Formation of Segregated and Integrated Groups

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Summary

A model of group formation is presented where the number of groups is fixed and a person can only join a group if the group's members approve the person's joining. Agents have either local status preferences (each agent wants to be the highest status agent in his group) or global status preferences (each agent wants to join the highest status group that she can join). For both preference types, conditions are provided which guarantee the existence of a segregated stable partition where similar people are grouped together and conditions are provided which guarantee the existence of an integrated stable partition where dissimilar people are grouped together. Additionally, in a dynamic framework we show that if a new empty group is added to a segregated stable partition, then integration may occur.

Keywords: Group Formation, Stable Partition, Segregation, Integration

JEL Classification: C7, D6

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1. Introduction

There are many situations where people join groups, the number of groups is fixed, and where a person can only join a group if this group approves the person's joining. Examples include students choosing a university, nurses joining a hospital, managers joining a firm, academics joining a department, athletes joining a team and college students joining a fraternity. We examine such situations where agents are concerned with either local status (each agent wants to be the highest status agent in his group) or global status (each agent wants to join the highest status group possible).

Specifically, each person is endowed with a quality level and receives a (hedonic) payoff from the group he joins which depends only on who is in the group (or only on the quality levels of the people in the group). We consider two such possible payoff functions. The first is the average quality (or global status) payoff function where an agent's payoff is increasing in the average quality of the agents in his group. Such a person is concerned with global status since he wants to be a member of the most prestigious group (or the group with the highest average quality).[1] The second payoff function considered is the big fish (or local status) payoff function. Here an agent prefers the group where he is the highest quality agent (or the "big fish") in the group. Such an agent is concerned with local status, since he cares about his quality ranking within his group. For example, a local status person prefers a position at a less prestigious firm if he is the "big fish" there.[2]

When people choose with whom to associate they often end up in segregated partitions where

[1]Since an agent changes the average quality of a group once he joins it, we assume an agent includes himself when calculating average quality. As a consequence, a low quality agent may have a bias towards joining a larger group since his quality does not decrease the average as much, while a high quality agent may have a bias towards joining a smaller group.

[2]A discussion of global versus local status and how a person may trade one for the other is given in Frank [1985]; an axiomatization of local status is given in Ök and Kockesen [2000].

agents of similar characteristics (or qualities) are grouped together.[3] We are interested in whether or not our preferences are also biased towards like agents seeking out like agents. Intuitively, both local and global status preferences seem somewhat biased towards segregation and in fact we find that under both types of preferences a segregated stable partition always exists.[4] However, in spite of this apparent bias, under big fish preferences an integrated stable partition almost always exists where people with dissimilar quality levels are grouped together and under average quality preferences an integrated stable partition exists if certain conditions are met.

We also investigate in a dynamic group formation model what happens to a segregated stable partition when a new empty group (or location) is added and show that the addition of such an empty location may cause integration to occur. As far as we know this is the first paper in the hedonic group formation literature to examine what happens to stable partitions when a new location is added.

We define a partition to be stable if whenever there exists an agent who wants to change locations, the non-strict majority of agents at the new location vetoes the move. This stability notion is related to both the concept of "individual stability" (see Greenberg [1978], Drèze and Greenberg [1980], and Bogomolnaia and Jackson [2002]) and to the concept of "Nash stability" (see Brams, Jones and Kilgour [2002], Bogomolnaia and Jackson [2002], and Milchtaich and Winter [2002]). Under individual stability an agent needs unanimous approval by agents at the new location in order

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[3]For instance consider the local public good literature of Tiebout [1956], Wooders [1980] and Greenberg and Weber [1986] where agents prefer those with preferences regarding local public good production given taxation most similar to themselves and often end up in segregated partitions. Alternatively, Milchtaich and Winter [2002] examine group formation where agents prefer to be with others similar to themselves and provide conditions under which stable partitions are segregating and Pareto efficient.

[4]To see this bias note that if preferences are average quality (respectively, big fish) and if agents are in an integrated partition, then often high (respectively, mid or low) quality agents both want to and can leave an integrated group.

to move, while under Nash stability an agent can move without anyone's approval. Nash stability is more demanding than individual stability, while our definition of stability is in between.[5]

The paper most closely related to the current one is Milchtaich and Winter [2002] who also study group formation when the number of groups is fixed. Their model differs from ours in that agents want to join the group which has agents who are the most similar to them and agents do not need permission from the new group in order to join it. Milchtaich and Winter [2002] show that segregated, stable partitions exist and that a dynamic model of group formation always converges to a stable, segregated partition. Additionally, in their model integrated stable partitions are not weakly Pareto efficient, while in our model an integrated stable partition can be Pareto efficient.[6]

The literature on coalition formation in hedonic games (where an agent's payoff is based solely on who else is in his coalition) is also closely related to our paper; see founding paper Drèze and Greenberg [1980], as well as Banerjee, Konishi, and Sönmez [2001], Cechlárová and Romero-Medina [2001], Bogomolnaia and Jackson [2002], Burani and Zwicker [2003], Diamontoudi and Xue [2003], Ballester [2004], Dimitrov et.al. [2004], Dimitrov and Sung [2004], and Pápai [2004]. Most of these papers focus on restrictions on preferences which lead to stable coalition partitions.[7]

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[5]Nash stability here often results in no stable partitions since with average quality payoffs a high quality agent at a low quality group wishes to move to a higher quality group, while with big fish payoffs any high quality agent not ranked first wants to move to a lower quality location. Individual stability applied to big fish payoffs can result in a large number of stable partitions since all moves to a new location which displace the rank of an existing agent are vetoed. Our stability notion allows existence, but refines the number of stable partitions.

