Dynamic Production Teams with Strategic Behavior*

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Abstract

We analyze if intergenerational teams reveal workers' productivities. Some uncertainty on agents' productivities persists when (i) each agent must work independently, or (ii) technological shocks are agent-specific in compulsory teams. However, when technological shocks are team-specific in compulsory teams, each worker's productivity is revealed. When agents choose to work independently or in teams, that problem falls in the class of dynamic games. Elective teams are preferred by high-productivity young workers when the technological shocks are agent-specific, and maximize the expected utility of a young worker when shocks are team-specific.

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1 Introduction

In this paper we study the extent to which intergenerational teams can provide information on the productivity of workers in the long run. To do so we consider heterogenous agents in a dynamic stochastic environment with information asymmetry between employers and employees. We compare the steady-state wages and expected utility under three possible work arrangements. In the first, each worker must work independently. In the second, two workers of different age are forced to work together. Finally, two workers of different age can choose freely between working together or independently. The third scenario requires that we compute the equilibrium work strategies and study how they are affected by a worker's age, reputation, productivity, as well as side payments.

Previous studies have generally assumed that an employer cannot isolate each worker's individual contribution to the team's output. In these models, some employees may shirk and cause moral hazard inefficiencies while the low productivity of others may be undetected.[1] Furthermore, these analysis are often carried out in a static framework while assuming that employees have no choice but to work in an exogenously given team. Our approach differs from the traditional team production literature in two respects. We use a fully dynamic framework to emphasize how persistence arising from intergenerational teams affects steady-state wages and utility. We also endogenize the decision to work or not in teams. This departs from the team literature which usually assumes the *ex-ante* existence of production teams

[1] See Alchian and Demsetz (1972), Holmstrom (1982), Rasmusen (1987), and Sjöström (1996) on moral hazard inefficiencies, and McAfee and McMillan (1991),Itoh (1991), Meyer (1994) and Vander-Veen (1995) on the identification of low-productivity workers. See also Prat (1998) for related mechanism design issues.

and focuses on the incidence of the *ex-post* inefficiencies caused by asymmetric information between employees and employers.

To motivate our analysis of elective teams, consider as an example the decisions faced by these three co-authors. First we were neither forced to work, nor prevented from working, together. Second we are at different stages of our careers. Hence, this paper can be viewed as the output of an elective intergenerational heterogeneous production team. Third, in deciding to work or not together, we balanced the costs and benefits of co-authorship. For a less established author, co-authorship may help signal his or her productivity, although there is always the possibility that a favorable outcome may be credited to the other members of the team. As for more established authors, they may use their reputation to earn side payments in exchange for co-authorship. However, their reputation may suffer if the team's output is unfavorable. Although employers may not value team-work per se, they will use the information from the team and its output to evaluate each individual's productivity. As a result, employees, in search of future higher wages and promotions, must choose their teams accordingly. Finally, co-authoring a research project may involve side payments. For instance, the difference in the amount of work done by each co-author may be seen as utility transfers between the co-authors.

The above representation is particularly fitting in the case of academic research. Scholars are seldom forced to work (or prevented from working) in teams. They usually choose with whom they want to work with, and for how long. Moreover, partially informative signals, such as publications, teaching evaluations, and the like, are used by the employer as a basis for promotion. Because individual contributions are harder to single out, high-productivity scholars may prefer to publish on their own leaving co-authorship to low-productivity scholars only. This does not however appear to be the case in economics where co-authorship is in constant progression.[2]

Elective teams are not exclusive to academia. One manager at the Jet Propulsion Laboratory states that: "...labor is confined in specialized groups. Reputation is somewhat known. There is some say by team members on whom they want to work with. Regarding rewards, a good job by the team bestows the reputation for further jobs. Promotions to managers are based on both team and individual success." (Sherstyuk 1998, fn. 5). Other examples of elective teams include referrals by an incumbent for job openings in production teams. The decision whether or not to refer an acquaintance for an opening in one's production team can be interpreted as a choice to team or not with that person.

In section 2 we start our analysis by considering agents who work independently. On the labor market, workers differ in age, reputation and productivity which they observe privately. The agents are risk-neutral, maximize their expected utility, supply labor services inelastically in a competitive market, and work independently. Each worker's output is the sum of her productivity and a random uncorrelated technological shock. As in pure-experience matching models, a principal uses current output and past beliefs on an agent's productivity (i.e. the agent's reputation) to update her priors (Jovanovic 1979). The revised belief is the agent's wage. We find that some uncertainty about the agents' productivities

[2]For example, McDowell and Melvin (1983) find that co-authorship in the top economics journals has increased from less than 5% to over 30% between the mid 40's and the mid 70's. Laband and Piette (1995) find 415 coauthored articles in top journals out of a sample of 1,051 in 1984. Possible explanations for this trend include benefits of specialization, reliance on publications as a promotion criterion, as well as diversification of risk associated with the reviewing process (McDowell and Melvin 1983, Barnett, Ault and Kaserman 1988, Laband and Piette 1995, Mixon 1997).

persists at the steady state, benefiting low-productivity agents to the detriment of high-productivity workers.

In Section 3, we impose random matching between two agents of different age who observe each other's productivity. We let the technological shock: (i) be the same for both teammates (common shock) and (ii) be independent (idiosyncratic shock). In this model, the principal evaluates each teammate's contributions from the team's output and each agent's reputation. Under the common shock technology the principal can conclude with certainty whether the team is composed of (i) two high- or two low-productivity workers, or (ii) one high- and one low-productivity worker. Hence, as soon as one worker's productivity is known, the productivity of all other team members is revealed recursively. Under idiosyncratic shocks there is more uncertainty since two independent shocks affect the output. The employer cannot determine whether the teammates are of the same or of different productivities. In the long run, not all workers are paid at their true productivity. In this case, low-productivity workers win while high-productivity agents lose because the signal-to-noise ratio of output falls.

Next, in section 4, we set up a dynamic game where agents choose between the two work options: individual or team production. The nature of the game does not allow for closed-form solutions. As a result, we use numerical methods to solve for the Nash equilibrium. The algorithm is given in appendix A and the results are discussed section 5. In equilibrium both independent and team work are observed over some regions of the adult worker's reputation. When the technological shocks are common the result depends on the nature of the team. In homogenous matches, i.e. two agents with the same productivities, low-reputation adults compensate high-reputation young workers. In heterogenous matches, i.e. two agents with different productivities, low-reputation adults are compensated by young teammates. When the technological shocks are idiosyncratic a low-productivity young worker must compensate a low-reputation adult for the latter to form a team because the adult stands to lose in such teams.

Our results show that when teams are elective some workers are not paid at their true productivity at the steady state independently of the technological shocks assumptions. However, the percentage of workers who receive a wage equal to their productivity is higher under common shocks than idiosyncratic shocks. It follows that when the technological shocks are common, the welfare of a high-productivity worker is closer to what she would obtain under the compulsory team work arrangement where all information is revealed at the steady state. When shocks are idiosyncratic, low-productivity workers benefit the most from elective teams because of the increased uncertainty. The freedom to choose between independent and team work also yields the highest expected utility for young workers of unknown productivity. Consequently, if the employer's objective is to benefit the next cohort of young workers, irrespective of their productivity, then elective team is optimal. We conclude with a summary of our results and present further research avenues in section 6. All tables are in appendix B and the graphs are in appendix C.

2 Compulsory Independent Organization

In this section we construct an overlapping-generations (OLG) economy populated by a large number of heterogeneous agents (workers), and principals (employers) who hire workers to produce a homogeneous good. We first discuss the demand and supply of labor and next study the steady-state wages and utility when workers are compelled to work individually.

2.1 Labor Market

Agents live three periods, denoted by $1, 2, 3$, to represent young, adult and old respectively and are distributed in equal proportions over the population. An agent j is endowed with one unit of non-leisure time which is supplied inelastically on the labor market in exchange for a wage w_j. Each agent is characterized by her productivity denoted by $\eta_j \in \{0, 1\}$, where 0 represents low productivity and 1 represents high productivity. In our model, the economy is populated with a proportion ϕ of high-productivity agents and $(1 - \phi)$ of low-productivity agents. Productivity is assumed to be time-invariant, uncorrelated across agents and privately observed as of age 1 by the agent.

Agents are risk-neutral expected-utility maximizers with preferences defined exclusively over the consumption of a composite nonstorable good denoted c. Let v_j denote agent's j expected utility. Then, for all agents j

$$v_j(x_j) = c_j + \beta \mathrm{E}(v_j(x'_j) \mid x_j), \tag{1}$$

where a prime ($'$) denotes next-period, $\beta \in (0, 1)$ is a subjective discount factor, and $\mathrm{E}(\cdot \mid x_j)$ is the expectations operator conditional on the agent's information set x_j. By monotonicity and nonstorability, the agent's budget constraint is binding and she consumes all her current wage in each period. Given that the old agent is in the last period of her life, her utility equals her current wage. The adult's utility equals current wages plus the discounted expected future wage received when old. The young agent's utility is the current wage plus the discounted expected utility obtained when she becomes an adult.

The demand side of the labor market is composed of a large number of identical employers. Each employer has access to the same technology:

$$y_j = \eta_j + \varepsilon_j \tag{2}$$

where y_j is agent j's output and ε_j is a technological shock, associated with agent j, which equals 0 or 1 with probabilities $1 - \mu$ and μ respectively. The technological shocks are assumed to be uncorrelated with an agent's productivity. It is assumed that a representative employer (principal) can only observe the output of each agent in every period.

Given our assumptions about an agent's productivity and technology (2), output can take on 3 values $\{0, 1, 2\}$. When output equals 2, the worker is of high productivity. When the output equals 0, the worker is of low productivity. Hence there is no uncertainty about the worker's productivity in those two instances. However, when output equals 1 the worker's productivity is uncertain. That is, it may be the case that the worker is of high productivity yet experienced an adverse technological shock, or vice versa. As a result, the employer must evaluate the worker's productivity given the available information.

Denote by Ω the public information set including all current and past outputs as well as the probability beliefs on all agents. As in pure-experience matching models, the principal uses Ω to revise her probability belief about each agent's productivity through Bayesian updating and calculates the conditional probability that the agent is of high productivity $\Pr(\eta_j = 1 \mid \Omega)$. We assume that wages are determined before output is observed and that each worker is paid her conditional marginal product,

$$w_j = \Pr(\eta_j = 1 \mid \Omega). \tag{3}$$

As the employer has no information about young workers, then applying (3), all new workers receive the same wage which is the unconditional probability ϕ. By Bayesian updating, a worker's history of outputs can be summarized by the last paid wage and the contemporaneous observable output.

To simplify the notation, the remainder of this paper identifies each agent by her age. Given a current-period adult whose wage equals w_2, the next-period old (adult) agent's wage is denoted w_3' (w_2'). Table 1 in appendix B gives the updated wage schedules for each feasible output and current-period wages. For example, by (3), a young worker who produces 1 unit in the current period earns a wage equal to $\phi(1-\mu)/[\phi(1-\mu)+\mu(1-\phi)]$ in the next period. While w_3' is a function of w_2, w_2' depends exclusively on ϕ and μ.

2.2 Steady-State

Given the wage schedule reported in Table 1, it is straightforward to compute the population steady-state distribution of wages in each age group. Table 2 presents this information. First, all young workers are paid the unconditional probability that each is of high productivity. Second, a share $(1-\phi)(1-\mu)$ of adults receive a wage of zero. This share is the proportion of low-productivity agents who incurred a zero technological shock. Similarly, a share $\phi\mu$ of adults receive a wage of one. Finally, a share $\phi(1-\mu)$ of high-productivity agents have a zero technological shock and a share $(1-\phi)\mu$ of low-productivity agents have a shock equal to 1. The sum of these two shares is the total share of agents who produce 1 unit.

