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>Vicente Calabuig
Universitat de València and ERI-CES, Spain
>Gonzalo Olcina
Universitat de València and ERI-CES, Spain
>Fabrizio Panebianco
Paris School of Economics

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Vicente Calabuig, Gonzalo Olcina and Fabrizio panebianco
University of Valencia and ERI-CES and Paris School of Economics

Abstract

In this paper we study cultural diversity in values or personal norms concerning effort or work ethics, the related and observable diversity in behavior and its economic consequences. Our goal is to investigate the impact on this type of cultural diversity of primitive economic and behavioral parameters of the group such as the distribution of skills in the group population, the sharing rule on total income that determines income distribution and the levels of materialism, conformism and consistency in the group.

Agents participate each period in a team production game by choosing their level of costly effort. We analyze the emergence and evolution of a culture in a group in which members are guided by economic incentives and also follow personal norms of behavior. We take materialism, skills and the income distribution rule as given, but personal norms evolve along the life-cycle of the individuals according to two psychological forces: cognitive dissonance or consistency and informational conformity.

We characterize the long-run outcomes of the group and study how the levels of diversity, both in personal norms and in behavior and the level of incoherence between both variables are determined by the primitives of the model. We also analyze how these parameters affect group aggregate production and social welfare.

1 Introduction

An idea almost universally accepted in the management and organization economic theory would go more or less as follows. Any long-lived group or organization that is involved in a long run activity, faces the challenge of building an organizational culture, and the features of this culture seem closely related to the levels of satisfaction or welfare of its members and its levels of performance. Managers and organization economists are so convinced about this idea that they will claim that even if there is no conscious and purposeful activity directed to the building of a particular culture, and just letting the organization work alone period after period, a culture will emerge endogenously, although perhaps not a very efficient one. Quite recently mainstream general economics imported this idea to society as a whole. Similarly to the previous argument, a society faces the challenge of building a culture and its characteristics deeply influence its levels of aggregate performance and welfare (see Guiso, Sapienza and Zingales, (2006), Fernandez, (2008, 2013), Landes (1998)). Culture, and its economic effects, has thus become a hot topic in economics. Moreover, there is a recent and growing literature on the effects of cultural diversity in an organization, a society or a group. But few research has been produced on the origins and emergence of group cultures, and on how the initial conditions of the group determine features of the resulting culture such as its diversity, coherence and displayed levels of performance and welfare.

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In this paper we study cultural diversity in values or personal norms concerning effort or work ethics, the related and observable diversity in behavior and its economic consequences. Our goal is to analyze the impact on this type of cultural diversity of primitive economic and behavioral parameters of the group such as the distribution of skills in the group population, the sharing rule on total income that determines remunerations and income distribution, and the levels of materialism, conformism and consistency displayed by agents in the group. Notice that most of the recent literature on diversity (literatura) analyzes diversity of observable traits such as ethnic origins or race, age, nationality, gender, tenure, occupation and similar. In our opinion, this cannot be very relevant per se but because observable traits might be statistically related, for example, to different distributions of skills and/or social capital. This, then, comes to be policy relevant if groups are economically or socially segregated with a consequent polarization in their skills levels or in the shares of disposable income.

Cultural diversity or homogeneity concerning values and behavior is undoubtedly an important topic in other social sciences (social psychology , sociology,...), but it also has deserved much attention in the management science. In fact, the most common definition of corporate culture in this field views a corporate culture as homogeneity in values of the members of the organization, that is, shared values (Schwartz and Davis, 1981, Schein 1990, Van den Steen, 2010a). For instance, Van den Steen (2010a) defines the strength of a culture in the sense of its levels of homogeneity in values. A strong (resp. weak) culture is an homogeneous (resp. diverse) one. In this work we will use the following minor variation of Van den Steen´s definition. Culture is the degree to which members of a group (organization or society) share similar behavior and values or beliefs. With this definition at hand, it is straightforward to define what is meant by cultural diversity or homogeneity. Notice that, as economists, we posit that behavior is also an important element of an organizational culture, and obviously the degree of coherence between behavior and values is also a relevant feature of an organization. Notice also that part of economic literature addresses these questions looking at how culturally homogenous groups interact with each others and how it is possible to observe long run presence of both groups, so that heterogeneity is ensured, or to have long run cultural homogeneity. In this paper we divert from this cultural transmission approach (see, for example, Bisin and Verdier, 2001) since we do not analyze the population dynamics of the different groups but the long run dispersion of individual norms and behaviors.

There are several important questions that have to be answered with respect to an organizational culture. Do all groups and societies tend to homogeneity? Why some organizations and societies are more homogeneous and others are more diverse? What are the determinants of the levels of homogeneity and /or diversity of a culture? Are these levels related with the degree of coherence between actions and beliefs? And finally, what are the economic consequences of cultures with different levels of diversity? How does diversity and incoherence affect ultimate group performance and its members' levels of satisfaction or unsatisfaction? Empirical research on cultural organizational differences reveals four broadly accepted findings (see for instance, Bednar, Bramson, Jones-Rooy and Page, 2010):

1. Cultures exhibit homogeneity both in behavior and in beliefs or preferences.

2. Behavior and preferences exhibit coherence.

3. Despite the previous findings cultures exhibit substantial within-group diversity or heterogeneity and behavior and preferences also exhibit varying levels of incoherence.

4. Cultures differ (inter-group diversity).

Therefore, empirical evidence shows that cultures exist, they differ from one another , they are coherent and yet diversity and incoherence persists within them. A candidate for a good theory or model on the emergence and formation of organizational cultures should explain all these findings and show the determinants of the levels of diversity and incoherence of different cultures, and more importantly, from the economist point of view, it should explain the consequences on aggregate production and social welfare.

Our approach views the diversity of a culture as an endogenous product of individuals' interactions. We analyze the emergence and evolution of a culture in an organization or a group in which members are guided by economic incentives and also follow personal norms of behavior. These personal norms or values assess the level of effort that should be chosen by the agent. In this sense, individuals have an internal standard for a particular conduct concerning the "good" effort to exert. Agents participate each period in a team production game (similar to a public goods game) by choosing their level of costly efforts. We allow for a huge heterogeneity in the initial condition of the group concerning not only the individuals' personal norms (or intrinsic motivation) but also concerning their levels of materialism, that is the weight they assign in their utility function to their material interest. Heterogeneity also concerns their individual skills or productivities and their shares in the total income distribution rule (in short, their remunerations). We take materialism, skills and the income distribution rule as given, but personal norms evolve along the life-cycle of the individuals according to two psychological forces: cognitive dissonance or consistency and informational conformity. Consistency is an individual force that drives personal norms towards actual behavior. People tend to seek consistency in their beliefs and behavior. When there is a discrepancy between them, something must change in order to eliminate or reduce the dissonance. (Akerlof and Dickens 1982, Kuran and Sandholm 2008, Nordblom and Zamac 2012). Conformity, by driving personal norms towards the average actual group behavior, captures how social interaction impact on diversity. Conformity is a type of social influence involving a change in belief or behavior in order to fit in with a group (Bernheim 1994, Kandel and Lazear 1992, Akerlof 1997, Fischer and Huddart 2008). In this way our model departs from the literature of conformity and peer effects that puts the conformity part directly into the utility of agents through complementarities in behavior; conversely, we make conformity playing only at the norm formation level with no direct effect on the utility function. In a next subsection we will analyze and justify with more details the role of personal norms and the forces that make them change along time.

We assume that elements such as the societal distribution of materialism, remuneration and skills but also consistency and conformism are held fixed in the analysis, while personal norms or preferences gradually evolve along the life-cycle and behavior instantaneously adjusts in each production period. In a sense, this is a three-speed dynamic model where the societal distribution of human capital, the societal income distribution rule and the society levels of materialism, conformism and consistency evolve more slowly than personal norms do and the latter in turn evolve more slowly than behavior does.

We characterize the long-run outcomes of the group (the steady states of the dynamics of personal norms) and study how the levels of diversity in personal norms and in behavior, and the level of incoherence between both variables are determined by the primitives of the model: the income distribution in the group, the distribution of skills and the levels of materialism, conformity and consistency in the population. We also analyze how these parameters affect group aggregate production and social welfare. [1]

We first find that in the Nash equilibrium of the team production game played each period, agents exert an effort which is a weighted average of their individual marginal revenue and their personal norm where the weight is given by their level of materialism. If the dynamics of personal norms is governed only by consistency, personal norms and equilibrium behavior converge both to a level equal to the Nash equilibrium of the team production game in material payoffs. There is complete coherence between behaviour and values with each individual having a personal norm that dictates an effort that coincides with her individual marginal revenue. Therefore, consistency provides a dynamic foundation of conventional Nash equilibrium. Norms and behavior diversity reflects the dispersion of the individual marginal revenues in the society, which is in turn determined by the distribution of skills and the income distribution rule. If the dynamics of personal norms is governed only by conformism, all agents' personal norms converge to the same value which coincides with

1. In this work we do not analyze the influence of a leader or of some "influential individuals" in the final organizational culture (see in this issue, Hernandez, Olcina and Toral 2014). And we also make two further simplifications. On the one hand, the members of the group are fixed and equally long-lived. In other words we do not incorporate a turnover rate in the organization. On the other hand, there are no exogenous changes in the environment where the organization operates. Of course these exogenous shocks would make flexibility a priori more valuable (see Bolton et al (2013)).

the average marginal revenue of the members of the organization. Therefore, the group tends to complete homogeneity in values. But notice that even if all agents have the same personal norm, each agent performs a different action given the different incentives derived from skills, income sharing rule and materialism. Thus, there is diversity on behaviour and consequently high levels of incoherence. This result drives us away from standard findings obtained when conformism is part of the utility function *via* peer effects; In that case, if only conformism is at work, then a complete homogeneity in behavior is shown. Here we allow for the presence of behavior heteregeneity even if agents form norms in a full conformist way. We also analyze, for the case of a dynamics with only conformism, the effects derived from the presence in the group of a subset of either non-conformists individuals, or non-materialistic agents or finally completely materialistic individuals. In all these cases, a strong culture still arises in the long-run. That is, a homogeneous culture in personal norms (values) but not in behaviour. The presence of non-conformist agents, non-materialistic agents or selfish agents only affects the particular value of the homogeneous personal norm in the steady state.

We turn next to the general case when the personal norms dynamics displays positive levels of consistency and conformity. Each agent's personal norms in the steady state is a convex combination between her individual marginal revenue and the average marginal revenue in the group. We define as diversity of both norms and behaviour in the long run, their respective variances in the steady state. We also define the level of incoherence of a culture as the variance of the distances between values and behaviour in the steady state. Our model shows how the diversity and coherence of an organizational culture depends on the primitive economic and behavioral variables of the group and establishes some clear predictions. Accordingly with the stylized facts stated above, we find that behavior and values diversity are correlated, even if behavior is always more diverse than values. Looking at the effects of skills, we have that a more unequal distribution increases the variance of the distribution of productivities in the group and yields a culture with more diversity in behavior and values and more incoherence. Similarly, a more unequal sharing distributional rule which increases the variance of the income distribution will also yield a culture with more diversity in behavior and values and more incoherence. The same effect appears if there is an increase of the levels of materialism of the society. Finally, we found that conformism decreases the level of diversity while consistency increases diversity.

In the last part of the paper we focus on the long run effects of the cultural dynamics described on aggregate production and social welfare. We first derive aggregate production and welfare in terms of variance and covariance of skills and distribution of income. However, to get clear results we focus on two different situations: the case in which the realisation of skills is unobserved when sharing rules are set up, and the case in which they are observed (assuming symmetric beta distribution of skills), so that some sort of correlation between skills and revenues is possible. Our results go in three directions: i) If skills are unobserved, then the policy maker should prefer a totally egualitarian income distribution in order to maximize aggregate production, in order to avoid giving high compensation to low-skills workers and low compensation to high-skills; ii) If skills are observed, the more equal is the distribution of skills, the more unequal and biased towards high-skills workers should be the aggregate production maximizing income distribution, in order to give to the few high skills workers enough incentives to maintain high their production; iii) If we consider welfare, and thus the loss associated to the difference between norms and actual behavior, then the policy maker should always choose a more egualitarian income distribution than the one that maximizes aggregate production.

Related literature and Economic Relevance.

As we discussed previously the issue of diversity or heterogeneity of a corporate culture has obtained much attention in management. But, why the homogeneity or diversity of an organizational culture is important? Some previous results, in the management literature (see Van den Steen 2010b, for example) show that a strong culture (an homogeneous culture) leads to: more delegation, higher utility, less monitoring, higher effort, faster coordination, less influence activity and less biased communication. These are the benefits of homogeneity. But there are also costs associated with homogeneity: less information collection and less experimentation. Summarizing there are costs and benefits coming from the homogeneity or strength of an organizational culture.

Our paper highlights how the income and skills distribution in a group or society and the levels of deep behavioral social features such as materialism, conformism and consistency determine the diversity and coherence of a culture and its welfare properties.
There also exist a very recent growing economics literature on diversity. A very popular word nowadays in the literature. The empirical results obtained seem to show that diversity generates negative effects on growth, on the level of spending on public goods or on the quality of government. Although these results are not clear in fully democratic countries.

But again in this literature diversity might have costs and also benefits. Homogeneity is good because facilitates or enhances trust, cooperation, provision of public goods, but is bad because it reduces experimentation.

Notice that most of this literature on diversity analyzes diversity of observable traits such as ethnic or race, age, nationality, gender, tenure, occupation and similar. But it is quite obvious that this cannot be vey relevant per se but because they might be statistically related to different distribution of skills and of social capital.

In our work we study diversity in personal norms concerning effort i.e. intrinsic motivation and the related and observable diversity in behavior. And we are able to analyze the impact on these types of diversity of the diversity or heterogeneity of skills, remunerations and the levels of materialism, conformism and consistency in the society.