[6]Consider an example with four agents with respective quality levels $\{4,2,1,0\}$ and two locations A and B. Under both average quality and big fish preferences the integrated stable partition where agents 1 and 3 are located at A and 2 and 4 are at B is Pareto efficient.

[7]Exceptions are Pápai [2004] which focuses on restrictions of permissible coalitions which result in unique stable partitions and Ballester (2004) which focuses on complexity issues.

There are four main differences between the current paper and this literature. First, this literature assumes the number of coalitions formed is endogenous, while in our model the number of groups formed is fixed. Second, most of this literature considers preference domains which do not include average quality or big fish preferences (examples include symmetric and separable preferences, single-peaked preferences with ordered characteristics, preferences depending only on the best or worst person in the group, etc.). Exceptions include the top-coalition preferences of Banerjee, Konishi, and Sönmez [2001] (both average quality and big fish preferences are subsets of this domain) and the aversion to enemies preferences of Dimitrov et. al. [2004] (big fish preferences are a subset of this domain).[8] The third difference between the current paper and this literature is the stability concept; these papers use core stability, individual stability, Nash stability, and contractual individual stability. Lastly our focus is different in that we are interested in the composition of stable partitions and in what happens to segregated partitions when a new empty location is added.

The local public goods literature is also related to group formation since in these models agents join jurisdictions (or groups) which produce local public goods. Here agents prefer to join jurisdictions where other people have preferences for levels of local public good production (given a specific tax structure) which are similar to their own preferences. See Wooders [1980], Bewley [1981], Guesnerie and Oddou [1981], Greenberg and Weber [1986] and [1993], Jehiel and Scotchmer [1997], Konishi, Le Breton and Weber [1998], and Gravel and Thoron [2004].

2. Model

[8]Note that both of these papers use core stability, which is quite different from the stability concept used here. Dimitrov and Sung [2004] examine individually stable partitions with aversion to enemies preferences and Nash stable partitions with aversion to enemies preferences when mutuality is imposed; big fish preferences do not satisfy mutuality.

Denote the set of *agents* by $N=\{1, 2,...,i,...,n\}$. Each agent i is endowed with *quality level* q_i. An agent's quality level may represent many different things such as an agent's athletic ability, academic ability, or publishing ability. Without loss of generality we assume that agents are indexed such that $q_1 \geq q_2 \geq ... \geq q_n$. Let $Q' = \{q_1, q_2, ..., q_n\}$ and $Q \subseteq Q'$ represent the largest set of distinct quality levels so that $q_i, q_j \in Q$ and $i \neq j$ imply $q_i \neq q_j$.

There are *m locations* which are represented by the set $L=\{A,B,...,G,...,M\}$. Each agent is positioned at exactly one location. If $\{i,...,j\}$ are the only agents located at G, we write $\{i,...,j\}=G$. An agent's location may represent many different things such as his athletic team or academic department. Thus, an agent's location represents a group that he joins. A *partition* $\sigma: N \rightarrow L$ is an assignment of each agent to exactly one location.

Consider the following general *payoff function*. If $\{i...,j,...,k\}=C$, then j receives a payoff of $u_j(i,...,j,...,k)$ or $u_j(C)$. For any ℓ such that $\sigma(\ell) \neq C$, ℓ's payoff if he moves to C is $u_\ell(C+\ell)$.

We focus our analysis on the following two specifications of u_j. Let $\mu(X)$ represent the cardinality of integer set X and if $\{i,...,k\}=G$, then let $\mu(G)=\mu(\{i,...,k\})$.

Definition 1. Let $\{i,...,j,...,k\}=G$. If $u_j(G)$ is a strictly increasing function of $aq(G) \equiv (q_i+...+q_k)/\mu(G)$, then agent j's preferences can be represented by the *average quality payoff function*

Definition 2. Under the *big fish payoff function*, each agent prefers to be the highest quality agent (or the "big fish") in the group. Let $j \in G$. Here $u_j(G)$ is strictly decreasing in $\mu(\{\ell \in G | q_\ell \geq q_j \text{ and } \ell \neq j)$. We refer to $r_j(G) \equiv (1+ \mu(\{\ell \in G | q_\ell \geq q_j \text{ and } \ell \neq j)$ as j's *quality ranking* (or *rank*) at G. Thus, $r_j(G)=1$ if $\mu(\{\ell \in G | q_\ell \geq q_j \text{ and } \ell \neq j)=0$ and by definition this is j's most preferred rank. In addition, if $r_j(C+j)=r_j(D+j)$ and $\mu(C) \neq \mu(D)$, then j strictly prefers to be a member of the larger group.

Definition 3. A given partition is *stable* if and only if for all $i \in D \neq G$, $u_i(D) < u_i(G+i)$ implies that

$u_j(G) \geq u_j(G+i)$ for the non-strict majority of agents $j \in G$.[9]

Definition 4. A partition $\sigma: N \rightarrow L$ is called *segregated* if:

(i) for all $i,j,k \in N$ such that $\sigma(i)=\sigma(j)$ and $q_k \in (q_i, q_j)$ we have $\sigma(k)=\sigma(i)$.

(ii) there does not exist $i,j,k,\ell \in N$ with $q_i, q_j \geq q'$ and $q_k, q_\ell \leq q'' < q'$ such that $\sigma(i)=\sigma(k) \neq \sigma(j) = \sigma(\ell)$.

Definition 5. A partition is called an *integrated partition* if it is not segregated.