The wages of old agents reflect their past production, i.e. when they were young and adult. For example, all high-productivity old agents who obtained at least one technological shock equal to 1 have had their productivity revealed. They therefore receive a wage of 1. Conversely, low-productivity old agents who incurred a zero technological shock at least once in the past are also identified without uncertainty. These old workers receive a wage equal to zero. Otherwise, a proportion of old agents equal to the probability that a worker produces 1 when he is both young and adult, receive a wage associated with partially revealed information.

A main result, given in Table 2, is that at the steady state some workers are not paid at their true productivity. For ϕ and $\mu \in (0,1)$, some agents always receive a wage that is not equal to their true productivity. In panel 1.a of Figure 1 we plot the unconditional steady-state distribution of adult wages for $\phi = 0.75$, and $\mu = 0.35$.[3] For these parameter values, 57.5 per cent of workers receive a wage of 0.85, rather than their true productivity of 0 or 1. It is of interest to calculate the percentage of the high or low productivity workers who are not paid at their true productivity. We find that only 35 (65) per cent of high-productivity (low-productivity) adult workers receive their true wage, the rest earn a wage of 0.85. The share of high-productivity workers who receive a wage of 1 increases to 57.75 per cent in

[3]The steady-state wage distributions in panels 1.b and 1.c are discussed in sections 3.1 and 3.2 respectively. Those in panels 1.d and 1.e are explained in section 5.1 and 5.2 respectively.

the third period of their life, while that of low-productivity workers who receive a wage of 0 increases by 35 per cent relative to the second period.

Nonetheless, the percentage of workers who receive a wage which is different from their productivity falls as they become older. One reason why some workers are not paid at their true productivity in the steady state is that an employer has access, at most, to a sequence of two outputs in order to infer the agent's true productivity. If the employee produced at a higher frequency and for a very long period, the likelihood that a high-productivity worker has an unbroken series of bad technological shocks would tend to zero. That is, asymptotically the agent's true productivity would be revealed since by the law of large numbers a high-productivity agent would have at least one good technological shock and produce a fully revealing output equal to 2. A similar argument holds for low-productivity workers.

Hence, because of the asymmetric information between the employee and employer, a more or less long observation period is necessary before all workers' productivities are known. Such a process can be expensive and warrants the study of alternative work arrangements which, in the steady state, would reveal information on the productivity of all generations of workers. For example, it is possible that if two agents of different age work together the steady-state wages could be closer to the workers' true productivity. This issue is explored in the following section.

3 Compulsory Team Organization

In this section we keep the same labor market structure as before but assume that each young agent is randomly matched with an adult. Following a match, both agents observe each other's productivity but not that of other agents. Each young and adult pair are forced into forming a production team and submit the sum of their individual outputs to the employer. As a result, the employer observes only the team's total production $y_1 + y_2$ and not the agents' independent production. In this model, the old agent continues to work independently, as is discussed in section 2, which can be viewed as mimicking a retirement policy. As in Meyer (1994), a team's output is therefore the sum of each agent's productivity plus the technological shock that is uncorrelated with the team members' productivities. For completeness, we consider two possible scenarios for the technological shocks ε: (i) common shocks and (ii) idiosyncratic shocks.

3.1 Common Technological Shocks

Common shocks are defined as a single technological shock affecting each of the two workers in a team. Under this assumption, a team's output is given by:

$$y_1 + y_2 = \eta_1 + \eta_2 + 2\varepsilon. \tag{4}$$

With technology (4), a team's output takes on one of five possibilities as given in the first column of Table 3. As in section 2, some production outcomes reveal the workers' productivities while others do not. When the team produces 0, both workers are of low-productivity, and when the team produces 4, both workers are of high productivity. Otherwise, there is some uncertainty about each worker's productivity. It is important to note, however, that there is an informational difference between a team output of 2 rather than that of 1 or 3. Because of the constraints imposed by equation (4), when the output equals 1 or 3, the two workers must be of different productivities. We label henceforth this team-type as "heterogeneous". When the team produces 2 this reveals that both workers have the same productivity. We label henceforth this team-type as homogeneous.[4] Furthermore, in such a case, and as reported in the second and third columns of Table 3, both teammates are assigned the same probability of being of either low or high productivity.

This link between the two workers' probabilities of being identified as being of high productivity allows us to define two effects which will prove useful later on.

Definition 1 (Lump and wedge effects) *There is a lump effect in a team when an increase in a teammate's probability of being of high productivity increases the probability for the other teammate also. There is a wedge effect between the two teammates when their probability of being of high-productivity are inversely related.*

A lump effect may be viewed as a complementarity between the teammates' expected productivities while the wedge effect may be viewed as a substitute between teammates expected productivities. The employer uses (3) to compute the wages which are reported in Table 3. Contrary to section 2, w_2' is now a function of w_2.

[4]Obviously, a team which produces 0 or 4 is also homogenous and each teammate has the same probability of being of high productivity: 0 in the first case and 1 in the second.

Taking into account this intergenerational wage dependence we investigate the steady-state distribution of wages. We first compute a transition matrix for a current-period adult's wage to the next-period adult's wage. Second, we calculate a similar transition matrix for current-period adults to next-period old workers. In order to construct the transition matrices, suppose that there is a limited number M of wages $\mathsf{w}^m \in \mathsf{W} \equiv \{\mathsf{w}^m : m = 1, \ldots, M\}$. This assumption can be interpreted as wages being rounded off to some precision corresponding to the discretized grid W. Let s_k represent the share of agents of a given age in some period who receive a wage equal to w^k. We use a Markov-chain analysis to find the steady-state distribution of wages. Define $q_{kl} \equiv \Pr(w_2' = \mathsf{w}^l | w_2 = \mathsf{w}^k)$ as the probability, when an adult team member receives a wage w^k, that her current young teammates wage equals w^l in the next period. Construct the $(M \times M)$ matrix $\mathbf{Q} = [q_{kl}]$. A line k of $\mathbf{Q}$, corresponding to a wage w^k for the adult member of the team, contains at most 5 positive entries because a team can only produce one of 5 possible outcomes.[5] These entries are given in Table 4 where it is apparent that $\mathbf{Q}$ contains no absorbing states. Hence, the $(1 \times M)$ vector s^* representing the steady-state distribution of wages in the adult population satisfies

$$s^* \mathbf{Q} = s^*, \tag{5}$$

under the constraint that $\sum_{m=1}^{M} s_m^* = 1$. Solving for s^* in (5) yields the following result:

Proposition 1 *When technological shocks are common, compulsory teams result in a steady-state proportion ϕ of the adult population receiving a wage of 1 while the remaining share, $(1 - \phi)$, receive a wage of 0.*

[5]In fact there are at most 4 positive entries because an output of 1 or 3 by a current-period team gives the same wage to the next-period adult.

Proof. By verifying that the vector $(1-\phi, 0, \ldots, 0, \phi)$ solves the linear system (5) which can be verified (numerically) to be of rank M. ∎

Proposition 1 states that in the long run, the productivity of all adult and old workers are revealed. The intuition for this result is straightforward. First, under common technological shocks, a team's output reveals whether it is homogeneous or heterogeneous. Next, as soon as one output is fully revealing, an event which must occur with positive probability, the productivities of both teammates are revealed. By recursion, the productivity of each agent in subsequent matches is revealed. Panel 1.b of figure 1, in appendix C, plots the steady-state distribution of adult wages for $\phi = 0.75$, and $\mu = 0.35$. In the long run, all high-productivity adults, who form 75 per cent of the population, receive a wage equal to their true marginal product of 1 while the remaining 25 per cent of adults who are of low-productivity, receive a wage of 0.

The steady-state distribution of wages in the population of old agents, denoted $s^{\dagger}$, satisfies

$$s^{\dagger} = s^{*}\mathbf{Q}^{\dagger} \tag{6}$$

where an element $q^{\dagger}_{kl} \equiv \Pr(w'_3 = \mathsf{w}^l \mid w_2 = \mathsf{w}^k)$ of matrix $\mathbf{Q}^{\dagger}$ represents the probability, when an adult member has wage w^k, that she will receive a wage w^l in her old age. $\mathbf{Q}^{\dagger}$ is computed in a similar manner as $\mathbf{Q}$.[6] A corollary of proposition 1 is that a share ϕ of old workers receive a wage equal to 1 while the remainder receive a wage of 0. All workers are paid their true productivity.

[6]Note that (6) does not require solving for a fixed-point as in (5).

We have demonstrated that compulsory intergenerational teams generate enough information persistence for all workers to be paid at their true productivity in the steady-state. However, this result depends on the assumption that the technological shocks are identical across workers. We next relax this assumption.

3.2 Idiosyncratic shocks

When the technological shocks are idiosyncratic to each team member, the production of a team becomes

$$y_1 + y_2 = (\eta_1 + \varepsilon_1) + (\eta_2 + \varepsilon_2). \tag{7}$$

As is the case in the common shock technology, a team's output can take one of 5 possible values. In this case, however, when the principal computes the wage of a next-period adult or old worker she must take into account that ε_1 and ε_2 may now differ. This explains the difference between the workers' next-period wages reported in Table 3 for common shocks and in Table 5 for idiosyncratic ones.

It is obvious that when a team produces 0 or 4 under either of the two technologies both workers earn the same wage. Otherwise, under the idiosyncratic technology the next-period adult's wage, w_2', is decreasing in the current-period adult's reputation, w_2. When the employer assigns a higher probability that a current-period adult is of high productivity, it implies that the next-period adult's probability of being of high productivity falls. This wedge effect can clearly be seen by comparing the next-period adult's and old worker's wages when a team produces 1 (see Table 5). Thus, unless the team produces 0 or 4, a higher *ex-*

post wage for one agent necessarily implies that the other worker receives a lower wage when shocks are idiosyncratic.

The differences noted above between the two technologies are also likely to affect the transition probabilities. Under the common shocks assumption, for each current-period adult's wage w^k, a current-period young worker can receive only one of four wages. On the other hand, with the idiosyncratic technology, she can receive one of 5 possible wages. It is of interest to compare the steady-state wage distribution under the two technologies. The 5 positive entries in line k of the transition matrix $\mathbf{Q}$, corresponding to the adult's wage w^k, are reported in Table 6. Note that the transition probabilities in Table 6 differ from those in Table 4 in that they take into account the joint probability of the two potentially different technological shocks. This affects the probability support of the possible wages.

An interesting insight can be gained by computing these transition probabilities for the case when the current-period adult's productivity is known. For example, setting $\mathsf{w}^k = 1$ we find that when the shocks are common a current-period young high-productivity worker is sure to obtain a wage equal to 1 in the next-period while a current-period low-productivity young worker earns a wage of 0. However, when the shocks are idiosyncratic, the high-productivity young worker earns an expected wage of 0.851 and a low-productivity earns a wage of 0.447. This is just an example of the wedge effect which arises when the shocks are idiosyncratric and not common.

We now use the transition matrix given in Table 6 to compute the adult workers' steady-state distribution of wages. That distribution is obtained by solving the linear system (5). The results for the same parameters as in section 3.1 are reported in panel 1.c of Figure 1.

Contrary to the common shock technology, the steady-state adults' wages are almost continuously distributed over [0,1]. A very small proportion of workers are paid at their true productivity. There is a concentration of wages over [0.75,1], however almost all feasible wages are observed. As illustrated by the above numerical example for $\mathsf{w}^k = 1$ this result arises because the output structure when shocks are idiosyncratic precludes any lump effect from taking place.

