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Spillover Effects of the Opioid Epidemic on Labor and Innovation

By Dimitris Petmezas (Durham University)

With
Christodoulos Louca (Cyprus University of Technology)
Roni Michaely (University of Hong Kong and ECGI)

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BACKGROUND

- Opioid abuse is a ***global epidemic*** which has reached unprecedented levels in the U.S., with an estimated 10.1 million people (or 3.7% of the U.S. population) misusing opioids (National Survey on Drug Use and Health, 2019).

  - Such a phenomenon has led to a dramatic rise in emergency department visits (Centers for Disease Control and Prevention, 2020) and a record number of deaths.

MOTIVATION

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- Beyond such tragic effects on health and mortality rates, the opioid epidemic also has enormous ***direct*** – i.e., through personal addiction – **economic consequences** (Florence, Luo, and Rice, 2021).
  - Addiction to opioids leads to declining labor force participation, mostly concentrated among less educated, blue-collar individuals (Krueger, 2017).
  - This, in turn, has adverse effects for firm value and investments (Ouimet, Simintzi, and Ye, 2021), the housing market (Custodio, Cvijanovic, and Wiedemann, 2022) and access to finance of affected municipalities (Cornaggia, Hund, Nguyen, and Ye, 2022).

- Less is known, however, ***whether opioid abuse have significant spillover effects on non-addicted participants*** in the labor market and, if so, what the potential implications are for firms.

- ***Spillover* effects** on non-addicted individuals could arise ***because of actions of the addicted individuals***.
  - For instance, due to lower productivity or even job loss, addicted individuals are exposed to greater economic difficulties.
    - Not only their compensation is reduced, but they may also face increasing needs to secure finances to procure substances, something that may lead to illicit market activities and crime (e.g., Maclean, Mallatt, Ruhm and Simon, 2022).

- Such safety and security problems ***make an area less appealing to live and work at***, and adversely affect the quality of life of individuals who are not addicted, which may ***prompt them to move away and live elsewhere***.

OBJECTIVE

- The objective of this study is to investigate whether the opioid epidemic affects firms in a setting where outcomes are unlikely to be driven by personal addiction: ***corporate innovation*.**

- This setting has **two** main advantages.

1) Innovation is typically generated by creative and well-educated individuals. Such individuals are ***unlikely to make use of opioids*** (Case and Deaton, 2020).
    - In this respect, **any effect of the opioid epidemic on corporate innovation should be *indirect***, and thus, distinct from prior literature which focuses on firm implications arising from the direct effect of addicted individuals.

2) Innovation inputs, such as inventors, and outcomes, such as patents, are externally observable and important to firms' long run growth (e.g., Fich, Nguyen, and Petmezas, 2022).
   - ❑ Thus, we ***can zoom-in*** on inventors by tracking them over time.
   - ❑ This is **helpful to understand spillover effects** of the opioid epidemic on firms, such as those reflected in corporate innovation and inventor mobility.

WHAT WE DO IN THIS PAPER – MAIN RESULT (1)

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To establish the causal effect of the opioid epidemic on corporate innovation ***we employ two separate and independent methods***.

1) We use an ***exogenous positive supply shock in opioid distribution*** to instrument opioid mortality (Cornaggia et al., 2022).
    - ❑ The instrument is based on the supply of a variety of opioids with the highest (i) addictive potential and (ii) desirability to addict, through distribution channels that exhibit little oversight.
    - ❑ Cornaggia et al. (2022) show that this *supply chain* instrument is highly correlated with the opioid mortality rates.
- ❑ We measure corporate innovation using patents, citations and innovation value (Seru, 2014; Kogan, Papanikolaou, Seru, and Stoffman, 2017).
- ❑ We find that firms in **counties associated with opioid abuse** experience a ***decrease*** **in corporate innovation** driven by migration of high skilled labor.
    - ❑ Economically, the effect of opioid abuse on corporate innovation is substantial (**annual reduction of about -10.8% in the number of patents**)

2) We complement the instrumental variable analysis using ***a quasi-natural experiment*** that exploits the ***adoption of state-level legislation which aims at limiting opioid prescriptions***.
   - ❑ The passage of these laws is not related to the economic environment and the political economy with the probable exception of opioid overdose death rate (Ouimet et al., 2021).
   - ❑ Therefore, the timing of these laws is plausibly exogenous to corporate innovation, creating an effective setting to examine whether the passage of these laws affects corporate innovation.