The rest of the paper is organized as follows. Section 2 presents conformity and consistency as the main driving forces behind the dynamics of personal norms. Section 3 describes the team production game played in each period and the utility function of any member of the group. In section 4, we study the evolution of personal norms governed only by a dynamics of consistency and in section 5 when personal norms dynamics is governed only by a dynamics of conformity. In section 6 we will analyze the dynamics when both forces work together and characterize the determinants of cultural diversity and incoherence. Finally in section 7 we present the effects of diversity on social welfare while section 8 concludes.

2 Personal Norms

In order to better analyze how a culture becomes homogeneous or diverse, it is now crucial to discuss in depth the role of personal norms and the forces that make them change in time. We can take for granted that each agent has personal norms, innate or derived from some form of social pressure or internalization of society's stimuli. When choosing for an action, each agent also considers what her own personal norms dictate since they may provide some intrinsic motivation to act in a certain way. More specifically, intrinsic motivation can be seen as a way to take into account self-punishments and self-rewards that may derive from acting coherently with the norm (Schwartz (1977)). Deci and Ryan (1985), Ryan and Deci (2000) and Thøgersen (2006) provide some additional evidence for the existence of this internalized norms as forces for behavior. Frey (1997) reintroduced intrinsic motivation and personal norms in the economic debate, not considering them as negligible elements (see Lindenberg (2001) for a review on intrinsic motivations). Furthermore, the recent literature on cultural evolution and transmission, starting with Bisin and Verdier (2001) also relies on the endogeneity of preferences or values.

2.1 Personal norms evolve

The internalization process of personal norms opens the road to the possibility of the evolution and change of the norms themselves. We consider intragenerational transmission of personal norms: agents update their own norms depending on what happens in the surrounding environment, and this mechanism implies that norms, and thus preferences, are not stable over the lifetime. Some

examples can be derived from Cialdini and Trost (1998) for the psychological literature, Postlewaite (2010) for the economics literature and Matthied et al. (2012) for the evolution of norms in pro-environment settings. Bednar et al. (2010) identify two main forces that are at work while norms are formed: conformity and consistency. Nordblom and Žamac (2012) also implement these two forces for studying the evolution of norms for tax evasion. We also use them as driving forces for the analysis of the evolution of personal norms and for the study of the emergence of a culture.

2.1.1 Conformity

Conformity in our paper means looking at how personal norms or values depend on others' values and behaviors. If others' values are considered in the own personal norm formation process then we can talk about informational conformism, while if others' observed behavior is taken into account then we can talk about normative conformism (see Nordblom and Žamac (2011)). From an economist's point of view, we find normative conformism to be more plausible since it does not assume agents to inspect others' minds and infer their true norms, but just observe others' choices and get influenced by them. However, in some cases as norms concerning opinions, informational conformism can be more appropriate. Looking at normative conformism, Bernheim (1994) was the first one to introduce this in economics. However, the first formalization is due to Manski (1993) who introduced it using the peer effects concept. In Manski's framework, peer effect is the result of the influence of the more prevalent behavior in the environment on agents' choices and the resulting positive correlation between the two. Notice that in all these cited models the peer effect is included in the utility function of the individual and directly influences her behavior. Whereas in our approach conformity or peer effects influence the process of the preference evolution and thus indirectly affects behavior .

2.1.2 Consistency

Consistency is the second mechanism we consider for the personal norms formation scheme. In particular, consistency assumes that agents would like to have their own personal norms and behaviors to be positively correlated, otherwise they experience a psychological cost for not having followed their personal norm. As Bednar et al. (2010) and Bednar and Page (2007) suggest, consistency finds its roots in the desire of reducing a potential cognitive load agents may experience if behavior and norms happen not to be in line. Festinger (1957) was the first one to formalize this phenomenon using the notion of cognitive dissonance. Notice that avoiding cognitive dissonance can be the result of two distinct processes: agents updating values considering their own past behavior and agents behaving taking into account their own values. However, while the first process regards the norm formation mechanisms, the second one is captured by the specific decision process modeled. In our framework we consider both these forces to hold. The former, the behavior-to-norm force, can be again rooted in the cultural evolution evidence since, when forming their own attitudes and norms, agents tend to be partially stuck to their own past choices, as argued in Aronson (1999), Beauvois and Joule (1996), Harmon-Jones and Harmon-Jones (2002), McGuire (1966). Bednar et al. (2010) also provide exhaustive literature on this topic. Notice finally that some links between cognitive dissonance and the self-signaling theory (Bem (1972), Benabou and Tirole (2004, 2006, 2010)) have been proposed. Self-signaling theory assumes that agents, by observing their own behavior, progressively discover their own true norms and update them in the direction of past behavior, so that norms and behavior progressively converge because of the behavior-to-norm force.

3 The Static Model

Consider a social group or an organization composed by N agents acting simultaneously. Each agent i chooses a level of non verifiable effort $e_i \geq 0$ to participate in a team production game, where effort is costly and this cost is given by $c(e_i) = (1/2)\, e_i^2$. The total revenue is given by the function $y = \sum_{i=1}^{N} s_i\, e_i$, where $s_i \geq 0$ is the productivity of each agent, being related to an idiosyncratic skill level. We assume that the total revenue generated by the team is divided according to a sharing rule **w,** being a vector of real numbers that assigns to each agent a share $w_i \in [0, 1]$ of the total revenue, with $\sum_{i=1}^{N} w_i = 1$.[2]

Besides the economic incentives, each agent i has a *personal norm* $\hat{e}_i \geq 0$ assessing the level of effort that should be chosen by the agent accordind to the norm. In this sense, all agents have an "internal standard for a particular conduct" concerning the "good" effort to exert, and any deviation of actual behavior from their personal norms will yield disutility. We assume that the loss function is given by $(1/2)\,(e_i - \hat{e}_i)^2$. This loss depends on the difference between the actual agent's effort and her personal norm. Therefore, each agent is motivated to act by two forces: economic incentives and personal norms. Each individual may assign different levels of importance to these two factors putting a weight $\beta_i \in [0,1]$ to the material payoffs and $(1-\beta_i)$ to the intrinsic motivation (personal norms $\hat{e}_i$). Therefore we will denote β_i as the level of materialism of player i.

Summarizing, the utility of a player in the team production game is given[3] by the following linear quadratic function:

$$u_i(\mathbf{e}) = \beta_i \left[w_i \sum_{j=1}^{N} s_j e_j - \frac{1}{2} e_i^2\right] - (1-\beta_i)\,\frac{1}{2}\,(e_i - \hat{e}_i)^2 \tag{1}$$

where $\mathbf{e}$ is the vector of efforts of the N agents. Note that agents differ not only in personal norms $\hat{e}_i$, but also in the weight assigned to material incentives and personal norms β_i, in the share of income w_i and in the skill s_i. The standard case of no intrinsic motivation is obtained as a special case of (1) for $\beta_i = 1$.

The Nash equilibrium (NE) of the simultaneous game in each period t is given by:

$$\bar{e}_i^{\,t} = \beta_i\,(w_i\,s_i) + (1-\beta_i)\,\hat{e}_i^{\,t}, \text{for } i = 1, 2.... N \tag{2}$$

Notice, for instance, that if the same weight is assigned to both material payoffs and personal norms (i.e., $\beta_i = 1/2$) and with equal sharing (i.e., $w_i = 1/N$), then the NE is given by: $\bar{e}_i = \frac{(s_i/N) + \hat{e}_i^{\,t}}{2}$.

Notice also that the efficient effort that maximizes social welfare is

$$e_i^* = s_i \sum_j \beta_j\,w_j + (1-\beta_i)\,\hat{e}_i, \text{for } i = 1, 2.... n \tag{3}$$

By comparing (2) and (3), we have that $e_i^* \geq \bar{e}_i$, so that the effort level chosen in the NE is always smaller or equal[4] than the one chosen to maximize social welfare. This is because each individual, while choosing the optimal effort $\bar{e}_i$ does not take into account the positive externality her choice exerts on all the other agents. In fact, the marginal product of effort $\bar{e}_i$ is partially taken by the agent i with share w_i, while a share $1 - w_i$ goes to the rest of the society. As it is clear, this inefficiency is not due to the presence of the intrinsic motivation; In fact, if $\beta_i = 1$ (only material payoffs matter), the NE given by $\bar{e}_i = w_i\,s_i$ is inefficient since it is smaller than the efficient effort level given by $e_i^* = s_i$.

Once we have defined the static problem, we now introduce the possibility for personal norms $\hat{e}_i^{\,t}$ to evolve gradually over time. We consider a two-speed dynamics: gradual changes in preferences (personal norms) are accompanied by immediate behavioral adjustment in each period's equilibrium play. In the following sections, we assume that individuals may change their personal norms through two psychological mechanisms: a) *consistency* (or cognitive dissonance), that is, personal norms move towards the actual behavior of the agent and b) *informational conformism* (conformity), that induce personal norms to move towards the average of the actual behavior of the organization. In the next two sections we will analyze these two motives for the evolution of behavior and personal norms, separately in order to get a better understanding of the influence of each mechanism.

2. Note that with equal sharing we get $w_i = 1/N$.

3. For simplicity we assume that the material costs of exerting efforts and the loss function regarding personal norms are quadratic.

4. Note that only when $\beta_i = 0$, the effort level chosen in the Nash equilibrium is efficient, that is, $e_i^* = \bar{e}_i$.

4 Dynamics of personal norms with consistency

In this section, we assume that only consistency holds so that, when there is a discrepancy between beliefs and behaviors, something must change in order to eliminate or reduce the dissonance. In particular, we assume that this dissonace is reduced by making preferences of each agent i to evolve in the direction of her own actual Nash equilibrium behavior, with the following rule:

$$\hat{e}_i^{t+1} = \gamma_i \, \bar{e}_i^{\,t} + (1 - \gamma_i) \, \hat{e}_i^t \tag{4}$$

where $\gamma_i \in (0, 1)$ is the weight that agent i assigns to the actual equilibrium behavior, and $1 - \gamma_i$ indicates how much the agent is anchored to her own past personal norm. Using the continuous time limit of the dynamics in (4), we get the following differential equation system:

$$\frac{d\hat{e_i}}{d\,t} = \gamma_i \, (\bar{e}_i^{\,t} - \hat{e}_i^t) \text{ for } i = 1, 2.... \, N \tag{5}$$

Substituting, in each period, the NE into (5), we get a set of independent linear ODE:

$$\frac{d\hat{e_i}}{d\,t} = (\gamma_i \beta_i) \, (w_i \, s_i - \hat{e}_i^t) \text{ for } i = 1, 2, ..., n \tag{6}$$

Then, calling $\hat{e}_i^{\infty}$ and $\bar{e}_i^{\infty}$ the long run values of personal norms and equilibrium behavior, we obtain the following result.

Proposition 1. *If the dynamic of personal norms is governed by consistency as in (4), then personal norms $\hat{e}_i^{\infty}$ and equilibrium behavior $\bar{e}_i^{\infty}$ converge to a level equal to the Nash equilibrium of the team game in material payoffs ($\hat{e}_i^{\infty} = \bar{e}_i^{\infty} = w_i \, s_i$). Moreover, $\hat{e}_i^{\infty}$ is a globally stable steady state.*

Proposition 1 states that, if consistency is the unique driving force for the evolution of personal norms, then personal norms will tend to the Nash Equilibrium in material payoffs of the team production game. This means that each agent personal norm evolves to a specific effort level equal to her individual marginal revenue which is determined by the product of her own skills and the share of total income she is assessed. Consequently, at steady state, personal norms dictate inefficient efforts. For example, even if agents start with personal norms for efficiency ($\hat{e}_i^0 = s_i$), in the steady state personal norms get eroded and will tend to the individual marginal revenue $w_i \, s_i$. Clearly, when there is no influence of the actual behavior ($\gamma_i = 0$) and/or the material payoffs are not important ($\beta_i = 0$) , then $\hat{e}_i^t = \hat{e}_i^{t+1}$, and thus in the steady state personal norms coincide with the initial personal norm of each agent, $\hat{e}_i^{\infty} = \hat{e}_i^0$, since no dynamic at all is shown.

Notice that both individual personal norms and behavior converge to the same value. Therefore there is complete coherence between behavior and values. In other words there is no cognitive dissonance in the steady state of the group. Diversity of both behavior and values reflects the dispersion of the individual marginal revenues in the society which is in turn determined by the distribution of skills and the income distribution rule.

Finally, it is important to notice that, since equations in (6) are all independent, if some agent has $\gamma_i = 0$, $\beta_i = 0$ or $\beta_i = 1$, this only has an effect on her own dynamics maintaining unchanged the dynamics of personal norms and behaviors of all the other agents.

An interesting by-product of our theory is that we have shown that consistency provides a novel dynamic foundation of conventional Nash Equilibrium (NE). In evolutionary game theory a NE is reached under the replicator dynamics in which the most profitable alternative chosen by other agents is imitated. In our model this is not possible since we have heterogeneous agents and not an homogenous population, so that each agent has her own most profitable action. Moreover, by using only cognitive dissonance we rule out, for the time being, any form of social learning and imitation. However we show that social imitation is not needed in order to reach conventional NE in material payoffs, but just agents correcting their own norms from their past actions. Another difference is that in standard evolutionary game theory agents are not rational and are planned to play one strategy, thus imitation takes the place of rationality. In our framework, agents are rational and thus this creates the dynamics towards NE.

5 Dynamics of Personal Norms with Conformity

We now consider what happens if conformity (or informational conformism) is the unique force driving the change of personal norms. By conformity, personal norms tend to move towards the average of the actual behavior of the organization, this average being considered what one "*should*" do in that specific social context. In this sense, conformity is a type of social influence involving a change in values in order to fit in with a group.