Thus, at an integrated stable partition agents of similar quality are not always located together.

Definition 6. This definition is only needed for the case where $q_1 > q_2 > ... > q_n$ and so for ease of exposition we restrict the definition to this case. A group (or location) G is called an *integrated group* if there exists agents i, j, and k such that $q_i > q_j > q_k$, $i \in G$, $k \in G$, but $j \in D \neq G$. A group that is not integrated is called a *segregated group*. Thus, segregated partitions consist entirely of segregated groups. However, integrated partitions may consist of both integrated and segregated groups.

3. Average Quality Payoff Results

In this section, we examine the type of stable partitions that exist when all players want to be in the group with the highest average quality. We also define a dynamic process and use this process to look at what happens when a new empty location is added to a segregated stable partition.

Theorem 1: A partition is stable iff for all $i \in D \neq G$, $q_i > aq(G)$ implies $aq(D) - aq(G) \geq (q_i - aq(D))/\mu(G)$.

Proof: First we show that stability implies the stated condition. Assume there exists $i \in D \neq G$ such

[9] We assume that if i is indifferent about changing locations, then he chooses to stay where he is. Additionally, approval for a move is granted only if agents are made strictly better off by having the new agent join, while in Bogomolnaia and Jackson [2002] approval is granted as long as agents are not made worse off by the addition of the new agent. However, if each agent has a different quality level, then the addition of a new agent almost always changes average quality and the two notions of approval coincide for average quality payoffs.

that $q_i > aq(G)$. Thus, the agents at G always allow i to move from D to G. Stability requires that i does not want to move or that $aq(D) \geq aq(G+i)$; this implies that $aq(D) \geq (\mu(G)+1)aq(G+i)/(\mu(G)+1) = (\mu(G)aq(G)+q_i)/(\mu(G)+1)$. Rearranging yields $aq(D)-aq(G) \geq (q_i - aq(D))/\mu(G)$. Next, assume that the condition of Theorem 1 is met, but that the partition is not stable. Thus, there exists $i \in D$ who wants to and can move from D to G. Thus, $aq(D) < aq(G+i)$; this is equivalent to $aq(D)-aq(G) < (q_i - aq(D))/\mu(G)$. Such an i can move from D to G only if $q_i > aq(G)$. However, by assumption this inequality implies that $aq(D)-aq(G) \geq (q_i - aq(D))/\mu(G)$; this is a contradiction. ◊

Notice that here if the addition of a new agent raises the average quality of the group, then everyone in the group approves the new person joining. Thus, majority approval for a move and unanimous approval (or even the stricter stability notion of requiring the approval of just one current group member) always coincide.

Proposition 1: There exists a segregated stable partition which is strongly Pareto efficient.

Proof: First we show that the following segregated partition, call it σ_s, is stable. Let $\sigma_s(1)=A$ and $\sigma_s(i)=A$ for all i such that $q_i=q_1$. Let $\sigma_s(j)=B$ for all j with the second highest quality level. Continue in this fashion until there are either no more agents or no more locations. If $\mu(Q)>\mu(L)$, then place all remaining agents at M. If $\mu(Q)<\mu(L)$, then M is empty. For all $i \in D \neq G$ with $q_i > aq(G)$ we know that $D<G\leq M$ or that $q_i=aq(D)>aq(G)$. Thus, $aq(D)-aq(G) \geq (q_i - aq(D))/\mu(G) = 0$, and the conditions of Theorem 1 are met. Thus, σ_s is stable.

Next, we show that σ_s is strongly Pareto efficient. The agents at A already have the highest possible utility level, so any Pareto improvement should leave them at this level. The only way to not decrease $aq(A)$ is to have A stay together without anyone else. So, in any Pareto improvement these agents occupy their own location(s) and we are left with at most *(m-1)* locations for other agents. Given this, the agents located at B should also be alone and we are left with at most *(m-2)* locations for other agents. Continue in this fashion. All agents located at $G \neq M$ remain by themselves; otherwise, at least one of them is made worse off. Thus, if $\mu(Q) \geq \mu(L)$, then M is nonempty and σ_s is strongly Pareto efficient. If $\mu(Q) < \mu(L)$, then $\mu(M)=0$. If there exists agents $i \in G$ and $j \in G$ such that $q_i = q_j$, then we can move j to M. The payoffs at this new partition are exactly the same as the payoffs at σ_s. Thus, such a move is not Pareto improving. ◊

Example: Not all segregated partitions are stable.

Let $m=2$, $n=4$, $q_1 = 20$, $q_2 = 10$, $q_3 = 9$, $q_4 = 8$. The segregated partition $\{1,2,3\}=A$ and $\{4\}=B$ is not stable since $aq(A)=13$, but $aq(B+1)=14$. Thus, 1 prefers to move from A to B.

Proposition 2: Assume $q_1 > q_2 > ... > q_n$. If $q_i > max\ \{(q_1+q_{i+1})/2,\ (q_1+q_2+q_{i+1})/3, ...,\ (q_1+q_2+...+q_{i-1}+q_{i+1})/i\}$ for all $i \in \{2,...,n-1\}$, then there does not exist an integrated stable partition.

Proof: The proof is by contradiction. Assume agents are in an integrated stable partition and that for all $i \in \{2,...,n-1\}$, $q_i > max\ \{(q_1+q_{i+1})/2,\ (q_1+q_2+q_{i+1})/3, ...,\ (q_1+q_2+...+q_{i-1}+q_{i+1})/i\}$. Since the partition is integrated, there exists at least two non-empty groups one of which, say C, is integrated. Let $\{i,...,k\}=C$ with $q_i > ... > q_k$, but let there exist $j \in D \neq C$ such that $q_i > q_j > q_k$.