- ❑ Using a difference-in-differences analysis, we find a ***positive impact*** (i.e., the mirror image of our previous findings), providing further support for the causal interpretation of opioid epidemic effects on corporate innovation.
  - ❑ Economically, after the passage of the laws, firms in the affected states experience ***a 15.5% increase in the number of firm patents*** relative to the innovation of rival firms in unaffected states.

The **setting** of these two experiments is **not only independent but also allows us to test whether the effect is symmetric**.

- The reason is that the state legislation is expected to have a **negative impact on opioid consumption** and the resulting supply shock is expected to ***lead to an increase in corporate innovation*** – which is what we find.

EXPLANATION OF THE RESULTS-INVENTOR MOBILITY (1)

- We explore the ***inventor mobility channel as a plausible mechanism*** in explaining the results.
- Particularly, we investigate whether the opioid epidemic *indirectly* affects the "industrial organization" of innovation by impeding a firm's ability to retain existing (productive) inventors and attract new ones.
- We use inventor-level data, which track individual inventors over time across two successive patent applications assigned to different firms.
  - We obtain a ***positive relation between the instrumented opioid mortality rates and out-of-county moves***, suggesting a causal link between opioid abuse and inventor mobility.
  - We also find a ***negative relationship between instrumented opioid mortality rates and within-county moves***, which suggests that if inventors move to another firm, it is less likely to move to firms within the same opioid-affected county.

EXPLANATION OF THE RESULTS-INVENTOR MOBILITY (2)

- We show that **moving inventors** are ***more (less) likely*** to move to a ***lower (higher) crisis county***.

- Concentrating particularly on the characteristics of relocating inventors, we find that ***more productive (so-called "star") and younger inventors*** who face lower adjustment costs are more likely to relocate to a lower crisis county.
  - Hence, firms located in counties that are affected more by the opioid epidemic lose both their most productive inventors and youth creativity.

SAMPLE AND DATA - OVERVIEW

- We merge the opioid epidemic data and the innovation data with county characteristics from the U.S. Census, BEA and ARDA, and financial and accounting information from the CRSP and Compustat databases.
- Our firm-level sample excludes all firms without headquarters in the U.S. and with missing ZIP codes.
- We focus on innovative firms and, thus, exclude firm-years without positive R&D expenditures.
- Our inventor-level sample measures mobility focusing on active inventors, defined as inventors that filed at least one patent over the previous three years.

SAMPLE AND DATA - OPIOID

- Multiple Cause of Death data found in the **NCIPC of the CDC** .
  - As in Cornaggia et al. (RFS, 2022), we follow the 10th Revision (ICD-10) classifications by the International Classification of Diseases, to identify deaths caused by opioid.
  - The main variable of interest, ***Opioid Death***, is defined as the ***county drug overdose mortality rate per 100,000 residents***.

INSTRUMENT: OPIOID PRESCRIPTIONS & DISTRIBUTION CHANNELS

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- We ***instrument mortality rates*** using a supply chain variable that is ***based on information about prescriptions and distribution of opioids by type***.
  - We obtain the relevant information from the DEA, which collects data from manufacturers and distributors (https://www.slcg.com/opioid-data/) through the Automated Reports and Consolidated Ordering System (ARCOS).
- The data are comprehensive and contain information about every opioid pill sold in the U.S. during the period **2006-2014** for every retail distributor, including pharmacies, hospitals, etc.
- Because each opioid pill may exhibit different strength, following the public health literature, ***we convert their opioid strength using the Morphine Milligram Equivalent (MME) value***. Then, we use the retail distributor's zip codes to geolocate pills to counties.
- **Our instrument, *MME*, is defined as the county MME value per 100,000 residents.**

