Non-compete Covenants: Knowledge Spillovers, Hold-ups, and Economic Growth through Innovation

Nicolas Fernandez-Arias

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1 Introduction

There is a large literature considering the optimal enforcement of non-competes (for an excellent survey, see Marx & Fleming 2012). The general consensus that has emerged is that enforcement of non-competes is deleterious to the development of a vibrant labor market and startup culture. In fact, starting with Gilson 1999, many authors have ascribed Sililcon Valley's displacement of former high-tech hub Route 128 to California's blanket refusal to enforce such contracts.[1] This story receives support from a variety of empirical papers, exploiting both time-series and cross-sectional variation (across US states) in the enforcement of non-competes.[2]

One may be tempted to conclude from this body of work that non-compete agreements deter growth (I certainly am). Yet the evidence does not yet fully support this view. Especially in light of evidence from Marx et. al. 2015 that there is brain drain from enforcing states to nonenforcing states, the overperformance of non-enforcing jurisdictions could simply be redistribution of economic activity rather than aggregate economic growth.[3] More broadly, to date there has not been an aggregate welfare analysis using a workhorse general equilibrium macroeconomic model of long-run industry evolution.

There are three main questions that can in principle be answered with a general equilibrium model and not with the kinds of studies that have so far been conducted. First, welfare in an economy where all workers are bound by non-competes can be compared to welfare in an economy where non-competes are not enforced. Next, can we write a general equilibrium model with enforcing and non-enforcing regions which can reproduce the existing empirical evidence (i.e. brain drain causing differential performance). Finally, in reality, workers and jobs are heterogeneous, so that in certain cases non-competes have relatively more pros than cons. In this vein, one can ask the question: to what extent does the market endogenously

[1] Citation.

[2] Cite relevant literature here.

[3] Need to do back-of-the-envelope calculation with estimates from that paper.

assign / enforce non-competes to workers whose consequent lack of mobilty is on balance relatively less harmful to the aggregate economy?[4]

The contribution of this paper is to provide a theoretical framework for conducting an analysis of the first question above. I develop a model based on Klette & Kortum 2004 (itself a modification of Hopenhayn 1992), endogenizing knowledge spillovers by way of worker flows. To perform this analysis the model must be rich enough to include the various decisions by employers and employees that can be distorted by the presence of non-competes. These include firm investments in R&D, firm investments in the worker's human capital, and employee's investments in their own human capital. [5]

The paper connects three literatures: (1) the work on the contribution of entrants / incumbents to aggregate growth. Haltiwanger et. al. 2015, Akcigit & Kerr 2017[6], Acemoglu & Cao (sp?) 201x; and (2) the work on spillovers / startups due to employee flows such as Franco & Filson 2006, Klepper & Sleeper, and others; and (3) the more general literature on industry dynamics and the effects on growth of changing rates of entry and reallaction (c.f. Acemoglu, Akcigit et. al. "Investment Reallocation and Growth", Klette & Kortum itself, and so on).

Franco & Filson 2006 ([10]) shows that, in a similar setup, the competitive equilibrium is Pareto optimal. The logic is essentially that spinning out is a weakly positive sum game; as a result, employees will be willing to take lower wages that exactly compensate (or even more than fully compensate) the incumbents for the leaking knowledge. To break this result (and create a need, either individually or in aggregate, for noncompete agreements), we need to make spinouts a negative-sum game. This can be accomplished in multiple ways. Workers can be made risk-averse (they compete with other spinouts, and cannot insure against this idiosyncratic risk); financial frictions can be introduced to make spinning out more costly; firms can have private information about the quality of knowledge the worker will learn (many ways to model this) – adverse selection problem leads to market unraveling, which is the just the same thing as everyone being bound by non-competes. [7]

Finally, can this model be used to explain any macroeconomic series, such as the decrease in dynamism (specifically, decrease in short-term jobs)? Well, an increase in the use of non-competes certainly *could* in principle, but I don't think it's a decrease in the turnover rate of high-skill jobs that's really causing this shift. It seems like it's short-term work (potentially the rise of temp agencies etc.) that does this. Plus, I'm not really that interested in this...sure, that would make this a more traditional "macro-labor" paper, but whatever...this is a legitimately interesting question, in my opinion, and my model is a step

[4] e.g. principal agent problems "Should you make your employee sign a non-compete" paper.

