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WORKING PAPER SERIES

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Working Paper n. 587

This Version: November, 2016

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http://www.igier.unibocconi.it

Culture and team production *

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November 2016

Abstract

This paper addresses theoretically the question whether culture has an effect on economic performance in team production, and which would be the optimal team culture. The members of the team are guided both by economic incentives and by personal norms, weighed according to their prevailing level of materialism. We assume that personal norms evolve following a dynamics driven by a combination of psychological mechanisms such as consistency and conformism. The different vectors of materialism, consistency and conformity shared by the group result in a continuum of cultures with different combinations of individualism and collectivism.

Our main results show how team culture turns out to be a fundamental determinant for group performance. When income distribution is not completely egalitarian or the members of the team display heterogeneous levels of skills, culture matters in the sense that there exists an optimal culture that maximizes team production and its characteristics depend on the specific distributions of income and skills. A higher average productivity or a more inegalitarian dispersion of remunerations requires a more collectivist culture. And a higher dispersion of individual productivities requires a more individualist culture.

1 Introduction

Any long-lived group or organization that is involved in a long run activity, develops an organizational culture, and the features of this culture seem closely

*Previous versions of this paper have benefited from comments of the participants of the following conferences: 4th Workshop on Dynamic Games and Management Strategy in Padova in December 2012, PET 2013 in Lisbon in July 2013, a Seminar in the University of Middlesex London in May 2014 and PET16 in Rio de Janeiro July 2016. This work has been supported from the project ECO2011-29230 of the Spanish Ministry of Economia y Competitividad; and also from the project ECO2014-58297-R

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related to the levels of satisfaction or welfare of its members and its levels of performance (see Van den Steen 2010a,2010b). Similarly, societies also develop along history a culture whose 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.

This paper addresses theoretically the question whether culture has an effect on economic performance in team production, and which would be the optimal team culture in this case. Team production is ubiquitous in human social relationships along the history of humanity. Since the dawn of *homo sapiens* a strong team-orientation became a basic tool for its evolutionary success (Marean, 2015). The capacity to cooperate in teams was very likely one of the main determinants of the conquer of the world by our species. Still nowadays, team production is increasingly important in modern industrial production (Che and Yoo, 2001, provide relevant examples). Additionally other important economic problems faced by human groups such as public goods provision share exactly the same strategic structure as team production.

In a team production setting team members choose theirs levels of effort and obtain a revenue from joint production. This joint production depends also on the team members´ distribution of skills and the sharing rule used to divide this revenue. We assume the usual team situation where individual remunerations cannot be linked to effort or to individual levels of skill because of the standard non-verifiability problems of these variables. The members of the team are guided both by economic incentives and by personal norms (regarding the level of effort to be chosen) weighed according to their prevailing level of materialism. Norms and behavior evolve. We assume that personal norms follow a dynamics driven by a combination of psychological mechanisms, such as cognitive dissonance and conformism. Cognitive dissonance, or consistency, implies that individual norms change towards actual individual behavior. Conformity changes individual behavior in the direction of the average behavior of the peers. This is an important departure with most usual models of team production that only consider material incentives to promote effort of the members of the group. In this paper we analyze how the prevalent culture in a team or organization influences its performance that is, the level of steady state aggregate production achieved by the team.

Culture has been an ambiguous concept in economics. However, in many recent economic applications is defined as the group or society distribution of beliefs or personal norms (see for instance, Alesina and Giuliano 2015). Nevertheless, the long run distribution of personal norms will depend not only on psychological or behavioral primitives shared by the group, but also on the remuneration rule or income distribution prevailing in the group, and on the existing distribution of skills or productivities. Therefore we believe that this is not a good definition for team culture, as it is determined also by these technological and distributional fundamentals. We need a definition that disentangles these different elements and allows us to separate its effects on team production.

Culture in this paper is defined as a primitive set of variables with psychological content that shape the long run evolution of norms and behavior in the group, jointly with other technological and distributional fundamentals. These cultural variables are the levels of materialism, consistency and conformism which prevail among the members of the team. Materialism captures how members weigh material payoffs and intrinsic motivation in their utility. Consistency, how strongly and quickly members adjust theirs norms to their actual individual behavior, trying to reduce their cognitive dissonance. And conformism, how strongly and fast members adjust their behavior to the average actual behavior of the team, that is how reactive they are to peer effects.

The combination of these three parameters yields observably very different cultures. Relatively high levels of consistency and/or materialism compared to the level of conformism, result in what we will denote as an individualist team culture. When the dynamics of norms is driven by high levels of conformity as compared to consistency and there exist low levels of materialism in the group the resulting team culture will be denoted as a collectivist culture. In an individualist culture individual efforts and norms tend to the individual marginal revenue which depends on the income distribution rule and on the individual skills. In the extreme case of a group with no conformism operating at all, the situation corresponds to the Nash equilibrium in material payoffs that is, to the prediction of static conventional game theory when individuals display selfish preferences and only care about their material payoff. Whereas in a case with no consistency operating and low levels of materialism (i.e. only conformism), behavior and norms will tend to homogeneity. This common norm coincides with the per capita productivity of the group if there is no correlation between remunerations and skills.

In the dynamic situation, the evolution of personal norms influenced by these psychological mechanisms modifies indirectly the evolution of the behavior of the team members. We show that in steady state, the individual behavior is given by a weighted average of individual marginal revenue and the group average marginal revenue, the weights depending on the team culture.

Our main results show how team culture turns out to be a fundamental determinant for group performance but in a way that depends on the existing distribution of income and skills. When income distribution is not completely egalitarian, or the members of the team display heterogeneous levels of skills, culture matters in the sense that there exists an optimal culture that maximizes team production and its characteristics depend on the distributions of income and skills. Specifically in an heterogenous-skilled team, if there is a very unequal distribution of income it is optimal a more collective culture. Whereas in more egalitarian teams it is optimal a more individualist culture. On the other hand, in more productive teams with a higher average productivity, the optimal team culture requires a larger weight of conformism as compared to the weight attached to consistency. Finally, in teams with a high dispersion of skills the optimal culture is the one where consistency and materialism matter relatively more than conformism: a more individualist culture.

The only exception for this result is a completely egalitarian team where all its members have exactly the same productivity. In this particular case, whatever the culture is and whatever the initial distribution of personal norms is in the group, the team ends up with a common norm and effort equal to the per capita productivity.

Besides characterizing the optimal culture, we also study the impact on aggregate production of exogenous shocks of average team productivity and of a mean preserving spread of individual productivities. In both cases we show that for some combinations of team culture and income distribution, this impact can be paradoxically negative. For instance, in a team where there is some level of inequality in the distribution of income, a positive shock on average team productivity or a mean preserving spread of the distribution of skills can paradoxically result in an smaller level of team production, provided the team culture is excessively individualist. The reason is that culture amplifies or reduces the effects on team production of external shocks on skills or on remunerations. And it does so through its effects on team revenue and team aggregate costs. In an heterogeneous-skilled team, individualism works as a "cultural" incentive for those members of the team above the average marginal revenue boosting team revenue. But it also increases aggregate costs by increasing the dispersion of equilibrium efforts. Team income inequality and individualism like determinants of the team aggregate cost, operate as substitutes. A low level of inequality moderates the increase in the variance of efforts. But if there is enough inequality the increase in team cost derived from individualism will turn out to be higher than the increase in team revenue. All things considered a positive shock on average productivity will result in this case in a decrease on team production if the team culture has a too high level of individualism.