SAMPLE AND DATA - INNOVATION

- We use the patent dataset created by Stoffman et al. (2022).
- Due to data limitations in our instrument, ***our final sample covers the period 2007-2015*** and includes 2,951 firms with 15,178 firm-year observations.
- We construct **3 main measures of corporate innovation**:
  - The natural logarithm of one plus the number of ***patents*** filed (and subsequently granted) by a firm, in a given year.
  - The natural logarithm of one plus the number of ***citations*** across all patents filed by a firm, in a given year
  - ***Innovation quality***, defined as the natural logarithm of one plus the cumulative economic value (in millions of nominal U.S. dollars) of patents that a firm applies for each year.
- To measure **inventor mobility**, we check whether an inventor files two successive patent applications which are assigned to different firms. We create **4 variables**:
  - ✓ an out-of-county move,
  - ✓ a within-county move,
  - ✓ a move to a lower crisis county,
  - ✓ a move to a higher crisis county
- Our final sample includes 274,627 inventors with 629,763 inventor-employer-year observations.

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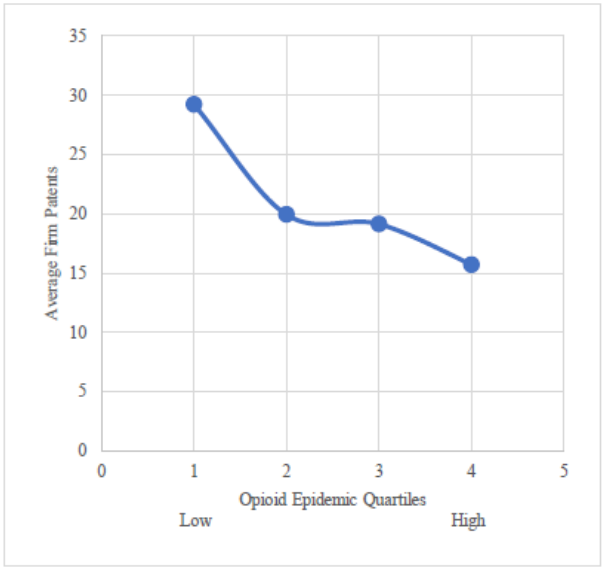
2-Stage Least Square Regressions:

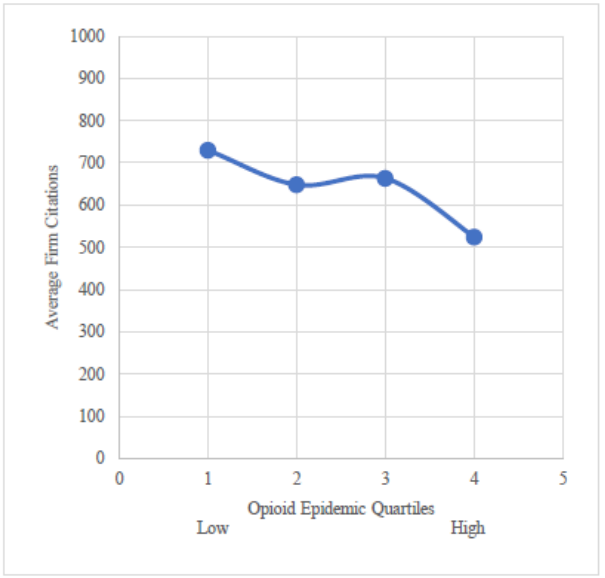
$$Ln(Opioid\ Deaths + 1)_{l,t} = a_0 + a_1 MME_{l,t} + \beta' X_{i,l,t} + \gamma' Z_{l,t} + a_h + a_t + u_{i,l,t} \quad (1)$$