The results obtained so far for the compulsory work organization depend on the technological assumptions. As mentioned in the introduction, employers frequently allow workers to chose if they want to work together. We incorporate this element in the next section and recompute the steady-state distribution of wages.

4 Elective Team Organization

We modify the above model to allow for elective team formation. Instead of forcing the two randomly matched agents to submit a joint output, we allow agents to choose between team and independent production. A team is observed if and only if *both* agents select the team option, otherwise, both must work independently. As explained in section 4.1, this modification gives rise to a dynamic game involving the two workers. We also define in 4.1 the workers's strategies and the equilibrium concept that we use.

In order to capture the potential bargaining between teammates, such as discussed in the introduction, we allow for side payments in a team. For simplicity, we assume that an agent can transfer part of her current wage to a reluctant coworker in order to help convince the latter of forming a team. Moreover, we assume that the side payment is set so as to leave the losing agent indifferent between the team and the individual option, i.e. we abstract from strategic bargaining issues (Rubinstein 1982, Wolinsky 1987).

Recall that the evaluation function of a worker aged j is given by (1). In a given state x_j, the worker's expected utility equals her current period consumption, and the conditional expected utility that she derives in the future period. Which state, x'_j, is reached in the next period depends upon the worker's choice and her capacity to team-up with the worker with whom she is matched. Hence, as explained in section 4.2, this requires that she takes into account the evaluation function of that worker to determine whether she can afford to pay the side payments if need be.

As mentioned in the introduction, a reasonable characterization of some team work environment (e.g. academic research) is the absence of implicit or explicit incentives scheme designed to foster or impair team formation. Accordingly, we assume that the principal does not modify her payment scheme to internalize the team decision. Let $w'_j(d, y, w_2)$ denote the agent's next-period wages given decision d, output y and the wage w_2 paid to the adult in the match. The decision variable d equals 0 in the case of independent production (wage schedule given by Table 1), and d equals 1 under team production (wage schedule given by Table 3 or Table 5). That is, we abstract completely from mechanism design issues intended to foster or prevent a particular outcome.

4.1 Game

At the beginning of each period, the principal computes the wages of all employees by using last period's outputs and decisions. The principal then makes the corresponding wage offers. Afterwards, in a given match, an agent $j \in \{1, 2\}$ chooses either action 0 (independent) or 1 (team). A team is formed if and only if both agents choose action 1. Uncertainty is resolved: nature's contribution is drawn and output is observed by the principal. At the end of the period aging takes place, a new cohort of young workers is hired and each young worker is matched randomly with an adult.

Our elective team structure is based on overlapping generations games, a framework which has been used in various settings. Goenka, Kelly and Spear (1998) derive a Real Business Cycles model in which complex equilibrium dynamics are the result of strategic market interactions between agents of different generations. Inter-generational transfers have also been modelled as an OLG game (Esteban and Sakovics 1993, Rosenzweig and Wolpin 1994, Hori 1997). Contrary to this literature, we focus on agents who do not behave altruistically. Finally, folk theorems have been adapted to the context of repeated OLG games (Salant 1991, Smith 1992, Kandori 1992, Bakshar 1998). As in this last strand of literature, the games are played by teams of players of different generations.[7] At the end of each period, the older player exits, and is replaced by a younger-generation player. The game is then repeated.

Define $I \equiv \{0, 1\}$. The agent's decision to work independently or in a team is based on the following information: (i) the adult's wage, (ii) her own productivity and (iii) the other

[7] Kandori (1992) considers same-generation teams.

worker's productivity, such that a state x is a triple (w_2, η_1, η_2), and the relevant state space is $X = [0,1] \times I^2$. An agent of age j uses policy $\delta_j : X \to I$, for $j = 1, 2$. Let δ_j also denote the strategy that consists in using policy δ_j at any time period and denote Δ_j as the set of all such strategies.[8] Denote δ the strategy pair (δ_1, δ_2) and $\Delta \equiv \Delta_1 \times \Delta_2$. Let superscripts denote strategies, and $v_j^\delta(x)$ denote agent j's expected utility under the probability distribution over future states induced by the strategy pair $\delta \in \Delta$ and the starting state $x \in X$. We consider an equilibrium strategy pair δ^* in the sense of Nash:

Definition 2 (equilibrium) *An equilibrium $\delta^* \in \Delta$ is a strategy pair such that, for all $x \in X, \gamma \in \Delta_j$, and for $j \in \{1, 2\}$:*

$$v_j^{\delta^*}(x) \geq v_j^{[\delta^{*-j}, \gamma]}(x), \tag{8}$$

where the notation $[\delta^{-j}, \gamma]$ represents a strategy pair where player j uses strategy γ and the other player, say player i, uses strategy δ_i.

Notice that the structure of the game is such that, for any given state x, a strategy such that $\delta(x) = (0, 0)$ satisfies the equilibrium condition (8) for this state. This results from the fact that deviating unilaterally from the strategy will leave the game's outcome unchanged. Nothing is changed unless *both* players decide to form a team. Therefore, the strategy $\delta(x) = (0, 0)$ $\forall x \in X$ is indeed an equilibrium. We are however interested in computing strategies where forming a team is stable in a subset of states.

[8] Note that this notation implies that the strategy is stationary in the sense that in a given age group the decision rule does not change with time.

4.2 Pareto Improvement

Suppose that the wage functions w_2' and w_3' are defined for the adult and old member of a match by the Bayesian updates in Table 1 for single, while for the team option these wages are in Table 3 when the shocks are common, and in Table 5 for idiosyncratic shocks (recall that $w_1 = \phi$). From those tables it is clear that next-period wages are a function of (i) the worker's wage in the current period, (ii) her decision to work in a team or by herself, (iii) her output and (iv) whether the technological shock is idiosyncratic or common.[9] Consider the set V of all bounded functions $v : X \to \Re$. Let $\mathrm{E}_{d,x}$ denote the expectation operator given the probability distribution induced by action $d \in I$ and state $x \in X$.

Define the operator $G_1 : V \to V$ and the function $g_2 \in V$ by

$$G_1(v)(x) \equiv \beta(\mathrm{E}_{1,x}v - \mathrm{E}_{0,x}v), \tag{9}$$

$$g_2(x) \equiv \beta(\mathrm{E}_{1,x}w_3' - \mathrm{E}_{0,x}w_3'). \tag{10}$$

The function $G_1(v)$ represents, for each state, the expected utility gain for player 1 (young) from using a team action relative to working independently, if her utility from adult age is given by the function v. In the same way, function g_2 represents the expected utility gain for player 2 (adult), given that her wage in her old age is determined by function w_3'. We define the potential Pareto improvement criterion (Kaldor 1939) as follows:

[9] Note that we do not explicit the dependency of the wage function so as to avoid introducing additional notation.

Definition 3 (Kaldor) *There is a potential Pareto improvement in state x for v if:*

$$G_1(v)(x) + g_2(x) > 0. \tag{11}$$

Given a function v defining future utility for the young player, a team is potentially Pareto improving if the sum of expected utilities is greater than the one corresponding to the strategy of submitting separate outputs at x. This implies that it is possible to compensate the loser in order to leave her indifferent, while still obtaining a net gain for the other agent.

Denote $\tau_j : V \to V$ the operators yielding the transfer function of a given state x, from agent j to agent $i, i \neq j$. We assume that:

$$\tau_1(v)(x) = \begin{cases} \min\{\phi, \max\{-g_2(x), 0\}\}, & \text{if (11),} \\ 0, & \text{otherwise;} \end{cases} \tag{12}$$

$$\tau_2(v)(x) = \begin{cases} \min\{w_2, \max\{-G_1(v)(x), 0\}\}, & \text{if (11),} \\ 0, & \text{otherwise} \end{cases} \tag{13}$$

where w_2 is the first element of the state x. If a team is potentially Pareto improving, then a transfer can be made only when one of the agent loses and the other agent gains. Moreover, the compensation is set so as to leave the loser indifferent between team and individual outputs. Finally, the transfer may not exceed the revenues of the winner, i.e. a winner cannot borrow against future wages to compensate the loser.

The local utility function for player $i = 1, 2$ at $(d, x, v) \in I \times X \times V$ is then:

$$r_1(d, x, v) \equiv \phi + d \times (\tau_2(v)(x) - \tau_1(v)(x)) + \beta \mathrm{E}_{d,x} v, \tag{14}$$

$$r_2(d,x,v) \equiv w_2 + d \times (\tau_1(v)(x) - \tau_2(v)(x)) + \beta \mathrm{E}_{d,x} w_3', \tag{15}$$

where w_2 is the first element of the state x.

An equilibrium strategy pair δ^* for the team production game thus satisfies, $\forall x \in X$:

$$\left(v_1^{\delta^*}(x), v_2^{\delta^*}(x)\right) = \left(r_1(1,x,v_1^{\delta^*}), r_2(1,x,v_2^{\delta^*})\right) \tag{16}$$

if

$$r_1\left(1,x,v_1^{\delta^*}\right) = \max_{d \in I} r_1\left(d,x,v_1^{\delta^*}\right), \tag{17}$$

and

$$r_2\left(1,x,v_2^{\delta^*}\right) = \max_{d \in I} r_2\left(d,x,v_2^{\delta^*}\right). \tag{18}$$

Otherwise,

$$\left(v_1^{\delta^*}(x), v_2^{\delta^*}(x)\right) = \left(r_1\left(0,x,v_1^{\delta^*}\right), r_2\left(0,x,v_2^{\delta^*}\right)\right). \tag{19}$$

Hence, in equilibrium, neither of the players in a team has an incentive to submit her independent output.

A value function at equilibrium is defined recursively by a dynamic programming argument, where, in each state, the equilibrium condition must hold for each player considering the sum of her expected payoffs over the remaining part of her life. Such a value function does not admit a closed-form solution. Therefore we use numerical methods to obtain equilibrium strategies and value functions. Finally, notice that, even if each player has a finite horizon of three periods, the resulting dynamic program is solved using a method akin to the ones used in infinite-horizon dynamic programming since the game is played between players of different ages.

When team are formed endogenously we must account for the workers' equilibrium strategies when computing the transition matrices $\mathbf{Q}$ and $\mathbf{Q}^{\dagger}$. A line k of these matrices can now contain at most 8 possible entries corresponding to the 5 possible outcomes when the workers choose to work in a team and the 3 possible outcomes when they choose to work independently. Each entry is computed by evaluating the joint probability, when the adult member in a random match has a wage w^k, of choosing the single or team production, and of obtaining a given output. Tables 8 to 11 give the entries of these matrices. Note that under elective teams, at the steady-state, the probability that an adult is of high productivity no longer equals her wage but has to be evaluated considering the equilibrium strategies of the workers.

5 Equilibrium Computation

In this section we first outline the value-iteration algorithm used to compute agents' optimal strategies. The complete algorithm is in appendix A. We then apply this algorithm to compute each worker's optimal strategy under (i) the common shock technology and (ii) the idiosyncratic shock technology.

Step 1: Initialization We initialize all parameters and select the discretization mesh for the wages. We then compute, and store, the (discretized) wage schedules and the expected gain from cooperation of the adult player, both of which are invariant in the main loop. The adult's expected utility is independent of the value function since it involves only the worker's expected wages in the last period according to her decision to work in a team or independently. These expected wages are computed by taking into account the various possibilities for nature's shocks according to the technology considered. The gain from cooperation is stored in a table indexed by the current wage of the adult player and the productivities of both members of the possible team. Finally, an initial iterate for the value function is also chosen, for instance, the null function.