Hereafter we will denote by $\langle a \rangle$ the average of variable a_i, that is, $\langle a \rangle = (1/N) \sum_{i=1}^{N} a_i$. The difference equations that characterize the evolution of personal norms in this case take the following form:

$$\hat{e}_i^{t+1} = \alpha_i \langle \bar{e}^{\,t} \rangle + (1 - \alpha_i)\, \hat{e}_i^t, \text{ for } i = 1, 2, \ldots N \tag{7}$$

where $\alpha_i \in (0, 1)$ is the parameter that measures the degree of conformism and $\langle \bar{e}^{\,t} \rangle$ is the average of the NE of the group in period t. Then, we can state the following:

Proposition 2. *If the dynamics of personal norms is governed by informational conformism as in (7), then in the steady state the personal norm of all agents converge to the same value,* $\hat{e}_i^{\infty} = \frac{\langle \beta\, w\, s \rangle}{\langle \beta \rangle}, \forall i$.

The main message of proposition 2 is that, if only informational conformisms is at work, then in steady state all agents end up having the same personal norm. The group tends to a completely homogeneous culture in values. Moreover, note that the steady state personal norm is entirely independent of the initial distribution of personal norms and is only grounded on the levels of skills, sharing rule and preference parameter β . We can simplify this result, assuming that the random variables β_i and $(w_i s_i)$ are statistically independent. We will use this example along all the paper to explain the results. In this case we can approximate $\langle \beta\, w\, s \rangle \simeq \langle \beta \rangle \langle w\, s \rangle$. Then:

Corollary 1. *If personal norms are governed by a dynamics as in (7), and the variables* β_i *and* $(w_i s_i)$ *are statistically independent, then the personal norm of each agent in the steady state is* $\hat{e}_i^{\infty} = \langle w\, s \rangle, \forall i$ *and the equilibrium behavior is* $\bar{e}_i^{\infty} = \beta_i\, w_i\, s_i + (1 - \beta_i) \langle w\, s \rangle$*, for* $i = 1, 2 .... N$.

This result states that having just informational conformism, each agent personal norm converges to a common value that is the average marginal revenue of the group. As previously noticed, this norm generally assesses an inefficient effort level. Notice that with this dynamics, even if all agents have the same personal norm, each agent performs a different action given the different incentives deriving from skills, sharing rules and preference parameters. Therefore, there is a strong culture concerning values but there is diversity concerning behavior. Moreover, there is perpetual cognitive dissonance or incoherence, $\bar{e}_i^{\infty} \neq \hat{e}_i^{\infty}$, since in the steady state the equilibrium action will be different from their personal norm. Notice that

$$\text{if } w_i\, s_i \gtreqless \langle w\, s \rangle \text{ then } \bar{e}_i^{\infty} \gtreqless \hat{e}_i^{\infty}$$

so that when agents have higher (lower) individual revenue than the average of the group they will choose a higher (lower) level of effort than the one prescribed by the common personal norm. Only if agents are in the average of the group in terms of individual revenue, then their equilibrium effort choice will coincide with the personal norm. However notice that this does not help any agent to reach an efficient effort; When we compare the level of equilibrium effort chosen in the steady state with the efficient given by (3), the effort level chosen is inefficient since $e_i^* > \bar{e}_i^{\infty}$, also for the high skill agents.

We have assumed in the previous results that all agents have a positive level of conformism since $\alpha_i > 0$ for all agents. Next we will analyze different cases in which not all agents have positive values for conformism, α_i or they have a extreme value 0 or 1 in the weight assigned to the material payoff, β_i. We will analyze the influence of subsets of this kind of agents in the group both on the evolution of personal norms and the equilibrium behavior in the long run. With respect to the case of agents showing only conformism, here the dynamic equations are not independent so that we expect an effect on the long run equilibrium.

Case 1: The effect of non-conformist agents in the group.

We now analyze the case in which there exists a number N_0 of non-conformists agents with $\alpha_i = 0$. Note that $\beta_{i.} > 0$, $\forall i$. By (7), these N_0 agents show $\hat{e}_i^{\infty} = \hat{e}_i^0$, since they are not influenced by the behavior of the rest of the agents so that their personal norms remain constant along all the trajectory. We now study how the presence of these non-conformist agents influence the outcomes of standard conformist agents. Defining as $\langle \cdot \rangle_{N_0}$, the average of variable $\cdot$ in the population subset N_0, we show the main result in the following proposition:

Proposition 3. *If personal norms are governed by a dynamic of informational conformism in (7), but a number N_o of agents are non-conformist ($\alpha_i = 0$), then in steady state:*

i. Non-conformist agents: $\hat{e}_i^{\infty} = \hat{e}_i^0$ and $\bar{e}_i^{\infty} = \beta_i (w_i s_i) + (1 - \beta_i) \hat{e}_i^0$

ii. Conformist agents: $\hat{e}^{\infty} = \frac{\langle \beta w s \rangle + \frac{N_0}{N} \langle (1-\beta) \hat{e}^o \rangle_{N_0}}{\langle \beta \rangle + \frac{N_0}{N} \langle 1 - \beta \rangle_{N_0}}$ and

$$\bar{e}_i^{\infty} = \beta_i (w_i s_i) + (1 - \beta_i) \frac{\langle \beta w s \rangle + \frac{N_0}{N} \langle (1-\beta) \hat{e}^o \rangle_{N_0}}{\langle \beta \rangle + \frac{N_0}{N} \langle 1 - \beta \rangle_{N_0}}.$$

The main message of proposition 3 is that, even in presence of some non-conformist agents, all conformist agents have their own personal norms converging to the same value. This value, however, is different from the convergence level in the case in which all agents are conformists. In particular, the convergence value depends on the initial level of personal norms of non-conformist that, in this sense, drive the results of the dynamics process, being the ones who do not change their own personal norms, but whose actions are taken into account by conformists. In order to give a simple example, consider the case in which $w_i = 1/N$ (equal sharing rule) and $\beta_i = \beta = 1/2$. Then, in steady state we get

$$\hat{e}^{\infty} = \frac{\frac{\langle s \rangle}{2N} + \frac{N_0}{2N} \langle \hat{e}^o \rangle_{N_0}}{1/2 + \frac{N_0}{2N}} = \frac{\langle s \rangle + N_0 \cdot \langle \hat{e}^o \rangle_{N_0}}{N + N_0} = \frac{\langle s \rangle + \sum_{i \in N_0} \hat{e}_i^0}{N + N_0} \tag{8}$$

If we compare it with the case of all conformist agents ($\hat{e}^{\infty} = \frac{\langle s \rangle}{N}$), the difference between the two convergence values depends on the number of non conformist agents and on their initial personal norm level. In particular the higher the aggregate personal norms of non conformist, the higher $\hat{e}^{\infty}$. This is due to the fact that higher conformists' personal norms have a positive impact on conformists'aggregate action and, if N_0 is unchanged, this results in a higher $\langle \bar{e}^{\,t} \rangle$ imitated by conformists. On the other side, the larger N_0, the lower $\langle \bar{e}^{\,t} \rangle$, with a negative effect on conformists' personal norms convergence value.

Case 2: The effect of agents only guided by personal norms

We now consider the case of a subset N_0 of agents acting only looking at own personal norms without regards of material incentives ($\beta_i = 0$). Note that $\alpha_i > 0$. We know that for these agents $\bar{e}_i^t = \hat{e}_i^t$, but they still update their personal norms at each period so that the result in proposition 2 holds for everyone so that all the members' personal norms converge to the same value given by $\hat{e}^{\infty} = \frac{\langle \beta w s \rangle}{\langle \beta \rangle}$. However, since for some agents $\beta_i = 0$, this implies that $\hat{e}^{\infty} = \frac{\langle \beta w s \rangle_{N/N_o}}{\langle \beta \rangle_{N/N_o}}$, so that only the $(N - N_o)$ agents with $\beta_i > 0$ influence the steady state social norm. Finally, note that if there is statistical independence between β_i and $(w_i s_i)$, then $\hat{e}^{\infty} = \langle w\, s \rangle_{N/N_o}$. This means that, even if a subset of agents is only guided by own personal norms, in steady state a strong culture arises as well if conformism holds. It is now interesting to analyze what happens if the whole group has $\beta_i = 0$. Then, the results on personal norms and equilibrium behavior change.

Proposition 4. *If personal norms are governed by a dynamics of informational conformism in (7), and all agents are only guided by personal norms ($\beta_i = 0, \forall i$), then the steady state personal norm is $\hat{e}^{\infty} = \frac{\langle \frac{\hat{e}^o}{\alpha} \rangle}{\langle \frac{1}{\alpha} \rangle}$*

so that in steady state the common personal norms is the average of the personal norms at time 0. This happens since, if all agents have $\beta_i = 0$, the subset N/N_o, which drives the overall dynamics, is empty. Agents thus, keeping imitating each others' behavior, end up by imitating just their personal norms, converging to the average of norms at time 0.

Case 3: The effect of materialistic agents in the group.

We now consider the case in which a number $N_0 < N$ of agents choose looking only at their own material incentives without regards to personal norms: N_0 agents with $\beta_i = 1$ and $N - N_0$ agents with $\beta_i \in (0,1)$. We assume that every non-materialistic agent has $\alpha_i > 0$. Obviously, materialistic agents do not have any $\hat{e}_i$, or it is irrelevant for the model. Therefore, for this group of agents it holds that $\bar{e}_i^{\,t} = w_i\, s_i = \bar{e}_i^{\,\infty}$ and the behavior in the steady state coincides with the Nash equilibrium in material payoffs. Analysing also non-materialistic agents we can state:

Proposition 5. *If personal norms are governed by a dynamics of informational conformism in (7), and there is a number N_0, of materialistic agents ($\beta_i = 1$), then in steady state:*

i. Materialistic agents: no personal norm and $\bar{e}_i^{\,\infty} = w_i\, s_i$

ii. Non-materialistic agents: $\hat{e}^{\infty} = \frac{\langle \beta\, w\, s \rangle}{\langle \beta \rangle}$ and $\bar{e}_i^{\,\infty} = \beta_i\, w_i\, s_i + (1-\beta_i)\, \frac{\langle \beta\, w\, s \rangle}{\langle \beta \rangle}$.

As a matter of example, if we assume statistical independence between β_i and $w_i\, s_i$ we get that $\hat{e}^{\infty} = \langle w\, s \rangle$ for $i \in N/N_0$.

Summarizing, note that in all the previous cases if personal norms evolve exclusively because of conformism, a strong culture arises in the long-run, a homogeneous culture in personal norms (values) but not in behavior. The presence of non-conformist or non-materialistic or materialistic agents only affects the particular value of the homogeneous personal norm in the steady state.

Let us next analyze the evolution of personal norms and the equilibrium behavior in the group when the dynamics of the personal norms is a mix between consistency and informational conformity.

6 The Determinants of Cultural Diversity and Incoherence.

It is now interesting to study what happens when both Consistency and Conformity enter into the dynamics of personal norms. We assume that with probability $(1-\tau_i)$ the personal norm $\hat{e}_i^{\,t+1}$ of individual i moves towards the average equilibrium behavior in the group, and with probability τ_i the personal norm moves in the direction of the individual equilibrium behavior. In summary, people update their norms influenced by their own past behavior and/or by the attitude of their peers, with different weights. We assume that the law of motion of personal norms is given by the following expression:

$$\hat{e}_i^{\,t+1} = \underbrace{\tau_i\, (\gamma_i\, \bar{e}_i^{\,t} + (1-\gamma_i)\, \hat{e}_i^{\,t})}_{\text{Consistency}} + \underbrace{(1-\tau_i)\, (\alpha_i \langle \bar{e}^{\,t} \rangle + (1-\alpha_i)\, \hat{e}_i^{\,t})}_{\text{Informational Conformism}} \tag{9}$$

We denote by $a_i \equiv \tau_i\, \gamma_i$ the weight associated to consistency and by $b_i \equiv \alpha_i(1-\tau_i)$ the weight associated to conformism for each player, where both $a_i,\, b_i \in (0,\, 1)$. For simplicity we allow for individual heterogeneity of these weights while the level of materialism β will be the same for all players $\beta_i = \beta, \forall i$. Then, the following result on steady state personal norms and behavior is shown:

Proposition 6. *If personal norms are governed by a dynamics that is a mix of consistency and informational conformism as in (9), the steady state personal norm of each agent is*

$$\hat{e}_i^{\,\infty} = \left(\frac{a_i\, \beta}{a_i\, \beta + b_i} \right) (w_i\, s_i) + \left(\frac{b_i}{a_i\, \beta + b_i} \right) \langle w\, s \rangle, \textit{ for } i = 1, 2, \ldots N \tag{10}$$

.

Moreover, the equilibrium behavior is

$$\bar{e}_i^{\infty} = (\beta + (1-\beta)(\frac{a_i\,\beta}{a_i\,\beta + b_i}))\,(w_i\,s_i) + (1-\beta)\left(\frac{b_i}{a_i\,\beta + b_i}\right)\langle w\,s\rangle, \textit{for } i = 1, 2, \ldots N \tag{11}$$

By proposition 6, we know that, in the steady state, personal norms are a convex combination between individual marginal revenue and average marginal revenue. Using previous results, note that the first part is driven by consistency and the latter by conformity. The main consequence in terms of the resulting culture can be seen by looking at the steady state behavior. Note that there is no consensus among agents on how to form behavior, since each agent weights differently the information deriving from her own material incentives ($w_i s_i$) and from the overall society$\langle w\,s\rangle$ and this weight depends on her levels of materialism, conformism and consistency. In what follows we analyze the diversity of behavior and personal norms arising from this process.

6.1 Diversity of Personal Norms and Behavior.

Now we are ready to define a general measure of the diversity of an organizational culture in the long run. We will study both diversity on personal norms and diversity on behavior, and their relationship. Let us begin by analyzing diversity on norms, or values.