Case 1: $aq(D) \leq aq(C)$. Since C is integrated, $aq(C) \leq max\{(q_1+q_{j+1})/2,\ (q_1+q_2+q_{j+1})/3, ...,\ (q_1+q_2+...+q_{j-1}+q_{j+1})/j\}$. Since $q_j > max\{(q_1+q_{j+1})/2,\ (q_1+q_2+q_{j+1})/3, ...,\ (q_1+q_2+...+q_{j-1}+q_{j+1})/j\}$, we know that $q_j > aq(C)$. Thus, $aq(C+j) > aq(C) \geq aq(D)$. So, j prefers to join C and the agents at C allow j to join. Thus, the partition is not stable.

Case 2: $aq(D) > aq(C)$. Either D is integrated or it is not. Assume D is integrated. Since

$q_i > q_j$, but $i \in C$ and $j \in D$, then $aq(D) \leq max\{(q_1+q_{i+1})/2, (q_1+q_2+q_{i+1})/3,..., (q_1+q_2+...+q_{i-1}+q_{i+1})/i\}$. By assumption, $max\{(q_1+q_{i+1})/2,(q_1+q_2+q_{i+1})/3,...,(q_1+q_2+...+q_{i-1}+q_{i+1})/i\} < q_i$. Thus, $aq(D+i) > aq(D) > aq(C)$. So, i wants to move from C to D and the agents at D agree to this. If D is not integrated, then q_i is strictly larger than the quality of every agent located at D. Thus, $aq(D+i) > aq(D) > aq(C)$, and so i wants to join D and the agents at D let i join. Thus, the partition is not stable. ◊

Notice that the conditions of Proposition 2 are close to those necessary for i (respectively k) to join G (resp. H). For instance, if $G=\{1,2,...,i-1,i+1\}$, then $q_i > (q_1+q_2+...+q_{i-1}+q_{i+1})/i$ is a necessary condition for i to join G. However, if $G=\{2,3,...,i-1,i+1\}$, then $q_i > (q_2+q_3+...+q_{i-1}+q_{i+1})/(i-1)$ is a necessary condition for i to join G; this condition is a weaker one than our $q_i > (q_1+q_2+...+q_{i-1}+q_{i+1})/i$. Since we want i (resp. k) to join any such G (resp. H), it is unlikely that the conditions of Proposition 2 can be substantially weakened.

Proposition 3: Assume $m=2$ and that $q_1 > q_2 > ... > q_n$. If there exists $i \in \{2,...,n-1\}$ such that $(q_1+q_2+...+q_{i-1}+q_{i+1})/i > max\,\{q_i, (q_1+q_i+q_{i+2}+q_{i+3}+...+q_n)/(n-i+1)\}$, then there exists an integrated stable partition.

Proof: We show that the integrated partition where $\{1,2,...,i-2,i-1,i+1\}=A$ and $\{i,i+2,i+3,...,n\}=B$ meets the conditions of Theorem 1 and so this partition is stable. By assumption, $aq(A) = (q_1+q_2+...+q_{i-1}+q_{i+1})/i > q_i$. Thus, if there exists $k \in D \neq G$ such that $q_k > aq(G)$, then $k \in A$. If $q_k > aq(B)$, then Theorem 1 requires that $aq(A)-aq(B) \geq (q_k - aq(A))/\mu(B)$. This inequality is equivalent to $aq(A) \geq aq(B+k)$, which by assumption is always true. ◊

Dynamics

The following *dynamic process* is used in Propositions 4 and 7. Agents begin in a partition which may or may not be stable. There is a set of periods $\{1,2,...,t,...\}$ and at every t a pair $p_t=(i,G)$ is randomly identified with uniform probability; i is allowed to move to G if such a move strictly increases i's payoff and if i has strict majority approval for the move by the agents at G. If, after some t, no agents can move, then the dynamic process has reached a stable partition. A sequence of such partitions generated by the dynamic process is called an *improving path*.[10]

The following lemma is used in the proof of Proposition 4. This lemma shows that the dynamic process never becomes stuck in a cycle of partitions.

Lemma 1: Assume agents are in an unstable partition. The dynamic process leads to a stable partition with probability 1.

Proof: First note that since $p_t=(i,G)$ is randomly identified with uniform probability, the probability that the same (i,G) is chosen every period approaches 0 as $t\rightarrow\infty$. Thus, with probability 1 the dynamic process cannot become stuck in an unstable partition and leads to either a cycle of partitions or to a stable partition. We show next, that the process always leads to a stable partition and not a cycle.

Define $aq_{max}=\{aq(A),...,aq(M)\}$. Let G be such that $aq(G)=aq_{max}$ at time t. At time $t+1$, either G remains the same or some i joins G or some j leaves G. If i joins G, then $aq(G+i)>aq(G)$ (otherwise the agents at G refuse to let i join). If j leaves G, then j leaves for H with $aq(H+j)>aq(G)$. Thus, H becomes the new highest average quality location. Therefore, in each period either the group with aq_{max} remains the same, or the group changes and aq_{max} strictly increases. Since N, Q, L are all finite sets, it is not possible for the average quality of the highest average quality group to keep increasing. Thus, after some time period the group with aq_{max} remains unchanged. Starting at

[10] The notion of an improving path was originated by Jackson and Watts [2002] in the context of a dynamic model of network formation.

this time, consider the group with the second highest average quality. Similar analysis shows that this group also remains unchanged after some time period. Repeating this analysis shows that eventually a stable partition is reached. ◊

Next, a new location is added to a segregated stable partition and agents are given the opportunity to relocate. Proposition 4 provides conditions under which the dynamic process leads to an integrated stable partition. We focus on this case because it is the most interesting, since the results are somewhat surprising. Notice that if agents are instead originally in an integrated stable partition and if enough new empty locations are added, then all improving paths lead to segregated stable partitions. (Here any agent with quality level greater than the average quality at his current location prefers to move to an empty location.) Thus, one might expect that adding new empty locations leads to segregation. However, Proposition 4 shows this is not necessarily the case.

