

**Racial disparities and the role of prescriber networks in the development  
and sustaining of buprenorphine prescribing by waived physicians  
for OUD treatment in Massachusetts communities**

**Final Project Report  
June 15, 2021**

**The RIZE Massachusetts Foundation  
Insights and Solutions Initiative**

**Peter Kreiner, PhD  
Cindy Thomas, PhD  
Lee Panas, MS  
Robert Dunigan, PhD**

**Brandeis University  
Institute for Behavioral Health**

## Table of Contents

	<b>Executive Summary</b>		<b>3 - 8</b>
<b>I.</b>	<b>Introduction</b>		<b>9 - 10</b>
<b>II.</b>	<b>To what extent does access to buprenorphine treatment for OUD vary geographically by the race and ethnicity of residents?</b>		<b>10 - 18</b>
	Methods	11	
	Results	11 - 18	
<b>III.</b>	<b>How do properties of waived prescriber patient-sharing networks, thought to reflect prescriber access to peer information, support, and resources, vary in relation to community race and ethnicity?</b>		<b>19 – 27</b>
	Methods	19 - 22	
	Results	22 - 27	
<b>IV.</b>	<b>Do patient-sharing network ties among buprenorphine prescribers facilitate prescribers becoming waived initially, increasing their patient limits, and/or their provision of buprenorphine treatment (i.e., treatment duration, number of active patients)?</b>		<b>28 – 45</b>
	A. Initially becoming waived	30 - 33	
	B. Becoming waived for 100 patients	33 - 36	
	C. Becoming waived for 275 patients	37 - 42	
	D. Treatment duration	43 - 47	
<b>V.</b>	<b>Implications and Recommendations</b>		<b>48 - 52</b>
<b>VI.</b>			

## Executive Summary

Fatal and non-fatal opioid-related overdoses and cases of opioid use disorder (OUD) continue to increase nationally and in Massachusetts, driven in recent years by the prevalence of heroin, fentanyl, and fentanyl analogs. As the opioid epidemic has come increasingly to be understood as an epidemic of addiction, state and federal efforts to address it have focused on expanding the availability of treatment for OUD, in particular medication-assisted treatment with buprenorphine (MOUD). The growth in buprenorphine-waivered prescribers has substantially increased potential access to opioid agonist treatment. However, growth in waivered prescribers has been geographically uneven, providers have reported a number of barriers to prescribing buprenorphine, and many waivered providers are not prescribing buprenorphine at all or are prescribing to numbers of patients well below their waiver limits. Racial and ethnic disparities appear to account for at least some of the variation in access to treatment.

Mechanisms by which such racial/ethnic disparities develop and are maintained, however, are not well understood. In clinical settings involving cardiac surgery and hip replacement surgery, properties of physician patient-sharing networks thought to increase physician access to peer information, resources, and support – and hence to enhance patient outcomes – were found to vary systematically by the racial makeup of communities served by those physicians. This project followed a similar approach. We examined properties of patient-sharing networks among buprenorphine prescribers, properties thought to increase prescriber access to peer information, resources, and support for providing MOUD treatment, in relation to community racial/ethnic makeup. We thus sought to assess whether these networks might have contributed to racial/ethnic disparities in access to MOUD treatment in Massachusetts communities. And if so, to identify interventions, based on our findings and the literature of social networks, that might help to reduce such disparities.

This project is funded under the RIZE Massachusetts Foundation's *Insights and Solutions* initiative and builds on earlier work conducted with the Massachusetts Department of Public Health, Prescription Monitoring Program (MA PMP), using data provided by the PMP, with permission for its use in this project. Project work proceeded along three lines, findings from which are summarized below:

- (1) An assessment of prescriber capacity to provide MOUD treatment in Massachusetts counties, and evidence for racial/ethnic disparities in access to treatment;
- (2) An analysis of prescriber patient-sharing networks and evidence of racial/ethnic differences in network properties thought to increase prescriber access to peer information and support; and
- (3) At the individual provider level, analyses of the role of prescriber variables, in particular patient-sharing network ties, in the adoption of buprenorphine waivers for 30, 100, and 275 patients. Also at the individual patient level, an analysis of MOUD treatment duration in relation to patient, prescriber, and county demographic variables.