1.1 Related literature

Our paper is related to three important strands of literature. First, the existing literature where preferences or personal norms of individuals evolve along the life-cycle governed by cognitive dissonance and/or by conformism. Second, the literature analyzing the role of culture on economic performance, basically the influence of non-standard preferences of the players in the performance of a team. And finally, the very recent literature on the consequences in economic performance of a very important dimension of culture: individualism versus collectivism.

Consistency is an individual psychological 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 (Festinger, 1957). There are some recent works that analyze the impact on economic behavior of this important psychological force that drives the change in preferences or norms. Besides the early paper of Akerlof and Dickens (1982), there are some more recent works as Kuran and Sandholm (2008) and Nordblom and Zamac (2012). Conformity is another important force that might change preferences or norms widely employed in the economics literature. Conformity, by driving personal norms towards the average actual group behavior, captures how social interaction impact on individual norms and behavior. Most of the previous research has used static models of conformism (see for example, Bernheim (1994), Kandel and Lazear (1992), Akerlof (1997), Fischer and Huddart (2008)). Our paper deals with a dynamic model where personal norms evolve along the life-cycle of the individuals according to these two psychological forces: consistency and conformity.

There is a large literature on team production, just as very few examples consider the seminal work of Holmstrom (1982) and Che and Yoo (2001) who analyze team production in a static and dynamic setting respectively. But in most of these models players are endowed with standard preferences in terms of material payoffs. In our paper we depart from this assumption. We deal with a model in which players are motivated not just by economic incentives but also by a personal norm. The paper most closely related to ours is Gill and Stone (2015) in which the authors analyze the strategic implication of a meritocratic notion of desert under which team members care about receiving what they feel they deserve. Team members find painful to receive less than their perceived entitlement. Another examples of non-standard preferences are the work of Bartling and Siemens (2010) and Rey-Biel (2008) that analyze the effect of having team members with inequity averse preferences on the equal sharing rule in the first case and on wages and optimal output choice in the second work. The main difference between our paper and these works, is that we run a dynamic analysis where personal norms evolve and we define as a culture the psychological parameters driving this process: materialism, consistency and conformity.

An important insight of our paper deals with the importance of individualist versus collectivist culture on the actual working of the organization. The different vectors of materialism, consistency and conformity result in a continuum of cultures with different combinations of individualism and collectivism. Our work is in this sense strongly related to the work of Greif (1994) and Gorodnichenko and Roland (2011a, 2015) which characterize a culture as individualist or collectivist, in similar terms as we do. For them, individualists pursue their own interest without internalizing collective interest. Collectivism makes collective action easier in the sense that individuals internalize group interest to a greater degree. Gorodnichenko and Roland (2011a) show that only individualism has a robust effect on long run growth. In our model individualism is driven by materialism and consistency while collectivism is driven by conformity. The strong interaction between these psychological forces and the dimension individualism/collectivism has already been established in the cultural psychology literature (see Gorodnichenko and Roland (2011b) for a survey). As in the previously mentioned papers we also show that this dimension of culture strongly determines the long run performance of a team. Unlike them, in our paper the optimal level of individualism or collectivism depends on the skills distribution in the team and the existing income distribution rule. Our results show a precise interaction between income inequality, skills distribution and culture in terms of final team production.

The rest of the paper is organized as follows. Section 2 describes the team production game played in each period and the utility function of any member of the group. In section 3, we study the evolution of individual personal norms and behavior governed by a dynamics of consistency and conformity. In section 4 we present our definition of team culture. Section 5 presents our main results concerning the effects of culture on the long run performance of a team. Finally section 6 concludes.

2 The Team Production Problem

Consider a social group or an organization composed by N agents acting simultaneously each period. 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 $c(e_i) = (1/2)e_i^2$. 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. Notice that there is no complementarity or interdependence of any kind between agents´ effort decisions.

We assume that the total revenue generated by the team is divided according to a budget-balanced sharing rule $\mathbf{w}$, being a vector of real numbers that assigns to each agent a share $w_i \in [0, 1]$ of the total revenue, with $\sum_{i=1}^{N} w_i = 1$.

This sharing rule $\mathbf{w}$ is going to be our measure for income inequality and is closely related to the income distribution in the group. A change in the income sharing rule can be captured by a change in its variance $\sigma^2(w)$ and yields a change in the income (revenue) distribution. Notice that the variance of income distribution is given by $\sigma^2(y) = y^2 \cdot \sigma^2(w)$, where y is total revenue.

However the variance of income distribution is not a good measure of income inequality because it is not invariant to scale. For instance, suppose that there is a very egalitarian income distribution. An increase in aggregate revenue, due to an exogenous shock on skills or to an increase in the levels of effort, will cause an increase in the variance of income distribution whereas the degree of inequality is not affected. The percentages (shares) of total income obtained by the different individuals are a much better measure of inequality. Therefore, $\sigma^2(w)$ is a good proxy of the dispersion of the population income distribution[1]. Notice that the value of $\sigma^2(w)$ is always between 0 and 1.

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 according 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. This is a psychological cost capturing the

[1] The Coefficient of Variation (CV), also known as the relative standard deviation is a widely used measure in the literature on income inequality. It is easy to check that the Coefficient of Variation of the sharing rule is equal to the Coefficient of Variation of the income distribution. That is, CV(w) is the ratio to the standard deviation $\sigma(w)$ to the mean, which is a constant ($1/N$).

inner discomfort experienced by the individual when choosing an action different from the "right" one. 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[2] by the following linear quadratic function:

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

where $\mathbf{e}$ is the vector of efforts of the N agents. Notice that the standard case in conventional economic theory of no intrinsic motivation (i.e. selfish individuals) 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:

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

which in fact is an equilibrium in dominant strategies.

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 section, 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) *conformism* (conformity), that induce personal norms to move towards the average of the actual behavior of the organization.

3 Personal Norms and Effort in the long run

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

Consistency requires 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.

Conformity implies that personal norms tend to move towards the average of the actual behavior of the organization, this average being considered what

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

one "*should*" do in that specific social context. Hereafter we will denote by $\langle x \rangle$ the average of variable x_i, that is, $\langle x \rangle = (1/N) \sum_{i=1}^{N} x_i$.

Specifically, we assume that with weight $a_i > 0$ the personal norm $\hat{e}_i^{t+1}$ of individual i in period $t+1$ moves in the direction of the individual equilibrium behavior of the previous period t; with weight $b_i > 0$ the personal norm moves towards the average equilibrium behavior in the group on period t, with the remaining weight $1 - a_i - b_i$ the personal norm remains anchored to the previous value, where $a_i + b_i \leq 1$. In summary, people update their norms influenced by their own past behavior and/or by the attitude of their peers, with different weights. The law of motion of personal norms is given by the following set of coupled difference equations:

$$\hat{e}_i^{t+1} = a_i \bar{e}_i^t + b_i \langle \bar{e}^t \rangle + (1 - a_i - b_i) \hat{e}_i^t, i = 1, 2....N. \tag{3}$$

For simplicity in the rest of the paper we assume that the levels of materialism β, consistency a and conformism b are the same for all players. All the results hold with minor variations for individual heterogeneity of these weights.

The next proposition characterizes the steady state distribution of personal norms and equilibrium behavior.

