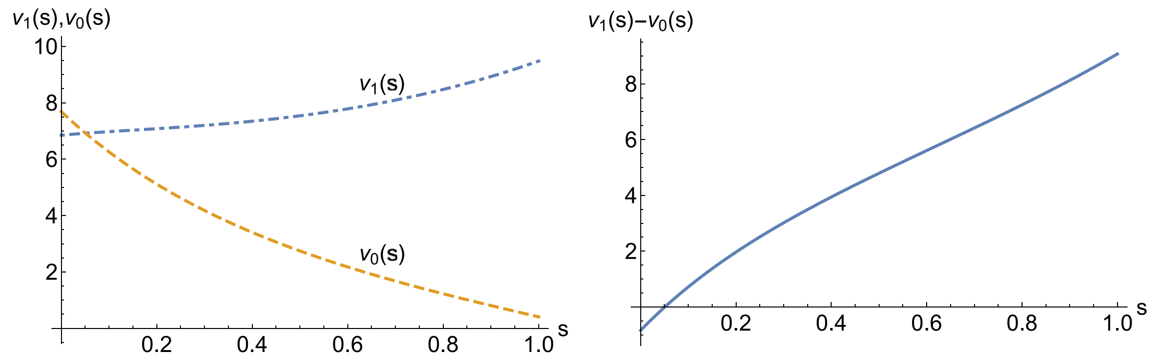
We start with some numerical examples that we adopt in the experiment. Treatments are labeled reflecting the number of players in the

[13] Similarly, a threshold Markov strategy profile $(\sigma_1(s), \dots, \sigma_n(s))$ satisfying (11), for which $\bar{s}_1 > 0$ and $\bar{s}_i > \frac{1}{n}$ for all $i \in \{2, \dots, n\}$, constitutes an equilibrium if (NPE_0) holds and we have $a^1 = a^2 = \dots = a^n = 0$ along the equilibrium path. The strategy, however, violates subgame perfection.

[14] For example, if $v_1(s + \frac{1}{n}) > v_0(s)$ for some $s > 0$, then a player will deviate from the strategy $\sigma(s) = 0$ at that s. In fact, if (MPE_1) holds, then there will always be some $s > 0$ such that $v_1(s + \frac{1}{n}) > v_0(s)$ even if $v_0(0) > v_1(\frac{1}{n})$.

[15] The fact that (NPE_0) and (NPE_1) are collectively exhaustive can be proved by showing that (NPE_1) must hold if (NPE_0) does not hold. Further, both (NPE_0) and (NPE_1) are simultaneously satisfied if $v_1(\frac{1}{n}) < v_0(0) < \sum_{t=1}^{n} v_1(\frac{t}{n})$.

[16] This is because if (MPE_1) holds, then (NPE_1) holds and if (MPE_1) does not hold, then (NPE_0) holds.



(a) Indirect-utility functions $v_0(s)$ and $v_1(s)$ (b) Utility difference: $v_1(s) - v_0(s)$

Fig. 3. Inter-regional payoff difference, $v_1(s) - v_0(s)$, for different values of σ in the case of asymmetric production technology ($\beta_0 = 1.01 > \beta_1 = 1$). Note: The parameter specification: $L_0 = L_1 = 1,\ \ \alpha = 0.5,\ \ \beta_0 = 1.01,\ \ \beta_1 = 1,\ \ \tau_{01} = \tau_{10} = 2$.

Table 1
Payoff at different state values with $n = 2$.

	$n_0(s)$	$v_0(s)$	$n_1(s)$	$v_1(s)$
$s = 0$	2	7.7	0	6.8
$s = 1/2$	1	2.7	1	7.5
$s = 1$	0	0.4	2	9.5

Table 2
Payoff at different state values with $n = 3$.

	$n_0(s)$	$v_0(s)$	$n_1(s)$	$v_1(s)$
$s = 0$	3	7.7	0	6.8
$s = 1/3$	2	3.9	1	7.2
$s = 2/3$	1	1.8	2	8.0
$s = 1$	0	0.4	3	9.5

game: *T*2 when 2 players, *T*3 when 3, and *T*4 when 4. A discussion of the experimental design to test the behavioral difference follows after the examples.

4.1. Numerical examples with parameters adopted in the experiment

The following examples consider indirect utility functions satisfying Assumption 1 and the condition (13), such that the unique equilibrium under MB is full agglomeration in region 0 (i.e., $s^n = 0$) and the unique MPE under FB is full agglomeration in region 1 (i.e., $s^n = 1$). We use the following parameter specifications to derive the indirect utility functions (equations (3)–(5)):

$$(L_0 = 1, L_1 = 1.25, \alpha = 0.5, \beta_0 = 1.363, \beta_1 = 1.15, \sigma = 2, \tau_{01} = \tau_{10} = 2.55)\,.$$

The indirect utility functions are illustrated in Fig. 3a and the inter-regional difference in utility in Fig. 3b. The examples differ in the number of players, i.e., the fraction of the population with migration opportunity in a period.

Example 2. (Treatment *T*2) Consider $n = 2$. The indirect utilities at various state values are given in Table 1 (where $n_i(s)$ refers to the number of players in region i at the state value s). The payoff functions satisfy (13) with $n = 2$.

Example 3. (Treatment *T*3) Consider $n = 3$. The indirect utilities at various state values are given in Table 2. The payoff functions satisfy (13) with $n = 3$.

Example 4. (Treatment *T*4) Consider $n = 4$. The indirect utilities at various state values are given in Table 3. The payoff functions satisfy (13) with $n = 4$.

Table 3
Payoff at different state values with $n = 4$.

	$n_0(s)$	$v_0(s)$	$n_1(s)$	$v_1(s)$
$s = 0$	4	7.7	0	6.8
$s = 1/4$	3	4.6	1	7.1
$s = 1/2$	2	2.7	2	7.5
$s = 3/4$	1	1.4	3	8.3
$s = 1$	0	0.4	4	9.5

4.2. Experimental design

The experiment was conducted at the Laboratorio de Economía Experimental (LEE) at Jaume I University (Spain). Experimental subjects gave their explicit informed consent to be included in the ORSEE database of LEE prior to being called to any session. The recruitment process of the laboratory was approved by the Deontology Commission of Jaume I University and subject data are stored following the data protection recommendations of the European Commission (GDPR, 2016).

The subjects were incentivized by earning real money depending on performance (paid in cash when leaving the lab): on average 24.40 euros, ranging from 13.60 to 42.70. The time spent in the lab was on average a little less than 2 h. The experiment was implemented as a computerized laboratory experiment programmed using the standard software z-Tree (Fischbacher, 2007).

The experiment contains 3 different treatments, with controls for reasoning ability,[17] risk aversion,[18] and inequity aversion.[19] We will first give a general outline of the design and then turn to more details on the different treatments.

