Endogenous Heterogeneous Innovation

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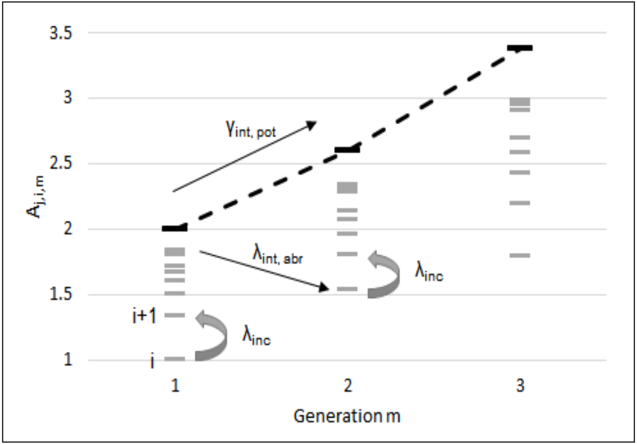
March 7, 2018

Theory Outline

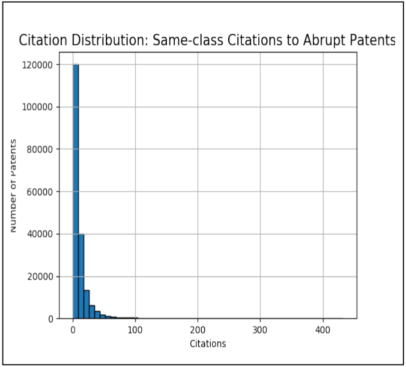
- Akcigit and Kerr (2016) included two different types of innovation (incremental and external abrupt). Firms can't do internal abrupt innovation (ex: no internal new product generation) and internal R&D has no diminishing returns.
- We want to endogenize those features. Firms choose how much to invest in internal abrupt or incremental innovations.
- We attempt to fit this model to patent citation distributions. The fit gives an impression of how well the model reflects reality. Also, the resulting parameter values have important theoretical interpretations.

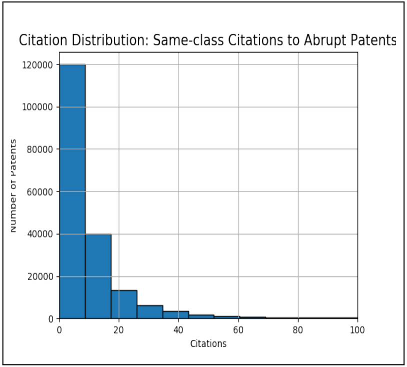
Framework - Innovation

Focus: Innovation: internal (incremental or abrupt), external, and entrants (the last two only abrupt).



Data - Patent Citation Distributions





Summary: # obs = 189,207; Mean = 10.06; Std. Dev. = 18.43

Theoretical Assumptions Regarding Patent Citations

- An abrupt patent is cited by every subsequent innovation within its technology cluster.
- Technology clusters are all contained within a patent classification.
- Abrupt patents will have a large number of citations overall (within and outside of their patent classifications)
- We need to choose a cutoff for distinguishing abrupt patents. The default is 10%. Later we test the robustness of our estimates to changes in this cutoff.

Parameters

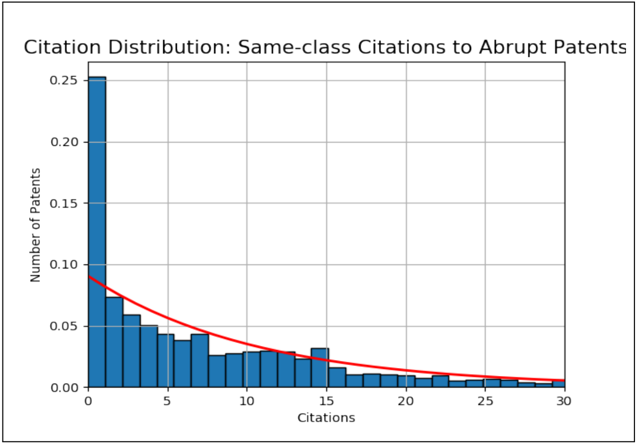
- Three parameters to estimate $\{\alpha, \lambda_{inc,0}, \lambda_{abr} + \tau\}$
- α relates to the diminishing returns of incremental innovations. A low α means that the step-size decreases very quickly. $\alpha = 1$ means that step sizes are constant.
- $\lambda_{inc,0}$ is the rate of incremental innovations for new technology clusters. It is actually a function of the exogenous parameters $\{D, \sigma, \varphi, \xi\}$, which cannot be separated using citation distributions.
- $\lambda_{abr} + \tau$ is the total arrival rate of abrupt innovations. It is also a function of exogenous parameters.