The lower the variation of personal norms, the stronger (the more homogeneous) is the group culture. The natural candidate for this measure of dispersion is the variance of the personal norms in the steady state. The higher this variance , the higher the cultural diversity of the organization. We denote the variance of personal norms in the steady-state as $\sigma^2(\hat{e}^{\infty})$. Then we have the following definition of diversity of personal norms in a culture.

***Definition* 1.** *The diversity of personal norms in a culture is given by:*

$$\sigma^2(\hat{e}^{\infty}) = \frac{1}{N}\sum_{i=1}^{N}(\hat{e}_i^{\infty} - \langle\hat{e}^{\infty}\rangle)^2 \tag{12}$$

Assuming statistical independence between both $a_i\,, b_i$ and $(w_i\,s_i)$, we can approximate the diversity as (see Appendix B for details)

$$\sigma^2(\hat{e}^{\infty}) = \left\langle\left(\frac{a\,\beta}{a\,\beta + b}\right)^2\right\rangle\sigma^2\,(w\,s) \tag{13}$$

Note first that $\left(\frac{a_i\,\beta}{a_i\,\beta + b_i}\right) < 1$, then $\left\langle\left(\frac{a\,\beta}{a\,\beta + b}\right)^2\right\rangle < 1$, therefore $\sigma^2(\hat{e}^{\infty}) \leq \sigma^2(w\,s)$.

Analogously, the measure of diversity of behavior would be the variance of the equilibrium actions in the steady state.

Definition 2. *The diversity of behavior in a culture is given by:*

$$\sigma^2(\bar{e}^{\,\infty}) = \frac{1}{N}\sum_{i=1}^{N}(\bar{e}_i^{\infty} - \langle\bar{e}^{\,\infty}\rangle)^2$$

Hence, with statistical independence between a_i and b_i and $w_i\,s_i$ we obtain

$$\sigma^2(\bar{e}^{\,\infty}) \simeq \left\langle\left(\frac{\beta\,(a+b)}{a\,\beta + b}\right)^2\right\rangle\sigma^2\,(w\,s) \tag{14}$$

Now, assuming homogeneity in the parameters, it is easy to check that the variance of the equilibrium behavior is increasing with the variance of marginal revenues (ws), with the degree of materialism (β) and with the level of consistency (a) and decreasing with the level of conformism (b). Rearranging terms we have:

$$\sigma^2(\bar{e}^{\infty}) = \frac{\left\langle \left(\frac{\beta\,(a+b)}{a\,\beta+b} \right)^2 \right\rangle}{\left\langle \left(\frac{a\,\beta}{a\,\beta+b} \right)^2 \right\rangle} \sigma^2(\hat{e}^{\infty}) \tag{15}$$

The most important result is that, for a distribution of weights in which $b>0$, while diversity in norms and behavior are correlated, $\sigma^2(\bar{e}^{\infty})$ is always greater than $\sigma^2(\hat{e}^{\infty})$, so that the variance of behavior is greater than the variance of personal norms. In this way, the diversity of behavior is always greater than the diversity of values in any group or organization and an increase in personal norm variance corresponds to a less than proportional increase in behavior diversity. Notice also that if $b=0$, so that there is only consistency, $\sigma^2(\bar{e}^{\infty}) = \sigma^2(\hat{e}^{\infty}) = \sigma^2(ws)$. Clearly in this case the only way to reduce the variance of personal norms and behavior is reducing the dispersion of "technical" factors like productivity or distributional factors like the income sharing rule. Summing up

Proposition 7. *The long run diversities of personal norms and behavior are always smaller or equal than the diversity in marginal incentives to exert effort; If personal norms are governed by a dynamics that is a mix of consistency and informational conformism as in (9), behavior diversity is always greater than norm diversity.*

We thus get the rough intuition that the dynamics of personal norms actually helps in creating some sort of homogeneity in the population personal norms but that behavior is always less homogenous than norms. Moreover, the dynamics makes always norms and behavior less diverse than the mere variance of marginal revenues. We now have to analyze the influence of several parameters on the variance of personal norms, and consequently, on the cultural diversity of the organization.

6.1.1 Effect of w and s. First, notice that an increase in $\sigma^2(w\,s)$ will yield an increase in the variance of personal norms. Generally, if w_i and s_i are not statistically independent we have

$$\sigma^2(w\,s) = \sigma^2(w)\sigma^2(s) + \frac{1}{N^2}\sigma^2(s) + \langle s\rangle^2\sigma^2(w) + \mathrm{cov}(w^2, s^2) - [\mathrm{cov}(w,s)]^2 + 2\langle w\rangle\langle s\rangle\mathrm{cov}(w,s) \tag{16}$$

Clearly, if the two variables are correlated, is hard to determine, ex ante, how $\sigma^2(ws)$ changes when the mean or the variance in variables w_i or s_i is considered. Following Goodman (1960) and assuming statistical independence between the variables w_i and s_i, we have that the variance of this product is:

$$\sigma^2(w\,s) = \sigma^2(w)\sigma^2(s) + (1/N^2)\sigma^2(s) + \langle s\rangle^2\sigma^2(w) \tag{17}$$

It is straighforward to check that an increase in the average of the skills $\langle s\rangle$ in the society will lead to an increase in $\sigma^2(w\,s)$, so that a society with higher productivities (due to innate or acquired skills) will cause a more diverse culture. If skills are thus a function of previous economics outcomes, it follows that the more a society invests in skills and rise the average skill, the more it will be characterized by diversity in norms and behavior.

On the other hand, an increase both in the variance of the distribution of skills and in the variance of the sharing rule, i.e. the income distribution, will cause an increase in $\sigma^2(w\,s)$ and, in turn, a rise in the variance of personal norms. In this way, the "technical" conditions (distributions of skills) and the "social" conditions (distribution of income) have an impact on the resulting culture, so that a culture is stronger (less diverse) if there is higher homogeneity in skills and remunerations. We can sum up by stating:

Proposition 8. *Long run norm and behavior diversity increases with diversity in skills, in income distribution and with average skills level.*

6.1.2 Effect of Conformism. Consider now the influence of changes in the weight that agents assign to conformism b_i. First, we will assume for simplicity that all agents assign the same weight to conformism $b_i = b, \ \forall i$. An increase in the level of conformism has the effect of decreasing the variance of personal norms. Clearly, a rise in the level of conformism in the group will lead to most of the agents to adopt similar personal norms reducing their variance. In this case the society will show a stronger culture. Consider the (extreme) case in which the dynamics is governed only by conformism ($a_i = 0$ and $b > 0$). As we previously noticed, in this case $\hat{e}^{\infty} = \langle w\, s \rangle$, so that the variance of personal norms is

$$\sigma^2(\hat{e}^{\infty}) = 0 \tag{18}$$

This is the strongest culture in the sense that all agents have the same personal norm. In this way a society characterized by a high degree of conformism shows a stronger culture. However behavior diversity remains positive. This is a major difference with respects to models that include conformism into the utility function by inserting some sort of complementarities in behavior. In those models, if only conformism holds, then complementarities act to the point of making all agents' behaviors converging to the same level. In our case, however, even if conformism is maximal, we still keep some degree of heterogeneity in behavior, in line with most of the empirical findings about culture diversity and behavior, as highlighted in the introduction.

Second, we return to the case of heterogeneity in the levels of conformism, $b_i > 0$. We will analyze the effects of a change in the dispersion of these weights. In order to make meaningful comparisons we analyze the impact of Mean Preserving Spread (MPS) changes in the dispersion of the distribution of the parameter $b_i > 0$. There is a well known result from Rothschild and Stiglitz (1970) that states that a MPS increases the expected value of a convex function. It is easy to check that the matrix of second derivatives of (10) with respect to b_i is positive, thus the function is convex and, consequently, an increase in the dispersion of the distribution of b_i, will increase the variance of the personal norms and this in turn implies a reduction of the strenght of the culture. The intuition of this result relies on the fact that in a society with a less dispersed level of conformism, culture is stronger (more homogeneous). It is easy to check that the same happens for behavior diversity. To sum up:

Proposition 9. *Long run norm and behavior diversity decreases with the overall level of conformism. Norm diversity is null if agents are only conformists, while behavior diversity is positive. If agents are heterogenous in their level of conformism, norm and behavior diversity increases under mean preserving spreads in the distribution of conformism.*

6.1.3 Effect of Consistency. Consider now an increase in the weight agents assign to consistency a_i. As in the previous case we will consider first for simplicity the case of an homogeneous $a_i = a, \ \forall i$. An increase in a raises the variance of personal norms, reducing the strenght of the culture. This is due to the fact that, by consistency, each agent will have her own personal norm moving towards the level predicted by her own material incentives, as found in section 4. If the force of consistency rises, the weight of "technical" factors like the productivity of agents increases. If, then, these factors are unevenly distributed, the homogeneity of the culture is reduced. Consider the (extreme) case in which the dynamics is governed only by consistency ($a > 0$ and $b = 0$). As we previously noticed, in this case $\hat{e}_i^{\infty} = (w_i \ s_i)$, so that the variance of personal norms is

$$\sigma^2(\hat{e}^{\infty}) = \langle \left(\frac{a\,\beta}{a\,\beta} \right)^2 \rangle \, \sigma^2 (w\, s) = \sigma^2 (w\, s) \tag{19}$$

This result means that the variance of personal norms in the steady state derives basically from both "technical" factors like the productivity of agents and in the distributional factors like the sharing rule and it reaches the maximal possible value. As conformism is not playing any role in the steady state, the organizational culture reaches the highest level of diversity since agents will only be guided by their own personal norms and they will stuck in them irrespectively of social pressure. For this reasons, also behavior diversity reaches the same value. Cognitive dissonance weakens the strenght of a culture. We can then state that a society characterized by a large degree of consistency is characterized by a high cultural diversity.

Next, we analyze the case of heterogeneity in the levels of consistency, $a_i>0$. The reader can check that the sign of the matrix of second derivatives of (10) with respect to a_i is unclear, so we cannot have a clear prediction neither on the variance of the personal norms nor on the strenght of the culture when there is an increase in the dispersion of the distribution of the weights of consistency.

Proposition 10. *Long run norm and behavior diversity increases with the level of consistency. If agents use only consistency, norm and behavior diversity are maximal and are equal to* $\sigma^2(w\,s)$.

6.1.4 Effect of Materialism. Finally, an increase in the weight of the level of materialism (β) in the utility function of agents, will lead to an increase in the variance of personal norms. An increase in the weight assigned to the material payoffs is equivalent to a reduction in the influence of personal norms and hence, a reduction in the pressure of the dynamics, resulting in a greater influence of productivity and/or sharing rule. Summarizing, for higher β, the individuals are more selfish and less influenced by personal norms, weakening the culture. Note that in the opposite case when β tends to 0, then $\sigma^2(\hat{e}^{\infty})$ tends to 0. In this case $\bar{e}_i^{\,t}=\hat{e}_i^{\,t},\forall t$, therefore, only conformism matters. Societies with very low levels of materialism will display very homogeneous cultures. The very same processes happen for behavior diversity.

Proposition 11. *Long run norm and behavior diversity increases with the level of materialism. If the level of materialism is null, long run norm and behavior diversity are null too.*

It is then clear that, even if the variance of behavior overestimates the diversity of a group culture, they are correlated and changes in the main elements of the model affect in the same direction both of them, so that diversity in behavior gives some elements to understand diversity in norms.

6.2 Analysis of Incoherence: Relationship between Behavior and Personal Norms

We define the level of incoherence of a culture as the variance of the distances between $\bar{e}^{\,\infty}$ and $\hat{e}^{\,\infty}$. In particular, the degree of incoherence of an organizational culture is given by $\rho^2=\frac{1}{N}\sum_{i=1}^{n}(\bar{e}_i^{\,\infty}-\hat{e}_i^{\infty})^2$. The reader can check that this degree of incoherence is given by:

$$\rho^2=\left\langle\left(\frac{\beta\,b}{a\,\beta+b}\right)^2\right\rangle\sigma^2(w\,s)\,. \tag{20}$$

This is the aggregate inconsistency between behavior and personal norms. Note for example that if there is only consistency , $b_i=0$, for all i, then $\rho^2=0$. On the other hand, if $a_i=0$, only conformism, for all i, then $\rho^2=\ \beta^2\,\sigma^2(w\,s)$.

The level of incoherence of a culture represents a social psychological cost and it increases with the variance of the group marginal revenues $\sigma^2(w\,s)$, with the level of materialism β , with the level of conformism b and decreases with the level of consistency a. This concept of incoherence will prove useful in the next Welfare analysis section.

7 The Effects of Diversity on Social Welfare

Once we have understood how norm diversity is shaped in the long run and how this norm diversity coevolves with and impacts behavior heterogeneity, it is possible also to understand how these diversities impact the performance of the economy. In particular we determine how long run levels of production and social welfare are shaped by the initial distribution of skills and by the distribution of revenues among agents. This turns to be crucial since the distribution of skills can be shaped by investements in education while the way in which these skills are compensated is the choice of the policy maker, being for example the management of a firm or, when labor unions are strong and salaries are negotiated at regional or national levels, this is a variable of choice at the political level.