Step 2: Iteration We iteratively update the value function by evaluating, for each possible state, a local value function and corresponding equilibrium strategies. We first compute the expected gain from cooperation for the young player. Next, the expected utilities for the young player, according to the decision to work in a team or independently, are computed. This computation takes into account the various possible technological shocks and the next-period would-be teammate's productivity, and uses the value function of an adult player.

Given the expected gains for cooperation of both players in this state, we verify (i) if the team is potentially Pareto improving and (ii) if some side payments would take place, according to (12)-(14). The local utility function value, at this state, for both players, and for either joint decisions, is then obtained by adding these side payments to the discounted expected utilities. An equilibrium decision in this state is reached on the basis of this local utility function. This decision reflects the fact that a team will be formed in this state only if it is Pareto-improving and no player loses after compensation. The next iterate for the value multifunction is stored accordingly. A strategy vector is also stored in case convergence is obtained.

Step 3: Convergence In the final step, we verify if there is, for at least one state value, a significant change in the value multi-function. If not, in all states, (i) the local utility function is equal to the value function, (ii) the current strategy vector is an equilibrium and (iii) the current iterate for the value multifunction gives the expected value at equilibrium for each player. Otherwise, the value multifunction is updated and we repeat Step 2.

We implement that algorithm for $\beta = 0.5$, $\mu = 0.35$ and $\phi = 0.75$. The adult's (bold line) and young agent's (thin line) expected utility are graphed in Figure 2 for the common-shock technology and in Figure 3 for the idiosyncratic shock. We also report on the graphs the optimal strategies and the adults' steady-state equilibrium wage distribution (bold bars) conditional on her productivity. We verified that the nature of our results is robust to changes in the parameters. For brevity, we do not report these results which are available upon request. We also do not report the old agent's expected utility because it can be inferred directly as she has no choice but to work independently.

5.1 Common shock

Agents in homogenous matches choose the work-independently strategy when the adult's reputation is low, and the team strategy when the adult's reputation exceeds an endogenously determined threshold as illustrated in panels a and d of Figure 2. When the adult's reputation is above the threshold, but not too high, the adult must compensate the young agent in order to form a team. No side payments are necessary when the adult's reputation is relatively high. These strategies arise because of the lump effect which discourages a young agent from teaming up with a low-reputation adult, unless the latter can provide enough compensation. However, a low-reputation adult receives low wages and cannot afford these side payments. As the adult's reputation increases, her wages increase, and the compensation demanded by the young agent falls. The adult can thereafter compensate the young agent and the team strategy with compensation is optimal, up to a point after which side payments are no longer required.

Agents in heterogenous matches choose the team strategy with the young agent compensating the adult when the latter has a low reputation. The work-independently strategy is chosen when the adult's reputation is relatively high. These strategies and the corresponding utility are illustrated in panels b and c of Figure 2. These optimal strategies are a consequence of the wedge effect. A young agent teams with a low-reputation adult whom she compensates because the latter is more likely to be identified as a low-productivity type.

A low-reputation adult has a low expected lifetime utility, which implies that the young agent's current wage is sufficient to compensate her teammate for any reputation loss. As the adult's reputation increases, the young agent must increase the side payments to convince the adult to choose the team strategy. When the adult has a relatively high reputation, the young agent cannot afford the requested compensation. In addition, the team strategy is less attractive to the young agent since she is more likely to be identified as a low-productivity type. As a result the work-independently strategy becomes optimal. These strategies are mirrored in the agent's expected utility. In all 4 panels of Figure 2 the adult's expected utility is always an increasing function of her reputation because both her current and future expected wages are increasing in her reputation.[10]

A young agent's utility is increasing in the adult's reputation in homogenous matches leading to teams because of the lump effect. It is independent of the adult's reputation when the agent works independently, or is being compensated at her reservation wage for a reputations loss. The young worker's utility decreases in the adult's reputation in heterogenous matches leading to teams because of the wedge effect. Finally, note that a high-productivity agent systematically anticipates higher utility than a low-productivity agent since attainable outputs are always at least as high.

5.2 Idiosyncratic Shocks

As mentioned in section 3.2, only wedge effects are present under idiosyncratic shocks and we also highlighted the presence of additional noise around a worker's true productivity. These two elements explain why two high-productivity randomly matched agents choose to work independently as illustrated in panel a of Figure 3. In the absence of lump effects, the additional uncertainty regarding their true productivities results in lower expected wages, and therefore, the independent strategy is selected. For opposite reasons, two matched low-productivity workers benefit from the added uncertainty and choose the team strategy if the wedge effect is not too detrimental to one of the two agents. As illustrated in panel d of Figure 3, the low-productivity young worker pays side payments to the low-reputation

[10]Theoretically an adult's wage can equal 0 only if she is of low productivity. Therefore $w_2 = 0$ is excluded in panels a and c of Figure 2. Accordingly, in panels a and c of Figure 2 the adult's expected utility intersects the wage axis at $w_2 = 0$. Using a similar argument, $w_2 = 1$ is excluded in panels b and d of Figure 2.

low-productivity adult to work in a team. By doing so, the young worker takes advantage of the wedge effect which assigns a higher probability that the low-reputation adult is of low-productivity if the team production is an element of {1,2,3}.

A low-productivity worker who is matched with a high-productivity worker benefits from the increment in noise, whereas the latter prefers a more precise signal. For this reason, as illustrated in panels b and c of Figure 3, we find that side payments in heterogenous teams always flow from a low-productivity worker to a high-productivity worker. As is the case of common technological shocks, in both homogenous and heterogenous random matches, a high-productivity worker's expected utility is systematically higher than that of a low-productivity worker's. Because only wedge effects prevail, a young agent's utility is non-increasing in the adult's reputation. It is independent in the adult reputation when she is compensated to work in a team, or when she chooses the independent-work strategy (panel a of Figure 3).

When the team strategy is selected, w_2' is always decreasing in the current-period adult's reputation because only wedge effects prevail. Therefore, the expected utility of a current-period young agent is also non-increasing in the current-period adult's wage, unless the transfers she pays to the adult decline faster than her wages. One such case is reported in panel c of Figure 3. Recall that the probability of a good technological shock is 0.35, a relatively low number. An heterogeneous team has therefore a high probability of producing 1. This output yields an adult's wage which is increasing and convex in her reputation. As the adult's reputation increase, the side payments from the young agent decline very rapidly, while the young agent's wages decline less rapidly. Consequently, the young agent's net expected utility is slightly increasing in the adult's reputation when w_2 is sufficiently high.[11]

5.3 Steady-State

The unconditional steady-state distribution of adults' wages is plotted in panel d of Figure 1. Compared to the steady-state wage distribution under compulsory team organization, panel b, at the steady state not all workers under elective teams are paid at their true productivity. This result arises because some agents choose to work by themselves when they stand a greater chance to be identified as being of low-productivity by the employer if they were to work in a team. The steady-state distribution of wages is therefore a mixture of those obtained under compulsory independent-work (panel a of Figure 1) and compulsory team (panel b of Figure 1). As a result, the productivity of some agents remain unknown at the steady-state.

Panel e of Figure 1 plots the unconditional distribution of adults' wages at the steady-state. When compared to the compulsory team arrangement, in panel c of Figure 1, we find that the mass of the wage distribution is concentrated around fewer points. Moreover, it is of particular interest that a significantly higher proportion of high-productivity workers receive their true wage. Consequently, when technological shocks are idiosyncratic, elective teams yield less noise around a worker's productivity at the steady state compared to what is achieved under compulsory teams. Finally, similar to the comparison between panels b and

[11]This last result however is not robust the choice of parameters. Increasing the probability of a positive shock from nature results in monotonically decreasing young worker's utility.

c of of Figure 1, we find that the steady-state wage distribution when teams are elective and technological shocks idiosyncratic (panel e of Figure 1) includes more feasible wages than the steady-state wage distribution when the shocks are common (panel d of Figure 1).

It is also important to analyze the steady-state wage distribution conditional on the adult's productivity. For each technology we can compute two conditional steady-state wage distribution. These conditional steady-state distributions are plotted as bars in Figures 2 and 3. When the technological shocks are common more than 95 per cent of high-productivity workers earn a wage greater than 0.75 and 90.19 per cent earn a wage equal to 1 in the steady state. However, only 34 per cent of low-productivity agents earn a wage greater than 0.75 at the steady state. When the technological shocks are idiosyncratic 80 per cent of high-productivity workers earn a wage greater than 0.75 and 30 per cent earn a wage equal to 1. However, 23 per cent of low-productivity workers earn a wage equal to 1 at the steady state. Hence, although all workers' productivities are not revealed at the steady state, the percentage of error is smaller when the technological shocks are common rather than idiosyncratic.

In addition, these conditional steady-state distribution of wages show that only a subset of the wages are attainable. Hence, under common technological shocks, when a high-reputation adult chooses to work in a team it is most likely that both teammates are of high-productivity, $(\eta_1, \eta_2) = (1, 1)$. However, it is most likely that a low-reputation adult who chooses to work in a team is of low-productivity and that the young worker is of high-productivity. Conversely, for idiosyncratic technological shocks, a team with a high-reputation adult is likely to be heterogeneous, with a low-productivity young worker. A team where the adult has a low reputation would imply that both workers are of low-productivity.

Clearly, the principal cannot use the steady-state distribution to adjust wages. An employer who does so reveals that she is not committed to the proposed wage scheme. As a result, the steady-state wage equilibrium which we have computed would no longer hold and could not be used as a discriminating device.[12]

6 Conclusion

In this analysis we study the extent to which intergenerational teams, in a dynamic stochastic setup with adverse selection, can provide information on worker's productivity. We considered (i) independent work, (ii) exogenous teams and (iii) endogenous teams. We allow for reputation-based wages and side payments between workers. When agents must work independently there remains some uncertainty on their productivity at the steady state. By forcing two randomly matched agents of different age to work together, we introduce some information persistence. If both workers are subject to a common technological shock, then at the steady state all workers are paid at their true productivity. However, when the technological shocks are idiosyncratic to each teammate the productivity of some workers remains unknown at the steady state.

We then endogenize team formation and set up a dynamic game which we solve numerically. The results are two-fold. First we establish that it is optimal, in equilibrium, for some workers to work in team, to pay or receive sidepayments, while others choose to work independently. When the technological shocks are idiosyncratic and homogenous agents are

[12] In fact, we allowed the employer to iterate on the steady state and investigate if there is convergence. Our empirical experiments do not converge and an equilibrium is never reached.

matched, they choose to work in teams when the adult's reputation is sufficiently high. In heterogenous matches, the team strategy is optimal when the adult's reputation is relatively low but the young worker must give side payments to the adult worker. When the technological shocks are common, no two high productivity workers ever choose to work together.

Second, at the steady state under either of the two technologies, there are still some workers whose productivity is unknown. Fewer high-productivity workers receive a wage which is smaller than their true productivity when the technological shocks are common rather than idiosyncratic. As a result, the expected utility of high-productivity workers under elective teams is very close to what they would obtain under forced teams. On the other hand, when the technological shocks are idiosyncratic, the expected utility of low-productivity workers is close to what they would obtain under forced teams where the benefit from the added technological uncertainty. Finally, young workers of unknown productivity derive the highest expected welfare under elective teams. The ability to opt in or out of a match allows them to increase the precision of the output signal on their true productivity depending on their potential teammate's productivity. Hence, combining intergenerational teams with compulsory or elective work arrangements yields better information on workers' productivity.