According to Binmore (1999), economic theory can only be expected to predict in the laboratory if "the problem the subjects face is not only 'reasonably' simple in itself, but is framed so it seems simple to the

[17] Based on the reasoning ability scale of the Differential Aptitude Test. We use the Spanish version (Cordero and Corral, 2006): The 20 image series of the test are not programmed, they are presented on paper and only the answers are introduced within 20 min maximum time.

[18] The test by Sabater-Grande and Georgantzís (2002) was developed in our laboratory and is our standard measure of risk aversion. Using this test, Barreda-Tarrazona et al. (2011) obtain an estimate of a CRRA coefficient that is perfectly in line with the one estimated by Harrison et al. (2009) based on the more common Holt and Laury (2002) test.

[19] The Altruism scale (or inequity aversion test) consists of 4 situations that require an agent to sacrifice money to benefit another partner in a series of dictator like choices. The choices were taken from Charness and Rabin (2002).

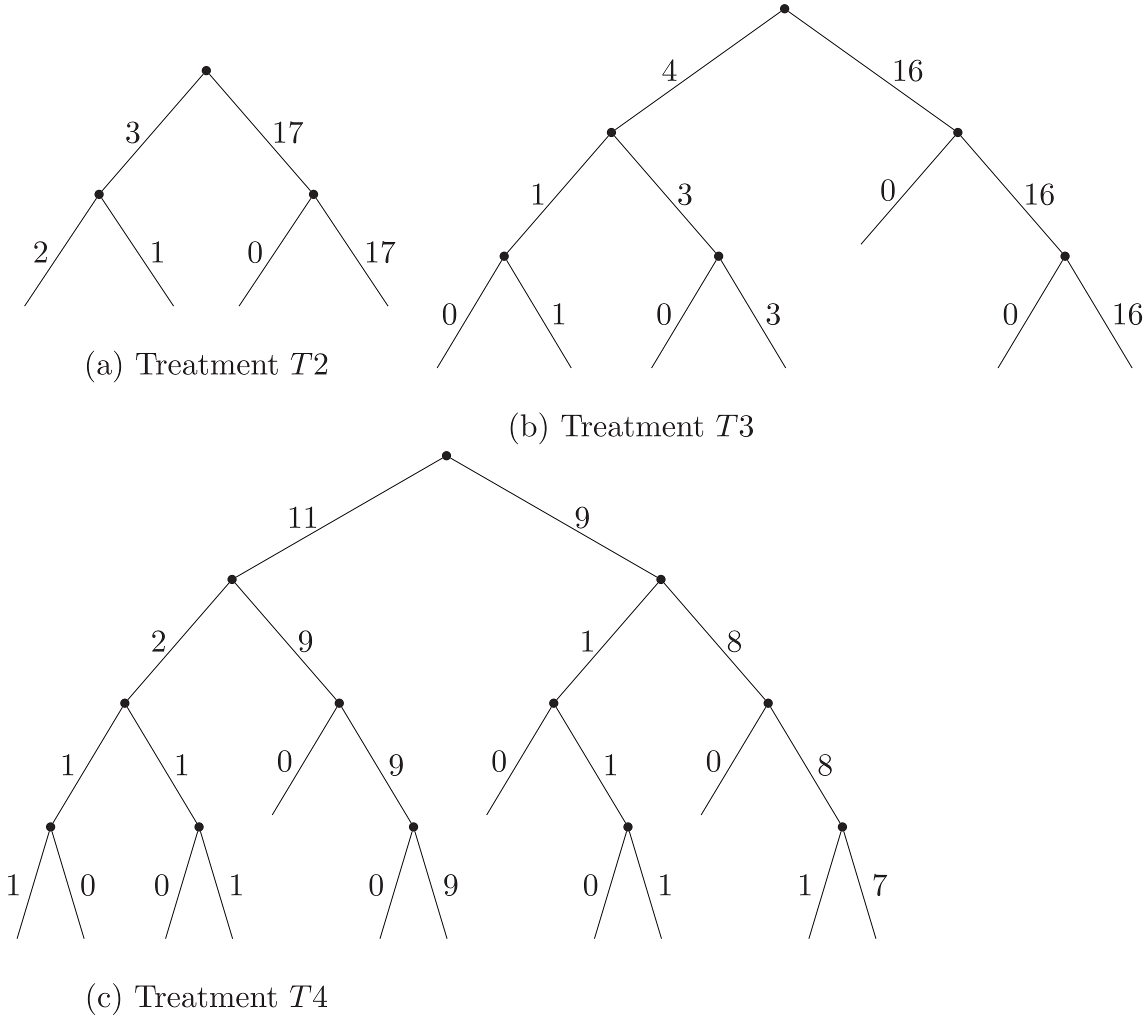


Fig. 4. Decisions by treatment on extensive form. Note: Number of stay (move) decisions to the left (right) of each node.

subjects". Hence, we use a framed experiment.[20] To keep the design clean, the treatments vary in one dimension only: the number of players (2, 3 or 4). Recall that, we denote treatments accordingly as *T*2, *T*3 and *T*4. *T*2 and *T*3 were run in November 2016 and *T*4 in March 2017. The baseline (*T*2) is described by low substitutability (low σ) and 2 players, both initially in region 0 (none in region 1).

In order to make the payoffs in the tables easy to compare for the subjects, we made a transformation with payoff equal to 200 x utility from the parameterized theoretical model minus 12.5. Payoff tables were made available to the subjects during the experiment and a comprehension test was run prior to the experiment in order to ensure that the task was fully understood.

We consider 20 independent observations per treatment variation a minimum for meaningful statistical inference. In the baseline treatment (*T*2), both players are initially in region 0. This calls for 40 subjects that play in either first or second position. *T*3 calls for 20 (independent observations) times 3 players per observation = 60 subjects. *T*4 requires another 80 subjects. With a pure between subject design, this implies 180 subjects in total playing a one-shot game.

In *T*2, the baseline treatment, the 40 subjects were randomly matched into 20 fixed pairs. In each pair, one subject was randomly designated as decision maker in the first period and the second subject left to make the decision in the second period.

In *T*3, the 60 subjects were randomly matched into 20 fixed triplets. To allow each subject to act as the single decision maker in each group in any period, the number of periods compared to the baseline treatment increased from 2 to 3.

In *T*4, we had 80 subjects randomly matched into 20 fixed quadruples. Each group played for 4 periods to let all subjects make decisions as they did in the previous treatments.

5. Results

We will first present and comment on the data for all decisions by treatment on extensive form. All decision data are presented in Fig. 4, whereas data on decisions to stay conditional on full agglomeration in region 0 are summarized in Table 4. Notice that only data on decisions in the first period can be used to discriminate between FB and MB across all treatments. We will therefore concentrate the analysis on this subset of data after we have presented and commented on all decision data.