First, consider the aggregate material payoffs. Set $z_i(e)=w_i\sum_{i=1}^{n} s_i e_i - \frac{1}{2}e_i^2$ where the first term represents the individual gain from production and the second term the cost associated with effort. Then the aggregate material production is given by

$$Y=\sum_{i=1}^{n} z_i(e) \tag{21}$$

Now, recall that in the steady state :

$$\bar{e}_i^{\infty}=\left[\beta+(1-\beta)\left(\frac{a_i\,\beta}{a_i\,\beta+b_i}\right)\right](w_i\,s_i)+(1-\beta)\left(\frac{b_i}{a_i\,\beta+b_i}\right)\langle w\,s\rangle \tag{22}$$

For simplicity we will denote $(\frac{a_i\,\beta}{a_i\,\beta+b_i})$ by A_i, therefore we can write the previous expression as:

$$\bar{e}_i^{\infty}=[\beta+(1-\beta)A_i]\,(w_i\,s_i)+(1-\beta)(1-A_i\,)\langle w\,s\rangle. \tag{23}$$

Thus, assuming statistical independence between A_i and $w_i s_i$, the aggregate net production in steady state is given by (see Appendix C for derivation):

$$Y=\frac{2N[\beta+(1-\beta)\langle A\rangle]-B^2(1+N^2\sigma^2(w\,))}{2N}\,\sigma^2(s\,)+\frac{2N-1-N^2B^2\sigma^2(w\,)}{2N}\,\langle s\rangle^2+[N(1-\beta)(1-\langle A\rangle)-1]\langle s\rangle\mathrm{cov}(w,s)-\frac{N}{2}[\mathrm{cov}(w,s)]^2+[N\beta+N(1-\beta)\langle A\rangle]\mathrm{cov}(w,s^2) \tag{24}$$

The way in which long run aggregate production depends on the distribution of skills and revenues is complex and strictly depends on the specific distribution functions. However we can notice that the net material payoff is decreasing in $\sigma^2(w\,)$. Then Y is non monotone in $\mathrm{cov}(w,s)$ and reaches a maximum in $\mathrm{cov}(w,s)=N(1-\beta)(1-\langle A\rangle)$. Without specific formulations about the distributions of skills and incomes, it is then quite hard to understand the effects of a change in the parameter. In fact, a change in the distributions changes expected values, variances and covariances. For this purpose the next two subsections are devoted to the analysis of some examples.

The presence of norms and the possible loss associated to behaviors that do not match them, makes the analysis of social welfare interesting. The whole utility function with the material and psychological payoffs is given by

$$u_i(e)=\beta\left(w_i\sum_{i=1}^{n} s_i e_i-\frac{1}{2}e_i^2\right)-\tfrac{1}{2}(1-\beta)(e_i-\hat{e}_i)^2 \tag{25}$$

Recalling that the level of incoherence is given by $\rho^2=\left\langle\left(\frac{\beta\,b)}{a\,\beta+b}\right)^2\right\rangle\sigma^2\,(w\,s)$ then we can write the aggregate social welfare W as

$$W=\beta Y-\frac{N}{2}(1-\beta)\rho^2 \tag{26}$$

So that incoherence shifts down the overall social welfare, that becomes (see Appendix C):

$$W=\beta\left[\langle s\rangle^2\left(1-\frac{1}{2N}\right)+\sigma^2(s)(\beta+(1-\beta)\langle A\rangle\right]-\left(\frac{N}{2}\right)\left[\beta\left\langle\left(\frac{\beta(a+b)}{\beta a+b}\right)^2\right\rangle+(1-\beta)\left\langle\left(\frac{\beta b)}{\beta a+b}\right)^2\right\rangle\right]\sigma^2\,(w\,s) \tag{27}$$

where $\sigma^2\ (w\,s)$ is given by (16). Again, as for the case of the aggregate net production, this is decreasing in $\sigma^2(w)$. However, again, it is impossible to get precise results without specific distributions for skills and revenues. In order to understand more precisely how aggregate production and social welfare depend on the initial distribution of skills and revenues we now consider two cases: first when skills are unobserved when salaries are decided and, then, when they are observable and salaries can be correlated to skills.

7.1 Unobserved Skills

Assume that w and s are two random variables distributed independently. Even if economic theory states that revenues should be strictly linked with productivity and, consequently, with skills, this does not always happen. This is particularly the case in which, when salaries are set, the level of skills of each agent is unknown, and just the overall distribution of skills is common knowledge. A similar situation happens when salaries are determined at a political level through collective negotiations with labor unions, so that a direct relationship between individual skills and salaries is hardly identified. These two situations can be represented as the choice of the best policy when salaries are determined without regards the level of the skills so that skills and salaries are independently distributed. This case helps to understand some basic properties of the aggregate net production and the social welfare. First of all notice that in this case $\text{cov}(w,s)=\text{cov}(w,s^2)=\text{cov}(w^2, s^2)=0$. Then in this case the aggregate net production is given by

$$Y=\frac{2N[\beta+(1-\beta)\langle A\rangle]-B^2(1+N^2\sigma^2(w))}{2N}\sigma^2(s)+\frac{2N-1-N^2B^2\sigma^2(w)}{2N}\langle s\rangle^2 \tag{28}$$

As it is clear, given any distribution of skills, the best that the policymaker can do is to choose $\sigma^2(w)=0$, a totally egualitarian distribution of revenues. Clearly, this is a compelling result, since it states that if it is impossible to link salaries to skills and productivity then it is better to set a unique level of salary rather than imposing salaries' variation unrelated to skills and productivity. This result comes from the fact that production function is linear and costs are convex. As Appendix C shows, aggregate gross production is independent of w and $\sigma^2(w)$ while the cost depends on $\sigma^2(w)$. Thus, changing the distribution of w does not change the aggregate production while increases the costs (this is as a mean preserving spread of a convex function).[5] Consider now the additional loss associated to the welfare, $L=-\frac{N}{2}(1-\beta)\left\langle\left(\frac{\beta b)}{a\beta+b}\right)^2\right\rangle\sigma^2(w\,s)$. Recall also that, if w and s are independent then $\sigma^2(w\,s)=\sigma^2(w)\sigma^2(s)+\langle w\rangle^2\sigma^2(s)+\langle s\rangle^2\sigma^2(w)$ so that, again, L is decreasing in $\sigma^2(w)$ so that the best that a policymaker can do is to choose a perfectly egualitarian distribution of revenues. Thus

Proposition 12. *If w and s are independently distributed, the policymaker that wants to maximize aggregate net production and social welfare must choose $\sigma^2(w)=0$, that is the egalitarian distribution.*

7.2 Observed Skills

From the previous sections we understand the the specific long run effects of norms dynamics on aggregate productions and welfare crucially depend on the properties of the distributions of s_i and w_i. We now consider the case in which it is possible to set salaries as a function of individual skills. In order to provide tractable framework we consider $s_i\sim\text{Beta}[\alpha,\beta]$, so that $s_i\in[0,1]$. We recall that the distribution function is given by $f(s)=s^{\alpha-1}(1-s)^{\beta-1}$. In particular we consider the cases in which $\alpha=\beta\equiv\delta>1$. Now, $\alpha=\beta$ imposes symmetry to the distribution while $\delta>1$ means that average skills are always more represented in the population. As Figure 1 shows, the higher δ the higher the probability of average skills, while the lower δ the fatter the tails.

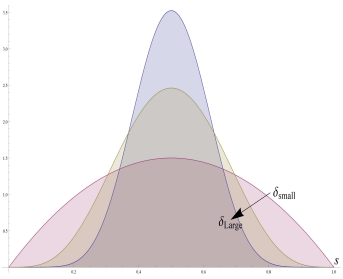

Figure 1.

5. Note that with a concave production function we should observe the same. In particular, production should be decreasing in the variance, while the cost is increasing in the variance, so that again the optimal choice is to set the variance equal to 0.

For simplicity we assume along this example that $A_i = A$ for all agents, then we can call $D_i = (\beta + (1-\beta)(\frac{a_i\beta}{a_i\beta+b_i})) = (\beta + (1-\beta)(\frac{a\beta}{a\beta+b}) = D$. We also assume that the share of production each agent gets is somehow correlated to her skills (notice, not to her marginal contribution to total production[6]). In particular we approximate the salaries as $w_i = s_i^\lambda$ with $\lambda \in \Re^+$, so that the higher λ the more the society gives relative high salaries to high skilled workers, while the lower is λ the higher gives relative higher salaries to low skilled workers, with the constraint that $w_i > w_j \Leftrightarrow s_i > s_j$. In particular, if $\lambda = 0$ then all agents get payed the same, while the higher λ the higher is the payment for the higher marginal skills and the lower the payment for the low marignal skills. Next figure shows the cumulative distribution fuction of w, where convex distributions are for $\lambda<1$ and concave for $\lambda>1$, for the particular case in which $\delta = 0$, but the generic case shares the same properties. (The case for $\delta = 0$, when the distribution collapses to a uniform distribution, is analyzed in Appendix E).

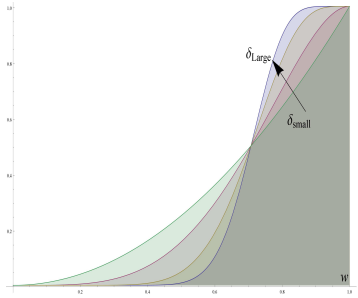

Figure 2.

In particular it is clear from this figure that the smaller λ the more the cumulative distribution is convex and thus the more there is a density peak close to 1. This is due to the fact that small λ implies that a larger share of population gets higher w_i up to the case in which $\lambda = 0$ and everyone gets 1, thus with all the density in w_i=1.

We consider the case of a Beta distribution such that $f(s) = s^{\delta-1}(1-s)^{\delta-1}$. In this case,

we get

$$G(w) = P(W \leqslant w) = P(s^\lambda \leqslant w) = P\left(s \leqslant w^{\frac{1}{\lambda}}\right) = \int_0^{w^{\frac{1}{\lambda}}} f(s)\mathrm{d}s = w^{\frac{1}{\lambda}} \tag{29}$$

so that,

$$G(w) = \int_0^{w^{\frac{1}{\lambda}}} f(s)\mathrm{d}s = \frac{1}{\delta}w^{\frac{\delta}{\lambda}} - \frac{1}{2\delta-1}w^{\frac{2\delta-1}{\lambda}} \tag{30}$$

and

$$g(w) = \frac{d}{dw}G(w) = \frac{1}{\lambda}w^{\frac{\delta-\lambda}{\lambda}}\left[1 - w^{\frac{\delta-1}{\lambda}}\right] \tag{31}$$

Then, in order to get the net aggregate production , it is then just a matter of algebra (Appendix) to see that aggregate net production si given by

$$Y = \frac{1}{2}(\delta-1)\left(-\frac{D^2}{(2\lambda+\delta+2)(2\lambda+2\delta+1)} - \frac{(\delta-1)(1-D)^2}{(1-2\lambda)^2(2\lambda+\delta)^2} - \frac{(\delta-1)(D-1)}{(2\lambda-1)\delta(\delta+1)(2\lambda+\delta)} + \frac{2(\delta-1)D(1-D)}{(2\lambda-1)(\lambda+\delta+1)(2\lambda+\delta)(\lambda+2\delta)} + \frac{2D}{(\lambda+\delta+2)(\lambda+2\delta+1)}\right) \tag{32}$$

6. Economic theory tells us that in order to be optimal, each agent has to be remunerated for her relative contribution. This, however, would be quite difficult to get since it should be $w_i = e_i s_i / \sum_j e_j s_j$ where $e_i(w_i)$ is given by (22). In the continuous setting, however, this would be zero. We thus decide to go for a distribution of shares strictly linked with the distribution of skills.

While it is very complex to understand from this formula what happens, we can still get some intuitions from a graphical analysys. Consider next figure where on the x-axis there is λ and on the y-axis there is D.

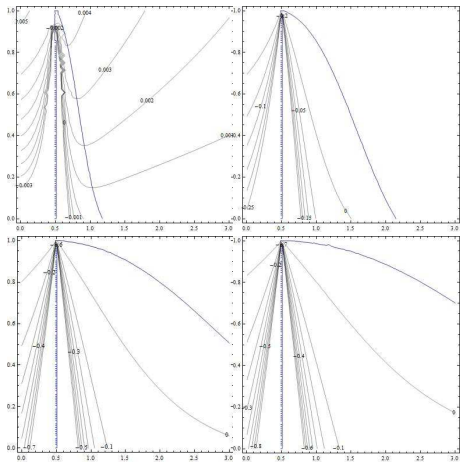

Figure 3. Simulations for $\delta = 1.1; 3; 10; 15$ from top-left to bottom-right

Level curves represent the aggregate net production, while the darker curve represent the optimal level of λ. At $\lambda = 0.5$ there is a discontinuity. As we can see, for given D, the optimal $\lambda > 0.5$. Moreover this level is increasing in δ. If we consider now the aggregate well being, it is again just a matter of computations to see that the aggregate loss is given by

$$L = \beta^2(1-A)^2\Bigg[\frac{\delta-1}{(2\,\lambda+\delta+2)(2\,\lambda+2\,\delta+1)} + \frac{(\delta-1)^2}{(2\,\lambda+\delta)^2(2\,\lambda-1)^2} + 2\frac{(\delta-1)^2}{(2\,\lambda+\delta)(2\,\lambda-1)(2\,\lambda+\delta+2)(2\,\lambda+2\,\delta+1)}\Bigg] \tag{33}$$

As in the previous case this is decreasing in λ so that by calling λ_W the optimal λ to maximize the social welfare we finally get

$$\lambda_W \in (0, \lambda_Y) \supseteq (0, 1)$$

Thus we can sum up:

Proposition 13. *If* $s_i \sim \text{Beta}[\delta, \delta]$ *with* $\delta > 1$ *and* $w_i = s_i^{\lambda}$ *then* $\lambda_Y > 0.5$ *and increasing in* δ*, so that more equal skills distribution should be associated to more unequal revenue distribution. Moreover* $\lambda_W \leq \lambda_Y$.

Given the parametrization in D, the higher δ, the higher the optimal level of λ_Y and, given β, also the higher the level of λ_W. This is due to the fact that a higher δ means a society in which there are more middle-skilled workers and lower low and high skilled workers. While the low level of low skilled does not create production problems, the decrease in high skilled workers damages the overall production. Thus it is needed an incentive mechanism that gives a larger revenue to them. Thus, by choosing a higher λ_Y or λ_W the policy maker obtains a double effect: on one side it provides larger incentive to the few high skilled workers to exert a higher level of effort, on the other side it lowers the incentive of low skilled workers by moving part of their income shares to high skilled. We can then sum up by saying that the more equal is the distribution of skills (high δ) the more unequal the distribution of revenues should be. Then it should be pointed out that in all cases the policy maker that tries to maximize social welfare has to bias down the optimal λ_W. In particular, the higher the importance agents give to material payoffs the larger this downward bias. This is due to the fact that a higher β leads agents to choose following material payoffs, thus moving potentially far from norms. This makes their loss larger. On the other side, their material payoffs increase. However, a net effect is impossible to be derived analytically.