Although our model is schematic, so as to simplify the exposition, it may easily be generalized. The technology may be modified subject to the restriction that output must be partially informative on agents' productivities. More general multiplicative production functions, and/or continuous, rather than discrete joint distributions on productivities and shocks, may be used. Implementation of the numerical solution would then be achieved through either (i) discretization of the state space, or (ii) stratification (e.g. high, medium and low productivities associated with pre-determined segments of the distribution support). Finally, our assumption of risk-neutral agents may be modified to introduce risk aversion, by using a monotone concave transform of wages.

Two important aspects of elective teams are ignored in this paper and remain on the research agenda. First, we assumed that agents are randomly matched and can only decide whether or not to form a team with that particular agent. A more realistic model would include search activities where the agent can also decide whom she wants to work with. Secondly, we assumed that the employer does not express a preference between team and individual production. This could be thought of as reasonable for some activities, such as academic research, but may be unsuited for the study of environments where scale economies, or risk-sharing objectives, are present. We plan to pursue both avenues in future research.

A Algorithm

The algorithm used to compute the equilibrium strategy and payoff functions when the technological shocks are common is given in section A.1. The modifications for the idiosyncratic shocks are in section A.2.

A.1 Common shocks

Step 1: Initialization

1.1 Select (i) a mesh size M, (ii) an accuracy level ξ, and (iii)$\phi, \mu, \beta \in (0,1)$

1.2 **Compute** for $j = 2, 3$, $m = 1, \ldots M$, the wage schedules:

- $w'_j(0, y, \mathsf{w}^m)$, for $y \in \{0, 1, 2\}$, using Table 1,
- $w'_j(1, y, \mathsf{w}^m)$, for $y \in \{0, 1, 2, 3, 4\}$, using Table 3.

1.3 **Compute** for $m = 1, \ldots, M$, $\eta_1 = 0, 1$, $\eta_2 = 0, 1$ the utility gain from cooperation for player 2:

$$\begin{aligned} E_{0,2}(\mathsf{w}^m, \eta_1, \eta_2) &= \mu w'_3(0, \eta_2 + 1, \mathsf{w}^m) + (1-\mu) w'_3(0, \eta_2, \mathsf{w}^m) \\ E_{1,2}(\mathsf{w}^m, \eta_1, \eta_2) &= \mu w'_3(1, \eta_1 + \eta_2 + 2, \mathsf{w}^m) + (1-\mu) w'_3(1, \eta_1 + \eta_2, \mathsf{w}^m) \\ g_2(\mathsf{w}^m, \eta_1, \eta_2) &= E_{2,1}(\mathsf{w}^m, \eta_1, \eta_2) - E_{0,2}(\mathsf{w}^m, \eta_1, \eta_2) \end{aligned}$$

1.4 **Roundoff** all $w'_2(\cdot,\cdot,\cdot)$, so that the corresponding wages $\mathsf{w}'_2(\cdot,\cdot,\cdot)$ are points on the mesh. Select an initial iterate for the value multifunction:

- **set** $k := 0$,
- **set** for $j = 1, 2$, $m = 1, \ldots, M$, $\eta_1 = 0, 1$, $\eta_2 = 0, 1$, $v_j^k(\mathsf{w}^m, \eta_1, \eta_2) := 0$

Step 2: Value function **do** for $m = 1, \ldots, M$, $\eta_1 = 0, 1$, $\eta_2 = 0, 1$:

2.1 Computation of the local gain function from the team action by a young agent:

$$\begin{aligned} E_{0,1} = \; & \phi\mu\, v_2^k[\mathsf{w}'_2(0, \eta_1 + 1, \mathsf{w}^m), 1, \eta_1] \; + \; (1-\phi)\mu\, v_2^k[\mathsf{w}'_2(0, \eta_1 + 1, \mathsf{w}^m), 0, \eta_1] \; + \\ & \phi(1-\mu)\, v_2^k[\mathsf{w}'_2(0, \eta_1, \mathsf{w}^m), 1, \eta_1] \; + \; (1-\phi)(1-\mu)\, v_2^k[\mathsf{w}'_2(0, \eta_1, \mathsf{w}^m), 0, \eta_1] \end{aligned}$$

$$\begin{aligned} E_{1,1} = \; & \phi\mu\, v_2^k[\mathsf{w}'_2(1, \eta_1 + \eta_2 + 2, \mathsf{w}^m), 1, \eta_1] \; + \; (1-\phi)\mu\, v_2^k[\mathsf{w}'_2(1, \eta_1 + \eta_2 + 2, \mathsf{w}^m), 0, \eta_1] \; + \\ & \phi(1-\mu)\, v_2^k[\mathsf{w}'_2(1, \eta_1 + \eta_2, \mathsf{w}^m), 1, \eta_1] \; + \; (1-\phi)(1-\mu)\, v_2^k[\mathsf{w}'_2(1, \eta_1 + \eta_2, \mathsf{w}^m), 0, \eta_1] \end{aligned}$$

$$G_1 = E_{1,1} - E_{0,1}$$

2.2 Kaldor condition and transfers:

- **compute** $K = G_1 + g_2(\mathsf{w}^m, \eta_1, \eta_2)$,
- **if** $[K > 0$ **and** $g_2(\mathsf{w}^m, \eta_1, \eta_2) < 0$ **and** $\phi + g_2(\mathsf{w}^m, \eta_1, \eta_2) \geq 0]$, $\tau_1 = -g_2(\mathsf{w}^m, \eta_1, \eta_2)$
  else $\tau_1 = 0$;
- **if** $[K > 0$ **and** $G_1 < 0$ **and** $\mathsf{w}^m + G_1 \geq 0]$, $\tau_2 = -G_1$
  else $\tau_2 = 0$

2.3 Local utility evaluation: **compute**

$$\begin{aligned} r_{1,0} &= \phi + \beta E_{0,1} \\ r_{1,1} &= \phi + \tau_2 - \tau_1 + \beta E_{1,1} \\ r_{2,0} &= \mathsf{w}^m + \beta E_{0,2}(\mathsf{w}^m, \eta_1, \eta_2) \\ r_{2,1} &= \mathsf{w}^m + \tau_1 - \tau_2 + \beta E_{2,1}(\mathsf{w}^m, \eta_1, \eta_2). \end{aligned}$$

2.4 Value function update

if $[K > 0$, **and** $r_{1,1} \geq r_{1,0}$ **and** $r_{2,1} \geq r_{2,0}]$,

for $j = 1, 2 : v_j^{k+1}(\mathsf{w}^m, \eta_1, \eta_2) = r_{j,1}$, $\delta_j(\mathsf{w}^m, \eta_1, \eta_2) = 1$

else for $j = 1, 2$: $v_j^{k+1}(\mathsf{w}^m, \eta_1, \eta_2) = r_{j,0}$, and $\delta_j(\mathsf{w}^m, \eta_1, \eta_2) = 0$,

Step 3: Convergence criteria

if $\max\{|v_j^{k+1}(\mathsf{w}^m, \eta_1, \eta_2) - v_j^k(\mathsf{w}^m, \eta_1, \eta_2)|$ for : $j = 1, 2,\ m = 1, \ldots M,\ \eta_1 = 0, 1,\ \eta_2 = 0, 1\}$ $\leq \xi$, **stop**

else set $k := k + 1$, and **go to** Step 2.

A.2 Modifications for the idiosyncratic shocks case

1.2 Use Table 5 instead of Table 3 to compute $w_j'(1, y, \mathsf{w}^m)$.

[1.3] $$\begin{aligned} E_{2,1}(\mathsf{w}^m, \eta_1, \eta_2) = & \quad \mu^2\, w_3'[1, \eta_1 + \eta_2 + 2, \mathsf{w}^m] + 2\mu(1-\mu)\, w_3'[1, \eta_1 + \eta_2 + 1, \mathsf{w}^m] \\ & + (1-\mu)^2\, w_3'(1, \eta_1 + \eta_2, \mathsf{w}^m) \end{aligned}$$

[2.1] $$\begin{aligned} E_{1,1} &= \phi\mu^2 v_2^k[\mathsf{w}_2'(1, \eta_1 + \eta_2 + 2, \mathsf{w}^m), 1, \eta_1] \\ &+ 2\phi\mu(1-\mu) v_2^k[\mathsf{w}_2'(1, \eta_1 + \eta_2 + 1, \mathsf{w}^m), 1, \eta_1] \\ &+ \phi(1-\mu)^2 v_2^k[\mathsf{w}_2'(1, \eta_1 + \eta_2, \mathsf{w}^m), 1, \eta_1] \\ &+ (1-\phi)\mu^2 v_2^k[\mathsf{w}_2'(1, \eta_1 + \eta_2 + 2, \mathsf{w}^m), 0, \eta_1] \\ &+ 2(1-\phi)\mu(1-\mu) v_2^k[\mathsf{w}_2'(1, \eta_1 + \eta_2 + 1, \mathsf{w}^m), 0, \eta_1] \\ &+ (1-\phi)(1-\mu)^2 v_2^k[\mathsf{w}_2'(1, \eta_1 + \eta_2, \mathsf{w}^m), 0, \eta_1] \end{aligned}$$

B Tables

The wage of a current-period adult is given by w_2 and that of a current-period old worker is denoted w_3. As for the next-period adult, her wage equals w'_2, and the next-period old agent's wage is w'_3. These wages are computed using Bayes rule given a worker's current output, y_1 for a young worker and y_2 for an adult worker. The unconditional probability that an agent is high productivity equals $\phi = \Pr(\eta_j = 1)$, and the unconditional probability of a positive technological shock is given by $\mu = \Pr(\varepsilon = 1)$. The employer uses the wage of the current adult, which equals to the conditional that $\eta_2 = 1$, when calcultaing w'_3.

Table 1: Next-period wages under individual production

Current-period individual output (y_1 or y_2)	Wages of the next-period adult (w'_2)	Wages of the next-period old agent (w'_3)
0	0	0
1	$\frac{\phi(1-\mu)}{\phi(1-\mu)+(1-\phi)\mu}$	$\frac{w_2(1-\mu)}{w_2(1-\mu)+(1-w_2)\mu}$
2	1	1

Note: The production technology is given in (1), y_1 (y_2) denotes the current-period young (adult) worker's output.

Table 2: Steady-state distribution of wages under individual production

Worker's age	Wages	Share of workers
Young		
	ϕ	1
Adult		
	0	$(1-\mu)(1-\phi)$
	$\frac{\phi(1-\mu)}{\phi(1-\mu)+\mu(1-\phi)}$	$\phi(1-\mu)+\mu(1-\phi)$
	1	$\phi\mu$
Old		
	0	$(1-\mu^2)(1-\phi)$
	$\frac{\phi(1-\mu)^2}{\phi(1-\mu)^2+\mu^2(1-\phi)}$	$\phi(1-\mu)^2+\mu^2(1-\phi)$
	1	$\phi\mu(2-\mu)$

Note: The third column of Table 2 gives the share of workers, of the corresponding age, who receive the wage appearing in the second column. For example all young workers are paid ϕ, while an adult receives one of three possible wages.

Table 3: Next-period wages under team work and common shocks

Current-period team's output $(y_1 + y_2)$	Wages of the next-period adult (w_2')	Wages of the next-period old agent (w_3')
0	0	0
1	$\frac{\phi(1-w_2)}{\phi(1-w_2)+(1-\phi)w_2}$	$\frac{w_2(1-\phi)}{w_2(1-\phi)+(1-w_2)\phi}$
2	$\frac{\phi w_2(1-\mu)}{\phi w_2(1-\mu)+(1-\phi)(1-w_2)\mu}$	$\frac{\phi w_2(1-\mu)}{\phi w_2(1-\mu)+(1-\phi)(1-w_2)\mu}$
3	$\frac{\phi(1-w_2)}{\phi(1-w_2)+(1-\phi)w_2}$	$\frac{w_2(1-\phi)}{w_2(1-\phi)+(1-w_2)\phi}$
4	1	1

Note: The production technology is given in (4), w_2 is the wage of the current-period adult.

