“Why do some countries produce so much more output per worker than others?” (Hall and Jones, QJE, 1999)

The channel discussed here:

*Differences in worker skill matter more for countries than for individuals*

**Evidence:** Hanushek/Kimko AER, 2000; Jones/Schneider EI, forthcoming

Builds on Kremer’s “O-Ring Theory” (QJE, 1993):

*A model of “fragile output” with strategic complementarities*

**Problem:** Predicts same return to skill across and within countries

What I add:

*A second diminishing-returns sector that uses less-skilled workers as close substitutes for skilled workers: The “Foolproof” Sector*
The O-ring sector’s production function

Each firm produces output this way:
(precisely following Kremer (QJE, 1993))

\[ Y_{O/\phi} = Bk^\alpha q^n n \]

\( Y_{O/\phi} \): O-ring sector output per firm.
B is an exogenous productivity factor \textit{identical across countries}.
k = capital per firm
q = skill level of a worker, \( 0 \leq q \leq 1 \)
n = number of workers

Output passes through \( n \) hands before becoming final output.

One worker has a small impact on output—no spillovers \textit{assumed}. 
Efficient Output in the O-ring sector

Kremer shows that it’s always privately *optimal* and socially *output-maximizing* to combine workers of identical skill within the same firm:

Example: Firm 1: [2 workers, q = 1]. Firm 2: [2 workers, q = 0.5]

*versus*

Firms 1 and 2: [1 worker, q = 1, 1 worker, q = 0.5]

\[
\text{Output: } 1^2 + 0.5^2 > 2 \times 0.5^2
\]

Nothing below changes this outcome—a key condition

*Assume free entry of O-ring firms*

In the O-ring sector, two mediocre lawyers are no substitute for one excellent lawyer.
Equilibrium Wages in the O-ring sector

After a surprisingly long derivation, Kremer proves:

$$w_0 = (1 - \alpha)Bk^\alpha q^n$$

Or, fraction $\alpha$ of output goes to capital owners,

$(1 - \alpha)$ is divided up among the firm’s $n$ workers.

*Nothing below changes this outcome—a key condition*

*If $q$ falls by $\varepsilon$, wage falls by factor of $\approx n\varepsilon$*

*Implication: Any firm offering a pay cut of less than $n\varepsilon$ gets all the low-skilled workers.*
The Foolproof Sector: The Labor Force

How workers are combined:

\[ \hat{L}_F = q_u L_u + q_h L_h \]

Foolproof Labor Force =

quality-weighted sum of all workers

\[ h = \text{high-skilled} \]
\[ u = \text{unskilled} \]

In the Foolproof sector, two mediocre lawyers can provide as much service as one excellent lawyer.

*Whenever a growth regression uses average years of schooling, this is the implicit model.*
The Foolproof Sector: Output and wages

Key assumption: Diminishing returns to labor in Foolproof sector

\[ Y_F = A(\hat{L}_F)^{1-\alpha} \]

\( A \): Level of technology, *same across countries*

\( \alpha \): Same as in O-Ring sector, only for simplicity

For workers of a given skill level \( s \), the competitive wage \( w_{FS} \) will equal the marginal product of their class of labor:

\[ w_{FS} = (1-\alpha)A(\hat{L}_F)^{\alpha}qs \]

*As quality-weighted pool of workers rises, wage falls.*

*If \( q \) falls by \( \varepsilon \), wage falls by factor of only \( \varepsilon \)*
Equilibrium between the O-Ring and Foolproof sectors

If workers of a given skill level are working in both sectors, then they must earn the same wage: Law of one price.

\[ W_{OS} = W_{FS} \]

\[ (1-\alpha)Bk^\alpha q_s^n = (1-\alpha)A(\hat{L}_F)^{-\alpha} q_s \]

In benchmark case, this holds for high-skilled workers.
General Equilibrium (1 of 2):
O-ring pins down labor wage, Foolproof pins down labor quantity

Stay with two-skill case: Lots of high-skill workers (h), plus a few unskilled workers (u), labor inelastic.

1. High-skilled workers work *somewhere*; consider the interesting **benchmark** case, where they work in both sectors:

   \[ L_h = L_{ho} + L_{hf} \]

2. This pins down *exact* wage in O-ring sector:

   \[ w_{ho} = (1-\alpha)Bk^\alpha q_h^n \]
General Equilibrium (2 of 2)

3. Quantity of O-ring workers is pinned down by Foolproof sector:

Too few quality-weighted workers in Foolproof: \( w_{Fh} > w_{ho} \)

Too many quality-weighted workers in Foolproof: \( w_{Fh} < w_{ho} \)

Benchmark case: Some skilled workers in both sectors.

Number of O-ring firms =

\[
\text{Number of skilled O-ring workers/workers per firm}
\]

4. In benchmark, Foolproof absorbs all unskilled workers plus enough skilled workers to keep high-skilled wage equal across sectors.
What this world looks like,
Ignoring capital and the Foolproof Magnet

\[ n = 5, A=B=1, \text{ignore capital} \]

Country 1: \( q_h = 1, q_u = 0.9 \)

Country 2: \( q_h = 0.9, q_u = 0.9^2 \)

\[ w^A_h = 1, w^A_u = 0.9 \]

\[ w^B_h = 0.59, w^B_u = 0.53 \]

*Big returns to skill across countries.* (As seen by growth econometrician)

*Low returns to skill within countries.* (As seen by labor econometrician)
But things aren’t *that* bad in Country 2: They’re worse!