8 Concluding Remarks

In this paper we have analyzed the evolution of personal norms and the emergence of organizational cultures when agents' personal norms follow a dynamics driven by a combination of cognitive dissonance and informational conformism. The main result in this case is that individual personal norms constitute a combination between the behaviour given by the Nash equilibrium of the agents (that depends on his own productivity and the income distribution rule) and the behaviour of the average of the Nash equilibria of the organization (that depends on the average of the product of the productivity and the sharing rule).

The consequence of this result is that, with heterogeneity of skills, there is both perpetual cognitive dissonance and non-conformism, because the personal norms never coincide with the equilibrium actions. We also show that these results hold when we allow for heterogeneity of the mechanisms in which the personal norms evolve.

An important insight of this research is that it is possible to identify the factors that determine the strenght of a culture (measured by the variance of the personal norms). The results obtained are that the strenght of a culture is greater, a) the lower the dispersion of skills or productivity, b) the lower the average of these skills, c) the lower the dispersion of sharing rule or remunerations, d) the higher the size of the level of conformism, e) the lower the dispersion of the distribution of the weights of conformism, f) the lower the size of consistency and g) the lower the level of materialism in the society.

Appendix A: Proofs of propositions.

Proof of Proposition 1

Note that $w_i\, s_i$ is the NE in material payoffs in the simultaneous game. If $(\gamma_i\ \beta_i) \neq 0$, the solution (or trajectory) of any of these independent linear ODE is:

$$\hat{e}_i^t = w_i\, s_i + (\hat{e}_i^0 - w_i\, s_i) \exp\left[-(\gamma_i\, \beta_i)\, t\right],\ \forall i \tag{34}$$

where $\hat{e}_i^0$ is the initial condition of the personal norm of agent i. In the steady state, when $t \to \infty$, we get

$$\hat{e}_i^\infty = w_i\, s_i$$

Finally, note that $\hat{e}_i^\infty$ is globally stable since $-\gamma_i\, \beta_i < 0$

Consider now the equilibrium actions: substituting the steady state personal norms obtained into (2) and computing the equilibrium, we get the result.

■

Proof of Proposition 2

From (2), we have

$$\langle \bar{e}^t \rangle = \langle \beta\, w\, s \rangle + \langle \hat{e}^t \rangle - \langle \beta\, \hat{e}^t \rangle. \tag{35}$$

Substituting (35) in (7) we get:

$$\hat{e}_i^{t+1} = \alpha_i \left[\langle \beta\, w\, s \rangle + \langle (1-\beta)\, \hat{e}^t \rangle \right] + (1-\alpha_i)\, \hat{e}_i^t \text{ for } i = 1, 2 ..... N. \tag{36}$$

Taking the continuous time limit of the dynamics, we get the following set of coupled ODE:

$$\frac{d\hat{e_i}}{d\, t} = \alpha_i \left[\langle \beta\, w\, s \rangle + \langle (1-\beta)\, \hat{e}^t \rangle - \hat{e}_i^t \right] \text{ for } i = 1, 2 ..... N$$

Provided that $\alpha_i > 0, \forall i$, we get the following expression in the steady state when $\frac{d\hat{e_i}}{d\, t} = 0$, $i = 1, 2 ..... N$, and when $t \to \infty$

$$\hat{e}_i^\infty = \langle \beta\, w\, s \rangle + \langle \hat{e}^\infty \rangle - \langle \beta\, \hat{e}^\infty \rangle \tag{37}$$

Taking averages in (37) we obtain:

$$\langle \hat{e}^{\infty} \rangle = \langle \beta\, w\, s \rangle + \langle \hat{e}^{\infty} \rangle - \langle \beta\, \hat{e}^{\infty} \rangle \tag{38}$$

Therefore

$$\langle \beta\, \hat{e}^{\infty} \rangle = \langle \beta\, w\, s \rangle \tag{39}$$

Substituting (39) in (37) we get the following result

$$\hat{e}_i^{\infty} = \langle \hat{e}^{\infty} \rangle, \text{for all } i \tag{40}$$

Therefore, in the steady state the personal norm of each agent will be the same for all agents, that is, $\hat{e}_i^{\infty} = \hat{e}^{\infty}$.

The next step is to obtain this value. Note that equation (39) becomes

$$\langle \beta\, \hat{e}^{\infty} \rangle = \hat{e}^{\infty} \langle \beta \rangle = \langle \beta\, w\, s \rangle \tag{41}$$

so that the result immediately follows.

■

Proof of Proposition 3

For the $(N - N_0)$ conformist agents with $\alpha_i > 0$, we know that

$$\hat{e}_i^{\infty} = \langle \beta\, w\, s \rangle + \langle \hat{e}^{\infty} \rangle - \langle \beta\, \hat{e}^{\infty} \rangle \tag{42}$$

and we know from (40) that $\hat{e}_i^{\infty} = \hat{e}^{\infty}\ \forall i \in N/N_0$, where we denote by N/N_0 the set of $N - N_0$ conformist agents. That is, all conformist agents converge to the same personal norm in the steady state, $\hat{e}^{\infty}$.

Let us compute this value $\hat{e}^{\infty}$.

$$\hat{e}^{\infty} = \langle \beta\, w\, s \rangle + (\frac{1}{N}) \sum_{i=1}^{n} (1 - \beta_i)\, \hat{e}_i^{\infty} = \tag{43}$$

$$= \langle \beta\, w\, s \rangle + (\frac{1}{N}) \left[\hat{e}^{\infty} \sum_{i \in N/N_0} (1 - \beta_i) + \sum_{i \in N_0} (1 - \beta_i)\, \hat{e}_i^{0} \right] \tag{44}$$

$$\hat{e}^{\infty} \left(1 - \frac{1}{N} \sum_{i \in N/N_0} (1 - \beta_i) \right) = \langle \beta\, w\, s \rangle + (\frac{1}{N}) \left(\sum_{i \in N_0} (1 - \beta_i)\, \hat{e}_i^{0} \right) \tag{45}$$

$$\hat{e}^{\infty} = \frac{\langle \beta\, w\, s \rangle + (\frac{1}{N}) \left(\sum_{i \in N_0} (1 - \beta_i)\, \hat{e}_i^{0} \right)}{\left(1 - \frac{1}{N} \sum_{i \in N/N_0} (1 - \beta_i) \right)} \tag{46}$$

■

Proof of Proposition 4

Recall that when $\beta_i = 0$,then $\bar{e}_i^t = \hat{e}_i^t$. Taking averages we get $\langle \bar{e}^t \rangle = \langle\, \hat{e}^t \rangle$. And substituting we have the following system of coupled ODEs,

$$\frac{d\, \hat{e}_i}{d\, t} = \alpha_i \left[\langle \bar{e}^t \rangle - \hat{e}_i^t \right], \text{for } i = 1, 2 \ldots N \tag{47}$$

Now we make $\frac{d\, \hat{e}_i}{d\, t} = 0$ in (47) and when $t \to \infty$, we get that $\hat{e}_i^{\infty} = \langle \bar{e}^{\infty} \rangle\ \forall i$ and therefore $\hat{e}_i^{\infty} = \hat{e}^{\infty}$.

Thus, multiplying both sides of equation (47) by $(1/\alpha_i)$ and taking averages we get:

$$\langle \frac{1}{\alpha} \frac{d\, \hat{e}}{d\, t} \rangle = \langle \bar{e}^t \rangle - \langle \bar{e}^t \rangle = 0$$

which implies that $\langle \frac{1}{\alpha} \frac{d\, \hat{e}}{d\, t} \rangle = \frac{d \langle \frac{\hat{e}}{\alpha} \rangle}{d\, t} = 0$, and therefore the following "conservation law" holds

$$\langle \frac{\hat{e}^{\infty}}{\alpha} \rangle = \langle \frac{\hat{e}^{o}}{\alpha} \rangle \tag{48}$$

and given that $\hat{e}_i^{\infty} = \hat{e}^{\infty}$, we get

$$\hat{e}^{\infty} = \frac{\langle \frac{\hat{e}^{o}}{\alpha} \rangle}{\langle \frac{1}{\alpha} \rangle}$$

■

Proof of Proposition 5

For the rest of the $N - N_0$ agents with $\beta_i \neq 1$ we know that $\bar{e}_i^t = \beta_i\, w_i\, s_i + (1-\beta_i)\, \hat{e}_i^t$. Therefore if we calculate the average Nash equilibrium of the team, we get

$$\begin{aligned}
\langle \bar{e}_i^t \rangle &= \frac{1}{N}\left(\sum_{i=1}^{N} \bar{e}_i^t\right) = \frac{1}{N}\left(\sum_{i\in N_0} w_i\, s_i + \sum_{i\in N/N_0} \beta_i\, w_i\, s_i + (1-\beta_i)\, \hat{e}_i^t\right) && (49)\\
&= \langle \beta\, w\, s\rangle + \frac{1}{N}\sum_{i\in N/N_0} (1-\beta_i)\, \hat{e}_i^t && (50)\\
&= \langle \beta\, w\, s\rangle + \frac{(N-N_0)}{N}\, \langle (1-\beta)\, \hat{e}^t\rangle_{N/N_0} && (51)
\end{aligned}$$

Now if we substitute the above expression in

$$\frac{d\,\hat{e}_i}{d\,t} = \alpha_i\, [\langle \bar{e}^t\rangle - \hat{e}_i^t], \text{for } i \in N/N_0 \tag{52}$$

we get

$$\frac{d\,\hat{e}_i}{d\,t} = \alpha_i \left[\langle \beta\, w\, s\rangle + \frac{(N-N_0)}{N}\, \langle (1-\beta)\, \hat{e}^t\rangle_{N/N_0} - \hat{e}_i^t\right] \text{for } i \in N/N_0 \tag{53}$$

In the steady state when $\frac{d\,\hat{e}_i}{d\,t} = 0$ we obtain

$$\hat{e}_i^{\infty} = \langle \beta\, w\, s\rangle + \frac{(N-N_0)}{N}\, \langle (1-\beta)\, \hat{e}^t\rangle_{N/N_0} \tag{54}$$

taking averages and operating we get

$$\langle \hat{e}^{\infty}\rangle_{N/N_0} = \langle \beta\, w\, s\rangle + \frac{(N-N_0)}{N}\langle \hat{e}^{\infty}\rangle_{N/N_0} - \frac{(N-N_0)}{N}\, \langle \beta\, \hat{e}^{\infty}\rangle_{N/N_0} \tag{55}$$

and

$$\frac{N_0}{N}\langle \hat{e}^{\infty}\rangle_{N/N_0} = \langle \beta\, w\, s\rangle - \frac{(N-N_0)}{N}\, \langle \beta\, \hat{e}^{\infty}\rangle_{N/N_0} \tag{56}$$

Substituting (55) in (54),we get

$$\begin{aligned}
\hat{e}_i^{\infty} &= \langle \beta\, w\, s\rangle + \langle \hat{e}^{\infty}\rangle_{N/N_0} - \langle \beta\, w\, s\rangle && (57)\\
\hat{e}_i^{\infty} &= \langle \hat{e}^{\infty}\rangle_{N/N_0} && (58)
\end{aligned}$$

Therefore

$$\hat{e}_i^{\infty} = \hat{e}^{\infty} \forall i \in N/N_0 \tag{59}$$

Substituting in (56),

$$\begin{aligned}
\frac{N_0}{N}\,\hat{e}^{\infty} &= \langle \beta\, w\, s\rangle - \hat{e}^{\infty}\, \frac{(N-N_0)}{N}\langle \beta\rangle_{N/N_0} && (60)\\
\hat{e}^{\infty} &= \frac{\langle \beta\, w\, s\rangle}{\frac{N_0}{N} + \frac{(N-N_0)}{N}\langle \beta\rangle_{N/N_0}} && (61)\\
\hat{e}^{\infty} &= \frac{\langle \beta\, w\, s\rangle}{\langle \beta\rangle} && (62)
\end{aligned}$$

■

Proof of Proposition 11

From (9), considering the continuous time limit, we get:

$$\frac{d\,\hat{e}_i}{d\,t} = \tau_i\, (\gamma_i\, (\bar{e}_i^t - \hat{e_i}^t)) + (1-\tau_i)\, \alpha_i\, (\langle \bar{e}^t\rangle - \hat{e}_i^t) \text{ for } i = 1, 2, .. N$$

We denote by $a_i \equiv \tau_i\, \gamma_i$ the weight associated to consistency, and by $b_i \equiv \alpha_i(1-\tau_i)$ the weight associated to conformism for each player, where both $a_i, b_i \in (0,1)$. Recall that the level of materialism β is the same for all players $\beta = \beta_i\, \forall i$. Thus, the above expression can be rewritten as:

$$\frac{d\,\hat{e}_i}{d\,t} = a_i\, (\bar{e}_i^t - \hat{e_i}^t) + b_i\, (\langle \bar{e}^t\rangle - \hat{e}_i^t) \tag{63}$$

If we substitute the results obtained in (2) and in (35) into equation (63) we get:

$$\frac{d\,\hat{e}_i}{d\,t} = (a_i\,\beta\,w_i\,s_i + b_i\,\beta\,\langle w\,s\rangle) + b_i\,\langle 1-\beta\rangle\langle\,\hat{e}^t\rangle - (a_i\,\beta + b_i)\,\hat{e}_i^t\,,\quad \text{for } i = 1, 2, .. n \tag{64}$$