[5] The model, by necessity, must have many parameters or assumptions (about relationships between the fewer assumed parameters). There is no way around this. I will offer some guidance as to how to obtain empirical discpiline on these parameters. My hope is that the policy prescriptions to emerge from my analysis will depend in a clear way on certain key elasticities, which will suggest a future path for research to uncover these for different industries.

[6] They actually suggest using their model to study non-compete enforcement, but they only have in mind startups, not workers moving around across incumbents. Moreover, I had this idea before I finished reading their paper...

[7] In general this could require a wage of zero (e.g., unpaid internships) or even a negative wage (e.g., funding your own PhD).

closer to knowing the answer than anything out there..

2 Data

Want to match the firm size distribution, the entry rate, the firm growth rate as a function of age and size, and, ideally, rates of workers moving from incumbents to start-ups or competitors. Need to think about this more - really, will need to work out the model to see what kinds of moments can identify the relevant parameters.

3 Model

Akcigit & Kerr 2017 (AK) assume a representative agent and push all heterogeneity into heterogeneity of *firms* in their economy. Then the representative agent simply holds a portfolio of all firms in the economy. This is not quite microfounded in the sense that the agents should then have an incentive to instruct all of the firms to collude with each other, and hence each firm wouldn't be maximizing its own *individual* profit. In other words, creative destruction externalities would be internalized. So they have simply abstracted away from firm ownership, but continue to assume that individual firms maximize their own profits.

This trick works in AK because knowledge is embodied in the *firm.* However, the whole point of my model is that workers have the knowledge, and worker flows are what is behind knowledge spillovers. Thus, I need to have knowledge embodied in workers. Each worker will have a set of intermediate goods that he is capable of "teaching" a firm how to produce. Therefore there will be a bunch of different wages and value functions to compute, it seems completely infeasible.

3.1 Preferences and Final Good Technology

(The exposition below mirrors AK).

There is a continuum of individuals indexed by $i \in [0, 1]$. Each individual maximizes[8]

$$U = \int_0^\infty \exp(-\rho t) C(t) dt$$

Each individual is endowed with one unit of labor that it supplies to the market inelastically. Individuals can also form intermediate goods firms (described below).

[8] AK uses log preferences, but I don't think it affects results (other than changing $r = \rho$ to $r = \rho + \dot{C}/C$)

Individuals consume a unique final good $Y(t)$. The final good is produced by labor and a continuum of intermediate goods $j \in [0,1]$ with production technology[9]

$$Y(t) = \frac{L^{\beta}(t)}{1-\beta} \int_0^1 q_j^{\beta}(t) k_j^{1-\beta}(t) dj$$

Here, $k_j(t)$ is the quantity of the intermediate good j and $q(t)$ is its quality. Normalize the price of the final good $Y(t)$ to be one in every period without loss of generality. The final good is produced competitively with input prices taken as given. From now on, the time index t will be supressed where it causes no confusion.

There is a measure F of incumbent firms producing intermediate goods in equilibrium[10]. We assume that each good $j \in [0,1]$ is produced with a linear technology,

$$k_j = \overline{q} l_j$$

where $\overline{q}$ is the average quality level in the economy. Borrowing Assumption 1 from AK, only the leader in good j will produce good j at any given time.[11]

[Fixed cost of operation $\phi \overline{q}$ in terms of final good at firm level]

Individuals can supply labor in three capacities: final good production (L), intermediate good production ($\tilde{L}$), and R&D ($\hat{L}$). The labor market satisfies

$$L_t + \tilde{L}_t + \hat{L}_t \leq 1$$

If K is the total fixed cost paid by firms, the final goods resource constraint of the economy is

$$Y = C + K$$

3.2 Research & Development

3.2.1 Details

Incumbent firms undertake R&D to improve the quality of the product they sell. A flow input of

$$R_I(z) = \hat{\chi} z^{\hat{\psi}}$$

units of labor yields quality improvements at an instantaneous Poisson flow rate of z. When this occurs, q_j is multiplied by a factor $1 + \lambda > 1$.

[9] Requiring labor input for the final good simplifies the computation of equilibrium.

[10] Don't know if it's necessary to talk about the measure F here.