Proposition 1 *If personal norms are governed by a dynamics that is a mix of consistency and conformism as in (3), the steady state personal norm of each agent is:*

$$\hat{e}_i^{\infty} = \left(\frac{a\beta}{a\beta + b} \right) (w_i s_i) + \left(\frac{b}{a\beta + b} \right) \langle ws \rangle, \textit{for } i = 1, 2, ...N. \tag{4}$$

Moreover, the steady state equilibrium behavior is:

$$\bar{e}_i^{\infty} = (\beta + (1 - \beta) \left(\frac{a\beta}{a\beta + b} \right))(w_i s_i) + (1 - \beta) \left(\frac{b}{a\beta + b} \right) \langle ws \rangle, \textit{for } i = 1, 2, ...N. \tag{5}$$

By proposition 1, we know that, in the steady state, personal norms are a convex combination between individual marginal revenue and the population average marginal revenue. Notice that the first part is driven by consistency and the latter by conformity. Agents weigh the information derived from their own material incentives $(w_i s_i)$ and from the overall society $\langle ws \rangle$ and this weight depends on their levels of materialism, conformism and consistency.

If consistency were 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. And the personal norm coincides with the equilibrium behavior. This can be easily checked by setting $b = 0$. As a consequence, even if agents start with personal norms for efficiency (i.e. $\hat{e}_i^0 = s_i$), in the steady state personal norms get eroded and will tend to the individual marginal revenue $w_i s_i$.

On the other hand, if only conformism is at work (i.e. $a = 0$), then in steady state all agents end up having the same personal norms that coincide with the average marginal revenue of the group $\langle ws \rangle$. The group tends to complete homogeneity in norms. Moreover, note that the steady state personal norm in this case is entirely independent of the initial distribution of personal norms, and is only grounded on the levels of skills and the sharing rule.

Notice that with a dynamics exclusively governed by conformism but provided there is a positive level of materialism, even if all agents have the same personal norm, each agent performs a different action given the different incentives derived from skills and the income sharing rule. Therefore, there is an homogeneous culture concerning values but there exists 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.

Coming now back to the general dynamics where both consistency and conformism are operating notice that:

$$\bar{e}_i^\infty = \hat{e}_i^\infty + \left(\frac{\beta b}{a\beta + b} \right) (w_i s_i - \langle ws \rangle) \tag{6}$$

Now given that $\frac{\beta b}{a\beta + b} > 0$, we can state the following result:

Result 1 *If marginal individual revenue of individual i is greater (equal or smaller) than the average revenue of the group then i's steady state level of effort will be greater (equal or smaller) than her steady state personal norm. That is, if $w_i s_i \gtreqless \langle ws \rangle$ then $\bar{e}_i^\infty \gtreqless \hat{e}_i^\infty$.*

Notice that a high individual marginal revenue might be due to either a high individual productivity or a high position in the hierarchy of the income distribution, or both of them.

Although our main goal in this paper is to analyze the interaction between culture and aggregate team performance we need to know the effects of the cultural variables on individual norms and behavior. These effects are shown in the following set of results. The formal proofs are relegated to the appendix.

Result 2 *Both individual effort $\bar{e}_i^\infty$ and personal norm $\hat{e}_i^\infty$ are increasing with individual skill s_i and remuneration w_i. For positive levels of materialism β the resulting increase in effort is higher than the increase in personal norm. The rise in both effort and norm is higher, the higher the levels of materialism and consistency, and the lower the level of conformism in the group.*

The last part of this result illustrates how different configurations of the cultural variables have an important influence on the final effect on individual norms and efforts of a change in productivity or in remuneration. Notice that conformism tends to reduce the effect while consistency and materialism tend to amplify it. The next two results confirm the relevant effects of changes in cultural primitives on the steady state equilibrium efforts and norms. Moreover they show a differential effect for those agents above or below of average marginal revenue.

Result 3 *An increase (decrease) on the level of materialism β or consistency a yields an increase (decrease) in the effort level of those individuals with a marginal revenue above the average and a decrease (increase) for those below the average. For positive levels of materialism the change in the norm is higher than the change in effort.*

Result 4 *An increase (decrease) on the level of conformism b yields an increase (decrease) in the effort level of individuals with a marginal revenue below the average and a decrease (increase) for those above the average. For positive levels of materialism the change in the norm is higher than the change in effort.*

Conformism also creates cross cultural effects on effort. Suppose there is a change (for example an increase) in the average marginal revenue $\langle ws \rangle$ but the particular w_i and s_i of player i does not change. Nevertheless for positive levels of conformism b, both individual effort $\bar{e}_i^{\infty}$ and personal norm $\widehat{e}_i^{\infty}$ of individual i will increase. Therefore, due to conformism even if nothing changes from the individual point of view, a change for instance in the productivity in another member of the team, causes also a change in the effort and norm levels of the rest of individuals.

Our main interest in this paper is to analyze the aggregate performance of the team arising from this cultural evolutionary process. In the following sections we present our definition of team culture, and study its influence on long run team performance.

4 Team culture: individualism versus collectivism.

In this work we are interested in the influence of culture on team economic performance. We define culture as a set of psychological variables that shape the evolution of norms and economic behavior in the group jointly with team technological and distributional parameters. These cultural variables are the levels of materialism, consistency and conformism which prevail among the members of the team.

Recall that the steady state equilibrium efforts are given by:

$\bar{e}_i^{\infty} = D(w_i s_i) + (1 - D)\langle ws \rangle$, for $i = 1, 2, ...N$, where $D = (\beta + (1 - \beta)\left(\frac{a\beta}{a\beta+b}\right) = \left(\frac{\beta(a+b)}{a\beta+b}\right)$.

We use expression D to capture and describe different **team cultures.** Expression D depends on the vector of levels of materialism, consistency and conformity (β, a, b) shared by the members of the group and reflects how they jointly interact to influence steady state equilibrium efforts. Notice that $D \in [\beta, 1]$, where we assume that $\beta \in (0, 1)$.

An additional reason for using expression D as our measure of culture is that it captures a crucial dimension of culture: the trade-off between individualism and collectivism. To keep in mind the intuition, a high value of D represents an **individualist culture** with very low levels of conformism and high levels of consistency and enough materialism. In this kind of culture personal norms and individual behavior tend to be consistent in the long run and to be equal to the individual marginal revenue. That is, individuals adjust their norms and behavior to their individual material incentives, and play in the long run the Nash equilibrium in material payoffs. As a consequence the outcome of this kind of culture is very close to the conventional economics outcome of a static model with selfish agents (β tends to 1).

On the other hand, low values of D represent a **collectivist culture** with very high levels of conformism and low levels of consistency and materialism. Individuals basically adjust their norms and behavior to the average (or collective) behavior. This group tends to complete homogeneity in norms and the steady state dispersion of behavior is also very low for low levels of materialism.

As a first step it is interesting to obtain the average effort of the group and its variance in the steady state, discuss its determinants and analyze whether culture D influences these values. By taking averages in the expressions of steady state norms and efforts we have the following result:

Result 5 *The group average personal norm and the average effort in the steady state are equal to the average marginal revenue of the group,* $\langle \hat{e}^{\infty} \rangle = \langle \bar{e}^{\infty} \rangle = \langle ws \rangle$.

Notice that this result holds even with heterogeneity in the individual levels of consistency and conformity if we assume, as it seems reasonable, that the variables (a_i, b_i) and $(w_i s_i)$ were statistically independent.

Therefore, average norm and behavior coincide in the long run and will be higher the higher is the average marginal revenue of the group. So, it is fully determined by the remunerations and the skills of its members while the levels of materialism, conformism and consistency in the group do not have any influence.