Table 4: One step transition probabilities for adult wages. Compulsory team with common shocks

Current-period team's output $(y_1 + y_2)$	Wages of the next-period adult w^l	Transition probability $q_{kl} \equiv \Pr(w_2' = \mathsf{w}^l \mid w_2 = \mathsf{w}^k)$
0	0	$(1-\phi)(1-\mathsf{w}^k)(1-\mu)$
1 or 3	$\frac{\phi(1-\mathsf{w}^k)}{\mathsf{w}^k(1-\phi)+\phi(1-\mathsf{w}^k)}$	$(1-\mu)\left[\mathsf{w}^k(1-\phi)+\phi(1-\mathsf{w}^k)\right] + \mu\left[\mathsf{w}^k(1-\phi)+\phi(1-\mathsf{w}^k)\right]$
2	$\frac{\mathsf{w}^k\phi(1-\mu)}{\mathsf{w}^k\phi(1-\mu)+\mu(1-\mathsf{w}^k)(1-\phi)}$	$\mathsf{w}^k\phi(1-\mu)+\mu(1-\mathsf{w}^k)(1-\phi)$
4	1	$\mathsf{w}^k\phi\mu$

Note: The transition probability $q_{kl} \equiv \Pr(w_2' = \mathsf{w}^l \mid w_2 = \mathsf{w}^k)$ is the probability, when the adult team member has a wage w^k, that her young team-mate will have a wage w^l in the next period. We use the wage w^l which is the closest on the mesh. Given the team production technology when shocks are common, (4), next-period wages are the same when the team's current-period output equals 1 or 3.

Table 5: Next-period wages under compulsory team work with idiosyncratic shocks

Current-period team's output $(y_1 + y_2)$	Wages of the next-period adult (w_2')	next-period old agent (w_3')
0	0	0
1	$\frac{\phi(1-w_2)(1-\mu)^2}{\phi(1-w_2)(1-\mu)^2+2(1-\phi)(1-w_2)\mu(1-\mu)+(1-\phi)w_2(1-\mu)^2}$	$\frac{w_2(1-\phi)(1-\mu)^2}{w_2(1-\phi)(1-\mu)^2+2(1-w_2)(1-\phi)\mu(1-\mu)+(1-w_2)\phi(1-\mu)^2}$
2	$\frac{2\phi(1-w_2)\mu(1-\mu)+\phi w_2(1-\mu)^2}{2\phi(1-w_2)\mu(1-\mu)+\phi w_2(1-\mu)^2+(1-\phi)(1-w_2)\mu^2+2(1-\phi)w_2\mu(1-\mu)}$	$\frac{2w_2(1-\phi)\mu(1-\mu)+w_2\phi(1-\mu)^2}{2w_2(1-\phi)\mu(1-\mu)+w_2\phi(1-\mu)^2+(1-w_2)(1-\phi)\mu^2+2(1-w_2)\phi\mu(1-\mu)}$
3	$\frac{\phi(1-w_2)\mu^2+2\phi w_2\mu(1-\mu)}{\phi(1-w_2)\mu^2+2\phi w_2\mu(1-\mu)+(1-\phi)w_2\mu^2}$	$\frac{w_2(1-\phi)\mu^2+2w_2\phi\mu(1-\mu)}{w_2(1-\phi)\mu^2+2w_2\phi\mu(1-\mu)+(1-w_2)\phi\mu^2}$
4	1	1

Note: The production technology for team production with idiosyncratic shocks is given in (7). The team's output is the sum of the young worker's production (y_1) and the adult's production (y_2), and is denoted $(y_1 + y_2)$.

Table 6: One step transition probabilities for adult wages: Compulsory team with idiosyncratic shocks

Current-period team's output $(y_1 + y_2)$	Wages of the next-period adult w^l	Transition probability $q_{kl} \equiv \Pr(w_2' = \mathsf{w}^l \vert w_2 = \mathsf{w}^k)$
0	0	$(1-\phi)(1-\mathsf{w}^k)(1-\mu)^2$
1	$\frac{(1-\mathsf{w}^k)\phi(1-\mu)^2}{\mathsf{w}^k(1-\mu)^2(1-\phi)+(1-\mathsf{w}^k)[\phi(1-\mu)^2+2(1-\phi)\mu(1-\mu)]}$	Denominator of w^l
2	$\frac{\mathsf{w}^k\phi(1-\mu)^2+2\mu(1-\mu)\phi(1-\mathsf{w}^k)}{\mathsf{w}^k\phi(1-\mu)^2+2\mu(1-\mu)(\mathsf{w}^k(1-\phi)+\phi(1-\mathsf{w}^k))+\mu^2(1-\mathsf{w}^k)(1-\phi)}$	Denominator of w^l
3	$\frac{2\mu(1-\mu)\mathsf{w}^k\phi+\mu^2\phi(1-\mathsf{w}^k)}{2\mu(1-\mu)\mathsf{w}^k\phi+\mu^2((1-\phi)\mathsf{w}^k+\phi(1-\mathsf{w}^k))}$	Denominator of w^l
4	1	$\mathsf{w}^k\phi\mu^2$

Note: The technology for team production with idiosyncratic shocks is given in (7), and w^k is the wage of the current-period adult. The denominator of w^l refers to the denominator of the wages of the next-period adult for the corresponding current-period team's output. For instance, when $y_1 + y_2 = 3$, $q_{kl} = 2\mu(1-\mu)\mathsf{w}^k\phi + \mu^2\left((1-\phi)\mathsf{w}^k + \phi(1-\mathsf{w}^k)\right)$.

Table 7: Transition probabilities from adult to old agents' wages: Compulsory team with idiosyncratic shocks

Current-period team's output $(y_1 + y_2)$	Wage of the next-period old worker w^l	Transition probability $q^{\dagger}_{kl} \equiv \Pr(w_3' = \mathsf{w}^l \mid w_2 = \mathsf{w}_k)$
0	0	$(1-\phi)(1-\mathsf{w}^k)(1-\mu)^2$
1	$\frac{\mathsf{w}^k(1-\mu)^2(1-\phi)}{\mathsf{w}^k(1-\mu)^2(1-\phi)+(1-\mathsf{w}^k)(\phi(1-\mu)^2+2(1-\phi)\mu(1-\mu))}$	Denominator of w^l
2	$\frac{\mathsf{w}^k\phi(1-\mu)^2+2\mu(1-\mu)\mathsf{w}^k(1-\phi)+\mu^2\mathsf{w}^k(1-\phi)}{\mathsf{w}^k\phi(1-\mu)^2+2\mu(1-\mu)(\mathsf{w}^k(1-\phi)+\phi(1-\mathsf{w}^k))+\mu^2\mathsf{w}^k(1-\phi)}$	Denominator of w^l
3	$\frac{2\mu(1-\mu)\mathsf{w}^k\phi+\mu^2(1-\phi)\mathsf{w}^k}{2\mu(1-\mu)\mathsf{w}^k\phi+\mu^2((1-\phi)\mathsf{w}^k+\phi(1-\mathsf{w}^k))}$	Denominator of w^l
4	1	$\mathsf{w}^k\phi\mu^2$

Note: The transition probability $q^{\dagger}_{kl} \equiv \Pr(w_3' = \mathsf{w}^l \mid w_2 = \mathsf{w}_k)$ of the transition matrix $\mathbf{Q}^{\dagger}$ represents the probability, when an adult team member has wage of w^k, that she will earn a wage equal to w^l in her old age. The technology for the team production with idiosyncratic shocks is given by (7).

Note for Tables 8 to 11

When computing the steady-state equilibrium in elective teams we take into account whether a worker is of high or low productivity. Consider high-productivity agents and denote the transition matrix for young workers falling in that category by $\mathbf{Q}^g$. That transition matrix is obtained by replacing ϕ by 1 in Table 8 and takes into account the fact that some wage realizations, such as a wage equal to 0, are not feasible when the agent is of high productivity. We use the transition matrix $\mathbf{Q}^g$ to calculate the vector $\mathsf{p} = [\mathsf{p}^k]$, with $k = 1, \ldots, M$ and which is defined as $\mathsf{p} = s^* \mathbf{Q}^g$. Note that p is used for the computation of $\mathbf{Q}^g$ which in turn defines p. Therefore, the vector p is in fact defined implicitly by a system of linear equations. Similarly, we can form a transition matrix for low-productivity young workers, denoted $\mathbf{Q}^b$, and use the same procedure as that outlined above to compute their steady-state distribution of wages.

Table 8: One step transition probabilities for adult wages. Elective team with common shocks

Next-period adult wages (w^l)	Transition probability $q_{kl} \equiv \Pr(w_2' = \mathsf{w}^l \mid w_2 = \mathsf{w}^k)$
0	$(1-\phi)(1-\mathsf{p}^k)(1-\mu)\delta^*(\mathsf{w}^k,0,0) +$ $(1-\phi)(1-\mu)\left[(1-\delta^*(\mathsf{w}^k,0,0))(1-\mathsf{p}^k)+(1-\delta^*(\mathsf{w}^k,0,1))\mathsf{p}^k\right]$
$\frac{\phi(1-\mathsf{w}^k)}{\mathsf{w}^k(1-\phi)+\phi(1-\mathsf{w}^k)}$	$\mu\left[\mathsf{w}^k(1-\phi)\delta^*(\mathsf{w}^k,0,1)+\phi(1-\mathsf{w}^k)\delta^*(\mathsf{w}^k,1,0)\right] +$ $(1-\mu)\left[\mathsf{p}^k(1-\phi)\delta^*(\mathsf{w}^k,0,1)+\phi(1-\mathsf{w}^k)\delta^*(\mathsf{w}^k,1,0)\right]$
$\frac{\mathsf{w}^k\phi(1-\mu)}{\mathsf{w}^k\phi(1-\mu)+\mu(1-\mathsf{w}^k)(1-\phi)}$	$\mathsf{p}^k\phi(1-\mu)\delta^*(\mathsf{w}^k,1,1)+\mu(1-\mathsf{p}^k)(1-\phi)\delta^*(\mathsf{w}^k,0,0)$
$\frac{\phi(1-\mu)}{\phi(1-\mu)+\mu(1-\phi)}$	$\phi(1-\mu)\left[(1-\delta^*(\mathsf{w}^k,1,0))(1-\mathsf{p}^k)+(1-\delta^*(\mathsf{w}^k,1,1))\mathsf{p}^k\right] +$ $\mu(1-\phi)\left[(1-\delta^*(\mathsf{w}^k,0,0))(1-\mathsf{p}^k)+(1-\delta^*(\mathsf{w}^k,0,1))\mathsf{p}^k\right]$
1	$\mathsf{p}^k\phi\mu\delta^*(\mathsf{w}^k,1,1)+\phi\mu\left[(1-\delta^*(\mathsf{w}^k,1,0))(1-\mathsf{p}^k)+(1-\delta^*(\mathsf{w}^k,1,1))\mathsf{p}^k\right]$

Note: $\delta^*(\mathsf{w}^k,\eta_1,\eta_2)$ is the equilibrium strategy under elective teams, where $\eta_j \in \{0,1\}$, for $j=1,2$, denotes worker j's productivity. p^k is an element of the vector p which is defined in the above note for Tables 8 to 11. A next-period wage w^l may be obtained either under the individual or team strategy. For example the next-period adult wage may equal 0 under two scenarios. First, both workers are of low productivity, work in a team and have a bad shock in which case the transition probability equals $(1-\phi)(1-\mathsf{p}^k)(1-\mu)$. Second the next-period adult is of low productivity, works individually and suffers a bad shock in which case the transition probability equals $(1-\phi)(1-\mu)$. Weighing those two terms by the equilibrium strategies gives the corresponding entry for q_{kl} that $\mathsf{w}^l=0$.

