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Arithmetics of Research Specialization*

Sergey V. Popov

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Abstract

I model the use of research specialization in hiring as a signal of ability. I demonstrate that rewarding for specialization can make an average non-specializing candidate on average better than average specializing candidate, and *vice versa*. Specialization works as a good ability signal only when both good and bad candidates are very likely to churn out good projects.

Keywords: specialization, research, job market.

JEL: A11, D4, I23, J4

> Jack of all trades, master of none, but oftentimes better than master of one.
>
> Proverb

Some researchers choose to specialize in a field; some prefer to work in separate, frequently unrelated fields. For the freshly minted PhD candidates in Economics, frequently without any publications, specialization in working papers becomes a point of discussion during hiring. Some argue that those who specialize must be better than those who don't because it is hard to work in multiple fields; others argue the opposite for the very same reason.[1] In my model, an environment without an explicit reward for specialization leads to a higher

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[1] Chicago faculty (na): "Make sure that you have a well-defined field, or at least make it appear as if you have one." Levine (na): "Describe one or two research projects that you would like to work on next. Most of your ideas should hang together, as if you were writing a book or two," but "At least one idea should be distinct from your thesis." Cawley (2019): "... the four most important pieces of advice regarding the job market. 1) Know where you fit in the discipline of economics; in particular, know: a. In what fields of economics you will specialize".

chance of hiring a good candidate if one picks a candidate with a specialized CV; but if there are market benefits to specialization, such as preference for hiring candidates with a specialized CV, it is possible that candidates *without* specialization are better than those who specialize.

What we would expect from an equilibrium is that the market outcomes, such as rewarding candidates for acting in a specific way, are consistent with the relatively higher likelihood of being good in a field conditional on acting in that specific way. That is, if the job market does not reward for specialization, those who focus should be less likely to be good than those who don't focus, and vice versa. In this paper, I show that there is a significant space of parameter values that leads to an inconsistency between incentives and results, namely

- *rewarding* for focusing leads to *lower* expected goodness of those who focus,
- while *not rewarding* for focusing leads to *higher* expected goodness of those who focus.

Both of these in the rest of the paper are referred to as the **adverse outcome**.

Idea Generating Process

There is a population of measure 1 of job market candidates. A proportion λ of candidates is *good* at topic 1, same λ proportion of candidates is *good* at topic 2, and being good at topic 1 is not correlated with being good at topic 2. Every candidate is endowed with two paper ideas in each topic, and being good at topic i means ideas in this topic are *good* with probability p, while not being good at topic i means ideas in this topic are *good* with probability αp, with $1 > p > 0$ and $1 > \alpha > 0$. Every candidate is characterised by a 6-dimensional binary type—two bits denote whether the candidate is good in each topic, and four more record goodness of candidates' paper ideas—so overall there's $2^6 = 64$ types in the economy.

Each candidate chooses paper ideas to work on that constitute that candidate's CV. In this choice, candidates are mostly motivated by eventual publication, so they prefer to work on good ideas rather than on bad ideas. Candidates choose two paper ideas to work on.[2] Candidates' preferences about which ideas to work on are lexicographic in respect to idea quality and expected monetary benefits: candidates choose to work on good ideas, and only motivated by monetary benefits when they are indifferent between multiple ideas.

[2] Rationalization of this outcome could be that the costs of working on three ideas are prohibitively high, while anyone who is working on only one idea is believed to be not good in both topics.

# of good ideas		Prob of focusing	
Topic 1	Topic 2	With reward	No reward
0	0	1/3	1
0	1	1/3	1
0	2	1	1
1	1	0	0
1	2	1/3	1
2	2	1/3	1

Table 1: Focusing decisions of candidates

If candidates have too many good ideas (say, 3), or too few (say, 1), and the market does not reward them for specialization, candidates pick ideas to work on at random. So, the candidate with three good ideas will pick 2 good ones at random, and the candidate with one good idea will pick 1 good idea and 1 bad idea at random. If the job market rewards for the specialization, only those who have exactly one good paper in each topic will not specialize; those with 4 and 0 good paper ideas will pick the topic of specialization at random. The candidate who works on both paper ideas on topic i is *focusing* on topic i.

Table 1 provides strategies for job market candidates. A candidate with one good idea in Topic 1 and no good ideas in Topic 2 behaves similarly to a candidate who has no good ideas in Topic 1 and one good idea in Topic 2, so some possible outcomes are omitted. If a candidate has only one good idea, he will focus for sure if there is a reward for this, but if there is no reward, he will work on the good idea, and will pick at random one bad idea. Since there is one idea that will make him focused, and two ideas that will make him not focused, the chance that he will focus if there is no reward is $\frac{1}{3}$. Same reasoning applies to other options; the only type that cannot be convinced to focus is the one with one good idea in Topic 1 and one good idea in Topic 2. Our parameters, p, α, and λ, will govern the conditional expectations.