Estimation Strategy

- First the parameters $\{\alpha, \frac{\lambda_{inc,0}}{(\lambda_{abr}+\tau)}\}$ are estimated using MLE on the abrupt, same-class citation distribution.
- Next the absolute values of $\lambda_{inc,0}$ and $\lambda_{abr} + \tau$ are determined using Compustat data on R&D intensity ($=$ R&D expenditure/Sales).

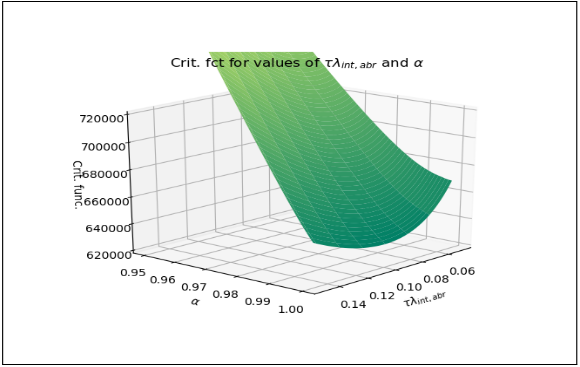
Estimation Results

- $\alpha = 1$, $\lambda_{int,0} = 0.357$, $\lambda_{abr} + \tau = 0.0355$



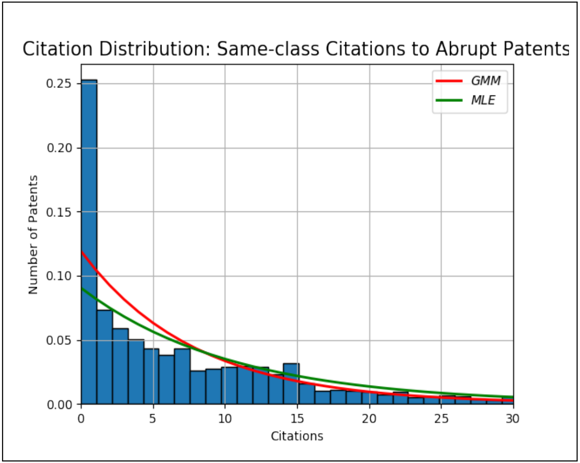
Confidence in global optimum

- The result is robust to changes in initial conditions.
- "Basin Hopping" confirms the minimum.
- We tried fixing α and running an unconstrained optimization. This gave the same results.



Robustness

- We ran a GMM estimation: $\alpha = 1$, $\lambda_{int,0} = 0.351$, $\lambda_{abr} + \tau = 0.047$



Robustness - GMM

- Moments (GMM):

Moment	Data	Model
Mean of citations	10.06	7.39
Mean of first 5 seq. ratios	0.57	0.88
Sum of first 2 bins	0.26	0.22
R&D Intensity	0.068	0.068
Criterion		0.386

- Untargeted moment: share of incremental R&D over total:

Moment	Data	Model
MLE		
Incremental/total	.90	.91
GMM		
Incremental/total	.90	.88

Robustness Results

- When the cutoff for abrupt patents is adjusted, we get similar results.

Robustness Specification Results

Abrupt Cutoff	.1	.2	.05
$\lambda_{inc,0}$	.357	.362	.347
$(\lambda_{abr} + \tau)$	.0355	.0239	.0568
α	1.0	1.0	1.0

Robustness Results

- We tried relaxing the assumption that abrupt patents are cited by every incremental patent in their technology cluster. Results were identical.

Robustness Specification Results

	Baseline	Flexible
$\frac{\lambda_{inc,0}}{(\lambda_{abr}+\tau)}$	.104	.104
α	1.0	1.0
p	-	1.0
log-likelihood	-627597	-627598

Conclusion

- The model fits most of the citation distribution, but badly underestimates the number of patents with zero citations.
- No evidence was found for an important feature of the model: the diminishing return from incremental innovations.
- We are confident, given our theoretical specification, that we have found the parameters that maximize the log-likelihood.
- Our results pass a number of robustness checks.
- However, many key theoretical assumptions are still unchecked.