Table 9: Transition probabilities from adult to old agents' wages. Elective team with common shocks

Next-period old agents' wages (w^l)	Transition probability $q^{\dagger}_{kl} \equiv \Pr(w'_3 = \mathsf{w}^l \mid w_2 = \mathsf{w}^k)$
0	$(1-\phi)(1-\mathsf{p}^k)(1-\mu)\delta^*(\mathsf{w}^k,0,0)+$ $(1-\mathsf{p}^k)(1-\mu)\left[\left(1-\delta^*(\mathsf{w}^k,0,0)\right)(1-\mathsf{p}^k)+\left(1-\delta^*(\mathsf{w}^k,0,1)\right)\mathsf{p}^k\right]$
$\frac{(1-\phi)\mathsf{w}^k}{(\mathsf{w}^k(1-\phi)+\phi(1-\mathsf{w}^k))}$	$\mu\left[(1-\phi)\mathsf{p}^k\delta^*(\mathsf{w}^k,0,1)+\phi(1-\mathsf{p}^k)\delta^*(\mathsf{w}^k,1,0)\right]+$ $(1-\mu)\left[(1-\phi)\mathsf{p}^k\delta^*(\mathsf{w}^k,0,1)+\phi(1-\mathsf{p}^k)\delta^*(\mathsf{w}^k,1,0)\right]$
$\frac{\mathsf{w}^k\phi(1-\mu)}{\mathsf{w}^k\phi(1-\mu)+\mu(1-\mathsf{w}^k)(1-\phi)}$	$\mathsf{p}^k\phi(1-\mu)\delta^*(\mathsf{w}^k,1,1)+(1-\mathsf{p}^k)(1-\phi)\mu\delta^*(\mathsf{w}^k,0,0)$
$\frac{\mathsf{w}^k(1-\mu)}{\mathsf{w}^k(1-\mu)+\mu(1-\mathsf{w}^k)}$	$\mathsf{p}^k(1-\mu)\left[(1-\delta^*(\mathsf{w}^k,1,0))(1-\mathsf{p}^k)+(1-\delta^*(\mathsf{w}^k,1,1))\mathsf{p}^k\right]+$ $(1-\mathsf{p}^k)\mu\left[(1-\delta^*(\mathsf{w}^k,0,0))(1-\mathsf{p}^k)+(1-\delta^*(\mathsf{w}^k,0,1))\mathsf{p}^k\right]$
1	$\mathsf{p}^k\phi\mu\delta^*(\mathsf{w}^k,1,1)+\mathsf{p}^k\mu\left[\left(1-\delta^*(\mathsf{w}^k,1,0)\right)(1-\mathsf{p}^k)+\left(1-\delta^*(\mathsf{w}^k,1,1)\right)\mathsf{p}^k\right]$

Table 10: One step transition probabilities for adult agents' wages: Elective team with idiosyncratic shocks

Next-period adult wages (w^l)	Transition probability $q_{kl} \equiv \Pr(w_2' = \mathsf{w}^l \mid w_2 = \mathsf{w}^k)$
0	$(1-\phi)(1-\mu)^2(1-\mathsf{p}^k)\delta^*(\mathsf{w}^k,0,0)+$ $(1-\phi)(1-\mu)\left[(1-\delta^*(\mathsf{w}^k,0,0))(1-\mathsf{p}^k)+(1-\delta^*(\mathsf{w}^k,0,1))\mathsf{p}^k\right]$
$\frac{(1-\mathsf{w}^k)\phi(1-\mu)^2}{\mathsf{w}^k(1-\mu)^2(1-\phi)+(1-\mathsf{w}^k)(\phi(1-\mu)^2+2(1-\phi)\mu(1-\mu))}$	$\mathsf{p}^k(1-\mu)^2(1-\phi)\delta^*(\mathsf{w}^k,0,1)+$ $(1-\mathsf{p}^k)\left[\phi(1-\mu)^2\delta^*(\mathsf{w}^k,1,0)+2(1-\phi)\mu(1-\mu)\delta^*(\mathsf{w}^k,0,0)\right]$
$\frac{\mathsf{w}^k\phi(1-\mu)^2+2\mu(1-\mu)\phi(1-\mathsf{w}^k)}{\mathsf{w}^k\phi(1-\mu)^2+2\mu(1-\mu)(\mathsf{w}^k(1-\phi)+\phi(1-\mathsf{w}^k))+\mu^2\mathsf{w}^k(1-\phi)}$	$\mathsf{p}^k\phi(1-\mu)^2\delta^*(\mathsf{w}^k,1,1)$ $+2\mu(1-\mu)(\mathsf{p}^k(1-\phi)\delta^*(\mathsf{w}^k,0,1)+\phi(1-\mathsf{p}^k)\delta^*(\mathsf{w}^k,1,0))$ $+\mu^2(1-\mathsf{p}^k)(1-\phi)\delta^*(\mathsf{w}^k,0,0)$
$\frac{2\mu(1-\mu)\mathsf{w}^k\phi+\mu^2\phi(1-\mathsf{w}^k)}{2\mu(1-\mu)\mathsf{w}^k\phi+\mu^2((1-\phi)\mathsf{w}^k+\phi(1-\mathsf{w}^k))}$	$2\mu(1-\mu)\mathsf{p}^k\phi\delta^*(\mathsf{w}^k,1,1)+$ $\mu^2((1-\phi)\mathsf{p}^k\delta^*(\mathsf{w}^k,0,1)+\phi(1-\mathsf{p}^k)\delta^*(\mathsf{w}^k,1,0))$
$\frac{\phi(1-\mu)}{\phi(1-\mu)+\mu(1-\phi)}$	$\phi(1-\mu)\left[(1-\delta^*(\mathsf{w}^k,1,0))(1-\mathsf{p}^k)+(1-\delta^*(\mathsf{w}^k,1,1))\mathsf{p}^k\right]$ $+\mu(1-\phi)\left[(1-\delta^*(\mathsf{w}^k,0,0))(1-\mathsf{p}^k)+(1-\delta^*(\mathsf{w}^k,0,1))\mathsf{p}^k\right]$
1	$\mathsf{p}^k\phi\mu^2\delta^*(\mathsf{w}^k,1,1)+$ $\phi\mu\left[(1-\delta^*(\mathsf{w}^k,1,0))(1-\mathsf{p}^k)+(1-\delta^*(\mathsf{w}^k,1,1))\mathsf{p}^k\right]$

Table 11: Transition probabilities from adult to old agents' wages: Elective team with idiosyncratic shocks

Next-period old agents' wages (w^l)	Transition probability $q^{\dagger}_{kl} \equiv \Pr(w'_3 = \mathsf{w}^l \mid w_2 = \mathsf{w}^k)$
0	$(1-\phi)(1-\mathsf{p}^k)(1-\mu)^2\delta^*(\mathsf{w}^k,0,0)+$ $(1-\phi)(1-\mu)\left[\left(1-\delta^*(\mathsf{w}^k,0,0)\right)(1-\mathsf{p}^k)+\left(1-\delta^*(\mathsf{w}^k,0,1)\right)\mathsf{p}^k\right]$
$\frac{\mathsf{w}^k(1-\phi)(1-\mu)^2}{\mathsf{w}^k(1-\mu)^2(1-\phi)+(1-\mathsf{w}^k)(\phi(1-\mu)^2+2(1-\phi)\mu(1-\mu))}$	$\mathsf{p}^k(1-\mu)^2(1-\phi)\delta^*(\mathsf{w}^k,0,1)+$ $(1-\mathsf{p}^k)\left[\phi(1-\mu)^2\delta^*(\mathsf{w}^k,1,0)+2(1-\phi)\mu(1-\mu)\delta^*(\mathsf{w}^k,0,0)\right]$
$\frac{\mathsf{w}^k\phi(1-\mu)^2+2\mu(1-\mu)(1-\phi)\mathsf{w}^k}{\mathsf{w}^k\phi(1-\mu)^2+2\mu(1-\mu)(\mathsf{w}^k(1-\phi)+\phi(1-\mathsf{w}^k))+\mu^2(1-\mathsf{w}^k)(1-\phi)}$	$\mathsf{p}^k\phi(1-\mu)^2\delta^*(\mathsf{w}^k,1,1)+2\mu(1-\mu)(\mathsf{p}^k(1-\phi)\delta^*(\mathsf{w}^k,0,1)+$ $\phi(1-\mathsf{p}^k)\delta^*(\mathsf{w}^k,1,0))+\mu^2(1-\mathsf{p}^k)(1-\phi)\delta^*(\mathsf{w}^k,0,0)$
$\frac{2\mu(1-\mu)\mathsf{w}^k\phi+\mu^2(1-\phi)\mathsf{w}^k}{2\mu(1-\mu)\mathsf{w}^k\phi+\mu^2((1-\phi)\mathsf{w}^k+\phi(1-\mathsf{w}^k))}$	$2\mu(1-\mu)\mathsf{p}^k\phi\delta^*(\mathsf{w}^k,1,1)+$ $\mu^2\left[(1-\phi)\mathsf{p}^k\delta^*(\mathsf{w}^k,0,1)+\phi(1-\mathsf{p}^k)\delta^*(\mathsf{w}^k,1,0)\right]$
$\frac{\mathsf{w}^k(1-\mu)}{\mathsf{w}^k(1-\mu)+\mu(1-\mathsf{w}^k)}$	$\mathsf{p}^k(1-\mu)\left[(1-\delta^*(\mathsf{w}^k,1,0))(1-\mathsf{p}^k)+(1-\delta^*(\mathsf{w}^k,1,1))\mathsf{p}^k\right]+$ $\mu(1-\mathsf{p}^k)\left[(1-\delta^*(\mathsf{w}^k,0,0))(1-\mathsf{p}^k)+(1-\delta^*(\mathsf{w}^k,0,1))\mathsf{p}^k\right]$
1	$\mathsf{p}^k\phi\mu^2\delta^*(\mathsf{w}^k,1,1)+$ $\phi\mu\left[(1-\delta^*(\mathsf{w}^k,1,0))(1-\mathsf{p}^k)+(1-\delta^*(\mathsf{w}^k,1,1))\mathsf{p}^k\right]$

Table 12: Steady-state expected utility of a young agent

Work arrangement	Agent's productivity High	Low	Unconditional
Compulsory single	1.441	0.926	1.313
Compulsory team			
• common shocks	1.500	0.750	1.313
• idiosyncratic shocks	1.380	1.110	1.312
Elective team			
• common shocks	1.495	0.929	1.354
• idiosyncratic shocks	1.442	1.003	1.332

Note: The steady-state equilibrium is calculated for $\beta = 0.5$, which corresponds to an annual discount rate of 3% over three 25 year generations, $\phi = 0.75$ and $\mu = 0.35$.

C Figures

Legends for figures

1. Each unconditional steady-state distribution of the adults' wages is computed for the relevant technology and using the corresponding transition matrix: Panel a: technology (2) and transition probabilities in table 2; Panel b: technology (4) and transition probabilities in table 4; Panel c: technology (7) and transition probabilities in table 6; Panel d: technology (4) and transition probabilities in table 8; Panel e: technology (7) and transition probabilities in table 10. The parameters used to generate the graphs are $\phi = 0.75$ $\mu = 0.35$, and $\beta = 0.5$.