[11] This assumption implies that the price will be constant in q, but quantity sold will vary such that profit will scale with q_j. Alternatively, we could have assumed that $k_j = q_j l_j$. Then the CES demand structure would imply that $p_j = \frac{w}{(1-\beta)q_j}$. However, it would not necessarily imply that $k_j = k$ as in my 3rd year paper, since we have assumed that q_j^{β}, rather than q_j, enters the final good production function. Look into this eventually, it doesn't seem like an important detail. In both cases the growth rate of the economy is just the growth rate of $\overline{q}$.

For product lines j whose blueprints have not yet entered the public domain, an additional (endogenous, time-varying even on BGP) mass m_j of entrants perform R&D. A flow input of

$$R_E(z, q; \overline{q}) = (q/\overline{q})\hat{\omega} z^{\hat{\psi}}$$

units of labor yields (plus a fixed cost of ϕq units of the final good)[12] quality improvements at an instantaneous Poisson flow rate of z with step size λ. Note the presence of the fixed cost of producing $R\&D$ [13]

For product lines j whose blueprints have entered the public domain, an endogenous mass F_j of entrants (pinned down by free entry condition that expected flow profits equal ϕq) perform $R\&D$, with the same technology R_E.

3.3 Knowledge spillovers

3.3.1 Details

[ADD SPILLOVERS FROM ENTRANTS EMPLOYING R&D WORKERS AS WELL, IF POSSIBLE. COULD EVEN HAVE DIFF ABILITY TO ENFORCE NONCOMPETES]

An individual who supplies l_j units of R&D labor to either an incumbent producing machine line j of quality q (to invent quality $(1+\lambda)q$) – or a spin-out competing with this incumbent to invent $(1+\lambda)q$ – acquires the ability to "spin-off" and compete in thee R&D race at an instantaneous Poisson rate νl_j. [14][15] I conjecture that as soon as an individual acquires this knowledge, they will switch their R&D labor supply to a different machine line, since the wage will be pushed down by workers willing to work for less in order to acquire this knowledge. This means that

$$\dot{m}_j = \nu \hat{l}_j$$

where $\hat{l}_j$ is the amount of labor used for R&D in sector j.

3.4 Non-competes

In the version of the model with non-competes, workers will be unable to spin-out until T_c years after leaving employment at their employer.[16] During this time, the worker can work

[12] Alternatively, could have $R_E(z, q; \overline{q}) = (q/\overline{q})\hat{\omega} z^{\hat{\psi}} + \mathbf{1}_{\{z>0\}}\phi(q/\overline{q})$ to get an equivalent result.

[13] The presence of the factor $q/\overline{q}$ ensures that the rate of creative destruction $\tau(q/\overline{q}, m)$ is constant in $q/\overline{q}$ on the BGP. This simplifies the analysis by reducing $\tau(q, m)$ to $\tau(m)$.

[14] Making spillovers a function of R&D employment, not total employment, both (1) makes sense intuitively, and (2) keeps the intermediate goods firms' *good output* decision simple and static, simplifying the model significantly. Of course, their R&D decision will now be distorted by the effect of employment on knowledge leaks. But this is the kind of result we want in the model - spin-outs distorting R&D and growth.

[15] Why perform R&D instead of simply forming a competitor of the incumbent producing the machine of quality q_j? We can assume they learn how to make machine q_j and still preserve this behavior by adding something analogoous to Assumption 1 here as well. If any spin-out has to pay a small cost to play, and we assume that competition *within* machine line is Bertrand (why? why not?), then no one will spin-out until they discover a truly superior quality product.

[16] For tractability, will actually assume a Poisson process "shocks" the workers out of "employment restricted" status. Calibrate this shock so that the average non-compete is T_c years long.

in any other industry but not the industry he was previously working at. However, there is a significant probability that the knowledge will become fully public, reducing the payoff to potentially attaining knowledge.

3.5 Equilibrium

3.5.1 Production

Let θ denote the (exogenous) rate at which knowledge enters the public domain and let $\tau_t(q_j, m_j)$ denote the (endogenous) rate at which a new spinoff is formed in product line j, given the efforts of the mass m_j of potential entrants. Let $\pi_t(q_j)$ denote the time-t flow profit to an incumbent with quality q_j (given optimal monopolistic competition pricing). Let $A_t(q_j, m_j)$ denote the time-t value of a frontier firm producing a good of quality q_j and mass m_j of potential entrants.[17] Then $A_t(q, m)$ satisfies the HJB

