The Opioid Epidemic and its Impact on Labor Productivity in Illinois

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Abstract
Illinois' labor force is shrinking at the rate of .24% per annum. Opioid-involved drug overdoses are contributing to this poor state of labor force, on average drug overdoses account for 17.2 deaths per 100,000 Illinoisans. This paper is an attempt to quantify the impact of opioid use on labor productivity. Results of a differential equation modeling of the opioid epidemic suggests that for every 1% increase in opioid prescriptions, the state will lose 4% of its labor productivity.

Keywords: Illinois, Labor Productivity, Opioid, Ordinary Differential Equation

1.0. Introduction

In 2017, 2,202 died of an opioid-involved drug overdose in Illinois[2]; rate-wise, this number translates to 17.2 deaths per 100,000 Illinoisans[3]. Comparatively, in 2017 the nation had 14.9 opioid-involved drug overdose deaths per 100,000 population. The market evolution of opioids can be traced back to the late 1990s, in response to claims that pain was undertreated in the population and assurances from drug manufacturers that their "new" opioid formulations were safe, opioid prescriptions in the nation during 1999 to 2017 grew at an annual compound growth rate of 12.54%[4] (Figure 1a). While this growth rate did slow down slightly during 2011-2013, Illinois mostly retained the linear growth and posted a 30% increase in opioid prescriptions in 2017 compared to 2016 (Figure 1b). Table 1 shows the growth in illicit opioid (heroin) related deaths in the nation and Illinois; during 2012 to 2017 the state outpaced the national growth in heroin use by more than 10 points.

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[2] The 'extensional' definition of opioids includes: natural opioids such as morphine and codeine; semi-synthetic opioids such as oxycodone; synthetic opioids methadone and drugs like fentanyl, and heroin (the illicit opioid synthesized from morphine).
[3] Rate per 100,000 population age-adjusted to the 2000 US standard population.
[4] ACGR computed using the log growth function.

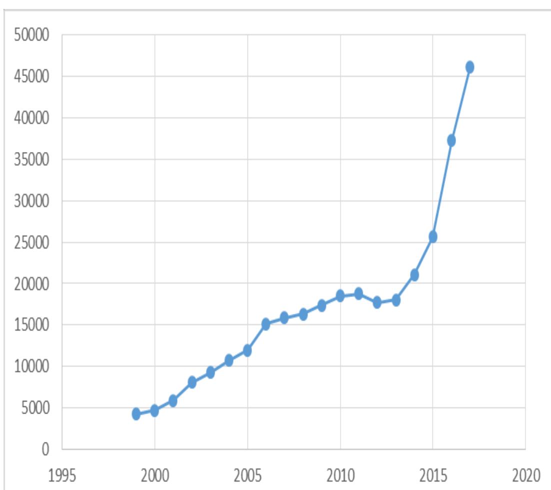
Table 1: Growth Rates of Drug Overdose Deaths, by Opioid Category

Time Period	Natural and Semi-Synthetic Opioids	Synthetic Opioids	Heroin
US			
1999 – 2005	12.37%	47.02%	0.41%
2006 - 2011	10.21%	34.43%	12.12%
2012 - 2017	5.27%	52.27%	19.21%
Illinois			
1999 - 2005	13.39%	15.88%	8.18%
2006 - 2011	8.66%	-20.17%	19.62%
2012 - 2017	20.75%	40.14%	29.69%

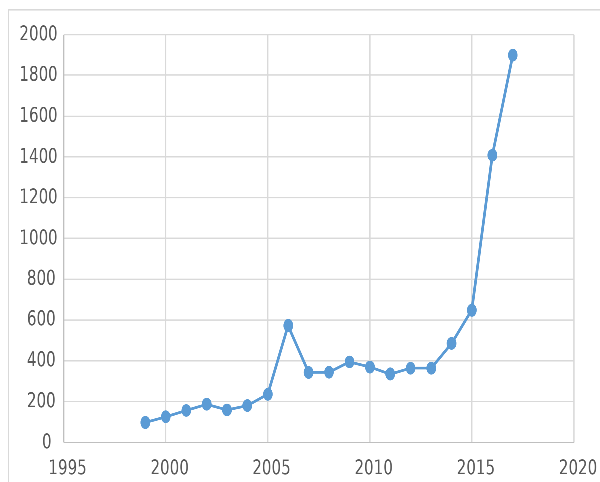
Source: Kaiser Family Foundation's State Health Fact.