In *T*2, only the first period decision matters for testing the hypothesis of perfect or sequentially rational FB (see Fig. 4 panel (a), first node, and Table 4, first row). 17 out of 20 subjects (85 percent) decided in the first period to move to region 1, consistent with the MPE in FB (inconsistent with MB). In the second period, in 2 out of the 3 pairs where the first period decision maker did choose to stay, the second period decision maker also made the decision to stay which is perfectly rational

[20] As emphasized by Loewenstein (1999, p. F30), "The context-free experiment is, of course, an elusive goal … Nor would a context-free experiment necessarily be a good thing if it were possible." For the context provided to subjects in our experiment, see the instructions in Appendix B.

Table 4
Decision to stay conditional on full agglomeration in region 0.

Treatment	Period 1	Period 2	Period 3
*T*2	3/20		
*T*3	4/20	0/4	
*T*4	11/20	2/11	1/2

Note: Number of decision makers in each period is 20 in each treatment. In total 60 in period 1, 60 in period 2, 40 in period 3 (*T*3 and *T*4) and 20 in period 4 (*T*4). Only period 1 is relevant for discriminating between MB and perfect FB in *T*2, period 1 and 2 are relevant for *T*3, and all periods except period 4 for *T*4. Only period 1 is relevant for all treatments.

Table 5
Treatment differences first period migration decisions.

	T2	T4
*T*3	$p = 1.000$	$p = 0.048$
*T*4	$p = 0.018$	

Note: N = 20 in each treatment. Wilcoxon signed rank tests (Mann Whitney U tests). The *p*-values have been Bonferroni corrected for multiple comparisons by multiplying by 2. The distribution of Period 1 migration decisions in the *T*3 treatment is not significantly different from the *T*2 baseline treatment, the *T*4 is (at the 2 percent level). *T*3 is significantly different from *T*4 (at the 5 percent level).

since payoff is 7.7 instead of 7.5 by moving. In one case, however, the second period decision maker made the decision to move.

In *T*3, as in the baseline treatment, the first period decision discriminates between MB and the MPE in FB. But now, also the second period decision may discriminate between the two, provided the first-period decision in the group was consistent with MB (see Table 4, second row). Just as in the baseline treatment, the last period decision is irrelevant for testing apart from discriminating between rational and irrational behavior. In the first period, 4 out of 20 subjects (20 percent) made the decision to stay in region 0, consistent with MB (see Fig. 4, panel (b), first node). Comparing first round behavior to the baseline treatment, the increase from 15 to 20 percent is clearly not enough to be statistically significant (see Table 5). In the second period, conditional on first period decision to stay, a decision to stay is consistent with MB and a decision to move consistent with the MPE in FB. The difference in payoff is small, but the decision context very simple. In 3 out of the 4 groups where the first period decision was to stay, the second period decision maker decided to move consistent with the MPE in FB. In the third period, perfect FB calls for a decision to move if at the beginning of this period there is at least already one subject in Region 1 (giving at least 8.0 by moving as opposed to maximum 3.9 by staying, according to Table 2) while the third mover should rather stay if the two preceding players also stayed (7.7 staying against 7.2 moving). Again, there is one subject (the one who should have stayed given the previous players in his group did not migrate) who fails to make the corresponding payoff maximizing decision.

In *T*4, unconditional discrimination between the two behavioral hypotheses is feasible in the first period as for all treatments. We may also compare second period decisions conditional on first period decisions consistent with MB to *T*3. In *T*4, it may even be feasible to discriminate between MB and perfect FB in the third period (see Table 4, row 3). Starting with the first period, now only 9 out of 20 decision makers chose to move (see Fig. 4, panel (c), first node). Hence, 11 out of 20 chose to stay consistent with MB. This is up 30 percentage points compared to baseline and clearly significant (see Table 5). Is there any evidence consistent with MB also in the second period? In 2 out of the 11 groups with MB in first period, the second period decision was also to stay consistent with MB. Finally, in the third period, for 1 out of the 2 groups that were still agglomerated in region 0, the third period decision was to stay consistent with MB.

We now concentrate on the first period where the decision can be used to discriminate between perfect FB and MB across all treatments. We start by asking if the first-period decision-makers are different across treatments in terms of background variables and the incentivized test results. Could difference in behavior in *T*4 compared to *T*3 and *T*2, be explained by an atypical sample of subjects? The answer is negative. Background variables are not too dissimilar across treatments, as can be seen from Table 6 (age, gender, laboratory experience, start of major, and standards of living). Neither is there any reason for concern regarding the test results (see Table 7).

In order to probe deeper into the possible effect of background variables and incentivized test results on the first period decision, we also did a regression analysis. Results are presented in Table 8. The results for the two tests for Inequity Aversion (IA1 interpreted as a measure of envy and IA2 interpreted as a measure of fairness) were clearly correlated (Spearman's rank correlation coefficient equal to 0.463 with *p*-value = 0.000). We therefore integrated the two into one measure when we did the regressions.

In the logit regression pooled over treatments, we observe a very significant (at the 1 percent level) negative effect of the most complex Treatment 4 on the likelihood of first period decision makers to actually choose to move. In fact, the dummy variable for *T*4 is the only significant variable on the 5 percent level as we can observe from first column in Table 8.

Analyzing the drivers of the first mover decisions in *T*4, we observe from the second column in Table 8 that both reasoning ability and economics background increase the likelihood of moving. In short, our regression analysis confirms the result obtained in the Wilcoxon signed rank tests: The increase in the number of players is the main identifiable driver of the increase in MB-consistent behaviors among treatments.

Is the outcome of our experiment in complex situations with increased number of decision makers likely due to MB or something else? At least two arguments could be suggested against myopic behavior. First, agents' behavior can follow expectations consistent with some non-perfect equilibrium under FB. Specifically, in one of the non-perfect equilibria in Markov strategies, staying is an equilibrium on the belief that all are staying and in such a case, staying may therefore have nothing to do with MB. While this is true, we may ask why subjects in the last treatment (*T*4) should have this belief and not the subjects in the other two treatments (*T*2 and *T*3)? Further, since the outcome in this non-perfect equilibrium with FB always coincides with the outcome under MB, the assumption of MB can still be considered as a good approximation for the prediction purpose.

The second argument could be that subjects have preferences not reflected in the theoretical model where only real wage differences are assumed to matter. For example, Inequity aversion could be a reason for not migrating in our game, as late movers stuck in a region that loses population see their income reduced while migrants see their income increased after new arrivals. Apart from controlling for individual inequity aversion in our regressions, without observing any significant effect, in order to shed further light into the question of whether inequity aversion was an important consideration for our subjects and whether it was distinctly so in the different treatments, we turn to our post-experiment questionnaire, in which we asked participants about the strategy they had followed in the migration game. In the great majority of cases, migrants declared to have consciously followed their egoistic interest even being aware of imposing lower gains on later movers, thus disregarding any inequity aversion. In the case of the stayers, about 20% of them declare, homogeneously for all treatments, to

Table 6
Subject characteristics for first period decision makers by treatment.