Finally, we discuss implications of project findings and recommendations for how racial/ethnic disparities in access to MOUD treatment in Massachusetts can be addressed.

- (1) Racial/ethnic disparities in access to MOUD treatment. Following the approach of the Massachusetts Department of Public Health, we measured access to MOUD treatment as the ratio of the average number of concurrent MOUD patients of waivered prescribers in each MA county, to the

total waiver capacity of those prescribers. We examined changes in access to treatment across the years 2011 – 2018 and in relation to county demographics. In pooled time-series analyses of access to MOUD treatment, controlling for the number of waived prescribers per 10,000 population in a county, the opioid-related overdose death rate (lagged one year), the number of methadone clinics per 100,000 population, and alternatively the percent of the population in poverty or the median household income, we found strong evidence for lower access to MOUD treatment in counties with a higher percentage of black residents and in counties with a higher percentage of Hispanic residents.

- (2) Selected properties of prescriber patient-sharing networks. To assess whether properties of prescriber patient-sharing networks might help account for such disparities, we followed previous research and constructed county-level networks of buprenorphine prescriber shared-patient ties of at least 10 MOUD patients in a given year. We assessed network properties found in other studies to promote provider access to peer information, resources, and support, namely the percent of prescribers in the network who are part of the largest connected component, the Small World Index – a measure of how reachable each prescriber in the network is by each other prescriber, and centralization – a measure of the extent network ties are organized around a few prescribers who each have many ties (network “hubs”).

In analytic models similar to those used in (1), for the years 2011 – 2018, we found strong evidence for disparities in the Small World Index and network centralization, and weak evidence for disparities in the percent of prescribers who are part of the largest connected component. That is, in counties with a higher percentage of black or of Hispanic residents, we found a significantly larger Small World Index (i.e., greater difficulty in peer access to other peers), significantly smaller centralization, and a marginally smaller percent of prescribers in the largest connected component. The findings imply poorer provider access to peer information, resources, and support in counties with a higher proportion of non-white residents.

In the analyses for both lines of work (1) and (2) above, we observed an inflection point in 2015 in changes in both access to treatment and the prescriber network properties over time. In particular, in models akin to those in (1) of access to treatment, we found, for the years 2015 – 2018 (but not for 2011 – 2014), strong evidence of an association between all three network properties and access to treatment, in the expected direction: counties with a higher percent of prescribers belonging to the largest connected component, a smaller Small World Index, and/or higher centralization, had higher access to treatment.

- (3) Adoption of the 30-, 100-, and 275-patient waivers. The inflection point in 2015 also impacted patterns in prescriber adoption of buprenorphine waivers for 30, 100, and 275 patients, and appeared to be driven by prescriber demand for the 275-patient limit waiver. The waiver for 100 patients began in January, 2007. Since our data began in 2011, we were only able to analyze adoption of this waiver for the years 2012 – 2018, where the pool of potential adopters was prescribers waived for 30 patients in or before the previous year. In models that controlled for

different adoption rates by county,<sup>1</sup> we found that both the median number of MOUD patients a prescriber had, and (negatively) the number of years they had been waived for 30 patients were highly significant predictors of adoption of the 100-patient waiver, for each year 2012 – 2018. We found that the number of shared-patient ties (of at least 10 patients) a prescriber had was a significant predictor for the years 2012 – 2014 and 2018, but not for 2015 – 2017. That is, prescribers waived for 30 patients who had more MOUD patients, were more recently waived for 30 patients, and (for 2012 – 2014 and 2018) had more shared-patient ties, were more likely to become waived for 100 patients.

In the literature on innovation diffusion in networks, the typical pattern of diffusion is that the first adopters are network members who have few network ties (that is, are on the edges of the network); as or if diffusion proceeds, network members who have more ties (are more central to the network) begin to adopt, then become the predominant adopters. Although we weren't able to examine the first adopters for the 100-patient waiver, we did find that, by 2012 (five years into the diffusion process), prescribers with more network ties had become the predominant adopters. This pattern was interrupted in 2015, due, we believe, to the availability of the 275-patient waiver in 2016.