Figure 1: Opioid Prescriptions, 1999-2017

a) US



b) Illinois



Note: CAGR for US: 12.54%; IL: 15.66%

Dowell et al (2017) posit that the opioid death toll has made drug overdoses the leading causes of death for Americans less than 50 years of age. CDC's drug surveillance report (2018) shows that prime-age workers in the 25-54 age group had the highest heroin death rate (Table 2).

Table 2: Opioid Overdose Deaths in the US, rates per 100,000. Prime-Age Worker Population

Age	Prescription Opioids	Heroin
25-34	7.7	11.3
35-44	9.2	9.0
45-54	10.1	7.0

Source: CDC's Annual Surveillance Report of Drug Related Risks and Outcomes, 2018

While the fatal costs are substantial, the council of economic advisers (2017) estimate the costs at $432 billion, the nonfatal costs of opioid epidemic are also important. For example, Florence et al (2016) argue that reduced productivity among those who do not die of an overdose amounts to $20.8billion.

How could we quantify the impact of opioid use on labor productivity? What is the economic cost of opioid crisis for the state of Illinois? This paper attempts to address these and other similar questions.

2.0. Illinois Labor Force

Illinois' labor force is shrinking; in 2017 the size of the Illinois labor force was smaller than it was in 2013, the attrition was 1% or 63, 532 workers. In contrast, during the same period the US gained 1% or 5,144,909 workers (Table 3).

In 2017, Illinois population over the age of 65 accounted for 18% of the labor force (Table 4). In fact, the proportion of the 65+ age segment in Illinois workforce has been steadily growing since 2012 (ACGR = 4.39%). This information, coupled with the low unemployment numbers make us conclude that Illinois cannot afford to lose labor force to preventable causes such as drug overdoses. It is essential for the purposes of economic development that the state understands the economic consequences of changes to its labor force, the association between opioid use and labor productivity.

Table 3: Labor Force, Segment of the Population

Illinois	2013	2014	2015	2016	2017	ACGR
Labor force	6,725,720	6,697,567	6,676,518	6,665,387	6,662,189	-0.24%
Employed	6,072,540	6,144,557	6,195,235	6,236,021	6,241,958	0.69%
Unemployed	653,181	553,010	481,283	429,365	420,230	-11.0%
Out of labor force	3,480,229	3,543,361	3,563,540	3,557,599	3,587,332	0.76%
Population (16+)	10,205,949	10,240,928	10,240,058	10,222,986	10,249,521	0.11%
Population (Over 65)	1,740,088	1,787,854	1,828,225	1,872,830	1,947,595	2.82%
United States						
Labor force	159,531,695	160,521,803	161,641,855	162,766,905	164,676,605	0.79%
Employed	145,234,043	148,095,945	150,626,642	152,448,876	155,556,856	1.72%
Unemployed	14,297,652	12,425,858	11,015,214	10,318,029	9,119,749	-11.2%
Out of labor force	91,304,304	93,067,144	94,525,903	95,183,816	95,887,643	1.22%
Population (16+)	250,835,999	253,588,947	256,167,758	257,950,721	260,564,248	0.95%
Population (Over 65)	44,663,990	46,214,893	47,732,480	49,215,165	50,815,712	3.23%

Source: American Community Survey, 1 year estimates.

Table 4: Labor Force under 65 Years of Age: Illinois and the US

Illinois	2013	2014	2015	2016	2017
Available labor force under 65	8,465,861	8,453,074	8,411,833	8,350,156	8,301,926
Percentage change	-0.09%	-0.15%	-0.49%	-0.73%	-0.58%
Labor force participation	6,421,687	6,390,933	6,357,711	6,339,620	6,307,499
United States	**2013**	**2014**	**2015**	**2016**	**2017**
Available labor force under 65	206,172,009	207,374,054	208,435,278	208,735,556	209,748,536
Percentage change	0.35%	0.58%	0.51%	0.14%	0.49%
Labor force participation	151,851,611	152,590,806	153,393,128	154,118,376	155,572,080

Source: Author's estimates, based on ACS data

2.1. Labor Productivity and Opioid Impacts

The operational definition of labor productivity is output per worker:

$$\frac{\textit{Gross State Product}}{\textit{Total Number of Labor or Work Hours}}$$

Table 5 shows the nominal labor productivity for Illinois. During 2007-2017, the state's labor productivity registered an annual compound growth rate of 2.56%.