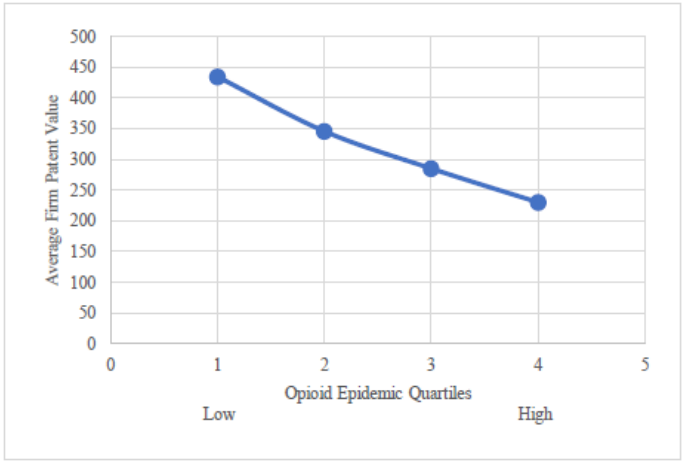
$$Ln(Y + 1)_{i,l,t+1} = \delta_0 + \delta_1 Ln(Opioid\ \widehat{Deaths} + 1)_{l,t} + \zeta' X_{i,l,t} + \eta' Z_{i,l,t} + a_h + a_t + \varepsilon_{i,l,t} \quad (2)$$

- where $Y_{i,l,t+1}$ are the dependent variables of interest – ***the corporate innovation measures*** – for firm *i*, located in county *l* in year *t+1*.
- The independent variable of interest is the **instrumented** $Opioid\ Deaths_{l,t}$ which captures the exposure to opioid epidemic in county *l* in year *t*.
- The coefficient δ_1 is the elasticity of corporate innovation with respect to opioid abuse
  - It measures the average difference in corporate innovation attributable to opioid abuse. The instrument is the supply chain *MME* for county *l* in year *t*.
- **Control Variables:** Ln (size), Tobin's Q, cash holdings, leverage, ROA, tangible assets, capital expenditures, Ln (firm age), Ln (county population), Ln (per capital personal income), educational attainment, religiosity and local seniors.

AVERAGE CORPORATE INNOVATION ACROSS OPIOID EPIDEMIC QUARTILES







THE IMPACT ON PATENTS, CITATIONS AND INNOVATION VALUE

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	First Stage	Second Stage		
	(1)	(2)	(3)	(4)
	Ln (Opioid Deaths)	Ln (#Patents+1)	Ln (#Citations+1)	Ln (Innovation Value+1)
Ln (MME)	0.042***			
	(0.003)			
Instrumented Opioid Deaths		-0.940**	-2.057**	-1.426**
		(0.040)	(0.021)	(0.042)
Ln (Size)	-0.002	0.486***	0.839***	0.815***
	(0.672)	(0.000)	(0.000)	(0.000)
Tobin's Q	0.001***	0.009***	0.015***	0.018***
	(0.009)	(0.000)	(0.000)	(0.000)
Cash Holdings	-0.036	0.738***	1.653***	0.932***
	(0.238)	(0.000)	(0.000)	(0.000)
Leverage	0.000	0.021	0.018	0.041**
	(0.939)	(0.112)	(0.432)	(0.042)
ROA	0.008**	-0.057***	-0.062***	-0.082***
	(0.011)	(0.000)	(0.000)	(0.000)
Tangible Assets	-0.005	0.178***	0.298***	0.219**
	(0.741)	(0.006)	(0.010)	(0.024)
Capital Expenditures	0.265*	0.937**	2.516***	1.896***
	(0.063)	(0.029)	(0.002)	(0.006)
Ln (Firm Age)	-0.005	0.134***	0.203***	0.205***
	(0.536)	(0.000)	(0.000)	(0.000)
Ln (Population)	0.007	0.116*	0.207*	0.176*
	(0.862)	(0.068)	(0.09)	(0.060)
Ln (Income Per Capita)	-0.334**	-0.384	-1.018*	-0.446
	(0.018)	(0.177)	(0.057)	(0.277)
Education	-0.228	-0.073	-0.117	-0.231
	(0.650)	(0.922)	(0.938)	(0.835)
Religion	-0.085	-1.127***	-2.018***	-1.682***
	(0.669)	(0.000)	(0.000)	(0.000)
Seniors	4.108***	4.615*	9.662*	7.721*
	(0.000)	(0.080)	(0.078)	(0.065)
Year Fixed Effects	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
Observations	15,178	15,178	15,178	15,178
Adjusted R^2	0.268	0.497	0.449	0.548