The waiver for 275 patients began in September, 2016. We were able to analyze its adoption for 2016 – 2018, and the first eight months of 2019, by prescribers who were waived for 100 patients in or before the previous year. In models that controlled for different adoption rates by county and for medical specialty,<sup>2</sup> we found that (a) the median number of MOUD patients a prescriber had was a significant predictor of adoption of the 275-patient waiver for 2016 – 2018, but not for 2019; the number of years a prescriber had been waived for 100 patients was a significant (negative) predictor for 2017 – 2019; and the number of shared-patient ties a prescriber had was a significant negative predictor for 2016, and a significant positive predictor for 2018 and 2019. That is, the first adopters of the 275-patient waiver were driven primarily by already treating higher numbers of patients (and likely by pressures external to the system), and were network members on the edges of the shared-patient network. By 2018, this pattern had changed, and prescribers with more shared-patient ties (i.e., were more central to the network) had become the predominant adopters. As with the adoption of the 100-patient waiver, adopters of the 275-patient waiver were relatively newly waived for 100 patients.

Not least, we also examined the effect, among non-waivered prescribers, of non-buprenorphine shared-patient ties with waived prescribers on the likelihood of initially becoming waived (i.e., for 30 patients). We found a significant and persistent effect of such ties on the likelihood of initially becoming waived over several years subsequent to the year of the observed ties. Having one or more non-buprenorphine shared-patient tie (of at least 10 patients in a year) with a waived

---

<sup>1</sup> In one or more counties in most years, there were too few adoptions to allow for a hierarchical model, which would have permitted us to examine racial/ethnic disparities in waiver adoption.

<sup>2</sup> Medical specialty, including nurse practitioner/physician assistant beginning in 2018, was not a significant predictor.

prescriber increased the likelihood of initially becoming waived by 400% or more in any of the three subsequent years.

We also examined MOUD treatment duration, in relation to patient and prescriber variables and county variables of patient residence. Specifically, we conducted survival analyses of 67,251 patients who had not received a buprenorphine prescription for at least 30 days prior to initiating treatment, for the years 2011 - 2018. Longer treatment duration was associated with being female, being older (age 50-60 more than age 40-49, in turn more than 30-39, and in turn more than 20-29), having more prescribers (three and up a greater duration than two, in turn two a greater duration than one), having a primary prescriber waived for 100 patients, and having a primary prescriber waived for 275 patients. Shorter treatment duration was associated with the primary prescriber being a nurse practitioner or physician assistant, with the primary prescriber having more shared-patient ties,<sup>3</sup> and with a higher percent of residents in the patient's county who are Hispanic or black. In the latter case, patients residing in counties with the highest percentages of Hispanic or of black residents had, on average, the shortest treatment duration, while patients residing in counties with somewhat lower percentages of Hispanic or black residents had somewhat less short treatment duration. Patients residing in both sets of counties had shorter treatment duration than patients residing in counties with the lowest percentage of Hispanic or black residents.

- (4) Implications. A number of our findings appear to converge as follows. The availability of the 275-patient waiver, starting in September, 2016, led to a surge in adoption of that waiver and also had a powerful upstream influence on the adoption of waivers for 100 and 30 patients. Adoptions of the 100- and, especially, the 275-patient waiver helped to stabilize prescriber shared-patient networks beginning in 2015: on average, prescribers with the 100-patient waiver had about three times as many shared-patient ties (of 10 or more patients in a year) as prescribers with the 30-patients waiver, and prescribers with the 275-patient waiver had, in turn, almost three times as many shared patient ties as prescribers with the 100-patient waiver.<sup>4</sup> That is, prescribers with waivers for the higher patient limits tended to be “hubs” in the shared-patient networks, linking many other prescribers and providing a kind of glue for the network as a whole. The presence of network hubs facilitates a network's having small-world properties,<sup>5</sup> whereby any network member is reachable in a few steps (i.e., prescriber ties) from any other member, and where the distribution of shared-patient ties among network members tends to follow a power law – a few highly-connected prescribers and many other prescribers with relatively few connections. Small world-ness is also associated with network stability and robustness in the face of external changes:

---

<sup>3</sup> Because the models tested for the effects of prescribers waived for 100 or 275 patients, who had relatively high numbers of shared-patient ties, this finding appears to relate to prescribers waived for 30 patients.