In the steady-state $\frac{d\,\hat{e}_i}{d\,t} = 0$ and operating we get

$$\hat{e_i}^{\infty} = \left(\frac{\beta(\,a_i\,w_i\,s_i) + \beta b_i\,\langle w\,s\rangle}{a_i\,\beta + b_i}\right) + \left(\frac{b_i}{a_i\,\beta + b_i}\right)(1-\beta)\langle\hat{e}^{\infty}\rangle \tag{65}$$

Assuming statistical independence between variables a_i, b_i and $w_i\,s_i$ and taking averages we obtain

$$\langle\hat{e}^{\infty}\rangle = \beta\left[\left\langle\frac{a}{a\,\beta + b}\right\rangle\langle w\,s\rangle + \left\langle\frac{b}{a\,\beta + b}\right\rangle\langle w\,s\rangle\right] + (1-\beta)\left\langle\frac{b}{a\,\beta + b}\right\rangle\langle\hat{e}^{\infty}\rangle \tag{66}$$

Rearranging terms we have,

$$\langle\hat{e}^{\infty}\rangle\left(1 - (1-\beta)\left\langle\frac{b}{a\,\beta + b}\right\rangle\right) = \beta\left[\left\langle\frac{a+b}{a\,\beta + b}\right\rangle\langle w\,s\rangle\right] \tag{67}$$

Finally, we get

$$\langle\hat{e}^{\infty}\rangle = \langle w\,s\rangle \tag{68}$$

Substituting (68) in (65) we get:

$$\hat{e_i}^{\infty} = \left(\frac{\beta\,(a_i\,w_i\,s_i)}{a_i\,\beta + b_i}\right) + \left(\frac{\beta\,b_i\,\langle w\,s\rangle}{a_i\,\beta + b_i}\right) + \left(\frac{b_i}{a_i\,\beta + b_i}\right)(1-\beta)\,\langle w\,s\rangle \tag{69}$$

and operating

$$\hat{e_i}^{\infty} = \left(\frac{a_i\,\beta\,w_i\,s_i}{a_i\,\beta + b_i}\right) + \left(\frac{b_i}{a_i\,\beta + b_i}\right)\langle w\,s\rangle \tag{70}$$

Note that $\hat{e_i}^{\infty}$does not converge to a unique value.
Therefore,

$$\hat{e_i}^{\infty} = \left(\frac{a_i\,\beta}{a_i\,\beta + b_i}\right)(w_i\,s_i) + \left(\frac{b_i}{a_i\,\beta + b_i}\right)\langle w\,s\rangle, \text{for } i = 1, 2, \ldots n \tag{71}$$

■

Appendix B: Variance Derivations

Case 1: Steady-state Personal Norms Variance

Consider first the following:

$$\hat{e_i}^{\infty} = \left(\frac{a_i\,\beta}{a_i\,\beta + b_i}\right)(w_i\,s_i) + \left(\frac{b_i}{a_i\,\beta + b_i}\right)\langle w\,s\rangle \tag{72}$$

From (49) we know that

$$\langle\hat{e}^{\infty}\rangle = \langle w\,s\rangle \tag{73}$$

Operating we obtain

$$\hat{e}_i^{\infty} - \langle\hat{e}^{\infty}\rangle = \left(\frac{a_i\,\beta}{a_i\,\beta + b_i}\right)(w_i\,s_i - \langle w\,s\rangle) \tag{74}$$

Substituting (74) in (12) we get

$$\sigma^2(\hat{e}^{\infty}) = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{a_i\,\beta}{a_i\,\beta + b_i}\right)^2(w_i\,s_i - \langle w\,s\rangle)^2 \tag{75}$$

Since we have assumed statistical independence between a_i and b_i and $w_i\,s_i$, we can approximate by

$$\sigma^2(\hat{e}^{\infty}) \simeq \langle\left(\frac{a_i\,\beta}{a_i\,\beta + b_i}\right)^2\rangle\,\sigma^2\,(w\,s) \tag{76}$$

Case 2: Steady-state Behavior Variance

Consider first the following

$$\bar{e}_i^{\infty} = [\beta + (1-\beta)(\frac{a_i\,\beta}{a_i\,\beta + b_i})]\,(w_i\,s_i) + (1-\beta)\Big(\frac{b_i}{a_i\,\beta + b_i}\Big)\,\langle w\,s\rangle$$

Therefore, assuming statistical independence between a_i and b_i and $w_i\,s_i$ and taking averages we obtain

$$\begin{aligned}\langle \bar{e}^{\infty}\rangle &= (\langle\beta\rangle + \langle(1-\beta)\,\frac{a\,\beta}{a\,\beta + b}\rangle)\,\langle w\,s\rangle + \langle(1-\beta)\,\frac{b}{a\,\beta+b}\rangle\,\langle w\,s\rangle \\ \langle \bar{e}^{\infty}\rangle &= (\langle\beta\rangle + \langle(1-\beta)\rangle)\,\langle w\,s\rangle = \langle w\,s\rangle\end{aligned}$$

Substituting we get

$$\bar{e}_i^{\infty} - \langle \bar{e}^{\infty}\rangle = \Big(\frac{\beta\,(a_i+b_i)}{a_i\,\beta + b_i}\Big)\,(w_i\,s_i - \langle w\,s\rangle) \tag{77}$$

Hence, with the statistical independence between a_i and b_i and $w_i\,s_i$, and susbtituting in (13), we obtain

$$\sigma^2(\bar{e}^{\infty}) \simeq \Big\langle\Big(\frac{\beta\,(a+b)}{a\,\beta+b}\Big)^2\Big\rangle\,\sigma^2\,(w\,s) \tag{78}$$

Appendix C: Aggregate Production and Social Welfare

Let us consider the costs.

Note that $\sum C(\bar{e}_i^{\infty}))=\frac{1}{2}\sum_{i=1}^{n}\bar{e}_i^{\,2}=\frac{N}{2}\langle(\bar{e}^{\,\infty})^2\rangle$.

Note also that $\sigma^2(\bar{e}^{\,\infty})=\frac{1}{N}\sum\,(\bar{e}_i-\langle\bar{e}\,\rangle)^2=\,\langle(\bar{e}^{\,\infty})^2\rangle-\langle\bar{e}\,\rangle^2$, therefore

$$C\big(\sum\,\bar{e}^{\,\infty}\big)=\frac{N}{2}(\sigma^2(\bar{e}^{\,\infty})+\langle\bar{e}\,\rangle^2). \tag{79}$$

Now, notice that $\sigma^2(\bar{e}^{\,\infty}) = \Big\langle\Big(\frac{\beta(a+b)}{a\beta+b}\Big)^2\Big\rangle\sigma^2(w\;\;s) \equiv B^2\sigma^2\;\;(w\;\;s)$ and that under statistical independence between $\frac{a_i\,\beta}{a_i\,\beta+b_i}$ and $w_i\,s_i$ we can write $\langle\bar{e}\,\rangle\backsimeq\langle w\,s\,\rangle$

Rearranging all these terms we have that

$C(\bar{e}_i^{\infty})=\frac{N}{2}(B^2\sigma^2\,(w\,s)+\langle w\,s\rangle^2)$

then we know that

$$\sigma^2(w\,s)=\langle w^2\rangle\langle s^2\rangle-\langle w\rangle^2\langle s\rangle^2$$

remember then that

$$\langle w^2\rangle=\sigma^2(w\,)+\langle w\rangle^2$$

$$\langle s^2\rangle=\sigma^2(s\,)+\langle s\rangle^2$$

so that

$$\sigma^2(w\,s)=[\sigma^2(w\,)+\langle w\rangle^2][\sigma^2(s\,)+\langle s\rangle^2]-\langle w\rangle^2\langle s\rangle^2$$

after simple algebra

$$\sigma^2(w\,s)=\sigma^2(w\,)\sigma^2(s\,)+\langle w\rangle^2\sigma^2(s\,)+\langle s\rangle^2\sigma^2(w\,)=\sigma^2(w\,)\sigma^2(s\,)+\frac{1}{N^2}\sigma^2(s\,)+\langle s\rangle^2\sigma^2(w\,) \tag{80}$$

Consider now

$$\langle \mathrm{ws} \rangle = \langle w \rangle \langle s \rangle + \mathrm{cov}(w,s) = \frac{1}{N}\langle s \rangle + \mathrm{cov}(w,s)$$

so that

$$\langle \mathrm{ws} \rangle^2 = \langle w \rangle^2 \langle s \rangle^2 + [\mathrm{cov}(w,s)]^2 + 2\langle w \rangle \langle s \rangle \mathrm{cov}(w,s)$$

Thus the final expression for the costs is

$$C = \frac{N}{2}\left\{ B^2 \left[\sigma^2(w)\sigma^2(s) + \frac{1}{N^2}\sigma^2(s) + \langle s \rangle^2 \sigma^2(w) \right] + \frac{1}{N^2}\langle s \rangle^2 + [\mathrm{cov}(w,s)]^2 + \frac{2}{N}\langle s \rangle \mathrm{cov}(w,s) \right\}$$

This is the expression of the aggregate material costs.
Let us consider now the expression of the gross production.

$$y = \beta \sum_{i=1}^{n} w_i s_i^2 + (1-\beta)\sum_{i=1}^{n} A_i w_i s_i^2 + (1-\beta)\langle w\, s \rangle \sum_{i=1}^{n}(1-A_i)s_i \tag{81}$$

the above expression with statistical independence between A and $w_i s_i^2$[7] becomes:

$$y = [N\beta + N(1-\beta)\langle A \rangle]\, \langle w\, s^2 \rangle + N(1-\beta)(1-\langle A \rangle)\langle w\, s \rangle \langle s \rangle \tag{82}$$

Finally note that

$$\langle \mathrm{ws}^2 \rangle = \langle w \rangle \langle s^2 \rangle + \mathrm{cov}(w, s^2) = \frac{1}{N}[\sigma^2(s) + \langle s \rangle^2] + \mathrm{cov}(w, s^2) \tag{83}$$

and therefore

$$y = [N\beta + N(1-\beta)\langle A \rangle]\left\{ \frac{1}{N}[\sigma^2(s) + \langle s \rangle^2] + \mathrm{cov}(w, s^2) \right\} + N(1-\beta)(1-\langle A \rangle)\langle s \rangle \left[\frac{1}{N}\langle s \rangle + \mathrm{cov}(w,s) \right]$$

Considering also the costs we get

$$y = [N\beta + N(1-\beta)\langle A \rangle]\left\{ \frac{1}{N}[\sigma^2(s) + \langle s \rangle^2] + \mathrm{cov}(w, s^2) \right\} + N(1-\beta)(1-\langle A \rangle)\langle s \rangle \left[\frac{1}{N}\langle s \rangle + \mathrm{cov}(w, s) \right] - \frac{N}{2}\left\{ B^2 \left[\sigma^2(w)\sigma^2(s) + \frac{1}{N^2}\sigma^2(s) + \langle s \rangle^2 \sigma^2(w) \right] + \frac{1}{N^2}\langle s \rangle^2 + [\mathrm{cov}(w,s)]^2 + \frac{2}{N}\langle s \rangle \mathrm{cov}(w,s) \right\}$$

rearranging terms

$$y = \left[\beta + (1-\beta)\langle A \rangle - \frac{N}{2}B^2\sigma^2(w) \right][\sigma^2(s) + \langle s \rangle^2] + \left[(1-\beta)(1-\langle A \rangle) - \frac{1}{2N} \right]\langle s \rangle^2 - \frac{B^2}{2N}\sigma^2(s) + [N(1-\beta)(1-\langle A \rangle) - 1]\langle s \rangle \mathrm{cov}(w,s) - \frac{N}{2}[\mathrm{cov}(w,s)]^2 + [N\beta + N(1-\beta)\langle A \rangle]\mathrm{cov}(w, s^2)$$

or differently

$$y = \left[\beta + (1-\beta)\langle A \rangle - \frac{N}{2}B^2\sigma^2(w) - \frac{B^2}{2N} \right]\sigma^2(s) + \left[1 - \frac{N}{2}B^2\sigma^2(w) - \frac{1}{2N} \right]\langle s \rangle^2 + [N(1-\beta)(1-\langle A \rangle) - 1]\langle s \rangle \mathrm{cov}(w,s) - \frac{N}{2}[\mathrm{cov}(w,s)]^2 + [N\beta + N(1-\beta)\langle A \rangle]\mathrm{cov}(w, s^2)$$

After some algebra

$$y = \frac{2N[\beta + (1-\beta)\langle A \rangle] - B^2(1 + N^2\sigma^2(w))}{2N}\sigma^2(s) + \frac{2N - 1 - N^2B^2\sigma^2(w)}{2N}\langle s \rangle^2 + [N(1-\beta)(1-\langle A \rangle) - 1]\langle s \rangle \mathrm{cov}(w,s) - \frac{N}{2}[\mathrm{cov}(w,s)]^2 + [N\beta + N(1-\beta)\langle A \rangle]\mathrm{cov}(w, s^2) \tag{84}$$

7. Note that under statistical independence $\langle \mathrm{Aws}^2 \rangle \simeq \langle A \rangle \langle \mathrm{ws}^2 \rangle \simeq \langle A \rangle \frac{1}{N}\langle s^2 \rangle$ and also $\langle \mathrm{As} \rangle \simeq \langle A \rangle \langle s \rangle$

Consider now the social welfare. Note that in the steady state $e_i = \bar{e}_i^{\infty}$ and $\hat{e}_i = \hat{e}_i^{\infty}$, therefore the last term of the expression is given by

$$(e_i - \hat{e}_i)^2 = \beta^2(1 - A_i)^2(w_i s_i - \langle \mathrm{ws} \rangle)^2$$

therefore when we add up all these terms for all players , that is, the the aggregate disutility, we get

$$\sum_{i=1}^{n}((e_i - \hat{e}_i)^2) = \sum_{i=1}^{n}\beta^2(1 - A_i)^2(w_i s_i - \langle \mathrm{ws} \rangle)^2 = \sum_{i=1}^{n}\beta^2(1 - A_i)^2(w_i^2 s_i^2 + \langle \mathrm{ws} \rangle^2 - 2 w_i s_i \langle \mathrm{ws} \rangle)$$