To calibrate the model, one would need to define what constitutes a good idea.[3] I am going to use a publication in the Top 5 as measure of success in the Economics profession for a recent PhD graduate. Conley and Önder (2014) count AER equivalents 6 years after graduation, and report that among top-30 Economics PhD programs, only Princeton's and Rochester's PhD programs show more than 20% of their graduates with a publication record of more than one AER equivalent, which gives an estimate from above of $\lambda = 0.2$. Baghestanian and Popov (2014) provide an estimate of p: even for economists in Top 100 of RePEc

[3] The reader can use other rationales and independently verify coherence of their calibration with my assertion that the boundaries on parameters that I obtain are not too restrictive.

the chance to publish in the Top 5 is at best 30%, so $p \leq 0.3$. Heckman and Moktan (2018) report that having a second Top 5 is key for tenure in competitive American schools. If top American schools are using a tenure decision rule with 5% Type I error, and that bad ideas are obfuscated by the tenure-track professors, then one can solve for α from

$$0.05 > P[\text{bad}|\text{2 good ideas}] = \frac{(1-\lambda)(\alpha p)^2}{(1-\lambda)(\alpha p)^2 + \lambda p^2} = \frac{0.8}{0.8 + 0.2(1/\alpha)^2} \Rightarrow \alpha < 0.1147,$$

$$\text{and } 0.05 < P[\text{bad}|\text{1 good idea}] = \frac{(1-\lambda)(\alpha p)^1}{(1-\lambda)(\alpha p)^1 + \lambda p^1} = \frac{0.8}{0.8 + 0.2(1/\alpha)} \Rightarrow \alpha > 0.01316.$$

Results

The next two Results consider the difference

$$D[\textit{policy}] = P[\text{Good in Either topic}|\text{Focus}] - P[\text{Good in either topic}|\text{Don't Focus}].$$

Using the definition of conditional expectations, it can be written as

$$\frac{P[\text{Good in Either topic and Focus}]P[\text{Not Focus}] - P[\text{Good in Either topic and Not Focus}]P[\text{Focus}]}{P[\text{Focus}]P[\text{Not Focus}]}. \tag{1}$$

Observe that the sign of the top of this fraction is the sign of $D[\textit{policy}]$, which will end up to be a polynomial and therefore easier to analyse than the whole fraction.

Result 1. *If there is no monetary reward for focusing, the probability for an agent to be good at any topic conditional on information that that agent focusing is higher than the probability for an agent to be good at any topic if that agent does not focus; the adverse outcome is observed for every* $(\alpha, p, \lambda) \in (0,1)^3$.

Proof. The sign of the top of the fraction (1) is proportional to

$$\propto D_1 = \lambda(1-\lambda)^3(1-\alpha)^2 p^2 > 0.$$

Therefore, focusing population on average is more likely to be good in at least one topic than non-focusing population. □

The driving mechanism is straightforward enough. It is unlikely that a candidate who is not good in anything gets two good ideas in the same topic, which means that a bad candidate is unlikely to focus. On the other hand, those who are good at both topics are also unlikely to focus: the chance to focus for a candidate with 3 or 4 good ideas is only 1/3. Maybe paying more to candidates who focus will motivate good candidates to focus?

Result 2. *If there is a monetary benefit for focusing, the probability for an agent to be good at any topic conditional on focusing is lower than the probability for an agent to be good at any topic if that agent does not focus as long as* $p(1+\alpha) < 1$.

Proof. The sign of the top of the fraction (1) is proportional to

$$\propto D_2 = \underbrace{\lambda(1-\lambda)^2(1-\alpha)p^2}_{>0}\overbrace{(p(1+\alpha)-1)}^{\gtrless 0}\left(2\alpha+\lambda-\alpha\lambda-\lambda p-2\alpha^2 p+\alpha^2\lambda p\right).$$