Proposition 4: Let $q_1>q_2>...>q_n$. Assume that agents are in a segregated stable partition where $aq(A)>aq(B)>...>aq(M)$, $\mu(A)\leq\mu(B)\leq...\leq\mu(M)$ and where there exists agent $k\in A$ and $\ell\in D\neq A$ such that $q_\ell > aq(D)$ and $(q_k+q_\ell)/2>aq(A)$. If a new location, Z, is added, then there exists an improving path leading the dynamic process to an integrated stable partition.[11]

Proof: <u>Step 1: Show k and ℓ join Z, but that there exists $i\in\{k+1,..., \ell-1\}$ who does not</u>. By Lemma 1, we know that with probability 1, the dynamic process ends in a stable partition. Since $q_\ell > aq(D)$, if ℓ is given the option to move to Z, he does. Since $(q_k+q_\ell)/2 > aq(A)$, k also wants to move to Z. Since $q_k > q_\ell$, ℓ allows k to move to Z. Next, we check that k and ℓ do not allow all agents $\{k+1,...,\ell-1\}$ to join Z and so Z is integrated. (By assumption $q_k > q_\ell$, which implies $q_k>(q_k+q_\ell)/2>aq(A)$ and

[11] In fact we show that if agents ℓ and k are given the first opportunity to move to Z, then all improving paths lead to integrated stable partitions.

thus that $\ell \geq k+2$.) Note that k and ℓ only allow i to join Z if $q_i > (q_k + q_\ell)/2 > aq(A)$. Since $q_1 > q_2 > ... > q_n$ and $q_k > aq(A)$, there exists $j \in A$ with $q_j < aq(A) < (q_k + q_\ell)/2$; such a j is not allowed to join Z. Since $j \in A$ and $q_j < aq(A) < (q_k + q_\ell)/2 < q_k$, then $j \in \{k+1, ..., \ell-1\}$. Thus, Z is integrated. (Note also that any $j \notin A$ and $j \neq \ell$ has $q_j < aq(A) < (q_k + q_\ell)/2$ and is not allowed to join Z.) So, far at least one agent has left A and ℓ has left D; we represent the agents currently at A and D by A' and D' and the original agents by A and D.

Step 2: Show that the only agents $i \notin Z$ who change locations are those who move to Z. By the stability of the initial partition, no agent i moves from C to G, for any $C, G \notin \{A', D', Z\}$. Next, we show i does not move from A' to $G \notin \{D', Z\}$. Since $\mu(A) \leq \mu(G)$ and $A' \subset A$, $\mu(A') < \mu(G)$. Combining $\mu(A') < \mu(G)$ with the fact that all agents at G have lower quality than those at A' yields $aq(A') \geq aq(G+i)$. We also show that no i moves from $G' \in \{A', B, ..., C\}$ to $D' = D-\ell$. We know $A' \subset A$ and for $G \in \{A, ..., C\}$, $\mu(G) \leq \mu(D)$. Thus, $\mu(G') \leq \mu(D)$. Since all agents at D have lower quality than those at G', $aq(G') \geq aq(D-\ell+i)$. Similar reasoning shows no i leaves D' for a lower ranked group. Note that $i \in D'$ cannot join a higher ranked group since such a group does not allow i to join. Thus, all $G \notin \{A', D', Z\}$ have the same agents located at them as under the initial segregated partition.

Step 3: Show that no agent leaves Z. Thus, Z remains integrated. First we show that k does not leave Z. By the stability of the initial partition, $aq(G+k) \leq aq(A) < (q_k + q_\ell)/2 \leq aq(Z)$ for $G \notin \{A', D'\}$. Thus, k does not leave Z for G. By reasoning similar to that used in step 2, $aq(D-\ell+k) \leq aq(A) < (q_k + q_\ell)/2 \leq aq(Z)$. Thus, k does not leave Z for $D' = D-\ell$. Since the only agents who left A are those with $q_i > (q_k + q_\ell)/2 > aq(A)$, $aq(A'+k) \leq aq(A) < (q_k + q_\ell)/2 \leq aq(Z)$. Thus, k does not leave Z for A'. Next, we show ℓ does not leave Z. Agent ℓ may want to leave Z for a group $G \in \{A', B, ..., C\}$ with $aq(G) > q_\ell$, but this group does not let ℓ join. Since ℓ is the only agent, who left D,

$aq(D'+\ell)=aq(D)< (q_k+q_\ell)/2\leq aq(Z)$. Thus, agent ℓ does not leave Z for D' . By the stability of the initial partition, $aq(G+\ell)\leq aq(D)<(q_k+q_\ell)/2\leq aq(Z)$. Thus, ℓ does not leave Z for G with $aq(G)<aq(D)$. From Step 1, any other $i\in Z$ was originally located at A and has $q_i>(q_k+q_\ell)/2>aq(A)$. Similar reasoning to that for k above shows i does not leave Z. ◊

4. Big Fish Payoff Results

In this section, we examine the type of stable partitions that exist when each player wants to be the highest quality agent in the group.