$$\begin{aligned}
\big(r + \theta + \tau_t(q,m)\big)A_t(q,m) &= \partial_t A_t(q,m) + \max_z \pi_t(q) + \theta B_t(q) + z\Big[A_t((1+\lambda)q, m) - A_t(q,m)\Big] \\
&\quad + \partial_m A_t(q,m)\dot{m}(z) - w_t(q,m)R_I^t(z,q) \\
&= \partial_t A_t(q,m) + \pi_t(q) + \theta B_t(q) \\
&\quad + \max_z \Big\{ z\Big[A_t((1+\lambda)q, m)) - A_t(q,m)\Big] \\
&\quad + \partial_m A_t(q,m)\nu R_I^t(z,q) - w_t(q,m)R_I^t(z,q)\Big\}
\end{aligned}$$

The FOC for maximization is

$$\overbrace{A_t((1+\lambda)q, m) - A_t(q,m)}^{\text{Marginal benefit}} = \overbrace{w_t(q,m)\partial_z R_I^t(z,q)}^{\text{Direct wage cost of R\&D}} - \overbrace{\partial_m A_t(q,m)\nu \cdot \partial_z R_I^t(z,q)}^{\text{Indirect cost of knowledge spillovers}}$$

Since $\partial_m A_t(q,m) < 0$ (obvious), this implies that there will be underinvestment in R&D relative to standard model. This force for underinvestment will be more severe the higher is the rate of knowledge spillover ν. This of course doesn't imply growth will be lower with more knowledge spillovers, since less R&D by incumbents could easily be offset by more R&D by entrants.

Let $\sigma_t(q_j)$ denote the (endogenous) rate at which startups are formed once knowledge q_j is in the public domain. Let $B_t(q_j)$ denote the time-t value of a quality q_j frontier firm whose knowledge has entered the public domain. Then $B_t(q)$ satisfies the HJB

$$\big(r + \sigma_t(q)\big)B_t(q) = \pi_t(q) + \partial_t B_t(q)$$

[17] In general, A_t would also depend on j. However, j only affects the value through q_j and m_j so we can drop the j superscript on A and write simply $A_t(q, m)$. Later, we will normalize by the average quality level in the economy and show that $A_t(q,m) = Q_t A(q/Q_t, m)$.

Maximization in the final goods sector and by the producers yields (see AK)

$$w = \tilde{\beta}\overline{q}$$

where

$$\tilde{\beta} \equiv \beta^{\beta}[1-\beta]^{1-2\beta}$$

3.5.2 Individuals

Because individuals simply maximize the present-value of their consumption, and because their wages from supplying labor do not depend on their entrepreneurial efforts, we can simply think of the behavior of individuals as resulting from the separate maximization of the utilization of their various forms of capital: their time and their knowledge.

Individuals supply labor to production of the intermediate goods as well as to R&D. Therefore, the flow value that a worker receives from R&D employment must be equal to the wage rate for intermediate goods production,

$$w = \tilde{\beta}\overline{q}$$

3.5.3 Spin-outs

Let $W_t^{NC}(q,m)$ denote the value to an individual of having acquired the technology to form a spin-out in a machine line of current quality q and mass of competing entrants m, but bound by a non-compete agreement. Let $W_t^F(q,m)$ denote the value to an individual once the non-compete has expired (F for "Free-agent"). Individuals flow out of competition restriction at instantaneous Poisson rate $\upsilon = 1/T_c$.[18] Recall that ideas enter the public domain at rate θ and are improved upon at rate $\tau_t(q,m)$. In both of these events, the value to an individual with the technology goes to zero: in the former case, due to free entry; in the latter case, due to Assumption 1. Further, recall that $\dot{m}$ is proportional to $\hat{L}_j$, and let $\hat{L}_t(q,m)$ denote the equilibrium labor allocation. Therefore, $W_t^{NC}(q,m)$ satisfies the HJB

$$(r+\theta+\tau_t(q,m)+\upsilon)W_t^{NC}(q,m) = \upsilon W_t^F(q,m) + \partial_m W_t^{NC}(q,m)\hat{L}_t(q,m) + \partial_t W_t^{NC}(q,m)$$