The last bracket is positive:

$$2\alpha+\lambda-\alpha\lambda-\lambda p-2\alpha^2 p+\alpha^2\lambda p = \alpha-\alpha^2 p+[\alpha+\lambda-\alpha\lambda]-p[\lambda+\alpha^2-\alpha^2\lambda] =$$

$$= \underbrace{\alpha-\alpha^2 p}_{>0}+[\underbrace{1-(1-\alpha)(1-\lambda)}_{>0}]-p[\underbrace{1-(1-\alpha^2)(1-\lambda)}_{>0}] >$$

$$> 1-(1-\alpha)(1-\lambda)-[1-(1-\alpha^2)(1-\lambda)] = (1-\lambda)\alpha(1-\alpha) > 0.$$

Therefore, the adverse outcome, when non-focusing population on average is more likely to be good in at least one topic than focusing population, can be observed if $p(1+\alpha) < 1$. □

Indeed, monetary remuneration for focusing can help, but this motivator also stimulates those who have no good ideas to focus on. If there's a lot of those (p is small enough), the informational benefit of better environment for focusing for those who are good is getting dominated by the abundance of those who are not good but now have incentives to focus. The only ones who don't focus when there's a premium for doing so are those who have a good idea in each field. For small p, these are likely people who are good in at least one field; for high αp, these are likely to be candidates who are not good in either field, because those who are good in a field are likely to face a high p and therefore likely to have enough good ideas to focus on.

Is that threshold restricting? What is the chance of an idea to be good for those who are good in the field, and what is the chance of an idea to be good for those who are not good in the field? If the sum of these is below 1, then with a monetary reward for specialization, non-focusing candidates are more likely to be good than those who focus.

The next two Results consider the difference

$$D[policy] = P[\text{Good in T1}|\text{Focus on T1}] - P[\text{Good in T1}|\text{Don't Focus}].$$

Using the definition of conditional expectations, it can be written as

$$\frac{P[\text{Good in T1 and Focus on T1}]P[\text{Not Focus}] - P[\text{Good in T1 and Not Focus}]P[\text{Focus on T1}]}{P[\text{Focus on Topic 1}]P[\text{Not Focus}]}. \tag{2}$$

Frequently job search advertisements explicitly call for people who work in a specific field. While the first two results are informative for those who want to hire someone who is good at *something*, the next two results are informative for those who want to hire someone who is good in a specific topic. Therefore, we are going to contemplate whether rewarding people who work in topic i is useful to detect people who are good in topic i.

Result 3. *If there is no monetary reward for focusing, the probability for an agent to be good at topic i conditional on focusing on topic i is higher than the probability for an agent to be good at topic i if that agent does not focus.*

Proof. The top of (2) is proportional to

$$\propto D_3 = p(1-\alpha)(1-\lambda)Z(\alpha, p, \lambda),$$

$$\text{where } Z(\alpha, p, \lambda) = z(\alpha, p)\lambda^2 - (3(1-\alpha)p + z(\alpha, p))\lambda + \overbrace{(1-\alpha)p + (1-\alpha p)p + 1}^{>0},$$

$$\text{where } z(\alpha, p) = -2\alpha^3p^4 + \alpha^3p^3 + 4\alpha^2p^4 - \alpha^2p^3 + 2\alpha^2p^2 - 2\alpha p^4 - \alpha p^3 - 4\alpha p^2 + p^3 + 2p^2.$$

$z(\alpha, p)$ is positive: if one tries to solve $z(\alpha, p) = 0$ in terms of p, the solution would be $p^*(\alpha) = \frac{1+\alpha+\sqrt{\alpha^2+18\alpha+1}}{4\alpha}$, which is a decreasing function with respect to α, and at $\alpha = 1$ it is equal to $p^*(1) = \frac{2+\sqrt{20}}{4} = \frac{1}{2} + \sqrt{1.25} > 1$. Therefore, in the space of $(p, \alpha) \in (0,1)^2$, $z(\alpha, p)$ has a constant sign. Since the value of $z(\alpha, p)$ at $(0.5, 0.5)$ is 0.1563, we deduce that $z(\alpha, p) > 0$ everywhere at $(\alpha, p) \in (0,1)^2$. Therefore, in terms of λ, $Z(\cdot)$ is a U-shaped parabola.

$$Z(\alpha, p, \lambda = 0) = (1-\alpha)p + (1-\alpha p)p + 1 > 0,$$

$$Z(\alpha, p, \lambda = 1) = -3(1-\alpha)p + (1-\alpha)p + (1-\alpha p)p + 1 = \overbrace{1-(1-\alpha)p}^{>0} + \overbrace{\alpha(1-p)p}^{>0}.$$