<sup>4</sup> It is also true that the median number of MOUD patients increased substantially with waivers for the higher patient limits, and having more patients would increase the likelihood of having more shared-patient ties. However, median number of patients and number of shared-patient ties were only modestly correlated (correlation coefficient of about .3).

<sup>5</sup> The presence of hubs also facilitates the other two network properties we measured – the percent of network prescribers in the largest connected component and network centrality.

patterns of shared-patient ties tend to persist, even as the individual patients change, especially in networks with small-world properties.

Proportionally to the number of waived prescribers in a county, prescribers with the 275-patient waiver tended to be located in counties with lower percentages of black or Hispanic residents. Because 275-patient waived prescribers tend to treat higher numbers of patients, their location tends to support racial/ethnic disparities in access to treatment. Because 275-waived prescribers also have the most shared-patient ties, they tend to provide a scaffold for more robust shared-patient prescriber networks, whose small-world properties facilitate prescriber access to peer information, resource, and support. The 275-patient waiver thus also supports racial/ethnic disparities in the properties of these networks that support prescribers in treating more patients.

By 2018, adoption of the 275-patient waiver by prescribers already waived for 100 patients was driven by shared-patient ties as well as by the number of patients these prescribers were already treating, and by 2019, adoption was driven mainly by shared-patient ties. Also by 2018, generalist physicians had overtaken psychiatrists and neurologists as the primary adopters. Based on the foregoing implications, we offer the following recommendations.

Recommendations. (1) Existing shared-patient networks can be used to identify prescribers in the role of network broker, or “structural hole,” who serve to connect different subgroups of a network. To increase the small world properties of a network in which they are embedded, or to which their network is adjacent, these prescribers might be provided incentives to form new shared-patient connections with prescribers in network subgroups with which they currently do not share patients. Because such prescribers have experience in linking different subgroups, and presumably benefit by being able to access different sources of information and resources associated with these subgroups, they are more likely than other prescribers to be willing and able to make new connections. An educational or training event might bring them together with prescribers to newly connect with. However, maintaining ongoing connections requires an ongoing benefit, which might eventually take the form of information and resources different from those received elsewhere, but which probably needs an additional incentive to become established.

(2) In counties with lower access to treatment, and where prescriber networks are characterized by weaker small world properties, a mentorship program might be set up encourage prescribers currently waived for 30 or 100 patients to become waived for 275 patients, and to support them in providing treatment to more patients. Specifically, they might be paired with a prescriber currently waived for 275 patients (whether in the same or an adjacent county), whom they could observe and from whom they could receive coaching and support to build their own treatment practice. At least some prospective mentors may need an incentive to participate in such a program; for others, the possibility of assisting a peer to help address disparities in access to treatment may be enough. In addition to being waived for 275 patients, prospective mentors might be selected based on continuing growth in the number of patients they treat and their centrality (i.e., number of shared-patient ties) in their prescriber network.

(3) Further study is needed on the following topics to help tailor efforts to address racial/ethnic disparities in access to treatment.