2. $\eta_i \in \{0, 1\}$, for $i = 1, 2$, denotes the worker's true productivity. The individual technology is given by (2) and the common shocks technology is given in (4). The left-hand scale of each panel is for an adult's expected utility $v_2^{\delta^*}(w_2, \eta_1, \eta_2)$ (bold line) and the steady-state distribution of wages s^* (bars). Note that by definition s^* cannot exceed 1, and that, contrary to Figure 1, the steady state reported here is conditional on the worker's true productivity. For instance, in panel a, $w_2 = 0$ is not feasible given that the adult is of high productivity. The right-hand scale of each panel is for the young worker's expected utility $v_1^{\delta^*}(w_2, \eta_1, \eta_2)$ (standard line). τ_i, for $i = 1, 2$, denotes side payments paid by worker i to the agent with whom she is randomly matched. The parameters are as follows: $\phi = 0.75$, $\mu = 0.35$ and $\beta = 0.5$.

3. The idiosyncratic shocks technology is given in (7). For a description of the other elements see the note in Figure 2.

Figure 1: Steady-State Distribution of Adults' Wages

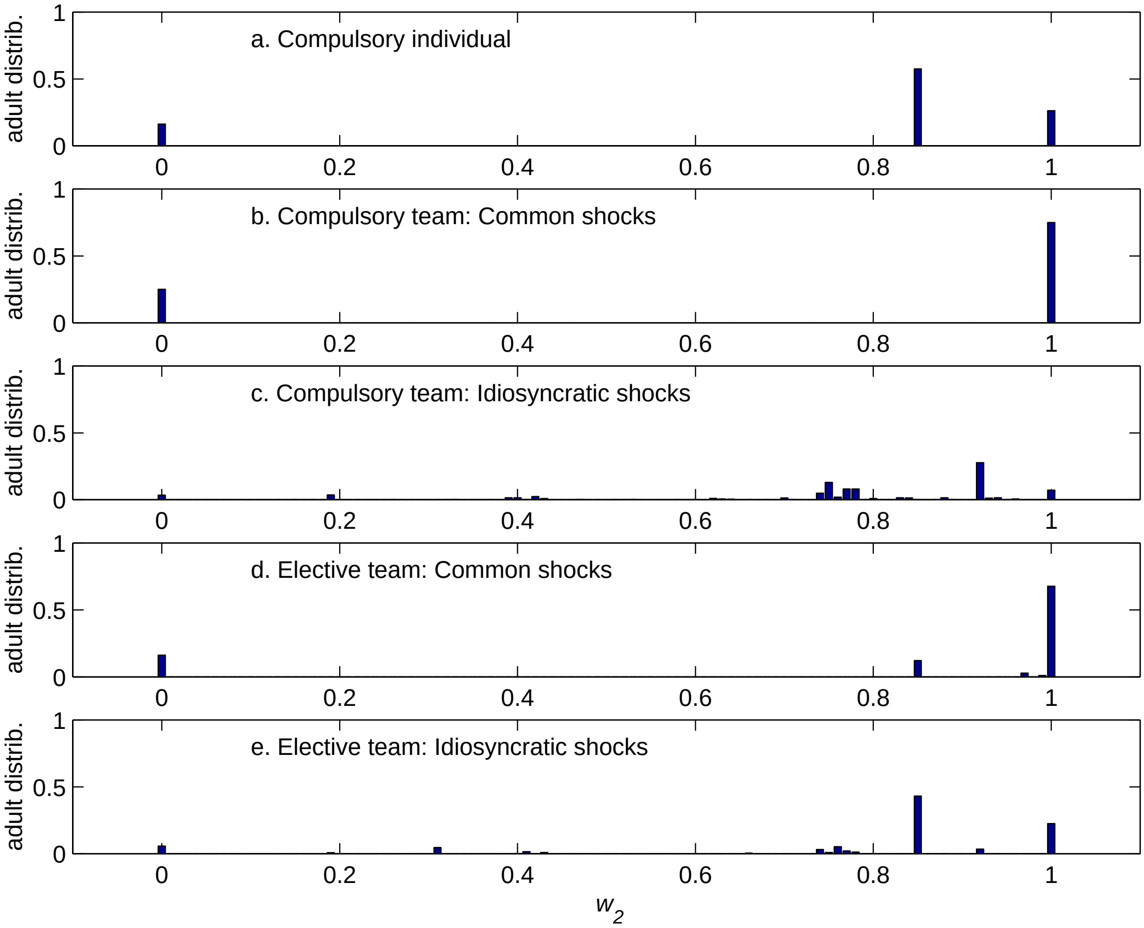


Figure 2: Utility and Steady-State Distribution of Adults' Wages. Common Shocks

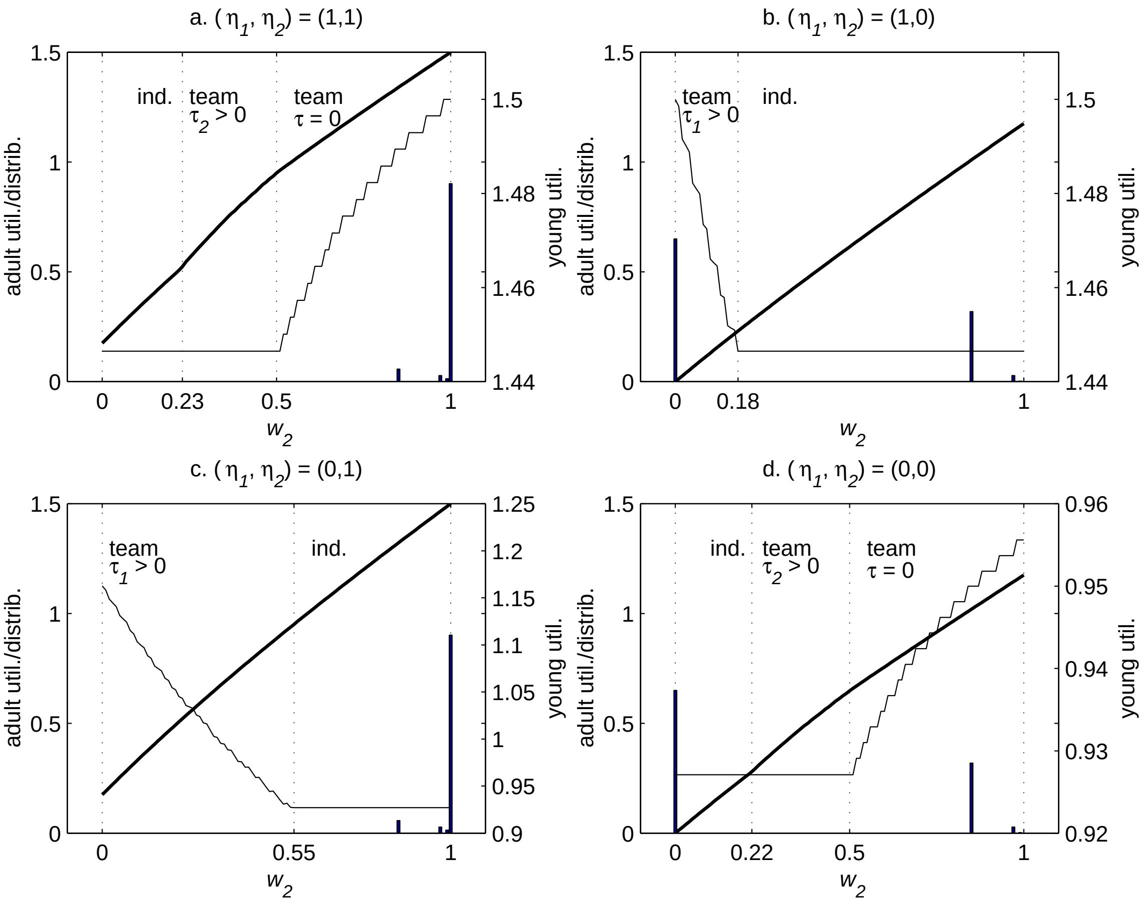
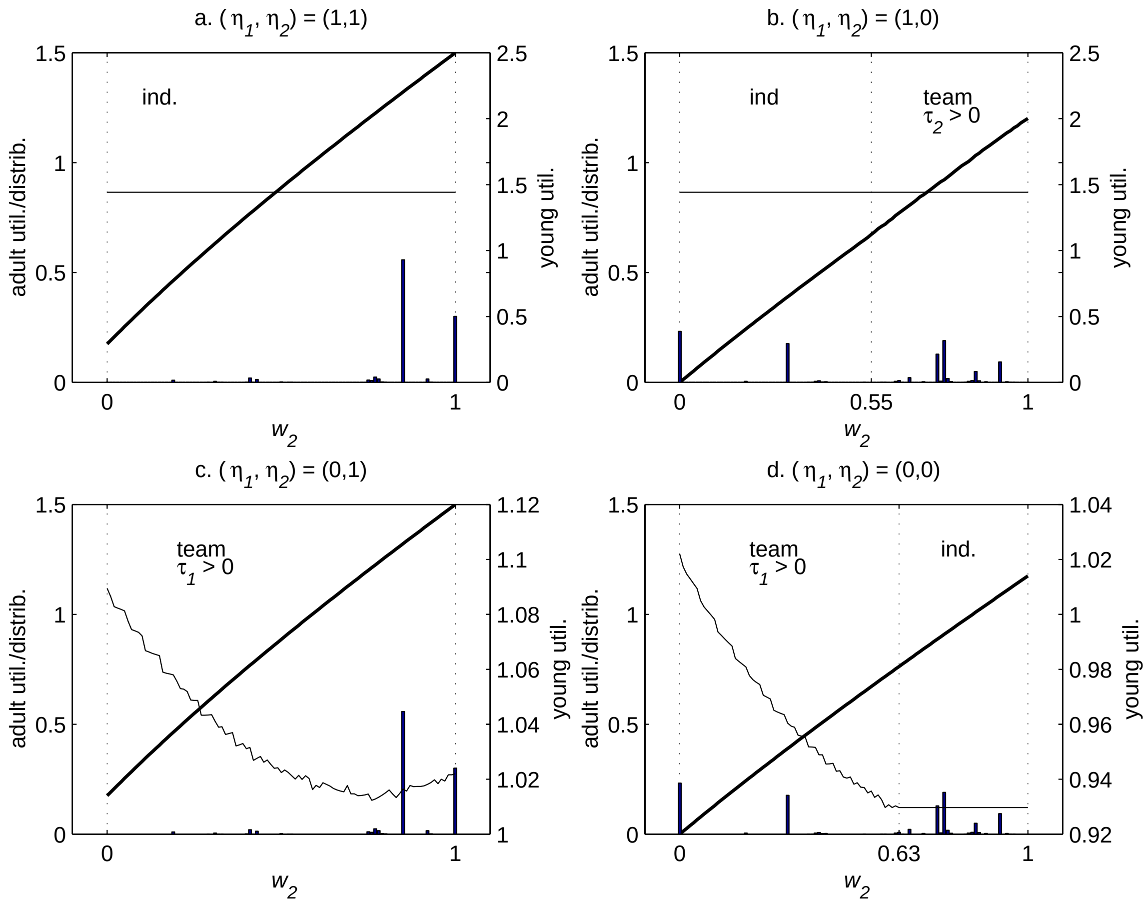


Figure 3: Utility and Steady-State Distribution of Adults' Wages. Idiosyncratic Shocks



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