Treatment	N	Age	Female Proportion	Lab experience	Start major	Standards of living
*T*2	20	21.80	0.45	2.75	2014	2.00
*T*3	20	22.45	0.30	2.50	2014	2.45
*T*4	20	22.55	0.55	2.80	2013	2.40

Note: Means. Lab experience measured from 1 = no experience to 5 = more than 9 times (3 is 4–6 times and 2 is 1–3 times). Living standards measured from 1 = affluent to 4 = very poor (2 is acceptable conditions and 3 is non-acceptable but slightly better than 4).

Table 7
Incentivized controls first period decision makers by treatment.

Treatment	N	Reasoning ability	Risk aversion	IA1	IA2
*T*2	20	5.0	4.2	1.4	1.4
*T*3	20	4.5	3.3	1.5	1.4
*T*4	20	4.9	4.7	1.6	1.4

Note: Means. Reasoning ability is measured by the profit earned from solving the 40 tasks of the Differential Aptitude Test. Risk aversion is measured by a scale based on the four items used by Sabater-Grande and Georgantzís (2002) - a higher number implies higher risk aversion. Inequity aversion is based on the four items used by Charness and Rabin (2002). IA1 for the two first items (averse against getting less than the others) and IA2 for the last two (averse against getting more than the others).

Table 8
Regressing decision by first period decision makers on treatments, incentivized controls and background variables.

Dependent variable: Move	All treatments (N = 60)	T4 (N = 20)
*T*3	−0.725(0.98)	
*T*4	**−2.921*****(0.92)	
Altruism Scale	0.770*(0.41)	4.516(2.80)
Risk aversion Scale	−0.054(0.38)	0.645(2.47)
Reasoning ability	0.060(0.06)	**0.393****(0.16)
Female	0.521(0.72)	0.638(3.13)
Age	0.224(0.22)	0.092(0.18)
Economics Major	0.409(0.83)	**7.147****(3.03)
Lab Experience	−0.216(0.29)	−0.933*(0.49)
Financial Situation	0.028(0.43)	−0.950(1.06)
Constant	−4.118(4.57)	−14.855(8.30)
R-squared	0.21	0.48

Note: Logit Regressions for first period decision makers for all treatments (left) and for T4 only. Entries are coefficient estimates with robust standard errors. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. *T*2 is left out in the pooled regression and will be picked up by the constant term. *R*-square for logit is a pseudo *R*-square.

have done it in order to maximize joint profits (which are symmetrically shared, given that all stay in the collusive solution), so we have no hint of increased importance of inequity aversion in any treatment, while 30% of the stayers (54% in *T*4) incorrectly thought to be maximizing own profit by not migrating, which points instead to some kind of myopia (increased in *T*4). Further, we find that higher reasoning ability significantly decreases the likelihood of behaving in a way consistent with MB in the most complex treatment.

6. Concluding remarks

In this paper, we study migration dynamics in the CP model of New Economic Geography. More specifically, we investigate the behavioral foundation of the perfect FB hypothesis. By implication, we also shed light on whether MB can be a good approximation for predicting the long run outcome. We use the analytically tractable elaboration by Forslid and Ottaviano (2003) of the original CP model (Krugman, 1991b) as basis for developing a game theoretical framework adapted to experimental analysis.

The paper contributes to the literature in several important ways: The first contribution lies in developing a theoretical framework suitable for experimental testing. To do so, we introduce a group-based migration process in the standard New Economic Geography framework and proceed by operating with a finite number of agents reflecting that the number of subjects in the laboratory is always finite. We also introduce sufficient asymmetry to make locations different with complete agglomeration in order to make places clearly distinctive for potential migrants. Our theoretical findings show that the outcome of the migration game can be different based on whether agents follow MB or perfect (sequentially rational) FB.

The second contribution lies in testing the model predictions by designing and running a framed experiment that closely captures the migration incentives considered in our theoretical study. Our experimental findings show that perfect or sequentially rational FB is less likely to prevail with a large number of participants in the migration game. More specifically, we find behavior consistent with perfect FB in treatments with 2 and 3 players (*T*2 and *T*3). However, with 4 players (*T*4), a majority retreat to behavior consistent with MB. It therefore seems that it does not take much complexity to reach a threshold where MB-consistent dynamics can be a good approximation for predicting the long run outcome from a behavioral perspective.

Number effects, similar to what we find, have also been found in other game theory experiments. Studying experimental oligopolies, Huck et al. (2004), using a neutral frame, find collusion in simultaneous games with 2 and 3 agents, but market outcomes at Cournot or above in games with 4 and more agents. Closer to our experiment, Dufwenberg and van Essen (2018) find behavior consistent with backward induction in a sequential game with two agents, but not when the number of agents is increased to 3 or 4. We may therefore ask if the number effect found in these very different settings could be the result of a more general phenomenon that could be revealed through additional experimental work.

Author statement

All authors have contributed equally to the paper.

Funding

Financial support by the Spanish Ministry of Science, Innovation and University (RTI2018-096927-B-100), Jaume I University (UJI-B2018-76/77) and UiT The Arctic University of Norway (grant 381940) are gratefully acknowledged.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

Earlier versions of this paper have been presented at the WRSA meeting in 2016, ICASS IX in 2017 and ESA European Meeting 2019. Thanks to participants and to members of the Arctic Economic Science (UArctic) network for helpful comments. We also want to thank Fuad Aleskerov, Lee Huskey, and Daniel Spiro for fruitful discussions. The usual disclaimer applies.

A. Proofs

Proof of Proposition 1

Proof. The proof follows the standard techniques used in characterizing the equilibria of typical CP models. For notational convenience, in this proof, we will generically use x_i to refer to the size of the skilled workers in region $i \in \{0,1\}$. For a given s, $x_0 = 1-s$ and $x_1 = s$. Let p_i^A denote the price of the traditional good in sector $i \in \{0,1\}$. The assumption of perfect competition in the traditional sector implies marginal cost pricing so that the price equals the wage of an unskilled worker. Further, the assumption of free trade of the traditional good implies that prices are the same between the regions. Without loss of generality, we consider the traditional good as numeraire, so that $p_i^A = w_i = 1$ for $i \in \{0,1\}$. We let $p_{ij}(q)$ denote the price of a variety q of the modern good D, which is produced in region j but sold in region i. Given the CES-type demand by residents in region i, we can write the CES price index P_i in region i as

$$P_i = \left[\int_0^{n_i} p_{ii}(q)^{1-\sigma} dq + \int_0^{n_j} p_{ji}(q)^{1-\sigma} dq\right]^{\frac{1}{1-\sigma}}. \tag{A.1}$$

An individual consumer in region i has income m_i, which equals r_i if she is a skilled worker or 1 if she is an unskilled worker. The total income in region i as $M_i = x_i r_i + L_i$. An individual consumer maximizes her utility, given by (1), subject to the budget constraint $\int_0^{n_i} p_{ii}(q) d_{ii}(q) dq + \int_0^{n_j} p_{ji}(q) d_{ji}(q) dq + A_i = m_i$. The solution of the utility-maximization problem gives the following individual demand:

$$d_{ji}(q) = \frac{p_{ji}(q)^{-\sigma}}{P_i^{1-\sigma}} \alpha m_i, A_i = (1-\alpha) m_i, i,j \in \{0,1\}. \tag{A.2}$$