Theorem 2: A partition is stable if and only if for all $i\in D\neq G$, (i) $\mu(\{j\in D|q_j\geq q_i \text{ and } j\neq i\}) >\mu(\{j\in G|q_j\geq q_i\})$ implies $\mu(G)\geq 2\,\mu(\{j\in G|q_j>q_i\})$ and (ii) $\mu(\{j\in D|q_j\geq q_i \text{ and } j\neq i\}) =\mu(\{j\in G|q_j\geq q_i\})$ and $\mu(D)<\mu(G)+1$ imply $\mu(G)\geq 2\,\mu(\{j\in G|q_j>q_i\})$.

Proof: First we show that stability implies the condition stated in the proposition. Assume there exists $i\in D\neq G$ such that $\mu(\{j\in D|q_j\geq q_i \text{ and } j\neq i\}) >\mu(\{j\in G|q_j\geq q_i\})$ or $\mu(\{j\in D|q_j\geq q_i \text{ and } j\neq i\}) =\mu(\{j\in G|q_j\geq q_i\})$ and $\mu(D)<\mu(G)+1$. Thus, $r_i(D)>r_i(G+i)$ or $r_i(D)=r_i(G+i)$ and $\mu(D)<\mu(G+i)$. So i wants to move to G. Stability requires that the majority of agents at G do not allow i to move or that $\mu(\{j\in G|q_j>q_i\})\leq\mu(\{j\in G|q_j\leq q_i\})=\mu(G)-\mu(\{j\in G|q_j>q_i\})$, rearranging yields $\mu(G)\geq 2\,\mu(\{j\in G|q_j>q_i\})$.

Next, assume that for all $i\in D\neq G$, $\mu(\{j\in D|q_j\geq q_i \text{ and } j\neq i\}) >\mu(\{j\in G|q_j\geq q_i\})$ or $\mu(\{j\in D|q_j\geq q_i \text{ and } j\neq i\}) =\mu(\{j\in G|q_j\geq q_i\})$ and $\mu(D)<\mu(G)+1$ implies $\mu(G)\geq 2\,\mu(\{j\in G|q_j>q_i\})$, but that the partition is not stable. Thus, there exists some $i\in D\neq G$ who wants to and can join G. If i can join G, then $\mu(G)<2\mu(\{j\in G|q_j>q_i\})$. If i wants to join G, then either $\mu(\{j\in D|q_j\geq q_i \text{ and } j\neq i\}) >\mu(\{j\in G|q_j\geq q_i\})$ or

$\mu(\{j \in D | q_j \geq q_i \text{ and } j \neq i\}) = \mu(\{j \in G | q_j \geq q_i\})$ and $\mu(D) < \mu(G) + 1$. However, by assumption these inequalities imply that $\mu(G) \geq 2\ \mu(\{j \in G | q_j > q_i\})$; this is a contradiction. ◊

Proposition 5: There exists at least one stable segregated partition.

Proof: Case 1: $n \geq m$. Let $\lfloor n/m \rfloor$ be the greatest integer not exceeding n/m. Let the remainder, $r \equiv n - m \cdot \lfloor n/m \rfloor$. Consider the following segregated partition, σ_F. Place agents $\{q_1, q_2, \ldots, q_{\lfloor n/m \rfloor + r}\}$ at A. Place $\{q_{\lfloor n/m \rfloor + r + 1}, q_{\lfloor n/m \rfloor + r + 2, \ldots,} q_{2\lfloor n/m \rfloor + r}\}$ at B. Continue placing the next $\lfloor n/m \rfloor$ agents at the next location until the last $\lfloor n/m \rfloor$ agents are placed at M. Thus, $\mu(A) = \lfloor n/m \rfloor + r \geq \mu(B) = \ldots = \mu(M) = \lfloor n/m \rfloor$. If there exists $i \in D \neq G$ such that $\mu(\{j \in D | q_j \geq q_i \text{ and } j \neq i\}) \geq \mu(\{j \in G | q_j \geq q_i\})$, then by the construction of σ_F, $D < G$. Thus, if i joins G, he is the highest ranked person (or is tied for the top rank). So, $2\mu(\{j \in G | q_j > q_i\}) = 0 \leq \mu(G)$ and the stability conditions of Theorem 2 are met.

Case 2: $n < m$. Place each agent at a different location. An argument similar to that above shows that such a segregated partition is stable. ◊

Notice that at this segregated stable partition, high quality agents may want to move to a lower quality group to improve their rank. However, all agents at the lower quality group veto the move. Thus, such a segregated partition is also stable even under the stricter stability notion where only one group member's permission is needed in order to join the new group.

Example: Not all segregated partitions are stable. Let $m=2$, $n=4$, and $q_1 > q_2 > q_3 > q_4$. The segregated partition $\{1\} = A$ and $\{2,3,4\} = B$ is not stable since 4 moves to A.

Note: An implicit assumption of the big fish payoff function is that a person is indifferent between being in a group with an agent of the same quality and being with an agent with strictly higher quality. We could have assumed instead that a person is indifferent between being in a group with an agent of the same quality or being with an agent with strictly lower quality. We chose the former assumption to capture the notion that big fish agents do not wish to share the limelight. However, even if we instead chose the later assumption, Proposition 5 still holds true.[12] In order to simplify the proofs (and since we do not wish to focus on these issues) we assume in the remaining propositions that $q_1>q_2>...>q_n$.[13]

Lemma 2: Let $q_1>...>q_n$. There exists a segregated stable partition which is strongly Pareto efficient.