We know that $\langle ws \rangle = \frac{\langle s \rangle}{N} + \mathrm{Cov}(w, s)$, but if we assume statistical independence between variables w and s, that is, if remunerations are not related to the skill levels, then $\mathrm{Cov}(w, s) = 0$ and thus $\langle ws \rangle = \frac{\langle s \rangle}{N}$. Therefore $\langle \hat{e}^{\infty} \rangle = \langle \bar{e}^{\infty} \rangle = \frac{\langle s \rangle}{N}$. In an organization where remunerations and skills are not correlated, the long run group average effort increases with the average skill and diminishes with the size of the group (the so-called and well-known "1/ N problem" in teams).

For our purposes the remarkable feature of this result is that the steady state team average effort does not depend at all on team culture D. It is fully determined by average productivity and the size of the team.

Result 6 *The variance of the individual levels of effort in the steady state is* *given by*

$$\sigma^2(\bar{e}^\infty) = D^2\sigma^2(ws). \tag{7}$$

Notice again that this result holds even with heterogeneity in the individual levels of consistency and conformity if we assume that the variables (a_i, b_i) and $(w_i s_i)$ were statistically independent.

Therefore, the dispersion of steady state behavior is positively related with the dispersion of individual marginal revenues but this relationship is mediated by the cultural parameters β, a and b which jointly determine expression D. Culture strongly influences the levels of effort dispersion in the long run while it does not influence average effort. For instance, in a fully individualist culture, that is, D close to 1, the dispersion of equilibrium efforts is close to the dispersion of individual marginal revenues i. e. $\sigma^2(\bar{e}^\infty) \approx \sigma^2(\hat{e}^\infty) \approx \sigma^2(ws)$. Whereas in a fully collectivist team culture, that is, D close to β, $\sigma^2(\hat{e}^\infty) = 0$ and $\sigma^2(\bar{e}^\infty) \approx \beta^2\sigma^2(ws)$ which will also be close to zero for very low values of materialism β. That is, individualism tends to increase the variance of efforts while collectivism tends to reduce it.

The aggregate effects of team culture on aggregate revenue and material costs are now analyzed in the next section. Our results show that the cultural variables (β, a, b) turn out to be a fundamental determinant for group performance.

5 The effects of culture on long run team performance.

We are interested on the long run level of performance of the group. Our main results show how team culture D determines the long run team aggregate production but in a way that depends on the existing distribution of income and skills.

5.1 Long run team production.

Let us first compute the levels of aggregate production of the group in the steady state of the dynamics. The more realistic and analyzed case in team production situations is the one in which due to non-observability or non-verifiability of effort and skills, there is statistical independence between skills and remuneration. Thus, following Goodman (1960) and with statistical independence between the variables w_i and s_i, we know that the variance of marginal revenues is given by:

$$\sigma^2(ws) = \sigma^2(w)\sigma^2(s) + (1/N^2)\sigma^2(s) + \langle s\rangle^2\sigma^2(w). \tag{8}$$

It is straighforward to check that an increase in the average of the skills $\langle s\rangle$ in the team, an increase both in the variance of the distribution of skills or in the variance of the sharing rule, i.e. the income distribution, will cause an increase in $\sigma^2(ws)$.

Let us consider the aggregate material production in the steady state. Set $Y_i(e) = w_i \sum_{i=1}^{n} s_i e_i - \frac{1}{2} e_i^2$ where the first term represents the individual revenue and the second term is the material cost associated with effort. Then the aggregate material production is given by $Y = \sum_{i=1}^{n} Y_i(e)$.

Therefore aggregate production as a function of steady state equilibrium efforts is given by:

$$Y(\bar{e}^{\infty}) = N\langle s\bar{e}^{\infty}\rangle - \frac{N}{2}\langle(\bar{e}^{\infty})^2\rangle = N(\langle s\rangle\langle\bar{e}^{\infty}\rangle + Cov(s,\bar{e}^{\infty})) - \frac{N}{2}(\langle\bar{e}^{\infty}\rangle^2 + \sigma^2(\bar{e}^{\infty})). \tag{9}$$

Recall, as obtained in Results 5 and 6, that when $Cov(w,s) = 0$, then $\langle\bar{e}^{\infty}\rangle = \frac{\langle s\rangle}{N}$ and $\sigma^2(\bar{e}^{\infty}) = D^2\sigma^2(ws)$. Moreover it can be computed that $Cov(s,\bar{e}^{\infty}) = D\frac{\sigma^2(s)}{N}$. See Appendix for derivation.

Thus aggregate team production expressed as aggregate team revenue minus aggregate team material costs is given by:

$$Y(\bar{e}^{\infty}) = [\langle s\rangle^2 + D\sigma^2(s)] - \frac{N}{2}[\frac{\langle s\rangle^2}{N^2} + D^2\sigma^2(ws)]. \tag{10}$$

Finally and taking into account the above expression for the variance of marginal revenues $\sigma^2(ws)$, the aggregate production in steady state is given by:

$$Y(\bar{e}^{\infty}) = \frac{2ND - D^2(1 + N^2\sigma^2(w))}{2N}\sigma^2(s) + \frac{2N - 1 - N^2D^2\sigma^2(w)}{2N}\langle s\rangle^2. \tag{11}$$

Recall that expression D captures team culture in our model. Therefore, note that team revenue increases with D and team material cost also increases with D. Culture influences team revenue because it affects the covariance between efforts and skills and influences team costs through its influence on the variance of steady state efforts.

5.2 Culture and optimal team performance.

A natural initial question is the following: which team culture (represented by expression $D(\beta, a, b)$) yields the maximal aggregate team production?

The next two propositions establish the optimal team culture D that maximizes aggregate production. Firstly, we analyze a team where all its members have homogeneous skills s (that is, $\sigma^2(s) = 0$).

Proposition 2 *Assume an homogeneous-skilled team with a common individual productivity s. The value of the team culture D^* which maximizes aggregate team production $Y(\bar{e}^{\infty})$ in the steady state is the following:*

i) if $\sigma^2(w) = 0$, then any culture D is optimal,
ii) if $\sigma^2(w) > 0$, then $D^{*}= \beta$, i.e. a fully collectivist culture.

Proof. See Appendix.

Therefore, in a team where there are no differences in individual productivity among its members, the culture that maximizes team production is a fully collectivist one whatever the group income distribution and the common level of skills are. The reason is that for any $\sigma^2(w) > 0$, culture D influences only aggregate costs, in particular increasing the variance of equilibrium efforts $\sigma^2(\bar{e}^{\infty})$. On the other hand, as the covariance of skills and efforts is zero, team culture does not affect team revenue. Consequently in order to maximize production it is needed to minimize aggregate costs by reducing D and in this way decreasing $\sigma^2(\bar{e}^{\infty})$. The optimal culture is a corner solution: full collectivism, $D^{*}=\beta$.

However, for the egalitarian distribution $\sigma^2(w) = 0$, not only full collectivism is optimal. In this particular case culture does not matter at all for the performance of the team because it is fully determined by the common level of productivity s. In other words, for any team culture D (i.e. whatever the levels of individualism and collectivism in the group are), all individual norms and behavior converge in the long run to the same value $\hat{e}^{\infty} = \bar{e}^{\infty} = \frac{s}{N}$.

Let us switch next to the heterogeneous skills case.