- a) Hampden County appears to be an outlier in our data, in that it ranked third among counties in percent of residents who are black and first in percent of residents who are Hispanic, yet it ranked in the upper half of counties in access to treatment. It also ranked high (better) in the percent of network prescribers in the largest connected component, the Small World Index, and network centralization. Understanding how Hampden County achieved this level of access to treatment and prescriber network properties could give clues to how other counties with relatively high percentages of black and Hispanic residents can increase access to treatment.
- b) Many prescribers waived for 30 patients stopped prescribing buprenorphine altogether. This was especially pronounced in counties with higher percentages of black or Hispanic residents. Understanding the reasons for their stopping (or never starting) and what would have helped them develop or maintain treatment of MOUD patients would inform efforts to prevent their stopping.
- c) To help counties facilitate their prescribers' adoption of the 275-patient waiver as well as increase shared-patient ties among prescribers, a more detailed understanding of these ties is needed. In particular,
  - I. To what extent does belonging to the same group practice account for shared-patient ties? Do shared-patient ties among members of the same practice have the same effects (e.g., in driving adoption of waivers for higher patient limits) as ties between prescribers in different practices? (Answering these questions requires access to data on membership in group practices, which we currently do not have.)
  - II. How do a prescriber's shared-patient ties change/increase as the prescriber becomes waived for higher patient limits? Which other prescribers do they connect with (i.e., medical specialty, waiver patient limits)? What factors facilitate growth in shared-patient ties and in number of MOUD patients?
  - III. Based on the data we have, we can only infer MOUD patient status. It would be helpful to link our data with, e.g., the Massachusetts All-payer Claims data to obtain clinical information about the patient. This data source also contains patient race (albeit missing for many patients), which would allow a more direct assessment of racial/ethnic disparities in treatment.
  - IV. Interviews with waived prescribers would be helpful to understand how and to what extent shared-patient ties increase the prescriber's access to peer information, resources, and support for providing MOUD treatment, as is true in other settings. Do these ties operate differently for different medical specialties? Does their utility change over time? How do these ties come into being, especially between prescribers not in the same practice?



## I. Introduction

Fatal and non-fatal opioid-related overdoses and cases of opioid use disorder (OUD) continue to increase nationally, driven in recent years by the prevalence of heroin, fentanyl, and fentanyl analogs.<sup>6</sup> As the opioid epidemic has come increasingly to be understood as an epidemic of addiction,<sup>7</sup> state and federal efforts to address it have focused on expanding the availability of treatment for OUD, in particular medication-assisted treatment with buprenorphine.<sup>8</sup> The growth in buprenorphine-waivered prescribers has substantially increased potential access to opioid agonist treatment.<sup>9</sup> However, growth in waived prescribers has been geographically uneven,<sup>10,11</sup> providers have reported a number of barriers to prescribing buprenorphine,<sup>12</sup> and many waived providers are not prescribing buprenorphine at all or are prescribing to numbers of patients well below their waiver limits.<sup>13,14</sup> Racial and ethnic disparities appear to account for at least some of the variation in access to treatment.<sup>15,16</sup>

However, mechanisms by which such racial/ethnic disparities develop and are maintained are not well understood. In clinical settings involving cardiac surgery and hip replacement surgery, properties of physician patient-sharing networks thought to increase physician access to peer information, resources, and support – and hence to enhance patient outcomes – were found to vary systematically by the racial

---

<sup>6</sup> Jalal H, Buchanich JM, Roberts MS, Balmert LC, Zhang K, & Burke DS. (2018). Changing dynamics of the drug overdose epidemic in the United States from 1979 through 2016. *Science*; 361(6408): eaau1184. Doi: 10.1126/science.aau1184.

<sup>7</sup> Kolodny A., Courtwright DT, Hwang CS, Kreiner P, Eadie JL, Clark TW, & Alexander GC. (2015). The prescription opioid and heroin crisis: A public health approach to an epidemic of addiction. *Annual Review of Public Health*, 36: 559-574, doi: 10.1146/annurev-pubhealth-031914-122957.

<sup>8</sup> Ballreich J, Mansour O, Hu E, Chingcuanco F, Pollack HA, Dowdy DW, & Alexander GC. (2020). Modeling mitigation strategies to reduce opioid-related morbidity and mortality in the US. *JAMA Open Network*; 3(11): e2023677. Doi:10.1001/jamanetworkopen.2020.23677.

<sup>9</sup> Dick AW, Pacula RL, Gordon AJ, Sorbero M, Burns RM, Leslie D, & Stein BD. (2015). Growth in buprenorphine waivers for physicians increased potential access to opioid agonist treatment, 2002-11. *Health Affairs*; 34(6): 1028-1034. Doi: 10.1377/nlthaff.2014.1205.

<sup>10</sup> Ghertner, R. (2019). U.S. trends in the supply of providers with a waiver to prescribe buprenorphine for opioid use disorder in 2016 and 2018. *Drug and Alcohol Dependence*; 204; . doi.org/10.1016/j.drugalcdep.2019.06.029.