The CES composite D_i of the modern varieties is

$$D_i = \alpha m_i \left[\int_0^{n_i} d_{ii}(q)^{\frac{\sigma-1}{\sigma}} dq + \int_0^{n_j} d_{ji}(q)^{\frac{\sigma-1}{\sigma}} dq\right]^{\frac{\sigma}{\sigma-1}} = \frac{\alpha m_i}{P_i^{1-\sigma}} \left[\int_0^{n_i} (p_{ii}(q)^{-\sigma})^{\frac{\sigma-1}{\sigma}} dq + \int_0^{n_j} (p_{ji}(q)^{-\sigma})^{\frac{\sigma-1}{\sigma}} dq\right]^{\frac{\sigma}{\sigma-1}} = \frac{\alpha m_i P_i^{-\sigma}}{P_i^{1-\sigma}} = \frac{\alpha m_i}{P_i}$$

Therefore, the indirect utility of a skilled worker with income $m_i = r_i$ is

$$v_i(s) = \alpha \ln\left(\alpha \frac{r_i}{P_i}\right) + (1-\alpha) \ln((1-\alpha) r_i). \tag{A.3}$$

After simplifying, the inter-regional difference in utility can be expressed as

$$v_1(s) - v_0(s) = \ln\left(\frac{r_1}{r_0}\right) - \alpha \ln\left(\frac{P_1}{P_0}\right) \tag{A.4}$$

We next solve the producer's problem to find the equilibrium price index. Aggregating individual demand (A.2), we write the aggregate demand function of a variety q, which is consumed in region $i = 0,1$ and produced in region $j = 0,1$, as

$$y_{ji}(q) = \frac{p_{ji}(q)^{-\sigma}}{P_i^{1-\sigma}} \alpha M_i, i,j \in \{0,1\}. \tag{A.5}$$

A manufacturing firm, which is located in region i and produces the modern-good variety q, maximizes profit:

$$\Pi_i(q) = p_{ii}(q) y_{ii}(q) + p_{ij}(q) y_{ij}(q) - \beta_i \left[y_{ii}(q) + \tau_{ij} y_{ij}(q)\right] - r_i. \tag{A.6}$$

Using (A.5), maximization of (A.6) yields the equilibrium prices:

$$p_{ii}(q) = \frac{\beta_i \sigma}{\sigma - 1}, p_{ij}(q) = \frac{\beta_i \tau_{ij} \sigma}{\sigma - 1}, i,j \in \{0,1\}. \tag{A.7}$$

The CES price index (A.1) is then given by $P_i = \frac{\sigma}{\sigma-1}\left[n_i\beta_i^{1-\sigma} + \rho_i n_j \beta_j^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$. As production of each variety requires one skilled worker, we have $n_i = x_i$, and so we can write the price index as

$$P_i = \frac{\sigma}{\sigma-1}\left[x_i\beta_i^{1-\sigma} + \rho_i x_j \beta_j^{1-\sigma}\right]^{\frac{1}{1-\sigma}}. \tag{A.8}$$

Next, we solve for the equilibrium wage of a skilled worker. The assumption of free entry and exit implies that the revenue equals the wage bill. Using (A.6), we derive[21]

$$r_i = p_{ii}y_{ii} + p_{ij}y_{ij} - \beta_i[y_{ii} + \tau_{ij}y_{ij}] = \alpha\left[\frac{p_{ii}^{1-\sigma}M_i}{P_i^{1-\sigma}} + \frac{p_{ij}^{1-\sigma}M_j}{P_j^{1-\sigma}}\right] - \alpha\beta_i\left[\frac{p_{ii}^{-\sigma}M_i}{P_i^{1-\sigma}} + \tau_{ij}\frac{p_{ij}^{-\sigma}M_j}{P_j^{1-\sigma}}\right]$$

$$= \alpha\left[\frac{p_{ii}^{1-\sigma}M_i}{P_i^{1-\sigma}} + \frac{p_{ij}^{1-\sigma}M_j}{P_j^{1-\sigma}}\right] - \alpha\left[\frac{\beta_i}{p_{ii}}\frac{p_{ii}^{1-\sigma}M_i}{P_i^{1-\sigma}} + \frac{\beta_i\tau_{ij}}{p_{ij}}\frac{p_{ij}^{1-\sigma}M_j}{P_j^{1-\sigma}}\right] = \alpha\left(1 - \frac{\sigma-1}{\sigma}\right)\left[\frac{p_{ii}^{1-\sigma}M_i}{P_i^{1-\sigma}} + \frac{p_{ij}^{1-\sigma}M_j}{P_j^{1-\sigma}}\right]$$

$$= \frac{\alpha}{\sigma}\left[\frac{\beta_i^{1-\sigma}M_i}{x_i\beta_i^{1-\sigma} + \rho_i x_j\beta_j^{1-\sigma}} + \frac{\beta_i^{1-\sigma}\rho_j M_j}{x_j\beta_j^{1-\sigma} + \rho_j x_i\beta_i^{1-\sigma}}\right] \tag{A.9}$$

As the aggregate income M_i, which is $x_i r_i + L_i$, is a function of r_i, (A.9) gives us a system of equations for $i = 0, 1$, that can be simultaneously solved to find r_0 and r_1. Defining $a_i := \frac{\alpha\beta_i^{1-\sigma}}{\sigma\left[x_i\beta_i^{1-\sigma} + \rho_i x_j\beta_j^{1-\sigma}\right]}$ and $b_i := \frac{\alpha\beta_i^{1-\sigma}\rho_j}{\sigma\left[x_j\beta_j^{1-\sigma} + \rho_j x_i\beta_i^{1-\sigma}\right]}$, we can write the system of equations as

$$r_1 = a_1x_1r_1 + b_1x_0r_0 + a_1L_1 + b_1L_0,$$

$$r_0 = a_0x_0r_0 + b_0x_1r_1 + a_0L_0 + b_0L_1. \tag{A.10}$$

Solving (A.10), we find

$$r_1 = \frac{a_1L_1 + b_1L_0 - L_1x_0\left(a_0a_1 - b_0b_1\right)}{1 - a_0x_0 - a_1x_1 + x_0x_1\left(a_0a_1 - b_0b_1\right)},$$

$$r_0 = \frac{a_0L_0 + b_0L_1 - L_0x_1\left(a_0a_1 - b_0b_1\right)}{1 - a_0x_0 - a_1x_1 + x_0x_1\left(a_0a_1 - b_0b_1\right)}. \tag{A.11}$$

Further, using (A.8) and (A.11), we can express the inter-regional difference in utility (A.4) as

$$v_1(s) - v_0(s) = \ln\left(\frac{a_1L_1 + b_1L_0 - L_1x_0\left(a_0a_1 - b_0b_1\right)}{a_0L_0 + b_0L_1 - L_0x_1\left(a_0a_1 - b_0b_1\right)}\right) + \frac{\alpha}{\sigma-1}\ln\left(\frac{x_1\beta_1^{1-\sigma} + \rho_1x_0\beta_0^{1-\sigma}}{x_0\beta_0^{1-\sigma} + \rho_0x_1\beta_1^{1-\sigma}}\right), \tag{A.12}$$

which is the functional form of the inter-regional payoff difference in (6).