- ✓ Moving from the 25th to the 75th percentile of the instrumented opioid mortality leads to **2.27 fewer patents**.
- ✓ Given the unconditional average number of firm patents, which equals 21.07, **there is a 10.8% decline in the number of patents for firms in the high group.**

ROBUSTNESS CHECKS

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Panel A: Alternative measures of innovation	(1) Originality	(2) Generality	(3) Ln (#Citations/(#Patents+1)	(4) Ln (#Patents/Employees+1)
Instrumented Opioid Deaths	-0.213**	-0.140**	-1.187**	-1.108**
	(0.016)	(0.035)	(0.026)	(0.012)
Controls	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
Observations	15,178	15,178	15,178	14,928
Adjusted R^2	0.257	0.179	0.310	0.248

Panel B: Excluding M&A firms	(1) Ln (#Patents+1)	(2) Ln (#Citations+1)	(3) Ln (Innovation Value+1)
Instrumented Opioid Deaths	-0.975**	-2.093***	-1.405**
	(0.045)	(0.007)	(0.039)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Observations	6,831	6,831	6,831
Adjusted R^2	0.291	0.245	0.347

Panel C: Excluding financial crisis period	(1) Ln (#Patents+1)	(2) Ln (#Citations+1)	(3) Ln (Innovation Value+1)
Instrumented Opioid Deaths	-0.965**	-2.104**	-1.414**
	(0.037)	(0.017)	(0.039)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Observations	11,711	11,711	11,711
Adjusted R^2	0.524	0.400	0.524

DIFF-IN-DIFF ANALYSIS: LIMITING OPIOID PRESCRIPTIONS

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Panel A: After law passage effect

	(1) Ln (#Patents+1)	(2) Ln (#Citations+1)	(3) Ln (Innovation Value+1)
After Law Passage	0.144**	0.232***	0.196***
	(0.023)	(0.007)	(0.001)
Controls	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes
Industry x Year Fixed Effects	Yes	Yes	Yes
Observations	9,724	9,724	9,724
Adjusted R^2	0.872	0.819	0.877

Panel B: Evolution of the law passage effect

	(1) Ln (#Patents+1)	(2) Ln (#Citations+1)	(3) Ln (Innovation Value+1)
Law Passage $_{t=-2^-}$	-0.049	0.158	0.073
	(0.518)	(0.342)	(0.553)
Law Passage $_{t=-1}$	0.041	0.365**	0.157
	(0.610)	(0.035)	(0.180)
Law Passage $_{t=0}$	0.097	0.407**	0.239**
	(0.226)	(0.010)	(0.033)
Law Passage $_{t=+1}$	0.157*	0.505***	0.327***
	(0.065)	(0.002)	(0.004)
Law Passage $_{t=+2^+}$	0.248*	0.670***	0.448***
	(0.054)	(0.001)	(0.003)
Controls	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes
Industry x Year Fixed Effects	Yes	Yes	Yes
Observations	9,724	9,724	9,724
Adjusted R^2	0.873	0.819	0.878

- ✓ There is a **15.5% increase** in the number of firm patents (model 1).
- ✓ The magnitude is comparable to the -10.8% decline in the number of patents.