I assume that R&D workers employed by spin-outs learn at the same rate as those employed by incumbents. Therefore they earn the same wage $w_t(q,m)$ whether employed by incumbents or spin-outs. Therefore, $W_t^F(q,m)$ satisfies the HJB

$$\begin{aligned}\big(r+\theta+\tau_t(q,m)\big)W_t^F(q,m) \quad &= \quad \max_z \Big\{ z\big[A_t((1+\lambda)q,0) - W_t^F(q,m)\big] - w_t(q,m)R_E(z)\Big\} \\ &\quad\; +\partial_m W_t^F(q,m)\nu(\hat{L}_t(q,m)+mL_t^E(q,m)) + \partial_t W_t^F(q,m)\end{aligned}$$

and $z_E(q,m)$ is the argmax. Note that, in contrast with the incumbent, individual spin-out does not take into account the effect of its level of employment on the spillovers of

[18] This ensures that the average length of a non-compete is T_c years.

knowledge. This is because each individual spin-out is infinitesimal relative to the entire mass of spin-outs or to the mass of the incumbent. **[make sure this makes sense].**

The effective flow wage received by a worker, including the flow value of the possibility of acquiring valuable knowledge, is given by

$$w(q,m) + \nu W_t^{NC}(q,m)$$

Due to Inada conditions on the R&D technology, we know we will have an interior solution. Therefore workers must be indifferent between supplying R&D to each type, and hence

$$w_t(q,m) + \nu W_t^{NC}(q,m) = \tilde{\beta}\overline{q}_t$$

3.5.4 BGP

Let $\tilde{q} = q/\overline{q}$. In this section, I look for a balanced growth path with a stationary joint distribution of $(\tilde{q},m)$; where policies are functions of $(\tilde{q},m)$ and invariant over time[19]; and where Q, wages, and value functions all grow at exponential rate γ.

First, recall that $\pi_t(q) = \pi q$. Suppose we are on a BGP with growth rate g and $B_t(q) = e^{gt}\tilde{B}(\tilde{q})$. Then

$$\partial_t e^{gt}\tilde{B}(e^{-gt}q) = ge^{gt}\tilde{B}(\tilde{q}) - ge^{gt}\tilde{q}\tilde{B}'(\tilde{q})$$

and the HJB becomes, after dividing by e^{gt} and rearranging,

$$\overbrace{(r+\sigma(\tilde{q})-g)}^{\text{Effective discount factor}} \quad \tilde{B}(\tilde{q}) \quad = \quad \underbrace{\pi\tilde{q}}_{\text{Flow profits}} \quad - \quad \underbrace{g\tilde{q}\tilde{B}'(\tilde{q})}_{\text{Obsolescence}}$$

Next, suppose $A_t(q,m) = e^{gt}\tilde{A}(\tilde{q},m)$. Then

$$\partial_t e^{gt}\tilde{A}(\tilde{q},m)] = ge^{gt}\tilde{A}(\tilde{q},m) - ge^{gt}\tilde{q}\partial_q\tilde{A}(\tilde{q},m)$$

and the HJB becomes

$$\begin{aligned}
\big(r+\theta+\tau(\tilde{q},m)-g\big)\tilde{A}(\tilde{q},m) \quad = \quad & \overbrace{\pi\tilde{q}}^{\text{Flow profit}} \quad + \quad \overbrace{\theta\tilde{B}(\tilde{q})}^{\text{Knowledge becomes public}} \quad - \overbrace{g\tilde{q}\partial_q\tilde{A}(\tilde{q},m)}^{\text{Obsolescence}} \\
& + \max_z \Big\{ \underbrace{z\big[\tilde{A}((1+\lambda)\tilde{q},m) - \tilde{A}(\tilde{q},m)\big]}_{\text{Expected flow capital gain from R\&D}} \\
& + \quad \underbrace{\partial_m\tilde{A}(\tilde{q},m)\nu R_I(z)}_{\text{Knowledge spillover cost of R\&D}} \quad - \underbrace{w(\tilde{q},m)R_I(z)}_{\text{Direct cost of R\&D}} \Big\}
\end{aligned}$$

Next, consider the value function $W_t^{NC}(q,m), W_t^F(q,m)$. Supposing $W_t^{NC}(q,m) = e^{gt}\tilde{W}^{NC}(\tilde{q},m)$

[19]Hence so are endogenous variables such as $\tau_t(q,m)$.

