Kremer's O-Ring Theory

I present here a highly simplified version of Kremer's O-Ring theory. The innovation in Kremer's paper is the idea that production of a good, say a space shuttle, involves the successful completion of a set of tasks e.g. building the frame of the shuttle, building the jets, manufacturing the O-rings, assembling all the parts. An error in completing even one of the tasks can mean that all the other tasks were carried out in vain, so the success of the project depends on the successful completion of *all* the tasks. Suppose that each task is appointed to one worker. Then the theory implies that good workers (i.e. those who are more likely to do the job successfully) can add greater value when their co-workers are good workers, than when their co-workers are bad workers. One of the central implications of the paper is that this kind of production technology can lead to very large differences in wages between workers who are only marginally different in terms of ability. Extending this logic, one can argue (and Kremer does) that the very large cross-country differences in income are due to O-ring-type production technology which amplifies the differences in skill level across countries.

Key to the argument is the demonstration of positive assortative matching, i.e. all the employees at an establishment tend to be of the same skill level. That's to say, we wouldn't see a celebrity chef working at McDonald's and neither would we see a high-school dropout working at Google (well, maybe we would). How does this assortative matching occur by itself? Notice that McDonald's wouldn't mind having a celebrity chef to flip burgers, so why doesn't it? The answer is that it wouldn't pay for McDonald's to do that. The wage it can pay any worker is no more than the value that he/she brings to the enterprise. The celebrity chef certainly brings more value than a part-time college student employee, but since all the other employees at McDonald's are low quality, the celebrity chef can add lower value by working in McDonald's than by working in a fancy restaurant (where all the other workers are high quality), and so the fancy restaurant is ready to pay more than McDonald's to hire the celebrity chef. Be clear that implicit in this story is the O-ring technology - if the value added by any one person is independent of what other employees are doing, then the above argument wouldn't hold water, and the celebrity chef would be indifferent between the two jobs.

To see this somewhat more formally, suppose that production of one unit of output requires the completion of two tasks. Let q_1 be the probability that task 1 is successfully completed and let q_2 be the (independent) probability that task 2 is successfully completed. Then the probability that the output is successfully produced is simply $q_1 q_2$ and this is the same as the expected output. The O-ring production function can therefore be written as:

$$y = q_1 q_2$$

where y is the expected amount of output.

Suppose now that each task is to be done by one worker and that there are two types of workers, High (denoted by H) and Low (denoted by L), whose probabilities of success at any task are q_H and q_L respectively, with $q_H > q_L$. Suppose that there are N workers of each type in the economy. How will they be paired in equilibrium? There's a quick way to answer this question: since the competitive equilibrium will be efficient, we can simply ask what would be the most efficient way of pairing workers. Can there be more than one team of workers who are not positively matched, that is, can there be two teams, each of which has one H worker and one L worker? The total output produced by these two teams is $2q_H q_L$, but if I were to shuffle the two teams and pair the H workers together, then total output produced by this new allocation would be $q_H^2 + q_L^2$ and this quantity is greater than $2q_Hq_L$ (because the difference in output is $q_H^2 + q_L^2 - 2q_Hq_L = (q_H - q_L)^2 > 0$). Thus an efficient allocation (and hence a competitive equilibrium allocation) cannot involve more than one non-equal pairing of workers.

What is the implication of this matching for wages? Intuitively, since the value added by a worker is greater when his co-worker is of type H than of type L, the pairing of H workers with each other increases their wages beyond what they could each have obtained by working with an L worker. Let's solve for the equilibrium wages of the two types of workers. To do this, let's utilize the fact that under competitive conditions, no firm can earn any profits in equilibrium, so the payments to the workers must equal the value of the output they produce. Since H workers are paired together, each such team produces q_H^2 and so they must each be paid $\frac{1}{2}q_H^2$ in wages. This is the wage of a type-H worker in equilibrium. By a similar argument, the wage of a type-L worker must be $\frac{1}{2}q_L^2$. The difference in wages is therefore $\frac{1}{2}(q_H^2 - q_L^2)$. More generally, it's easy to see that if there were n tasks, instead of just 2, the difference in wages would be $\frac{1}{n}(q_H^n - q_L^n)$. If q_L were to fall by an infinitesimal amount, call it dq_L, then the wage difference increases by more than dq_L (it actually increases by q_L^{n-1}). Similarly, if q_H were to increase by a small amount, dq_H, then the wage difference would increase by q_H^{n-1}. This is the implication I alluded to earlier - small changes in ability get magnified when converted into wages.

Notice that in this equilibrium, all firms make zero profits, even the ones that only hire H workers. Each firm is therefore indifferent between hiring only H workers and hiring only L workers. However, as I suggested in the example of the celebrity chef, at the equilibrium wages, it's always strictly better for a firm to pair workers of the same skill than to pair workers of different skills (as an exercise, try showing this for the case of 2 tasks).

Kremer notes some of the implications of O-ring theory that are commonly observed in the real-world:

1. O-ring theory accounts not just for why some countries are rich and some are poor, but also for the enormous differences in wages and productivity between rich and poor countries.
2. Firms tend to hire workers of the same skill level ("....McDonald's does not hire famous chefs, and Maxim's does not hire teenage waiters")
3. Workers in the same occupation working at different firms tend to be paid different amounts, and the wages of workers within firms across occupations tend to be positively correlated.

There are many more interesting implications that can be derived by extending the model. I leave these for you to read in the original paper.