OPIOID EPIDEMIC AND INVENTOR MOBILITY: INVENTOR-LEVEL ANALYSIS

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	All Inventors		Only Moving Inventors			
	(1) Out-of-County Move	(2) Within County Move	(3) Move to a Lower Crisis County	(4) Move to a Higher Crisis County	(5) Move to a Lower Crisis County	(6) Move to a Higher Crisis County
Instrumented Opioid Deaths	0.046*	-0.033**	0.963***	-0.548***	0.952***	-0.550***
	(0.053)	(0.016)	(0.001)	(0.004)	(0.001)	(0.003)
Star &Young Inventors					-0.410*	-0.075
					(0.056)	(0.706)
Instrumented Opioid Deaths * Star & Young Inventors					0.178**	0.024
					(0.047)	(0.776)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	629,763	629,763	25,807	25,807	25,807	25,807
Adjusted R^2	0.006	0.008	0.159	0.061	0.159	0.061

- **Moving inventors** are ***more likely*** to move to a ***lower crisis county***.
- **Moving inventors** are ***less likely*** to move to a ***higher crisis county***.
- ***More productive (so-called "star") and younger inventors*** more likely to relocate to a lower crisis county.
  - Hence, firms located in counties that are affected more by the opioid epidemic lose both their most productive inventors and youth creativity

HETEROGENEOUS EFFECTS

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- We focus on **heterogeneous effects** of specific firms in which **inventor moves** would have **smaller (or larger) consequences on innovation** and investigate the relationship between opioid mortality rates and corporate innovation.

- ✓ **Importance of employees' input to innovation (R&D expenses/Employee)**
  - The negative impact of the opioid epidemic on corporate innovation is lower when the importance of an employee's input to innovation is low.

- ✓ **High firm's growth per employee (Difference between market capitalization and common shareholder's capital, scaled by number of employees)**
  - Opioid abuse has a lower impact on firms with lower growth opportunities

- ✓ **Project size/complexity (Size of the firm)**
  - Negative relation between the instrumented opioid mortality rates and corporate innovation, which becomes weaker when firms have lower ability to handle larger, more complicated projects.

CONCLUSIONS

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- Using a corporate innovation setting, this study provides new evidence of ***spillover effects*** of the opioid epidemic on firms (i.e., when personal addiction is unlikely to be the main driver).

- By employing a positive supply shock in opioid distribution to instrument opioid mortality, we show that ***firms in counties associated with opioid abuse experience declines in patenting, citations and innovation value***.

- Along this vein, using a difference-in-differences analysis which exploits the staggered passage of state-level opioid-limiting legislations, we show that ***states which passed such laws experience an increase in corporate innovation***.

Both results support causal effects of opioid abuse on corporate innovation.

CONCLUSIONS

- Consistent with an inventor mobility explanation, we find a **positive (negative) relation** between **opioid abuse and out-of-county (within-county) moves**.
  - Conditional on moving, inventors, particularly ***the star and young ones, move to counties that suffer less from the opioid epidemic***.

Hence, the opioid epidemic impedes firms' ability to retain existing (good) inventors and attract new ones, resulting in deteriorating corporate innovation.

- Heterogeneous analysis reveals that the **opioid epidemic is more detrimental** for firms:
  - when employees' input to innovation is higher,
  - when firms exhibit higher growth opportunities, and
  - when firms handle larger and more complex projects.

Thank you!

DEFINITIONS OF THE VARIABLES

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Dependent variables

Ln (#Patents+1) - The natural logarithm of the total number of patents that a firm applies for (and are subsequently granted) each year plus one. This variable is created using data from Stoffman, Woeppel, and Yavuz (2022). (see, https://www.mikewoeppel.com/data).

Ln (#Citations+1) - The natural logarithm of the total number of citations obtained on all patents that a firm applies for (and are subsequently granted) each year plus one. This variable is created using data from Stoffman, Woeppel, and Yavuz (2022). (see, https://www.mikewoeppel.com/data).

Ln (Innovation Value+1) - The natural logarithm of the cumulative dollar value of patents (in millions of 2005 nominal U.S. dollars) that a firm applies for each year plus one. A patent's value is measured as the firm stock return in excess of the market over the three-day window around the date of patent approval (*t, t+2*), multiplied by the firm's market capitalization on the day prior to the announcement of the patent issuance. The dollar value of each patent is obtained from Stoffman, Woeppel, and Yavuz (2022). (see, https://www.mikewoeppel.com/data).