Proposition 3 *Assume an heterogeneous-skilled team with a distribution of skills with average $\langle s \rangle$ and variance $\sigma^2(s)$. The value of the team culture D^* which maximizes aggregate team production $Y(\bar{e}^{\infty})$ in the steady state is the following:*

i) if $\sigma^2(w) \leq \frac{\sigma^2(s)(N-1)}{(\sigma^2(s)+\langle s\rangle^2)N^2}$, then $D^* = 1$, i.e. a fully individualist culture,
ii) if $\sigma^2(w) > \frac{\sigma^2(s)(N-1)}{(\sigma^2(s)+\langle s\rangle^2)N^2}$, then $D^{*}= \frac{\sigma^2(s)}{N.\sigma^2(ws)} \in [\beta, 1)$.

Proof. See Appendix.

Therefore, if individuals display different productivities, then full collectivism is no longer optimal and the precise weight of consistency and conformity in the more productive culture depends on the income and skills distributions.

Starting with an egalitarian team, $\sigma^2(w) = 0$, notice that both team revenue and aggregate team costs depend positively on team culture D, and the dispersion of skills. In fact both variables are substitutes in these functions.

$$Y(\bar{e}^{\infty}) = [\langle s\rangle^2 + D\sigma^2(s)] - [\frac{\langle s\rangle^2}{2N} + \frac{D^2}{2N}\sigma^2(s)]. \tag{12}$$

It is easy to check that the increase in revenue due to an increase in D that is, an increase in the level of consistency and a lower level of conformity, is higher than the increase caused in aggregate costs for any positive value of $\sigma^2(s)$. Thus it is always production enhancing to have a team culture with more consistency and less conformity, i.e a more individualist culture. This is why we obtain again a corner solution: the optimal team culture is a fully individualist one, $D^* = 1$.

In general, for very egalitarian teams (case i) a fully individualist culture is optimal to maximize team production. More individualist egalitarian teams are more productive than more conformist ones. The intuition is that in this situation the more productive members of the team need to be "culturally" motivated to exert a higher effort given that remunerations are evenly distributed. Individualism provides such incentive.

In case ii) where $\sigma^2(w) > \frac{\sigma^2(s)(N-1)}{(\sigma^2(s)+\langle s\rangle^2)N^2}$, the optimal culture D* is no longer a corner solution. Note that this bound on the income distribution is well-defined in the sense that it is always smaller than 1 and notice also that it will be very small for large N. Now, the culture that maximizes team production is a mix of consistency and conformity.

Overall the intuition behind Proposition 3 is the following. An increase in individualism, that is a rise in D, increases the level of effort of those individuals with a marginal revenue above the average and decreases the level of effort of those below the average. Therefore, it increases both the variance of efforts, $\sigma^2(\bar{e}^\infty) = D^2\sigma^2(ws)$, and the covariance between skills and efforts $Cov(s,\bar{e}^\infty) = D\frac{\sigma^2(s)}{N}$, provided $\sigma^2(s) > 0$. The increase in Covariance increases team revenue. Individualism operates as a culturally motivated incentive for effort for the members of the team with the marginal revenue above the average. In some cases these are the more skilled members of the team and in other they maybe the wealthier. But in any case the increase in the variance of effort also increases the team material costs. Obviously, an increase in collectivism operates in the opposite direction concerning revenue and cost. Proposition 3 shows that in sufficiently egalitarian groups the members that exert the highest levels of effort are the more skilled and thus the revenue effect is higher than the cost effect. Consequently, the optimal culture is a fully individualist one. But for more inegalitarian groups the optimal culture combines appropiate levels of both individualism and collectivism till the point where the marginal aggregate revenue equates the marginal aggregate cost of a change in D.

Comparative statics

Let us calculate the marginal aggregate revenue of a change in the team culture. By a change in the team culture we mean an increase or decrease in expression D caused by a change in the relative weight of consistency and materialism as compared to conformism. Therefore, an increase in D will be denoted as an increase in individualism, and a decrease in D will be denoted as an increase in collectivism. We can define similarly the marginal aggregate cost of a change in team culture. Marginal aggregate revenue is constant and equal to $\sigma^2(s)$, while the aggregate marginal cost is given by $(N\sigma^2(ws)D)$ that is, it increases linearly with individualism with a slope determined by the variance of individual marginal revenues.

Now it is easy to see that the "interior" optimal culture D*$= \frac{\sigma^2(s)}{N.\sigma^2(ws)}$ is decreasing with income inequality $\sigma^2(w)$ and with team average productivity $\langle s\rangle$ and increases with the dispersion of individual skills $\sigma^2(s)$.

Starting with the income distribution $\sigma^2(w)$, the culture that maximizes production is more collectivist the more inegalitarian is the income group distribution. Whereas in more egalitarian teams is optimal a more individualist culture. The reason is that income distribution $\sigma^2(w)$ does not affect team revenue while it increases team material costs and in particular it also increases marginal aggregate cost.

Concerning the effect of an increase in the average group productivity $\langle s \rangle$, notice that it increases marginal aggregate costs but it does not affect marginal aggregate revenues. Therefore, in more productive teams, with a higher average productivity, the optimal team culture requires a larger weight of conformism as compared to the weight attached to consistency.

In teams with a high dispersion of skills $\sigma^2(s)$, the optimal culture is the one where consistency and materialism matter relatively more than conformism: individualist cultures. In fact at some point, if the dispersion of skills is sufficiently high, a culture with only consistency and no conformism is the optimal one. An increase in the dispersion of skills in the group yields an increase both on marginal aggregate revenue and on marginal aggregate cost but it is easy to show that the former is always greater than the latter and therefore the new optimal culture is a more individualist one.

Summarizing: culture matters for the performance of a team. If $\sigma^2(w) > 0$ or $\sigma^2(s) > 0$ culture matters in the sense that there exists an optimal culture that maximizes aggregate production and its characteristics depend on the team distributions of income and skills. A higher average productivity and a more inegalitarian dispersion of remunerations require a more collectivist culture. And a higher dispersion of individual productivities requires a more individualist culture. The only exception for this result is a completely egalitarian team where all its members have the same productivity s (i.e. $\sigma^2(w) = 0$ and $\sigma^2(s) = 0$). In this case whatever the culture is and whatever the initial distribution of personal norms in the group is, the team will end up with a common norm and effort equal to the per capita productivity.

In the next subsection we address a different question: the analysis of the impact on aggregate production of exogenous shocks in the income and skills distributions for a given team culture D, and we study how this impact is strongly influenced by the different types of culture.

5.3 Culture and income and skill distributions

Let us take the team culture as given, and study the effect on steady state team production of some exogenous shock on a technological or distributional parameter.

First of all it is easy to show that the egalitarian income distribution maximizes production for any team culture. Recall that individual remunerations cannot be linked to effort or to individual levels of skill because of the usual non- verifiability problems of these variables. Then, looking at the equation for aggregate production, given any distribution of skills, the particular income distribution that maximizes aggregate production is $\sigma^2(w) = 0$, that is, a totally egalitarian 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 gross production is linear and costs are convex in the levels of effort. Furthermore, aggregate team revenue is independent of $\sigma^2(w)$ while the aggregate cost depends on $\sigma^2(w)$. Thus a higher $\sigma^2(w)$ increases the long run dispersion of efforts. Since costs are convex in behavior, a higher variance induces a rise in steady state aggregate costs (this is as a mean preserving spread of a convex function), and thus a reduction of aggregate production[3].