Proof: Case 1: $n\geq m$. Assume agents are in the segregated stable partition, σ_F, of Proposition 5. Any agent currently ranked 1^{st} is ranked 1^{st} in any Pareto improvement otherwise that agent is made worse off. Thus, the same m agents are ranked 1^{st} in our m locations, and all 1^{st} ranked positions are occupied. Now consider agents who are currently ranked 2^{nd}. They also are ranked 2^{nd} in any Pareto improvement and all 2^{nd} ranked positions are occupied. Continue in this fashion. All $\lfloor n/m \rfloor^{th}$ ranked agents are ranked $\lfloor n/m \rfloor^{th}$ at any Pareto improvement and all $\lfloor n/m \rfloor^{th}$ positions are occupied. If $r=0$, then the current partition is strongly Pareto efficient. If $r>0$, consider the agent ranked $(\lfloor n/m \rfloor+1)^{th}$; this agent is ranked $(\lfloor n/m \rfloor+1)^{th}$ in any Pareto improvement. Since σ_F is segregated, this agent continues to be located with the agents he is originally located with at A as locating this agent in any

[12]One example of a segregated stable partition here involves placing agents with identical quality levels at the same location, for instance by placing all agents with the lowest quality level at one location, those with the second lowest at another location, and continuing in this fashion until just one location is left and placing all remaining agents there. Using logic similar to that in the proof of Proposition 5 one can show that this segregated partition is stable.

[13]Note that Lemma 2 still holds true even if $q_1\geq q_2\geq...\geq q_n$. By assumption if $q_i=q_j$ and if i and j are located in the same group, then both agents receive the same rank that j receives in the case of $q_i>q_j$. Thus, in the segregated stable partition of Proposition 5, if some agents have identical quality levels, then these agents may receive lower rankings than in the case where $q_1>q_2>...>q_n$. However, it is still true that raising one agent's quality level by moving him to a lower quality group decreases the rankings of the original agents in this lower group. Similarly, by construction of the original partition any other repartitioning of agents that increases one agent's rank decreases another's rank and is therefore not Pareto improving.

other group gives him a rank of 1 instead of $(\lfloor n/m \rfloor +1)$. Continue in this fashion. Thus, the $(\lfloor n/m \rfloor +r)^{th}$ agent remains at A as well in any Pareto improvement and the original partition is strongly Pareto efficient.

Case 2: $n<m$. Assume each agent is placed at a different location. Thus, each agent is currently ranked first at his location. In order to increase any agent's payoff he should be ranked first in a larger group. However, the other members of such a larger group are made worse off, since they are no longer ranked first. ◊

Proposition 6 shows that an integrated stable partition always exists as long as $n>m$. (If $n \leq m$, then each agent prefers to be at his own location. Thus, all stable partitions are trivially segregated.)[14]

Proposition 6: Let $q_1>...>q_n$. If $n>m\geq 2$, then there exists at least one stable integrated partition.

Proof: Let $\lfloor n/m \rfloor$ be the greatest integer not exceeding n/m. Let the remainder $r \equiv n - m\cdot\lfloor n/m \rfloor$. Let $s = r+1$ if $r \leq 1$ and let $s=r$ otherwise. Consider the following integrated partition, σ_I. Place agents $\{q_2, q_3,...,q_{\lfloor n/m \rfloor+s}\}$ at A. Place $\{q_1, q_{\lfloor n/m \rfloor+s+1}, q_{\lfloor n/m \rfloor+s+2,....,} q_{2\lfloor n/m \rfloor+r}\}$ at B. (Note that since $n>m\geq 2$, $\mu(B)\geq 2$ and B is integrated.) Place $\{q_{2\lfloor n/m \rfloor+r+1}, q_{2\lfloor n/m \rfloor+r+2,....,} q_{3\lfloor n/m \rfloor+r}\}$ at C. Continue by placing the next $\lfloor n/m \rfloor$ agents at the next location until the last $\lfloor n/m \rfloor$ agents are placed at M. Note that $\mu(A)=(\lfloor n/m \rfloor+s-1)\geq \mu(B)=(\lfloor n/m \rfloor+r-s+1)\geq \mu(C)=. ..= \mu(M)=\lfloor n/m \rfloor$.

If there exists $i\in D\neq G$, with $\mu(\{j\in D|q_j\geq q_i \text{ and } j\neq i\}) >\mu(\{j\in G|q_j\geq q_i\})$ or $\mu(\{j\in D|q_j\geq q_i \text{ and } j\neq i\}) =\mu(\{j\in G|q_j\geq q_i\})$ and $\mu(D)<\mu(G)+1$, then either $i=1$ or $i\neq 1$ and $D<G$. If i=1, then

[14] Note that in Propositions 6 and 7 we assume that $q_1>q_2>...>q_n$. If $q_1\geq q_2\geq ...\geq q_n$, then there may exist no integrated partition let alone an integrated stable partition. (For instance if $q_1=q_2=...=q_n$, then no integrated partition exists.)