Originality - One minus the Herfindahl concentration index of the number of cited patents across technological classes. We use the bias correction of the Herfindahl measures, described in Jaffe and Trajtenberg (2002), to account for cases with a small number of patents within technological categories. This variable is created using data from the NBER patent database *(https://www.nber.org/patents/)* and Bhaven Sampat's United States Patent and Trademark Office (USPTO) patent and citation database. (see, http://thedata.harvard.edu/dvn/dv/boffindata).

Generality - One minus the Herfindahl concentration index of the number of patents citing across technological classes. We use the bias correction of the Herfindahl measures, described in Jaffe and Trajtenberg (2002), to account for cases with a small number of patents within technological categories. This variable is created using data from the NBER patent database *(https://www.nber.org/patents/)* and Bhaven Sampat's United States Patent and Trademark Office (USPTO) patent and citation database. (see, http://thedata.harvard.edu/dvn/dv/boffindata).

Ln (#Citations/ #Patents+1) - The natural logarithm of citations obtained on all patents that a firm applies for (and are subsequently granted) scaled by the total number of patents that a firm applies for (and are subsequently granted) each year plus one. This variable is created using data from Stoffman, Woeppel, and Yavuz (2022). (see, https://www.mikewoeppel.com/data).

Ln (#Patents/ Employees+1) - The natural logarithm of the number of patents per 1,000 firm employees (EMP) plus one. This variable is created using data from Mike Woeppel's Website and Compustat.

Out-of-County Move - An indicator variable that takes the value of one if an inventor moves to another employer located in a different county, and zero otherwise. This variable is created using data from Stoffman, Woeppel, and Yavuz (2022). (see, https://www.mikewoeppel.com/data).

Within County Move - An indicator variable that takes the value of one if an inventor moves to another employer located in the same county as her previous employer, and zero otherwise. This variable is created using data from Stoffman, Woeppel, and Yavuz (2022). (see, https://www.mikewoeppel.com/data).

Move to a Lower Crisis County – It is based on the difference in drug overdose mortality rate per 100,000 residents of the county where the former employer is located relative to the county where the previous employer is located. An indicator variable that takes the value of one when the difference in mortality rates is above the 75th percentile of this difference for the moving inventors. The data are from NCIPC.

DEFINITIONS OF THE VARIABLES

Move to a Higher Crisis County - It is based on the difference in drug overdose mortality rate per 100,000 residents of the county where the former employer is located relative to the county where the previous employer is located. An indicator variable that takes the value of one when the difference in mortality rates is below the 25th percentile of this difference for the moving inventors. The data are from NCIPC.

Instrument

Ln (MME) - The natural logarithm of the per-capita Morphine Milligram Equivalent (MME) of strong opioids (i.e., those with MME > 1) dispensed by non-chain pharmacies in a given county-year per 100,000 residents. The data are from DEA.

Firm variables

Opioid Deaths - The number of deaths caused by drug overdose per 100,000 county residents. The data are from NCIPC.

Ln (Size) - The natural logarithm of total assets (AT). This variable is created using data from Compustat.

Tobin's Q - The market value of equity (CSHO*PRCC_F) plus book value of assets (AT) minus book value of equity (CEQ) minus balance sheet deferred taxes (TXDB), scaled by total assets (AT). This variable is created using data from Compustat.

Cash Holdings - Cash and short–term investments (CHE) scaled by total assets (AT). This variable is created using data from Compustat.

Leverage - The sum of long-term debt (DLTT) and debt in current liabilities (DLC) scaled by total assets (AT). This variable is created using data from Compustat.

ROA - Income before extraordinary items (IB) plus interest expense (item XINT) plus income taxes (item XINT), divided by total assets (item AT). This variable is created using data from Compustat.

Tangible Assets - Property, plant, and equipment (PPEGT) scaled by total assets (AT). This variable is created using data from Compustat.