Proposition 4 *For any team culture $D(\beta, a, b)$ and any distribution of skills, income inequality $\sigma^2(w)$ and aggregate production are negatively related. The egalitarian distribution $\sigma^2(w) = 0$, i.e. $w_i = 1/N$ for all i, maximizes team aggregate production in the steady state for any team culture.*

Consider next that the income distribution in the team determined by the total revenue sharing rule is given as the result of previous history or some other factor. Now suppose that there is an increase in the level of average skills in the group, caused by a shock in productivity or by a policy of increasing human capital, but maintaining unchanged the variance $\sigma^2(s)$. Its impact on team aggregate production will depend crucially on the level of income inequality $\sigma^2(w)$ held in the group and the prevailing team culture D.

Proposition 5 *Assume a given income distribution $\sigma^2(w)$ then*

i) if $\sigma^2(w) \leq \frac{2N-1}{N^2}$, an increase in the average group skill distribution $\langle s \rangle$ yields an increase in the steady state aggregate production for any team culture D,

ii) if $\sigma^2(w) > \frac{2N-1}{N^2}$, an increase in the average group skill distribution $\langle s \rangle$ yields an increase in the steady state aggregate production only if team culture D is smaller than a critical value given by $(\frac{2N-1}{N^2\sigma^2(w)})^{1/2} \equiv B_s(N, \sigma^2(w)) < 1$,

iii) for any $\sigma^2(w)$, an increase in the average group skill distribution $\langle s \rangle$ yields the maximal increase in the steady state aggregate production with team culture $D = \beta$, i.e. full collectivism.

Proof. See Appendix.

The more striking result in Proposition 5 establishes that in teams where there is some level of income inequality, namely $\sigma^2(w) > \frac{2N-1}{N^2}$, and in addition there is also an excessively individualist culture, $D > (\frac{2N-1}{N^2\sigma^2(w)})^{1/2}$, then an increase in average productivity $\langle s \rangle$ yields paradoxically a decrease in aggregate production. On the other hand, if $\sigma^2(w) \leq \frac{2N-1}{N^2}$, that is, in the case of very egalitarian teams, an increase of average productivity will always increase aggregate team production for any culture. Notice that expression $\frac{2N-1}{N^2}$ is very low for large values of N.

[3] Note that with a generic concave production function we should observe the same result. 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.

This result can be read in two complementary ways. Given an income distribution $\sigma^2(w)$, which team cultures are needed to obtain a positive shock on skills to be production enhancing. Or alternatively, given a culture D what income distributions permit a positive shock on skills to be production enhancing.

As a consequence of this result notice that in a non completely egalitarian setting more collectivist groups will be more "competitive" than less collectivist ones. To be more precise, the same exogenous shock on average productivity (for example, due to the adoption of a new technology) would increase the production of a sufficiently collectivist group while would yield a decrease in the production of a relatively individualist group. Now suppose that these groups compete for resources and their respective success depends on their respective levels of material production. Then the more collectivist group will likely be the winner in this competition. Notice that this advantage for collectivism disappears in very egalitarian teams.

The intuition behind the result of the proposition is the following. As we already know an increase in productivity yields an increase in individual steady state efforts. This causes an increase both in team revenue and in team material costs. The impact on team revenue is independent of the team culture D while the increase in team aggregate costs depends on culture through its impact on the variance of equilibrium efforts.

Notice that the increase in material costs is increasing in $\sigma^2(w)$. If income inequality is sufficiently large then the dispersion of the individual marginal revenues will be high and consequently the dispersion of equilibrium efforts $\sigma^2(\bar{e}^{\infty})$ will be also high. This causes that the rise in convex costs is higher than the rise in total revenue with a negative total effect on aggregate production. Nevertheless the impact of the dispersion of individual marginal revenues on the variance of equilibrium efforts crucially depends on the cultural variables captured by expression D which amplify or reduce the effect on this dispersion. In groups with a very conformist culture (a low D) all individual norms and efforts will be close to the population average marginal revenue and therefore an increase on average productivity will result in an increase in team production whatever the sharing income rule is. However, in groups with a sufficiently high individualist culture (a high D) there will be a high dispersion of equilibrium efforts and unless there is enough income equality the shock on productivity will not increase aggregate production.

Finally, as the impact on team revenue of an increase on average productivity is independent of culture D, while the increase in team costs depends on culture through its impact on the variance of equilibrium efforts, it follows that the maximal increase on production happens for a fully collectivist culture.

Next we analyze the effects of a mean-preserving spread in the distribution of skills in the team. We will show similarly to the previous case in proposition 5, that an increase in the variance of individual skills $\sigma^2(s)$, while keeping the average $\langle s \rangle$ unchanged, results in an increase on team production only if the team culture D (i.e. the level of individualism) is smaller than a bound which depends on the existing income distribution. We formally state this result in the next proposition.

Proposition 6 *Assume a given income distribution $\sigma^2(w)$ and a given average productivity $\langle s \rangle$ then*

i) if $\sigma^2(w) \leq \frac{2N-1}{N^2}$, an increase in the dispersion of skills $\sigma^2(s)$ yields an increase in the steady state aggregate production for any team culture D,

ii) if $\sigma^2(w) > \frac{2N-1}{N^2}$, an increase in the dispersion of skills $\sigma^2(s)$ yields an increase in the steady state aggregate production only if the team culture D is smaller than a critical value given by $\frac{2N}{1+N^2\sigma^2(w)} \equiv B_{\sigma s}(N, \sigma^2(w)) < 1$,

iii) for any $\sigma^2(w)$ an increase in the dispersion of skills $\sigma^2(s)$ yields the maximal increase in the steady state aggregate production with team culture D $= \frac{N}{1+N^2\sigma^2(w)}$.

Proof. See Appendix

Notice that the critical value on the income distribution $\sigma^2(w)$ is the same as in proposition 5.

A mean-preserving spread in the distribution of skills has a positive impact both in team revenue and in aggregate costs. The difference with the impact of a shock on average productivity is that now the existing culture D influences both team revenue and costs. On the one hand revenue increases because there is an increase in the covariance of skills and efforts and on the other hand aggregate costs increase because there is an increase in the variance of efforts. The positive impact on revenue is reinforced by a higher level of individualism (a high level of D) while the impact on aggregate costs is reduced by a higher level of conformism (a low level of D). These two opposite effects explain the differences and similarities with the results obtained for the effects of a shock on average skills in Proposition 5.

In the case of a shock on the average productivity the increase in aggregate team production was maximal for a fully collectivist culture $D = \beta$. But now in the case of a mean-preserving increase in the dispersion of skills the culture that maximizes the impact on team production depends on the income distribution $\sigma^2(w)$. For very egalitarian distributions this culture is again the fully individualist one, D = 1. But for higher levels of inequality the weight of conformism increases for the culture where the impact on production is larger.

6 Concluding Remarks

In this paper we have analyzed whether culture affects economic performance of a production team. We have studied this question in a team in which members care about economic incentives and personal norms, and weigh both motivations according to their level of materialism. Furthermore, personal norms follow a dynamics driven by the forces of consistency and conformity. Our definition of team culture captures the joint effect of materialism, consistency and conformism in the steady state equilibrium efforts, and reflects the decisive importance of the individualism/collectivism cultural dimension. Relatively high levels of consistency and materialism jointly with low levels of conformism results in an individualist culture, while relatively high levels of conformism, jointly with low levels of consistency and materialism, results in a collectivist culture. However, a realistic feature of our theory is that this cleavage is not dichotomic but there is a continuum of cultures ranging from full collectivism to full individualism.