The minimum of $Z(\alpha, p, \lambda)$ for a given α and p is at

$$\lambda^*(\alpha, p) = \frac{z(\alpha, p) + 3(1-\alpha)p}{2z(\alpha, p)}.$$

We will now establish that $\lambda^*(\alpha, p) > 1$. This will be true if

$$z(\alpha, p) < 3(1-\alpha)p \Rightarrow -p(1-\alpha)(\alpha^2p^2 + \underbrace{2\alpha p^3 - 2\alpha^2 p^3}_{=2\alpha p^3(1-\alpha)>0} + 2\alpha p \underbrace{-p^2 - 2p + 3}_{=4-(p+1)^2>0}) < 0.$$

Since the minimum of the parabola is at $\lambda^* > 1$, there was no change in the value of $Z(\alpha, p, \lambda)$ from positive to negative for $\lambda \in (0, 1)$, and therefore the positivity of the value of $Z(\cdot)$ at the borders means positivity everywhere inside $(\alpha, p, \lambda) \in (0, 1)^3$. □

Result 4. *If there is a monetary benefit for focusing, the probability for an agent to be good at topic i conditional on focusing on topic i is lower than the probability for an agent to be good at topic i if that agent does not focus if $p < t^*$; or if $\alpha p < t^*$ and λ is small enough.*

Proof. The top of (2) is proportional to

$$\propto D_4 = -p^2(\overbrace{\alpha + \lambda - \alpha\lambda - \lambda p - \alpha^2 p + \alpha^2\lambda p}^{(1-\lambda)\alpha(1-\alpha p)+\lambda(1-p)>0})^2 Z(\alpha, p, \lambda),$$

where $Z(\alpha, p, \lambda)$ is a quadratic equation with respect to λ. The determinant of that quadratic equation is

$$8p^3(1-\alpha)^2 \overbrace{\left(-2\alpha^2p^3 + 4\alpha^2p^2 - \alpha^2 p + 4\alpha p^2 - 6\alpha p + 2\alpha - p + 2\right)}^{2\alpha^2p^2+2\alpha^2p^2(1-p)+4\alpha p(1-\alpha)+2\alpha(1-p)+1-p+1-\alpha^2p>0},$$

where the right-most bracket is positive everywhere. This means that $Z(\alpha, p, \lambda)$ might change its sign with λ.

For a given pair of α and p, the extremum is at

$$\bar{\lambda} = \frac{-\alpha^3p^3 - \alpha^2p^3 + 2\alpha^2p^2 + \alpha p^2 - 2\alpha p + 1}{p(1-\alpha)(\alpha^2p^2 + 2\alpha p^2 - 2\alpha p + p^2 - 2p + 2)} =$$

$$= 1 + \frac{(1-p)\overbrace{\left(\alpha p^2 - p + p^2 + 1\right)}^{\alpha p^2+(p-1/2)^2+3/4>0}}{p(1-\alpha)(\underbrace{\alpha^2p^2 + 2\alpha p^2 - 2\alpha p + p^2 - 2p + 2}_{>0})} > 1,$$

which means that there's at most one root of $Z(\alpha, p, \lambda)$ as a function of λ, which means there's at most one change of the sign as λ changes from 0 to 1.

At $\lambda = 0$, $Z(\alpha, p, \lambda = 0) = 2\alpha^4 p^4 - 4\alpha^3 p^3 + 4\alpha^2 p^2 - 4\alpha p + 1$. Observe that this can be rewritten as

$$2t^4 - 4t^3 + 4t^2 - 4t + 1 \text{ where } t = \alpha p. \tag{3}$$

This equation has two roots, and only $t^* = 0.3281$ is relevant. When $\alpha p < t^*$, $Z(\alpha, p, \lambda = 0)$ is positive; to the right, negative.

At $\lambda = 1$, $Z(\alpha, p, \lambda = 0) = 2p^4 - 4p^3 + 4p^2 - 4p + 1$. Observe that this equation is identical to (3). When $p < t^*$, $Z(\alpha, p, \lambda = 1)$ is positive; to the right, negative.