Capital Expenditures - Capital expenditures (CAPX) scaled by total assets (AT). This variable is created using data from Compustat.

Ln (Firm Age) - The natural logarithm of one plus the number of years since the firm's first appearance in the Center for Research in Security Prices (CRSP). This variable is created using data from CRSP.

Low Employee Input – An indicator variable that takes the value of one if the firm's ratio of R&D per employee belongs to the bottom tercile of the sample in a year, and zero otherwise. This variable is created using data from Compustat.

Low Ability – An indicator variable that takes the value of one if the firm's size measured by total assets belongs to the bottom tercile of the sample in a year, and zero otherwise. This variable is created using data from Compustat.

Low Growth – An indicator variable that takes the value of one if the firm's market capitalization minus common shareholder's interest in the firm, scaled by the number of employees, belongs to the bottom tercile of the sample in a year, and zero otherwise. This variable is created using data from Compustat.

DEFINITIONS OF THE VARIABLES

Durham University Business School

County Variables

Ln (Population) - The natural logarithm of the county-level population. This variable is created using data from the Census Bureau.

Ln (Income Per Capita) – The natural logarithm of the county-level income per capita. This variable is created using data from the U.S. Bureau of Economic Analysis (BEA).

Education – The ratio of people with a bachelor's degree or higher to the population aged 25 years or older in one county. This variable is created using data from the Census Bureau.

Religion - The portion of a county's population whose residents adhere to any religion in the county where the firm is headquartered. This variable is created using the "Churches and Church Membership" files from the U.S. Association of Religion Data Archives (ARDA).

Seniors – The portion of residents of a county's population who are aged 65 or older. This variable is created using data from the Census Bureau.

Inventor variable

Star & Young Inventor - An indicator variable that takes the value of one (a) if the cumulative number of patents filed in the past by an inventor since inception belongs in the top 20% relative to all inventors in that year, and (b) the time elapsed since the inventor first filed a patent within a firm is less than 5 years, and zero otherwise. This variable is created using data from Stoffman, Woeppel, and Yavuz (2022). (see, https://www.mikewoeppel.com/data).

SAMPLE DESCRIPTIVE STATISTICS

Durham University Business School

	Obs.	Mean	Std. dev.	p10	p50	p90
Panel A: Firm-Level Sample						
			Dependent Variables			
#Patents	15,178	21.071	83.472	0.000	0.000	34.000
#Citations	15,178	642.930	2,529.963	0.000	0.000	993.000
Innovation Value ($M)	15,178	324.337	1,435.306	0.000	0.000	327.806
			Firm-Level Variables			
Size	15,178	5.119	2.433	1.870	5.061	8.334
Tobin's Q	15,178	5.177	14.231	0.997	1.928	7.227
Cash Holdings	15,178	0.330	0.277	0.032	0.250	0.781
Leverage	15,178	0.351	1.108	0.000	0.098	0.553
ROA	15,178	-0.548	2.077	-1.069	-0.001	0.156
Tangible Assets	15,178	0.375	0.359	0.053	0.269	0.826
Capital Expenditures	15,178	0.033	0.039	0.003	0.022	0.074
Firm Age	15,178	16.284	12.800	2.000	13.000	37.000
			County-Level Variables			
Population	15,178	1,575,816	1,775,471	299,134	1,048,985	3,114,363
Income Per Capita ($)	15,178	56,187.43	19,553.38	38,031	51,460	75,455
Education	15,178	0.385	0.097	0.272	0.383	0.508
Religion	15,178	0.557	0.129	0.409	0.545	0.750
Seniors	15,178	0.124	0.025	0.094	0.122	0.152
Panel B: Inventor-Level Sample						
			Dependent Variables			
#Patents	25,808	2.556	3.036	1.000	2.000	5.000
#Citations	25,808	108.616	478.086	2.000	20.000	202.000
Innovation Value ($M)	25,808	52.730	125.148	3.067	18.710	119.926