and $W_t^F(q,m) = e^{gt}\tilde{W}^F(\tilde{q},m)$, have

$$\begin{aligned} \partial_t[e^{gt}W^{NC}(e^{-gt}q,m)] &= ge^{gt}W^{NC}(e^{-gt}q,m) - ge^{gt}\tilde{q}\partial_{\tilde{q}}W^{NC}(e^{-gt}q,m) \\ \partial_t[e^{gt}W^{F}(e^{-gt}q,m)] &= ge^{gt}W^{F}(e^{-gt}q,m) - ge^{gt}\tilde{q}\partial_{\tilde{q}}W^{F}(e^{-gt}q,m) \end{aligned}$$

The HJBs become

$$\begin{aligned} (r+\theta+\tau(\tilde{q},m)+v-g)\tilde{W}^{NC}(\tilde{q},m) &= \overbrace{ve^{gt}\tilde{W}^F(\tilde{q},m)}^{\text{Expiry of non-compete}} + \overbrace{\partial_m\tilde{W}^{NC}(\tilde{q},m)\hat{L}_t(q,m)}^{\text{Loss of rents due to knowledge spillovers}} \\ &\quad - \underbrace{g\tilde{q}\partial_{\tilde{q}}\tilde{W}^{NC}(\tilde{q},m)}_{\text{Obsolescence}} \\ (r+\theta+\tau(\tilde{q},m)+v-g)\tilde{W}^{F}(\tilde{q},m) &= \overbrace{\max_z\left\{z\left[\tilde{A}((1+\lambda)\tilde{q},0) - \tilde{W}^F(\tilde{q},m)\right] - w(\tilde{q},m)R_E(z)\right\}}^{\text{(Net) flow value from R\&D}} \\ &\quad + \underbrace{\partial_m\tilde{W}^F(\tilde{q},m)\hat{L}(\tilde{q},m)}_{\text{Loss of rents due to knowledge spillovers}} - \underbrace{g\tilde{q}\partial_{\tilde{q}}\tilde{W}^F(\tilde{q},m)}_{\text{Obsolescence}} \end{aligned}$$

3.5.5 Stationary joint distribution of q and m

There is clearly no stationary distribution of q. But maybe of q/Q? Even then, not clear - it could spread out over time due to memorylessness. But whatever, just try to calculate, given $\theta, \tau_t, z_I(q,m), z_E(q,m), \tilde{z}_E$ ($\tilde{z}_E$ is the rate of innovation by entrants once the idea is in the public domain).

4 Quantitative Analysis

4.1 Computer Algorithm 1

I solve the model as a fixed point over the growth rate g. The computational loop has the following steps:

1. Guess a growth rate g.
   (a) Guess a creative destruction rates τ_0, σ, as well as a guess of a wage function $w(\tilde{q},m)$ (and known w wage for final goods labor and for R&D labor for ideas in public domain).
      i. Solve for $z_I(\tilde{q},m), A(\tilde{q},m), B(\tilde{q})$ given σ and $\tau(\tilde{q},m) = m\tau_0$ and $w(\tilde{q},m)$.
         A. Solve for $z_E(\tilde{q},m), \tilde{z}_E$ given $A(\tilde{q},0)$. (No way to really simplify...)
         B. Set $F = \sigma/\tilde{z}_E$.
      ii. Check consistency of $\tau_0, \sigma, w(\tilde{q},m)$ guesses by updating to new τ, σ values according to:
         A. $\tau_0^+ = z_E$

B. Public domain free-entry condition: $\tilde{z}_E A((1+\lambda)\tilde{q}, 0) - wR_E(\tilde{z}_E, \tilde{q}) = \phi\tilde{q}$ (guaranteed to hold for some $\tilde{z}_E$, and same $\tilde{z}_E$ for each $\tilde{q}$ as well) and set $\sigma^+ = F$

C. R&D labor indifference condition: $w(\tilde{q}, m) = \tilde{\beta} - \nu\tilde{A}((1+\lambda)\tilde{q}, m)$

iii. If not converged, go to step (1ai).

(b) Given $\tau, \sigma, z_I(\tilde{q}, m)$, compute stationary joint distribution $\mu(q, m)$, using KF equation.

(c) Update growth rate using $g = \lambda(\int_0^\infty \sigma(q)\mu(q,0)dq + \int_0^\infty \tau(q,m)\mu(q,m)dqdm)$.

(d) If not converged, go to step (1a).

4.2 Computer Algorithm 2

1. Guess a growth rate g

   (a) Guess an R&D labor allocation, $\hat{L}(q, m)$

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