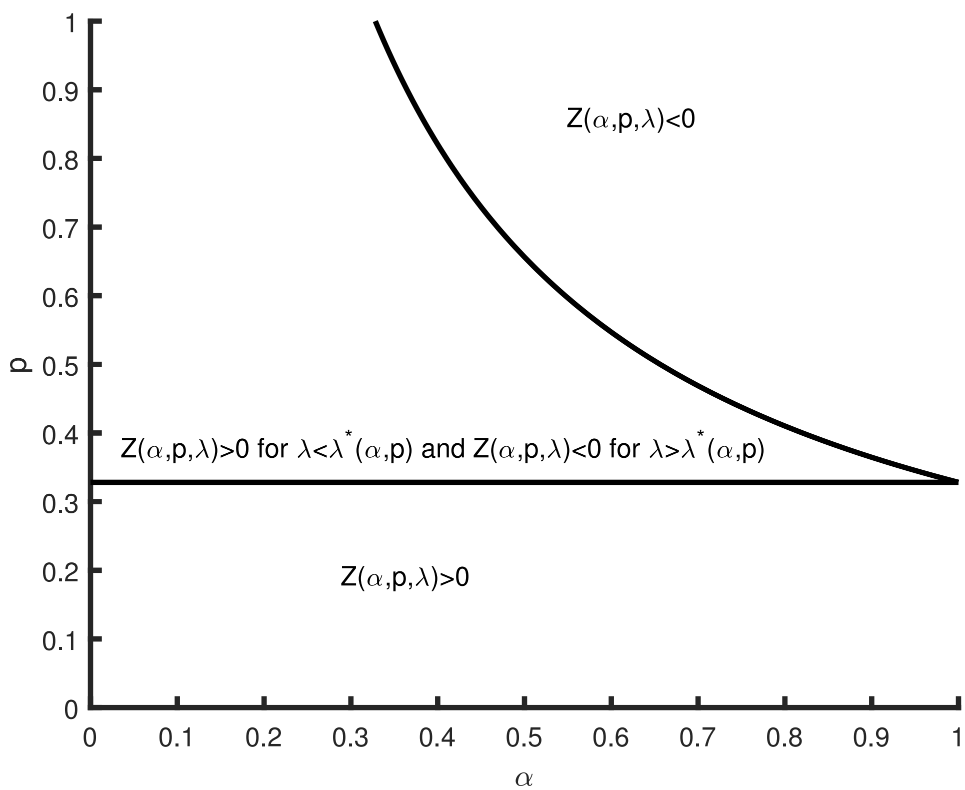

Figure 1: Result 4. The adverse outcome is observed where $Z(\cdot)$ is positive

Since there's at most one switch of the sign with respect of λ, values of (α, p) that yield a positive value of D_4 at $\lambda = 0$ and at $\lambda = 1$ must yield the same value in the interim, and those that yield a negative value of D_4 at $\lambda = 0$ and a positive value at $\lambda = 1$ must feature a $\lambda^*(\alpha, p)$ such that the value of D_4 is negative at $\lambda < \lambda^*(\alpha, p)$ and positive at $\lambda > \lambda^*(\alpha, p)$. $\square$

Discussion

In my model, I abstract away from the variation in the quality of ideas, limiting my distribution of quality to binary. This is relevant to some settings (for instance, tenure decisions seem to treat publications in Top 5 differently from publications in other journals, cf Heckman and Moktan (2018)), while in other settings some might find it acceptable to sacrifice a small difference in quality of an idea to focus on a field for a monetary gain. It is possible to reformulate the model taking the quality differentials into account, for instance in the spirit of Olszewski (2018) model, but the main takeaway, that the premium for specialization applies to good candidates and not good candidates alike, and—if there's a lot of not good candidates—will lead to perverse outcome is going to remain the same. Moreover, in my model, the total quantity of good ideas being worked on is socially optimal in both scenarios, but if one introduces a continuous measure of quality of the idea, some authors will work on worse ideas if specialization is encouraged, creating welfare losses, providing an additional reason to avoid premia for specialization.

In my model, I assume that being good in one field does not create an obstacle for being good in another field. While the true correlation might go one way or another, manipulating this correlation[4] does not seem to have too strong of an effect. Indeed, providing a focusing bonus works mostly for those who have a lot of good ideas (who are likely to be good at both fields) and those who have not a lot of good ideas (who are not likely to be good at both fields). If there is no people who are good in both fields, there's no point to force them to focus; if there are no people who are good in only one field, but there are some people who are good in both fields, those who don't focus if you pay them a premium for focusing are likely to be good in both fields.

Limiting of the quantity of ideas in each topic by 2 is somewhat arbitrary. A natural extension is to assume a Poisson distribution for the quantity of good ideas, and assume an unlimited supply of not good ideas. Then the number of working papers that a CV contains can be endogenized: it needs to be such that more papers does not signal a better ability, because otherwise candidates without good ideas will emulate productive ones. Conditional on working on X papers, however, the economics of stimulating specialization will remain the same, albeit the thresholds might change.

[4] Here I provide a Google Sheets worksheet that contains formulas to obtain conditional probabilities studied in the Results. One can make a copy to try other idea generating processes, or introduce correlations.

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