References

[1] Acemoglu, D., Akcigit, U., and Celik, M. A. Young, restless and creative: Openness to disruption and creative innovations. Working Paper 19894, National Bureau of Economic Research, 2014.

[2] Akcigit, U., and Kerr, W. R. Growth through heterogeneous innovations. forthcoming, 2016.

[3] Klette, T. J., and Kortum, S. Innovating firms and aggregate innovation. *Journal of Political Economy 112*, 5 (2004), 986–1018.

[4] Philippe Aghion, C. H. P. H., and Vickers, J. Competition, imitation and growth with step-by-step innovation. *Review of Economic Studies 68*, 3 (2001), 467–492.

Appendix: Framework - Innovation

- Law of motion ($A_{m+1} = A_m \gamma_{int,pot}$):

$$A_{t+\Delta t} = \begin{cases} A_m(1-\alpha^s) \ , \ \lambda_{inc}\Delta t \ , \ \alpha \in (0,1) \ , \ \ s \in \{1,2,...\} \\ A_t \gamma_{int,abr} \ , \ \lambda_{int,abr}\Delta t \\ A_t \ , \ \left[1-\lambda_{inc}\Delta t; 1-\lambda_{int,abr}\Delta t\right] \end{cases}$$

- Incremental R&D cost: $\psi_{inc}(\lambda_{inc}, A_t) = \xi_j A_t \lambda_{inc}^{\eta}$
- Catching-up: laggards pay $\psi_{inc}(\lambda_{inc}, A_t)$ and get an arrival $\lambda_{inc} + h$;
- Abrupt R&D cost (for $n_p > 0$): $\psi_{abr}(\lambda_{ext,abr}, \bar{A}_t) = \xi_j \bar{A}_t \lambda_{ext,abr}^{\eta}$, $\bar{A}_t$ sector average;
- Cournot competition: profits π_t scale with $\frac{A_{j,i,m}}{\sum_j A_{j,i,m}}$ within an industry.

Appendix: Framework - Innovation

Outside entrepreneur:

- Value function:
  $rV_0 - \dot{V}_0 = \max_{\lambda_{ext,abr}} \Big[\lambda_{ext,abr}\big[E_j\big[V(A_{t,m+1})\big] - V_0\big] - v\bar{A}_t\lambda_{ext,abr}\Big]$
- Cost: $C_E(\lambda_{ext,abr}, \bar{A}_t) = v\bar{A}_t\lambda_{ext,abr}$, v a constant;
- Free entry condition: $E_j\big[V(A_{t,m+1})\big] = v\bar{A}_t$
- $\Rightarrow$ Each firm faces an aggregate endogenous creative destruction (CD) of rate τ_{CE} and internal competition rate τ_I.

Appendix: Framework - Innovation

Incumbents:

- Value function: $rV(A_t) - \dot{V}(A_t) =$

$$\max_{\substack{\lambda_{inc},\, \lambda_{int,abr} \\ \lambda_{ext,abr}}} \left[\sum_{k}^{n_{j,p}} \left[\begin{array}{c} \pi_t n_{j,p} - \{\xi_j \lambda_{inc}^{\eta} A_{t,m}; \xi_j \bar{A}_t \lambda_{int,abr}^{\eta}\} \\ + \{\lambda_{inc}\left[V(A_{t,m}^{k-} \cup A_{t+\Delta t,m}^{k}) - V(A_{t,m})\right]; \\ \lambda_{int,abr}\left[E_j\left[V(A_{t,m}^{k-} \cup A_{t+\Delta t,m+1}^{k}\right] - V(A_{t,m})\right]\} \\ - \tau_I\left[V(A_{t,m} \setminus \bar{A}_{t+\Delta t,m}^{k}) - V(A_{t,m})\right] \\ - \tau_{CE}\left[V(A_{t,m} \setminus \bar{A}_{t+\Delta t,m+1}^{k}) - V(A_{t,m})\right] \end{array} \right] \begin{array}{c} \\ + \lambda_{ext,abr}\left[E_j\left[V(A_{t,m}^{k} \cup A_{t+\Delta t,m+1}^{k'}\right] - V(A_{t,m})\right] \\ - \xi_j \bar{A}_t \lambda_{int,abr}^{\eta} - \Phi \bar{A}_t \end{array} \right]$$

- 1st: instant returns - costs;
- 2nd, 3rd: return from int. R&D;
- 4th: internal competition;
- 5th: external CE;
- 6th: return from abr. R&D;
- 7th: Abr. R&D and fixed costs;