We show that culture can amplify or reduce the effects on team production of exogenous changes in the distribution of skills or in the income distribution in the team. Our theory illustrates how, in a heterogeneous-skilled team, more individualism increases the covariance of skills and efforts and therefore raises the revenue of the team. But individualism also increases the variance of efforts and thus the aggregate team costs. Which effect prevails depends on the distributional and technological parameters of the team.

However, in a team where members have exactly the same productivity, only the cost effect operates and as a consequence the optimal culture that maximizes team production is full collectivism. Nevertheless, in an heterogenous-skilled team, the optimal culture depends on the team income distribution. In very egalitarian teams, full individualism is optimal. Individualism operates as a culturally motivated incentive for effort for the more skilled members of the team. However, for more inegalitarian groups, the cost effect will increase resulting in an optimal culture that combines an appropriate mix of individualism and collectivism. Summarizing, in an heterogenous-skilled team if there is a unequal distribution of income it is optimal a more collectivist culture. Whereas in more egalitarian teams it is optimal a more individualist culture.

Similarly we have also shown that in more productive teams, with a higher average productivity, the optimal team culture requires a larger weight of conformism as compared to the weight attached to consistency. On the other hand, in teams with a relatively high dispersion of skills the optimal culture is the one where consistency and materialism matter relatively more than conformism: more individualist cultures.

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Appendix: Proofs of propositions and results.

Proof of Proposition 1.

From (3), considering the continuous time limit, we get:

$$\frac{d\hat{e}_i}{dt} = a(\bar{e}_i^t - \widehat{e_i}^t) + b(\langle \bar{e}^t \rangle - \hat{e}_i^t). \qquad (13)$$

If we substitute the results obtained in (2) and taking into account that $\langle \bar{e}^t \rangle = \beta\langle ws \rangle + (1-\beta)\langle \hat{e}^t \rangle$. Equation (13) becomes:

$$\frac{d\hat{e}_i}{dt} = (a\beta w_i s_i + b\beta\langle ws \rangle) + b(1-\beta)\langle \hat{e}^t \rangle - (a\beta + b)\hat{e}_i^t, \text{ for } i = 1, 2, ..n. \qquad (14)$$

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

$$\widehat{e_i}^\infty = \left(\frac{\beta a(w_i s_i) + \beta b\langle ws \rangle}{a\beta + b} \right) + \left(\frac{b}{a\beta + b} \right)(1-\beta)\langle \hat{e}^\infty \rangle. \qquad (15)$$

Taking averages we obtain

$$\langle \widehat{e}^\infty \rangle = \beta \left[(\frac{a}{a\beta + b})\langle ws \rangle + (\frac{b}{a\beta + b})\langle ws \rangle \right] + (1-\beta)(\frac{b}{a\beta + b})\langle \hat{e}^\infty \rangle. \qquad (16)$$

Rearranging terms we have,

$$\langle \widehat{e}^\infty \rangle \left(1 - (1-\beta)(\frac{b}{a\beta + b}) \right) = \beta \left[(\frac{a+b}{a\beta + b})\langle ws \rangle \right]. \qquad (17)$$

Finally, we get

$$\langle \hat{e}^\infty \rangle = \langle ws \rangle. \qquad (18)$$

Substituting (18) in (15) we get:

$$\widehat{e_i}^\infty = \left(\frac{\beta a(w_i s_i)}{a\beta + b} \right) + \left(\frac{\beta b\langle ws \rangle}{a\beta + b} \right) + \left(\frac{b}{a\beta + b} \right)(1-\beta)\langle ws \rangle. \qquad (19)$$

Therefore,

$$\widehat{e_i}^\infty = \left(\frac{a\beta}{a\beta + b} \right)(w_i s_i) + \left(\frac{b}{a\beta + b} \right)\langle ws \rangle, \text{for } i = 1, 2, ...n. \qquad (20)$$

Proof of Results 2, 3 and 4.

To ease the presentation let us denote $\bar{e}_i^\infty = \bar{e}_i$ and $\widehat{e_i}^\infty = \widehat{e}_i$.

Let us compute the derivative with respect to individual productivity s_i.

$\frac{\partial \bar{e}_i}{\partial s_i} = w_i(D + (1-D)(\frac{1}{N})) > 0$. A similar result is obtained with individual share w_i.

Let us define $A = \frac{a\beta}{a\beta+b}$. Then the derivative of the norm is: $\frac{\partial \widehat{e_i}}{\partial s_i} = w_i(A + (1-A)(\frac{1}{N})) > 0$.

As $D > A$ for $\beta > 0$, $\frac{\partial \bar{e}_i}{\partial s_i} > \frac{\partial \widehat{e_i}}{\partial s_i}$.

Let us now compute for instance the derivative w.r.t. the level of consistency a:

$\frac{\partial \bar{e}_i}{\partial a} = (w_i s_i - \langle ws \rangle)(1-\beta)\frac{\beta b}{(\beta a+b)^2}$. The sign is positive for individuals i such that $w_i s_i > \langle ws \rangle$ and negative for those with $w_i s_i < \langle ws \rangle$.

The rest of results follow similarly.

Proof that $Cov(s, \bar{e}^{\infty}) = D\frac{\sigma^2(s)}{N}$.

Let us denote for simplicity $\bar{e}^{\infty} = \bar{e}$.

We know that

$$Y(\bar{e}) = N\langle s\bar{e} \rangle - \frac{N}{2}\langle \bar{e}^2 \rangle = \quad (21)$$

$$N\langle s\bar{e} \rangle - \frac{N}{2}(\langle \bar{e} \rangle^2 + \sigma^2(\bar{e})). \quad (22)$$

Notice that $\langle \bar{e} \rangle = \frac{\langle s \rangle}{N}$ and $\sigma^2(\bar{e}) = D^2\sigma^2(ws)$.

Therefore

$$\langle s\bar{e} \rangle = \langle s \rangle\langle \bar{e} \rangle + Cov(s, \bar{e}) = \quad (23)$$

$$\frac{\langle s \rangle^2}{N} + Cov(s, \bar{e}). \quad (24)$$

By definition,

$$Cov(s, \bar{e}) = \frac{1}{N}\sum_{i=1}^{N}(s_i - \langle s \rangle)(\bar{e}_i - \langle \bar{e} \rangle) \quad (25)$$

where $\bar{e}_i = Dw_i s_i + (1-D)\frac{\langle s \rangle}{N}$, and thus

$$(s_i - \langle s \rangle)(\bar{e}_i - \langle \bar{e} \rangle) = (s_i - \langle s \rangle)(Dw_i s_i + (1-D)\frac{\langle s \rangle}{N} - \frac{\langle s \rangle}{N}) = \quad (26)$$

$$= (s_i - \langle s \rangle)(Dw_i s_i - D\frac{\langle s \rangle}{N}) = \quad (27)$$

$$= D[w_i s_i^2 - s_i\frac{\langle s \rangle}{N} - \langle s \rangle w_i s_i + \frac{\langle s \rangle^2}{N}]. \quad (28)$$

Taking averages we have

$$Cov(s, \bar{e}) = D[\langle ws^2 \rangle - \frac{\langle s \rangle^2}{N} - \langle s \rangle \langle ws \rangle + \frac{\langle s \rangle^2}{N}], \quad (29)$$

as $\langle ws \rangle = \frac{\langle s \rangle}{N}$ because $Cov(w, s) = 0$

$$Cov(s,\bar{e}) = D[\langle ws^2\rangle - \frac{\langle s\rangle^2}{N}]. \tag{30}$$

Now,
$\langle ws^2\rangle = \frac{\langle s^2\rangle}{N}$ because $Cov(w,s^2)=0$.
Note that $\langle s^2\rangle = \langle s\rangle^2 + \sigma^2(s)$ and $\langle ws^2\rangle = \frac{\langle s\rangle^2+\sigma^2(s)}{N}$.
Therefore,

$$\begin{aligned} Cov(s,\bar{e}) &= D[\frac{\langle s\rangle^2+\sigma^2(s)}{N} - \frac{\langle s\rangle^2}{N}] = & (31)\\ &= D\frac{\sigma^2(s)}{N}. & (32)\end{aligned}$$

Notice that $Cov(s,\bar{e}^\infty) = D\frac{\sigma^2(s)}{N} \geq 0$.