*Two forces at work in Country 2*

1. Capital multiplier in O-ring sector:
   - Low-skilled countries lose lots of capital
   - Low-skilled countries become less productive
   - Country 2 wages fall lower than 0.59

2. Fixed Total Factor Productivity (A) in Foolproof sector:
   
   *The Foolproof Magnet*
   - Lower O-ring wages lure skilled workers
     into Foolproof sector
   - Diminishing returns in Foolproof sector
     lower average productivity

*Result: Productivity plummets in Country 2 below Kremer’s levels*
Net results of Benchmark model: A review

In each country, the best workers work in O-ring sector.

Why?
Because less-skilled workers would rather work in Foolproof.

The Foolproof sector is “attached” to the O-Ring sector.

Why? Because skilled workers can and do work in both sectors.

In each country, unskilled workers earn a wage that is slightly less than that country’s skilled workers.

Why? See previous two answers.
Example: 30% difference in skill yields a 30X productivity gap: $A = B = 100$, $n = 3.8$, $r = 0.04$, $L_h = 1M$, $L_u = 100K$, $q_u = 0.9q_h$

The impact of skilled worker quality in a Foolproof/O-ring economy

This 30% skill gap would only create a 30% wage gap within a country
The Ladder: O-Ring Sectors as Rungs, Foolproof Sectors as gaps between rungs

The gap between the rungs; Here filled by Foolproof—other possibilities surely exist

Potential O-Ring (U) if there are enough unskilled

O-Ring (H)
Beyond the Benchmark: Unskilled workers out of reach of the O-Ring

Consider two-skill case: H and U:

If there are too many unskilled workers, then Foolproof wage falls too low:

\[
W_{Oh} > W_{Fh} \\
(1-\alpha)Bk^\alpha q_h^n > (1-\alpha)A(q_uL_u)^\alpha q_h
\]

N.B.: The Foolproof supply is all unskilled:
All skilled workers stay in O-ring sector.
Out of reach of the O-Ring (2)


If only a few too many unskilled:
   Labor econometrician sees big returns to skill:
   (e.g., time-varying returns to skill in U.S.? Bigger empirical returns in LDCs?)

If far too many unskilled:
   Wage falls to new O-Ring level:
   \[ w_{hU} = (1-\alpha)BkU^\alpha qU^n \]

*Unskilled* workers in both O-ring and Foolproof sectors:

*The cycle continues*

If many workers with many levels of skill: Kremer (QJE, 1993)

Kremer as limiting case
Implications

1. Low-skilled immigrants don’t hurt natives.
2. Border areas as regions of Foolproofness.
3. The Flat World: Increasing the reach of Foolproofness?
5. There can be only one Foolproof Sector in each economy; and it’s at the bottom.
6. These results generalize to continuous skills.
7. Empirical work can sort out “degrees of O-ringness” and “degrees of Foolproofness.” (Chad Jones, working paper)
8. A naïve prediction: Life at the top should be the same everywhere.

*Barbers should earn more in the Britain than in India, but corporate executives in Britain and India should live quite similar lives.*
Conclusion

The market abhors a vacuum:

*Diminishing (or constant) returns sectors will fill in gaps between rungs on the O-ring ladder.*

“To easy” to match the data:

*Chad Jones (working paper, 2007) develops degrees model with degrees of O-ring-ness…*

*…Can data point to the right degree?*

A story that fits some key facts…Without an appeal to externalities or variations in total factor productivity:

*Only exogenous cross-country difference: Persistent, measurable differences in individual worker skill across countries.*
Figure 1: IQ and Immigrant Skill
(Source: Jones and Schneider, Econ Inq., forthcoming)

Notes: The x-axis reports estimates for national average IQ for country $i$ from Lynn and Vanhanen (2006). The y-axis reports values for $uws_i$, the unmeasured worker skill estimate for immigrants from country $i$, as estimated in Hendricks (AER, 2002). $uws_i$ is the log average wage of immigrants for country $i$, adjusting for age and education. The trendline reflects the OLS coefficient of 0.95, and the $R^2$ is 22%.
Figure 2: National Average IQ (Lynn & Vanhanen, 2006) and Year 2000 GDP Per Worker

Y-axis shows GDP per worker in logarithmic scale. Coefficient on national average IQ is 0.067, and the $R^2$ is 58%. The outlier in the lower-right corner is China (IQ = 105).
A detour: Capital in partial equilibrium

Kremer shows that in O-ring sector,

\[ k^* = \left( \frac{\alpha q^n nB}{r} \right)^{\frac{1}{1-\alpha}} \]

Yields another a multiplier effect of quality in O-ring sector: Best workers get more machines, as in Cobb-Douglas world

Take \( r \) as given for simplicity. Justifications:
- Steady-state of Solow or Ramsey model
- A open-economy world with free flow of capital.