Table 5: Labor Productivity for Illinois, 2007-2017

Year	Labor Productivity	Year	Labor Productivity
2007	58.36959	2013	68.78667
2008	58.76132	2014	71.03518
2009	61.79482	2015	73.11917
2010	63.58465	2016	74.43691
2011	65.2549	2017	75.39001
2012	67.92491	**ACGR**	2.56%

Source: Author's calculations based on BLS data

Consider changes to labor productivity *P* over time *t* (Table 5) as a function of opioid prescriptions:

$$\frac{\delta P_t}{\delta t} = \alpha \times P_t + \beta \times O_t \frac{P_{Ideal} - P_t}{P_{Ideal}}, \text{ where} \qquad \text{(EQ. 1)}$$

P_t = labor productivity in Illinois at time t;
O_t = Opioid prescriptions in Illinois at time t,
P_{Ideal} = Labor productivity at the geographical region ranked as #1 in the US: the state of California with labor productivity of $81.8 as at 2017,
α = productivity-generated per unit of time when opioid prescription = 0, and
β = productivity-decay (labor productivity lost because of opioid use).

The right-hand side of equation 1 shows that the change in the rate of labor productivity, $\frac{\delta P_t}{\delta t}$, depends on several factors: it will be greater for higher levels of α and $\frac{P_{Ideal} - P_t}{P_{Ideal}}$ (Un-tapped potential for productivity growth), and it will be lower for higher values of β and O.

Data for labor productivity are given in Table 5. Opioid prescriptions (and use) among the population were obtained from the CDC (www.cdc.gov/drugoverdose/maps/rxrate-maps.html).

The parameter estimates of the calibrated model are given in Table 6[5]; Figure 2 shows the model fit, predicted versus actual labor productivity.

Table 6: Parameter Estimates

Parameter	Point Estimate	Std. Error	t value	P
α (productivity-generated when prescriptions =0)	0.596	0.09	6.62	<.05
β (productivity decay)	-0.27	0.03	9.00	<.05

Note: $R^2 = 0.265$

Table 6 suggests that when the number of opioid prescriptions become zero, labor productivity will reach $107 per hour. For every 1% increase in prescriptions, from the base 2017 time period[6], labor productivity will decrease by $3.08 per hour to $72.31. This translates into a 4% decline in the value of private non-farm production, from $686,221mil in 2017 to $658,168mil for the prediction. To aid in research and policymaking, we have programmed an interactive computer application to gain insights into various scenarios of changes to opioid prescriptions and resulting labor productivity. The application is available at: www.research.iira.org.

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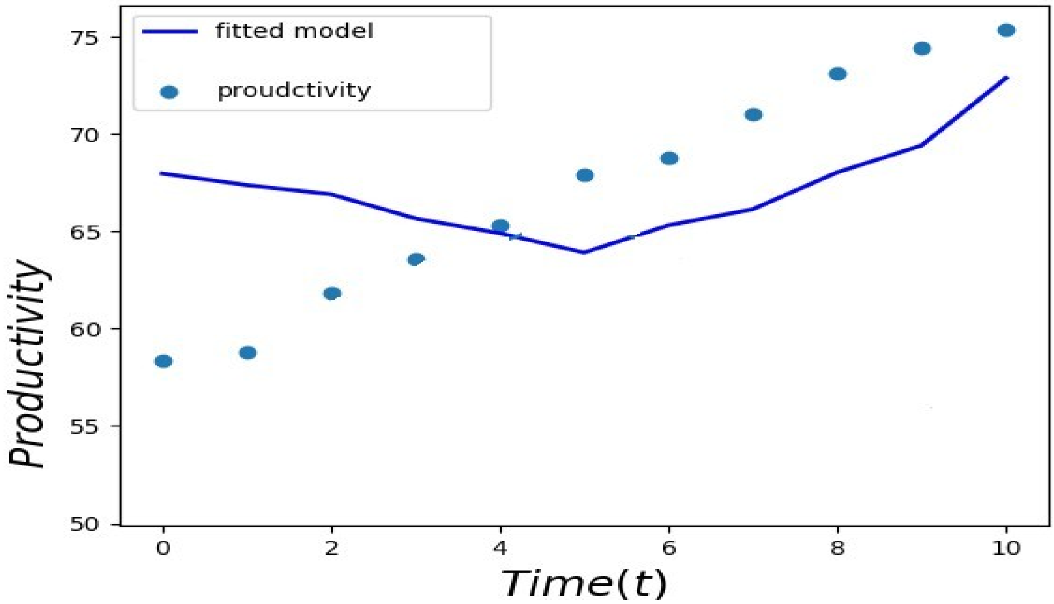
5 We calibrated the model using the solution to P_t:

$$P_t = \frac{\beta O}{1+[\frac{\alpha P_{Ideal}}{\beta O}]}[1 - e^{-[[\frac{\beta O}{P_{Ideal}}]+\beta]t}] + P(0)e^{-[[\frac{\beta O}{P_{Ideal}}]+\beta]t}$$

. See Appendix 1 for detailed derivations of the solution.

6 Works out to approximately 1025 prescriptions.

Figure 2: Model Fit



3.0. Summary and Conclusion

This paper provides empirical evidence of the destructive effects of opioids on Illinois' labor force. It is estimated that a 1% increase in opioid prescriptions will cost the state 4% in GDP.

CEA estimates that the opioid epidemic cost 2.8% of the nation's GDP, 2015 estimates (CEA, 2017). Benham et al (2017) posit that opioid abusers miss twice as many days of work compared with other employees. According to Quest Diagnostics (2016), during 2011 to 2015, the positivity testing for heroin increased 146% for the US workforce.

In business, market segmentation tools are often used to define markets and allocate resources across markets. It is time we adapt this approach to segment opioid use among prime-age worker population, curtail the spread of opioids, and reduce the drug's impacts on our labor force.

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Appendix 1: Solution to the Differential Equation (EQ 1)

$$\frac{dP_t}{dt} = \alpha \cdot P_t - \beta \cdot O_t . (\frac{P_{ideal} - P_t}{P_{ideal}})$$

$$\frac{dP_t}{dt} = \alpha \cdot P_t - (\frac{\beta \cdot O_t P_{ideal}}{P_{ideal}}) + (\frac{\beta \cdot O_t P_t}{P_{ideal}})$$

$$\frac{dP_t}{dt} = \alpha \cdot P_t - \beta \cdot O_t + (\frac{\beta . O_t . P_t}{P_{ideal}})$$

Factorize P_t :

$$\frac{dP_t}{dt} = -\beta . O_t + P_t (\alpha + \frac{\beta . O_t}{P_{ideal}})$$

Substitute $K = (\alpha + \frac{\beta \cdot O_t}{P_{ideal}})$:

$$\frac{dP_t}{dt} - P_t \cdot K = -\beta \cdot O_t$$

Multiplying the integrating factor $e^{\int K\,dt}$ (e^{Kt})

$$e^{Kt} . \frac{dP_t}{dt} + e^{Kt} . K \cdot P_t = e^{Kt} \cdot -\beta \cdot O_t$$

$$\frac{d}{dt} \cdot (e^{Kt} . P_t) = e^{Kt} . -\beta . O_t$$

$$\int \frac{d}{dt} (e^{Kt} . P_t) = \int (e^{Kt} . -\beta . O_t)\, dt$$

$$e^{Kt} . P_t = -\beta . O_t . \int e^{Kt}\, dt$$

$$e^{Kt} . P_t = -\beta . O_t . (e^{Kt} + constant)$$

$$e^{Kt} . P_t = -\beta . O_t . \frac{1}{K} . e^{Kt} + constant$$ Equation (1)

When t = 0, P_t = Po:

$$P_0 = -\beta . O_t . \frac{1}{K} + constant$$

$$constant = P_0 + \beta . O_t . \frac{1}{K}$$

Substitute $constant = P_0 + \beta . O_t . \frac{1}{K}$ into equation 1 to derive:

$$P_t = -\beta . O_t . \frac{1}{K} + (P_0 + \beta . O_t . \frac{1}{K}) . e^{-Kt}$$