Proof of Lemma 1

Proof. We prove by backward induction. Consider player n. Since player n's strategy must be optimal for any state s in period n, she migrates to 1 if and only if $v_1(s+\frac{1}{n}) > v_0(s)$. By Assumption 1, the optimal strategy is indeed a threshold strategy. Further, $\bar{s}_n$, the state value at which she is indifferent between migration or not, is the unique solution of $v_1(s+\frac{1}{n}) = v_0(s)$.

Folding back, we consider player $n-1$. At $\bar{s}_{n-1}$ (will show below that it is uniquely defined), she is indifferent between migrating to region 1 and staying back in region 0. First, consider the possibility that $\bar{s}_{n-1} < \bar{s}_n - \frac{1}{n}$. Then, her payoff from migration at $s = \bar{s}_{n-1}$ is $2v_1(s+\frac{1}{n})$; because she expects player n will not migrate in the following period as $\bar{s}_n > \bar{s}_{n-1} + \frac{1}{n}$. On the other hand, her payoff from staying back is $2v_0(s)$. Therefore, $\bar{s}_{n-1}$ must satisfy $2v_1(s+\frac{1}{n}) = 2v_0(s)$, which, given Assumption 1, contradicts the fact that $\bar{s}_n$ is the unique solution of the same equation and we have considered $\bar{s}_{n-1} < \bar{s}_n - \frac{1}{n}$.

Hence, $\bar{s}_{n-1} \geq \bar{s}_n - \frac{1}{n}$. In this case, at $s = \bar{s}_{n-1}$, player $n-1$ gets $v_1(s+\frac{1}{n}) + v_1(s+\frac{2}{n})$ by migration, and gets $2v_0(s)$ by staying back. Therefore, she migrates if $v_1(s+\frac{1}{n}) + v_1(s+\frac{2}{n}) > 2v_0(s)$. By Assumption 1, the optimal strategy is indeed a threshold strategy and $\bar{s}_{n-1}$ uniquely solves $v_1(s+\frac{1}{n}) + v_1(s+\frac{2}{n}) = 2v_0(s)$. Further, $\bar{s}_{n-1} < \bar{s}_n$, since at $s = \bar{s}_n$, $v_1(s+\frac{1}{n}) + v_1(s+\frac{2}{n}) = v_0(s) + v_1(s+\frac{2}{n}) > 2v_0(s)$ by Assumption 1.

Next, consider player i and assume that the lemma holds for all $k \in \{i+1, \ldots, n\}$. At $\bar{s}_i$, she is indifferent between migrating and staying. If $\bar{s}_i < \bar{s}_{i+1} - \frac{1}{n}$, then her payoff from migration at $s = \bar{s}_i$ is $(n-i+1)v_1(s+\frac{1}{n})$; because she expects no player will migrate in the following periods as $\bar{s}_n > \ldots > \bar{s}_{i+1} > \bar{s}_i + \frac{1}{n}$. On the other hand, her payoff from staying back is $(n-i+1)v_0(s)$. Therefore, $\bar{s}_i$ must satisfy $v_1(s+\frac{1}{n}) = v_0(s)$, which leads to a contraction because of Assumption 1 and the fact that $\bar{s}_n$ is the unique solution of the same equation.

Hence, we must have $\bar{s}_i \geq \bar{s}_{i+1} - \frac{1}{n}$. Then, at $s = \bar{s}_i$, player i gets $v_1(s+\frac{1}{n}) + \cdots + v_1(s+\frac{n-i+1}{n})$ by migration, and gets $(n-i+1)v_0(s)$ by staying back. Therefore, she migrates if $\sum_{t=1}^{n-i+1} v_1(s+\frac{t}{n}) > (n-i+1)v_0(s)$. By Assumption 1, the optimal strategy is indeed a threshold strategy and $\bar{s}_i$ uniquely solves $\frac{1}{n-i+1}\sum_{t=1}^{n-i+1} v_1(s+\frac{t}{n}) = v_0(s)$. Further, $\bar{s}_i < \bar{s}_{i+1}$, since at $s = \bar{s}_{i+1}$, $\frac{1}{n-i+1}\sum_{t=1}^{n-i+1} v_1(s+\frac{t}{n}) > v_0(s)$ by Assumption 1. By the logic of induction, the lemma, therefore, holds true for all $i \in \{1, \ldots, n\}$.

[21] For notational simplicity, we suppress the functional argument indicating variety q in the expressions of price and quantity.

Proof of Lemma 2

Proof. At the beginning of period i, the state value is s^{i-1} and player i decides whether or not to migrate. Suppose that player i migrates. Therefore, $s^{i-1} > \bar{s}_i$ by Lemma (1), and $s^i = s^{i-1} + \frac{1}{n}$. Together, $s^i > \bar{s}_i + \frac{1}{n} \geq \bar{s}_{i+1}$. The last inequality follows since $\bar{s}_{i+1} - \frac{1}{n} \leq \bar{s}_i$, by Lemma (1). $s^i > \bar{s}_{i+1} \Rightarrow$ player $i+1$ migrates. Next, suppose player i does not migrate. Therefore, $s^{i-1} \leq \bar{s}_i$ by Lemma (1), and $s^i = s^{i-1}$. Together, $s^i \leq \bar{s}_i \leq \bar{s}_{i+1}$. The last inequality follows from Lemma (1). $s^i \leq \bar{s}_{i+1} \Rightarrow$ player $i+1$ does not migrate.

Proof of Lemma 3

Proof. Note that to prove the lemma, it is sufficient to show that in any equilibrium in Markov strategy, it is not possible to have $s^n = k$ for some $k \in \{\frac{1}{n}, \dots, \frac{n-1}{n}\}$. We prove it by contradiction. Suppose, if possible, $s^n = k$ for $k \in \{\frac{1}{n}, \dots, \frac{n-1}{n}\}$. Let A_0 and A_1 denote the sets of players taking action 0 and action 1 respectively. Observe that if $s^n = k$ for $k \in \{\frac{1}{n}, \dots, \frac{n-1}{n}\}$, then both A_0 and A_1 are non-empty sets. Therefore, there must be at least one pair of consecutive players who take different actions. Let $(j, j+1), j \in \{1, \dots, n-1\}$ be the last of such pairs with different actions. Two possibilities can arise – case (i): $j \in A_1$ and all $j+1, \dots, n \in A_0$, and case (ii): $j \in A_0$ and all $j+1, \dots, n \in A_1$.