Proof of Proposition 2.
Consider $s_i = s\ \forall i, i.e. \sigma^2(s)=0$.
Then, if $\sigma^2(w)=0$, then $Y(\bar{e}) = (1-\frac{1}{2N})s^2$, for all D.
However, if $\sigma^2(w) > 0$

$$Y(\bar{e}) = s^2 - (\frac{1}{2N} + \frac{N}{2}D^2\sigma^2(w))s^2. \tag{33}$$

Then

$$\frac{\partial Y(\bar{e})}{\partial D} = -ND^2\sigma^2(w))s^2 < 0. \tag{34}$$

Therefore the maximum is a corner solution: $D^* = \beta$.

Proof of Proposition 3.

Consider an heterogeneous - skilled team with $\sigma^2(s) > 0$.

The F.O.C. for an interior solution in the maximization of team production yields,

$$\frac{\partial Y(\bar{e})}{\partial D} = (1 - ND(\sigma^2(w) + \frac{1}{N^2})\sigma^2(s) - ND\sigma^2(w)\langle s\rangle^2 = 0. \tag{35}$$

Then,

$$\begin{aligned} D^* &= \frac{\sigma^2(s)}{N(\sigma^2(w)\langle s\rangle^2 + \sigma^2(w)\sigma^2(s) + \sigma^2(s)\frac{1}{N^2})} = & (36)\\ &= \frac{\sigma^2(s)}{N\cdot\sigma^2(ws)}. & (37)\end{aligned}$$

It is easy to check that D^* depends negatively on $\sigma^2(w)$ and $\langle s\rangle$ and positively on $\sigma^2(s)$.

In order to get an interior solution $D^* < 1$, it is needed that

$$\sigma^2(w) > \frac{\sigma^2(s)(N-1)}{(\sigma^2(s) + \langle s\rangle^2)N^2}. \tag{38}$$

If this condition is satisfied, then we get a interior solution $D^* \in (\beta, 1)$.

Otherwise, if $\sigma^2(w) \leq \frac{\sigma^2(s)(N-1)}{(\sigma^2(s)+\langle s\rangle^2)N^2}$, as $D^* > 1$, we get a corner solution $D^* = 1$.

Now we compute the value of D* for $\sigma^2(w) = 1$, $D^*= \frac{\sigma^2(s)}{(N+\frac{1}{N})\sigma^2(s)+\langle s\rangle^2}$.

Then if $\beta > \frac{\sigma^2(s)}{(N+\frac{1}{N})\sigma^2(s)+\langle s\rangle^2}$, there exists a $\sigma^2(w) < 1$ such that for $\sigma^2(w)\epsilon[\frac{\sigma^2(s)(\frac{N-\beta}{\beta N^2})}{\sigma^2(s)+\langle s\rangle^2}, 1]$ the optimal culture is a corner solution, $D^* = \beta$.

Proof of Proposition 5.

i) and ii) Given any culture D, the impact of an external shock in average productivity $\langle s\rangle$ is given by

$$\frac{\partial Y(\bar{e})}{\partial \langle s\rangle} = 2(1 - \frac{1}{2N} - \frac{N}{2}D^2\sigma^2(w))\langle s\rangle. \tag{39}$$

Then, obviously its sign is non-negative if

$$1 - \frac{1}{2N} - \frac{N}{2}D^2\sigma^2(w) \geq 0.$$

Therefore,

$$D \leq (\frac{2N-1}{N^2\sigma^2(w)})^{1/2} = B_s(N, \sigma^2(w)).$$

But this bound has to be smaller than 1:

$$B_s(N, \sigma^2(w)) < 1 \text{ iff } \frac{2N-1}{N^2} < \sigma^2(w).$$

Therefore, for $\sigma^2(w) \leq \frac{2N-1}{N^2}$, the bound is higher or equal than 1 and thus any culture is production enhancing given a positive shock on $\langle s\rangle$.

But for $\sigma^2(w) > \frac{2N-1}{N^2}$, only D $< B_s(N, \sigma^2(w)) < 1$ are production enhancing cultures. Notice that the bound is decreasing on income inequality $\sigma^2(w)$.

iii) Note that $\frac{\partial Y(\bar{e})}{\partial\langle s\rangle}$ depends negatively on D. Then we get a corner solution: the production is maximal when $D = \beta$, that is, when there is only conformism.

Proof of Proposition 6.

i) and ii) Note that an increase in $\sigma^2(s)$ causes an increase in Y if

$$\frac{\partial Y(\bar{e})}{\partial \sigma^2(s)} = D - \frac{N}{2}(\sigma^2(w) + \frac{1}{N^2})D^2 \geq 0,$$

and this holds if

$$D < \frac{1}{\frac{N}{2}(\sigma^2(w) + \frac{1}{N^2})} = \frac{2N}{1 + N^2\sigma^2(w)} = B_{\sigma s}. \tag{40}$$

This bound is smaller than 1, when $\frac{2N-1}{N^2} < \sigma^2(w)$.

Therefore, again for $\sigma^2(w) \leq \frac{2N-1}{N^2}$, the bound is higher or equal than 1 and thus any culture is production enhancing given a mean preserving spread of skills.

But for $\sigma^2(w) > \frac{2N-1}{N^2}$, only D $< B_{\sigma s}(N, \sigma^2(w)) < 1$ are production enhancing cultures. Notice that this bound is decreasing on income inequality $\sigma^2(w)$.

iii) The function $\frac{\partial Y}{\partial \sigma^2(s)}$ reaches a maximum according to the F.O.C.

$$1 - N(\sigma^2(w) + \frac{1}{N^2})D = 0,$$

solving the equation,

$$\begin{aligned} D &= \frac{1}{N\sigma^2(w) + \frac{1}{N}} = & (41) \\ &= \frac{N}{1 + N^2\sigma^2(w)}. & (42) \end{aligned}$$

This expression depends negatively on $\sigma^2(w)$.

If $\frac{N-1}{N^2} \geq \sigma^2(w)$ then $D = \frac{N}{1+N^2\sigma^2(w)} \geq 1$, therefore we obtain a corner solution $D^* = 1$.

If $\beta > \frac{N}{1+N^2}$ then $\frac{N-\beta}{\beta N^2} < 1$. Thus for $\frac{N-\beta}{\beta N^2} \leq \sigma^2(w)$ then $D = \frac{N}{1+N^2\sigma^2(w)} \leq \beta$, therefore we obtain a corner solution $D^* = \beta$.

For other values of $\sigma^2(w)$ we obtain as an interior solution, $D = \frac{N}{1+N^2\sigma^2(w)}$.