$\mu(\{j \in B | q_j \geq q_i \text{ and } j \neq i\}) = 0 = \mu(\{j \in G | q_j \geq q_i\})$ for all $G \neq B$. So since $n > m \geq 2$, $\mu(G) \geq 1 > 0 = 2\mu(\{j \in G | q_j > q_i\})$. If $i \neq 1$ and $D < G$, then since $q_1 > ... > q_n$, $\mu(G) \geq 1 > 0 = 2\mu(\{j \in G | q_j > q_i\})$. By Theorem 2, σ_I is stable. ◊

Proposition 6 shows that integration is fairly easy to achieve with the big fish payoff function. Here each agent wants to be the highest quality agent in the group, but does not care about the quality of the other agents in the group as long as their quality is below his. Thus, a high quality agent is willing to be located with low quality agents whereas under the average quality payoff function high quality agents prefer to be located with other high quality agents.

Proposition 7 shows that integration may occur when a new location is added to a segregated stable partition. The dynamic process which was described prior to Proposition 4 is used in Proposition 7 and the corresponding proof. As in the case of Proposition 4, the results of Proposition 7 are somewhat surprising since if enough new locations are added to an integrated stable partition, the dynamic process always leads to a segregated stable partition. (Here any agent ranked last at his current location prefers to move to an empty location.) Thus, one might think that adding new empty locations causes segregation, but Proposition 7 shows that this is not always true.

Proposition 7: Let $q_1 > q_2 > ... > q_n$. Assume agents are in a segregated stable partition where $1 \in A$ and where there exists $D \neq A$ such that $\mu(D) \geq 3$. If a new location, Z, is added, then there exists an improving path leading the dynamic process to either an integrated stable partition or to a series of partitions where at least one location remains integrated at all times.[15]

[15]Specifically we show that if the lowest ranked agents at A and D are given the first chance to move to the new location, then all improving paths lead to either an integrated stable partition or to a series of partitions where at least one location remains integrated at all times.

Proof: Step 1: Convergence (or not) of the dynamic process. Since pairs of agents and locations are randomly identified every period in the dynamic process, with probability 1 the dynamic process cannot become stuck in an unstable partition. Thus, the dynamic process leads to either a stable partition or a series of partitions in which one agent changes locations at each step in the series. We show that in either case at least one location remains integrated at all times.

Step 2: Let $\{1,2,...,i\}=A$ and $\{j,j+1,...,k\}=D\neq A$ with $k-j\geq 2$. Note that segregation requires that $q_i>q_j$. If $i=1$, then k wants to move to A and 1 agrees to it. Thus, stability requires that $i>1$. Notice also that stability requires that no location is empty in σ_S (otherwise k is better off moving to this location which violates stability).

Step 3: Add Z. If i and then k are given the chance to move to Z, both do so.

Step 4: Check that no $j\in\{i+1, i+2,...,k-1\}$ joins Z. Currently $\{i,k\}=Z$. Agent k never allows j such that $q_j>q_k$ to move to Z; since strict majority approval is needed, the move does not occur. Therefore if ℓ joins Z, $q_\ell<q_k$; such a ℓ also votes against $j\in\{i+1,...,k-1\}$ joining Z.

Step 5: Check that i and k do not leave Z. Since $r_i(Z)=1$, i only wants to leave Z for G where $r_i(G+i)=1$ and $\mu(G+i)>\mu(Z)$. However, all the agents at G veto the move. Next, we check that k does not leave Z. Since $r_k(Z)=2$, k only wants to leave Z for G where $r_k(G+k)=1$ or for H where $r_k(H+k)=2$ and $\mu(H+k)>\mu(Z)$. However, k cannot move to G, since all agents at G veto the move. To move to H is also not possible since all agents ranked below him at H veto the move. ◊

5. Concluding Remarks

So far the average quality and big fish payoffs have been treated separately. However, it is also interesting to compare the two cases. We give a flavor of such a comparison here, but leave a formal analysis of this issue as an open topic for future research. For instance, if some agents have big fish payoffs while others have average quality payoffs, then it is possible that no segregated stable partition exists, while we know from Propositions 1 and 5 that if all agents have average quality or all have big fish preferences, then a segregated stable partition always exists. To see this, let $m=2$, $n=4$, $q_1>q_2>q_3>q_4$, and let agents *1* and *2* have big fish preferences while *3* and *4* have average quality preferences. Consider the segregated partition where $\{1\}=A$ and $\{2,3,4\}=B$; here *4* moves to *A*. Thus, this partition is unstable. Additionally, the partition where $\{1,2\}=A$ and $\{3,4\}=B$ is unstable since *2* moves to *B*. Similarly, no other segregated partition is stable as *2* always leaves for a group where he is ranked first. However, the integrated partition $\{1,3\}=A$ and $\{2,4\}=B$ is stable.[16] Thus, having a mixture of preference types may increase the likelihood of integration.

Finally another interesting open question is to examine what happens if agents care about both average quality and quality rankings.[17] Here again one may expect segregation to be less likely as low ranked agents may prefer to offset their low rank by being in a high quality group and high quality agents with low ranks may want to improve their rank by moving to a low quality group.

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[16]Notice here that to achieve stability we placed the top half of the average quality agents with the top half of the big fish agents at *A* and the bottom half of both types at *B*; such a partition is a natural extension of the partitions used to prove existence in Propositions 3 and 5. Such a partition often results in stability, but not always since it is possible that a big fish agent located at *A* wants to move to *B* and such a move is allowed if there are more average quality than big fish agents at *B* and if $aq(B)$ increases. Thus, stability with mixed preferences is difficult to obtain and we leave it as an open question as to whether or not a stable partition always exists.

[17]Note that Damiano, Li and Suen [2004] examine location choice in a model with two locations each of fixed size where agents care about both average quality and quality rankings. Our model differs in that it allows for any number of locations and allows the number of agents at a certain location to be endogenous.

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