First, consider case (i). Given that $s^n = k$, $n \in A_0$ implies

$$v_0\left(\frac{k}{n}\right) \geq v_1\left(\frac{k+1}{n}\right). \tag{A.13}$$

Further, since j is the last player to take action 1, it implies that $(n-j+1)v_1(\frac{k}{n}) > (n-j+1)v_0(\frac{k-1}{n})$, or equivalently, $v_1(\frac{k}{n}) > v_0(\frac{k-1}{n})$. Then, by Assumption 1,

$$v_1\left(\frac{k+1}{n}\right) > v_1\left(\frac{k}{n}\right) > v_0\left(\frac{k-1}{n}\right) > v_0\left(\frac{k}{n}\right), \tag{A.14}$$

which contradicts (A.13), and so, case (i) is not a feasible scenario.

Next, consider case (ii): Given that $s^n = k$,

$$n \in A_1 \quad \Rightarrow v_1\left(\frac{k}{n}\right) > v_0\left(\frac{k-1}{n}\right)$$

$$n-1 \in A_1 \Rightarrow v_1\left(\frac{k-1}{n}\right) + v_1\left(\frac{k}{n}\right) > v_0\left(\frac{k-2}{n}\right) + v_0\left(\frac{k-1}{n}\right)$$

$$\vdots$$

$$j+1 \in A_1 \quad \Rightarrow \sum_{i=k-n+j+1}^{k} v_1\left(\frac{i}{n}\right) > \sum_{i=k-n+j}^{k-1} v_0\left(\frac{i}{n}\right) \tag{A.15}$$

Now, as j is the last player to take action 0, j finds the state at the beginning of period j to be $k-n+j$ (since she does not migrate and the following $n-j$ players migrate to make the terminal state to be k), and j's decision not to migrate would be optimal if

$$\sum_{i=k-n+j}^{k} v_0\left(\frac{i}{n}\right) > \sum_{i=k-n+j+1}^{k+1} v_1\left(\frac{i}{n}\right). \tag{A.16}$$

The right-hand-side of (A.16) can be written as $\sum_{i=k-n+j+1}^{k} v_1(\frac{i}{n}) + v_1(\frac{k+1}{n})$ and the left-hand-side of (A.16) can be written as $\sum_{i=k-n+j}^{k-1} v_0(\frac{i}{n}) + v_0(\frac{k}{n})$. By Assumption 1 and (A.15),

$$v_1\left(\frac{k+1}{n}\right) > v_1\left(\frac{k}{n}\right) > v_0\left(\frac{k-1}{n}\right) > v_0\left(\frac{k}{n}\right),$$

and by (A.15), $\sum_{i=k-n+j+1}^{k} v_1(\frac{i}{n}) > \sum_{i=k-n+j}^{k-1} v_0(\frac{i}{n})$. Together, we get that the right-hand-side of (A.16) is greater than the left-hand-side of (A.16), which contradicts (A.16), and so, case (ii) is not a feasible scenario as well. We thus rule out all possibilities that can arise if $s^n = k$ for some $k \in \{\frac{1}{n}, \dots, \frac{n-1}{n}\}$. Hence, we must have $s^n = 0$ or $s^n = 1$, in which case, either $a^i = 0$ for all $i \in \{1, \dots, n\}$, or, $a^i = 1$ for all $i \in \{1, \dots, n\}$. This completes the Proof.

B. Instructions for the experiment

Experimental Instructions T4 (Translated from Spanish)

Welcome to the LEE. We are carrying out a research project on economic decision making. If you carefully follow the instructions and take good decisions you can earn a considerable amount of money. Your gains will be personally communicated to you and they will be paid in cash right at the end of the session. Your data will be confidentially treated and they will not be used for any purpose alien to this project. Your name will never be associated to your decisions when the results are published. Communication with other participants in the session will lead to immediate experiment termination for those participants breaching the rule. At the beginning of the session you will be assigned to a group with three other participants. You will never discover the identity of the other members of your group, as they also will never discover yours. The game will last four periods and it will not be repeated. Before the start of the paid periods you will answer a comprehension test about the instructions in your computer.

The Regions

There are 2 different regions regarding the wage (in experimental units) that they offer. The wage depends on the number of participants belonging to your group that there are in each region:

Participants in region 0	Participants in region 1	Wage region 0	Wage region 1
4	0	7.7	6.8
3	1	4.6	7.1
2	2	2.7	7.5
1	3	1.4	8.3
0	4	0.4	9.5

In each of the four periods that the game lasts you will get the wage corresponding to the region in which you are at the moment, which will be calculated depending on where the other three group members are. At the end of the session you will get in cash 0.55 euros for each experimental unit accumulated after the four periods.

In the upper region of the screen you will be shown in red colour information about how many participants of your group there are in that moment in each region.

Your Decision

You are now in region 0, as the other three members of your group. In each one of the four periods of the game, one member of your group will have to decide whether he or she prefers to remain in region 0 or move to region 1. The order of the decision will be random and will be determined at the beginning of the session. The participant who has to decide in a given period will know the number of group members that there are in each region in that moment.

The Information

At the end of each period you will be informed about how many participants of your group there are in each region and which wage do get in this period those who are in each region, including yourself. You will also be reminded about the accumulated gains up to that moment.

Experimental Instructions T4 (Original in Spanish)

Bienvenido al LEE. Estamos realizando un proyecto de investigación sobre la toma de decisiones económicas. Si sigues cuidadosamente las instrucciones y tomas decisiones acertadas puedes ganar una considerable cantidad de dinero. Tus ganancias se te comunicarán personalmente y se te pagarán en efectivo al final de la sesión. Tus datos se tratarán de modo confidencial y no se utilizarán para fines ajenos a este proyecto. Tu nombre nunca se verá asociado a ninguna de tus decisiones cuando se publiquen los resultados. La comunicación con otros participantes en la sesión supondría la automática finalización de la misma sin ninguna ganancia para los participantes que infrinjan esta regla. Al inicio de la sesión serás asignado a un grupo con otros 3 participantes. No conocerás la identidad de los otros miembros de tu grupo como tampoco ellos conocerán la tuya. El juego durará cuatro periodos y no se repetirá. Antes de iniciar los periodos pagados realizarás un test de comprensión de las instrucciones en tu ordenador.

Las Regiones

Existen 2 regiones distintas en cuanto al salario (en unidades experimentales) que ofrecen. Dicho salario depende del número de participantes de tu grupo que haya en cada una de ellas:

Participantes en región 0	Participantes en región 1	Salario región 0	Salario región 1
4	0	7.7	6.8
3	1	4.6	7.1
2	2	2.7	7.5
1	3	1.4	8.3
0	4	0.4	9.5

En cada uno de los cuatro periodos que dura el juego recibirás el salario que te corresponda según la región en la que te encuentres y según dónde estén los otros tres miembros de tu grupo. Al finalizar la sesión se te pagará en efectivo 0.55 euros por cada unidad experimental que hayas acumulado en los cuatro periodos.

En la parte superior de la pantalla te aparecerá en rojo la información acerca de cuántos participantes de tu grupo se encuentran en ese momento en cada región.