Assuming statistical independence between A_i and $w_i s_i$, then

$$\sum_{i=1}^{n}((e_i - \hat{e}_i)^2) = \beta^2(1 - \langle A \rangle)^2[\langle w_i^2 s_i^2 \rangle - \langle \mathrm{ws} \rangle^2]$$

Recalling that the level of incoherence is given by $\rho^2 = \left\langle \left(\frac{\beta\, b)}{a\,\beta + b} \right)^2 \right\rangle \sigma^2\ (w\ s)$, then $\sum_{i=1}^{n}\beta^2(1 - A_i)^2\,\sigma^2\,(w\,s) = N\frac{1}{N}\sum_{i=1}^{n}\beta^2\left(\frac{b_i}{a_i\beta + b_i}\right)^2\sigma^2\,(w\,s) = N\rho^2$

Hence the aggregate disutility is given by the expression:

$(1 - \beta)\frac{1}{2}\sum_{i=1}^{n}((e_i - \hat{e}_i)^2) = \frac{(1-\beta)}{2}\sum_{i=1}^{n}\beta^2(1 - A_i)^2\sigma^2\,(w\,s) = \frac{(1-\beta)}{2}N\rho^2.$

Therefore adding up all the terms to get the social welfare we obtain

$\mathrm{SW} = \beta Y - \frac{N}{2}(1 - \beta)\rho^2 =$

$$\mathrm{SW} = \beta\Big[\,\langle s \rangle^2\big(1 - \tfrac{1}{2N}\big) + \sigma^2(s)(\beta + (1 - \beta)\langle A \rangle) - \Big(\frac{N}{2}\Big)\Big\langle\Big(\frac{\beta(a+b)}{\beta a + b}\Big)^2\Big\rangle\sigma^2(\mathrm{ws})\Big] -$$
$$\Big(\frac{N}{2}\Big)(1 - \beta)\Big\langle\Big(\frac{\beta b)}{\beta a + b}\Big)^2\Big\rangle\sigma^2(\mathrm{ws})$$

$$\mathrm{SW} = \beta\big[\,\langle s \rangle^2\big(1 - \tfrac{1}{2N}\big) + \sigma^2(s)(\beta + (1 - \beta)\langle A \rangle\,\big] - \Big[\,\Big(\frac{N}{2}\Big)\beta\Big\langle\Big(\frac{\beta(a+b)}{\beta a + b}\Big)^2\Big\rangle + \Big(\frac{N}{2}\Big)(1 - \beta)\Big\langle\Big(\frac{\beta b)}{\beta a + b}\Big)^2\Big\rangle\Big]$$
$\sigma^2(\mathrm{ws})$

$$\mathrm{SW} = \beta\Big[\,\langle s \rangle^2\big(1 - \tfrac{1}{2N}\big) + \sigma^2(s)(\beta + (1 - \beta)\langle A \rangle] - \Big(\frac{N}{2}\Big)\Big(\beta\Big\langle\Big(\frac{\beta(a+b)}{\beta a + b}\Big)^2\Big\rangle + (1 - \beta)\Big\langle\Big(\frac{\beta b)}{\beta a + b}\Big)^2\Big\rangle\Big)$$
$\sigma^2(\mathrm{ws}).$

Appendix D: Beta Distribution

Notice first that $\langle w \rangle = \int_0^1 g(w) w\,\mathrm{dw} = \frac{(\delta - 1)}{(\delta + \lambda)(2\delta + \lambda - 1)}$.

Now, in order to analyze the aggregate net production we analyze the aggregate gross production and the aggregate costs. Now, the gross aggregate production si given by

$$y = \int_0^1 s_i \bar{e}_i^{\infty}\,\mathrm{ds} \tag{85}$$

where $\bar{e}_i^{\infty}$ is given by (22).

Notice first that, being $A_i = A$, then we can call $D_i = (\beta + (1 - \beta)(\frac{a_i\,\beta}{a_i\,\beta + b_i})) = (\beta + (1 - \beta)(\frac{a\,\beta}{a\,\beta + b}) =$ D so that

$$\bar{e}_i^{\infty} = D(w_i\,s_i) + (1 - D)\langle w\,s \rangle. \tag{86}$$

so that

$$y = \int_0^1 s_i \bar{e}_i^{\infty}\,f(s)\mathrm{ds} = D\int_0^1 w_i\,s_i^2\,f(s)\mathrm{ds} + (1 - D)\langle w\,s \rangle\int_0^1 s_i\,f(s)\,\mathrm{ds} \tag{87}$$

where

$$\int_0^1 w_i\, s_i^2\, f(s)\mathrm{ds} = \frac{(\delta-1)}{(\delta+\lambda+2)(2\delta+\lambda+1)} \tag{88}$$

and

$$\int_0^1 s_i\, f(s)\, \mathrm{ds} = \frac{(\delta-1)}{(\delta+1)2\delta} \tag{89}$$

Considering that

$$\langle w\, s\rangle = \frac{(\delta-1)}{(\delta+2\lambda)(2\lambda-1)} \tag{90}$$

we get

$$y = D\frac{(\delta-1)}{(\delta+\lambda+2)(2\delta+\lambda+1)} + (1-D)\frac{(\delta-1)^2}{(\delta+1)2\delta(\delta+2\lambda)(2\lambda-1)} \tag{91}$$

Consider now the aggregate costs, given by $c = \frac{1}{2}\int_0^1 (\bar{e}_i^{\infty})^2\, \mathrm{ds}$, can be written as

$$c = \frac{1}{2}\Big[D^2 \int_0^1 w_i^2\, s_i^2\, f(s)\mathrm{ds} + (1-D)^2\langle w\, s\rangle^2 + 2D(1-D)\langle w\, s\rangle \int_0^1 w_i\, s_i\, f(s)\mathrm{ds}\Big] \tag{92}$$

where

$$\int_0^1 w_i^2\, s_i^2\, f(s)\mathrm{ds} = \frac{(\delta-1)}{(\delta+2\lambda+2)(2\delta+2\lambda+1)} \tag{93}$$

$$\int_0^1 w_i\, s_i\, f(s)\mathrm{ds} = \frac{(\delta-1)}{(\delta+\lambda+1)(2\delta+\lambda)} \tag{94}$$

so that by substituting them back in the costs, we get the result. Turning now to the loss associated to the non materialistic part of the utility function is given by

$$L = \int_0^1 ((e_i - \hat{e}_i)^2)\mathrm{ds} = \beta^2(1-A)^2\Big[\int_0^1 w_i^2 s_i^2 \mathrm{ds} + \langle \mathrm{ws}\rangle^2 + 2\langle \mathrm{ws}\rangle \int_0^1 w_i s_i \mathrm{ds}\Big] \tag{95}$$

for which we already have all the elements in order to provide the result.

Appendix E: Uniform Distribution

We first start noting that if $\delta = 1$ then $s_i \sim U[0,1]$ (i.e. $f(s_i) = 1$). We know that $\langle s\rangle = \frac{1}{2}$, $\langle s\rangle^2 = \frac{1}{4}$, $\sigma^2(s) = \frac{1}{12}$. Now,

$$G(w) = P(W \leqslant w) = P(s^{\lambda} \leqslant w) = P\Big(s \leqslant w^{\frac{1}{\lambda}}\Big) = \int_0^{w^{\frac{1}{\lambda}}} f(s)\mathrm{ds} = w^{\frac{1}{\lambda}} \tag{96}$$

so that

$$g(w) = \frac{d}{dw}G(w) = \frac{1}{\lambda} w^{\frac{1-\lambda}{\lambda}} \tag{97}$$

with $0 < w < 1$ (since $0 < s < 1$ that means $0 < w^{\frac{1}{\lambda}} < 1$).
In order to perform the analysis we need to study the distribution of w_i. Notice that $\langle w\rangle = \frac{1}{\lambda+1}$. Now, in order to analyze the aggregate net production we analyze the aggregate gross production and the aggregate costs. Now, the gross aggregate production si given by

$$y = \int_0^1 s_i \bar{e}_i^{\infty}\, \mathrm{ds} \tag{98}$$

where $\bar{e}_i^{\infty}$ is given by (22).

Notice first that, being $A_i = A$, then we can call $D_i = (\beta + (1-\beta)(\frac{a_i\,\beta}{a_i\,\beta + b_i})) = (\beta + (1-\beta)(\frac{a\,\beta}{a\,\beta + b}) = D$ so that

$$\bar{e}_i^{\infty} = D(w_i\, s_i) + (1-D)\langle w\, s\rangle. \tag{99}$$

so that

$$y = \int_0^1 s_i \bar{e}_i^{\infty}\, \mathrm{ds} = D\int_0^1 w_i\, s_i^2\, \mathrm{ds} + (1-D)\langle w\, s\rangle \int_0^1 s_i\, \mathrm{ds} \tag{100}$$

.

Notice first that $w_i\, s^2 = s^{2+\gamma}$ so that $\int_0^1 w_i\, s_i^2\, \mathrm{ds} = \frac{1}{3+\gamma}$.

Consider now $\langle w\, s\rangle$. Notice that $w\, s = s^{\delta}$ with $\delta = \gamma + 1$. So, by (97), $g(ws) = \frac{1}{\gamma+1} w^{\frac{\gamma}{\gamma+1}}$ from which it follows that $\langle w\, s\rangle = \frac{1}{\gamma+2}$. Consequently (99) becomes

that becomes

$$y = D\frac{1}{3+\gamma} + (1-D)\frac{1}{2+\gamma} \tag{101}$$

Consider now the aggregate costs, given by

$$c = \frac{1}{2}\int_0^1 (\bar{e}_i^{\infty})^2\, \mathrm{ds} = \frac{1}{2}\Big[D^2 \int_0^1 w_i^2\, s_i^2\, \mathrm{ds} + (1-D)^2\langle w\, s\rangle^2 + 2D(1-D)\langle w\, s\rangle \int_0^1 w_i\, s_i\, \mathrm{ds}\Big] \tag{102}$$

Notice now that $\int_0^1 w_i^2\, s_i^2\, ds = \int_0^1 s^{2+2\gamma}\, ds = \frac{1}{3+2\gamma}$ and $\int_0^1 w_i\, s_i\, ds = \int_0^1 s^{\gamma+1}\, ds = \frac{1}{2+\gamma}$ so that the aggregate cost becomes

$$c = \frac{1}{2}\Big[D^2 \frac{1}{3+2\gamma} + (1-D)^2 \frac{1}{(\gamma+2)^2} + 2D(1-D)\frac{1}{(\gamma+2)^2}\Big] \tag{103}$$

Thus the total net production becomes

$$Y = -\frac{D^2}{4\,\gamma+6} + \frac{D}{\gamma+3} + \frac{1-D}{\gamma+2} + \frac{(D-1)\,(3\,D+1)}{2\,(\gamma+2)^2}$$

While it is complex to analyze this equation, we can try to understand which is the optimal level of λ in order to maximize the total net output. Figure 4 shows the level curves of the net production fuction and, with the dark curve, the locus of optimal λ, where on the x-axis there is λ and on the y-axis there is D, thus providing a full characterization of the optima choices.

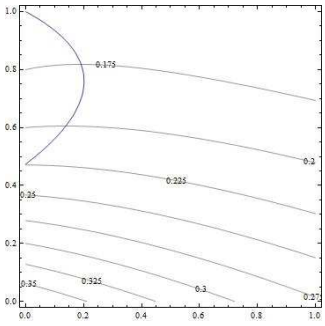

Figure 4. Optimal level of λ

Note that the optimal level of λ is always less than one. In particular if D is small, then it is always optimal to set λ=0. Call this level λ_Y. Thus it is optimal to remunerate marginal skills in a decreasing manner and, for low D, set all salaries equal. This result is quite similar to the case in which skills and revenues are independently distributed.

Turn now to the analysis of social welfare. From the previous discussion we also have that, in the time continuous approximation, the loss associated to the non materialistic part of the utility function is given by

$$L = \int_0^1 ((e_i - \hat{e}_i)^2)\mathrm{ds} = \beta^2(1-A)^2\Big[\int_0^1 w_i^2 s_i^2 \mathrm{ds} + \langle \mathrm{ws}\rangle^2 + 2\langle \mathrm{ws}\rangle \int_0^1 w_i s_i \mathrm{ds}\Big] \tag{104}$$

that becomes

$$L = \beta^2(1-A)^2\left[\frac{1}{(2\lambda+3)^2}+\frac{1}{(\lambda+2)^2}+2\frac{1}{(\lambda+2)^2}\right]$$

Now, notice that L is always decrasing in γ, so that it would be minimized by setting $\lambda = 0$, thus again by setting all salaries equal. This happens since a higher λ increases $\sigma^2(w\,s)$ that directly relates to the loss. We can understand it by noticing that an increase in λ results in an increase in $\langle w\,s\rangle$. From proposition 7 we can see that individual loss is increasing and convex in $\langle w\,s\rangle$, from which the result immediately follows. Recall now that the utility is a convex linear combination between material payoffs and loss from deviating from personal norm. In aggregate terms, the aggregate social welfare is

$$W = \beta Y + \frac{1}{2}(1-\beta)L$$

By calling λ_W the optimal λ to maximize the social welfare we finally get

$$\lambda_W \in (0, \lambda_Y) \supseteq (0, 1)$$

We can sum up the previous results:

Proposition 14. *If* $s_i \sim U[0,1]$ *and* $w_i = s_i^\lambda$ *then* $\lambda_Y < 1$. *Moreover* $\exists \bar{D}$: if $D < \bar{D}$ *then* $\lambda_Y = 0$. *Moreover* $\lambda_W \leq \lambda_Y$.

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