Tu Decisión

Estás actualmente en la región 0, al igual que los otros tres miembros de tu grupo. En cada uno de los cuatro periodos del juego, un miembro de tu grupo habrá de decidir si desea permanecer en la región 0° moverse a la región 1. El orden de las decisiones será aleatorio y se determinará al inicio de la sesión. El participante que deba decidir en un determinado periodo conocerá el número de miembros del grupo que hay en cada región en ese momento.

La Información

Al final de cada periodo se te informará de cuántos participantes de tu grupo hay en cada región y cuánto cobra en ese periodo quien esté en cada región y tú mismo. También se te recuerda las ganancias acumuladas hasta ese momento.

References

Allen, T., Donaldson, D., 2020. Persistence and Path Dependence in the Spatial Economy. NBER Working Paper Series, p. 28059.

Ashraf, N., Aycinena, D., Martínez, A., Yang, D., 2015. Savings in transnational households: a field experiment among migrants from El Salvador. Rev. Econ. Stat. 97, 332–351.

Baldwin, R.E., 2001. Core-periphery model with forward-looking expectations. Reg. Sci. Urban Econ. 31, 21–49.

Barreda-Tarrazona, I., Jaramillo-Gutiérrez, A., Navarro-Martínez, D., Sabater-Grande, G., 2011. Risk attitude elicitation using a multi-lottery choice task: real vs. hypothetical incentives. Span. J. Finan. Account. 40, 609–624.

Binmore, K., 1999. Why experiment in economics? Econ. J. 109 (453), F16–F24.

Binmore, K., McCarthy, J., Ponti, G., Samuelson, L., Shaked, A., 2002. A backward induction experiment. J. Econ. Theor. 104, 48–88.

Bryan, G., Chowdury, S., Mubarak, A.M., 2014. Underinvestment in a profitable economy: the case of seasonal migration in Bangladesh. Econometrica 82, 1671–1748.

Caliendo, L., Dvorkin, M., Parro, F., 2019. Trade and labor market dynamics: general equilibrium analysis of the China trade shock. Econometrica 87, 741–835.

Charness, G., Rabin, M., 2002. Understanding social preferences with simple tests. Q. J. Econ. 117, 817–869.

Combes, P.-P., Mayer, T., Thisse, J.-F., 2008. Economic Geography: the Integration of Regions and Nations. Princeton University Press, Princeton NJ.

Cordero, A., Corral, S., 2006. DAT-5 Tests de Aptitudes Diferenciales. TEA Ediciones, Madrid.

Costinot, A., Rodríguez-Clare, A., 2014. Trade theory with numbers: quantifying the consequences of globalization. In: Gopinath, G., Helpman, E., Rogoff, K. (Eds.), *Migration: Economic Change, Social Challenge*, Volume 4 of *Handbook of International Economics*. Elsevier, pp. 197–261.

Dekle, R., Deaton, J., Kortum, S., 2008. Global rebalancing with gravity: measuring the burden of adjustment. IMF Staff Pap. 55, 511–540.

Delventhal, M.J., 2018. The Globe as a Network: Geography and the Origins of the World Income Distribution. Mimeo, The Robert Day School of Economics and Finance, Claremont McKenna College.

Dhami, S., 2016. The Foundations of Behavioral Economic Analysis. Oxford University Press, Oxford.

Dufwenberg, M., van Essen, M., 2018. King of the hill: giving backward induction its best shot. Game. Econ. Behav. 112, 125–138.

Edwards, W., Huskey, L., 2008. Job search with an external opportunity: an experimental exploration of the Todaro Paradox. Ann. Reg. Sci. 42, 807–819.

Edwards, W., Huskey, L., 2014. The search goes on: parameter effects on the return migration decision. Mig. Let. 11, 79–89.

Fischbacher, U., 2007. z-tree: zurich toolbox for ready-made economic experiments. Exp. Econ. 10, 171–178.

Forslid, R., Ottaviano, G.I., 2003. An analytically solvable core-periphery model. J. Econ. Geogr. 3, 229–240.

Fudenberg, D., Tirole, J., 1991. Game Theory. MIT Press, Cambridge MA.

Fujita, M., Thisse, J.-F., 2013. Economics of Agglomeration: Cities, Industrial Location, and Globalization, second ed. Cambridge University Press, New York.

Fukao, K., Benabou, R., 1993. History versus expectations: a comment. Q. J. Econ. 108, 535–542.

GDPR, 2016. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32016R0679&from=EN. (Accessed 9 February 2021).

Greenwood, M.J., McClelland, G.H., Schulze, W.D., 1997. The effects of perceptions of hazardous waste on migration: a laboratory experimental approach. Rev. Reg. Stud. 27, 143–161.

Greenwood, M.J., Mueser, P.-R., Plane, D.A., Schlottmann, A.M., 1991. New directions in migration research. Ann. Reg. Sci. 25, 237–270.

Harrison, G.W., Lau, M.I., Rutström, E.E., 2009. Risk attitudes, randomization to treatment, and self-selection into experiments. J. Econ. Behav. Organ. 70, 498–507.

Holt, C.A., Laury, S.K., 2002. Risk aversion and incentive effects. Am. Econ. Rev. 92, 1644–1655.

Huck, S., Normann, H.-T., Oechssler, J., 2004. Two are few and four are many: number effects in experimental oligopolies. J. Econ. Behav. Organ. 53, 435–446.

Krugman, P., 1991a. History versus expectations. Q. J. Econ. 106, 651–667.

Krugman, P., 1991b. Increasing returns and economic geography. J. Polit. Econ. 99, 483–499.

Loewenstein, G., 1999. Experimental economics from the vantage-point of behavioural economics. Econ. J. 109 (453), F25–F34.

Maskin, E., Tirole, J., 2001. Markov perfect equilibrium: I. observable actions. J. Econ. Theor. 100 (2), 191–219.

McKenzie, D., 2015. Learning about migration through experiments. In: Dustmann, C. (Ed.), Migration: Economic Change, Social Challenge. Oxford University Press, pp. 68–82.

Ottaviano, G.I., 1999. Integration, geography, and the burden of history. Reg. Sci. Urban Econ. 29, 245–256.

Ottaviano, G.I., 2001. Monopolistic competition, trade, and endogenous spatial fluctuations. Reg. Sci. Urban Econ. 31, 51–77.

Oyama, D., 2009a. Agglomeration under forward-looking expectations: potentials and global stability. Reg. Sci. Urban Econ. 39, 696–713.

Oyama, D., 2009b. History versus expectations in economic geography reconsidered. J. Econ. Dynam. Contr. 33, 394–408.

Redding, S.J., Rossi-Hansberg, E., 2017. Quantitative spatial economics. Ann. Rev. Econ. 9 (1), 21–58.

Sabater-Grande, G., Georgantzís, N., 2002. Accounting for risk aversion in repeated prisoners' dilemma games: an experimental test. J. Econ. Behav. Organ. 48, 37–50.