<sup>11</sup> McBain RK, Dick AW, Sorbero M, & Stein BD. (2020). Growth and distribution of buprenorphine-waivered providers in the United States, 2007-2017. *Annals of Internal Medicine*; 172(7): 504-506.

<sup>12</sup> Arfken CL, Johanson C-E, di Menza S, & Schuster CR. (2010). Expanding treatment capacity for opioid dependence with office-based treatment with buprenorphine: National surveys of physicians. *Journal of Substance Abuse Treatment*; 39: 96-104. Doi: 10.1016/j.jsat.2010.05.004.

<sup>13</sup> Stein BD, Sorbero M, Dick AW, Pacula RL, Burns RM, & Gordon AJ. (2016). Physician capacity to treat opioid use disorder with buprenorphine-assisted treatment. *JAMA*; 316(11): 1211-1212.

<sup>14</sup> Thomas CP, Doyle E, Kreine, P, Jones CM, Dubenitz J, Horan A, & Stein BD. (2017). Prescribing patterns of buprenorphine waived physicians. *Drug and Alcohol Dependence*; 181: 213-218. dx.doi.org/10.1016/j.drugalcdep.2017.10.002.

<sup>15</sup> Hansen H, Siegel C, Wanderling J, & DiRocco D. (2016). Buprenorphine and methadone treatment for opioid dependence by income, ethnicity, and race of neighborhoods in New York City. *Drug and Alcohol Dependence*; 164: 14-21. Doi:10.1016/j.drugalcdep.2016.03.028.

<sup>16</sup> Lagisetty PA, Ross R, Bohnert A, Clay M, & Maust DT. (2019). Buprenorphine treatment divide by race/ethnicity and payment. *JAMA Psychiatry*; 76(9): 979-981.

makeup of communities served by those physicians.<sup>17,18</sup> This project followed a similar approach. We examined properties of patient-sharing networks among buprenorphine prescribers, properties thought to increase prescriber access to peer information, resources, and support for providing medication-assisted treatment for OUD, in relation to community racial/ethnic makeup. We thus sought to assess whether these networks might have contributed to racial/ethnic disparities in access to OUD treatment in Massachusetts communities. And if so, to identify interventions, based on the literature of social networks, that might help to reduce such disparities.

This project is funded under the RIZE Massachusetts Foundation's *Insights and Solutions* initiative to develop innovative approaches to addressing the opioid crisis in Massachusetts, with a focus on addressing racial/ethnic disparities in access to OUD treatment. The project builds on earlier work conducted with the Massachusetts Department of Public Health, Prescription Monitoring Program (MA PMP), using data provided by the PMP, with permission for its use in this project. We solicited input and feedback from the MA PMP to help ensure that this project would be of use to the Department as well as to the larger RIZE and Massachusetts communities.

This report is organized as follows. The next section describes our analysis of prescriber capacity to provide buprenorphine treatment in Massachusetts counties, and evidence for racial/ethnic disparities in access to treatment. Section III then presents our findings with respect to prescriber patient-sharing networks and evidence of racial/ethnic differences in network properties thought to increase prescriber access to peer information and support. The research presented in Sections II and III represents the county as the unit of analysis. In Section IV, the unit of analysis changes to the individual prescriber. This section provides more detail about how prescriber networks may contribute to disparities in access to treatment, including the association of prescriber patient-sharing ties with OUD treatment duration, and how such ties influence the likelihood of a prescriber initially becoming waived, then becoming waived for higher patient limits. A final section discusses network-related interventions to help address racial/ethnic disparities in access to treatment.

## **II. To what extent does access to buprenorphine treatment for OUD vary geographically by the race and ethnicity of residents?**

To analyze disparities in access to treatment and the contribution of buprenorphine-waivered prescriber patient-sharing networks to these disparities, we examined different geographical areas, including county, hospital service area (HSA), town/city, and zip code. The trade-off was to identify the unit in which prescriber behavior most likely reflected the geographic context, and which also yielded sufficient statistical power to conduct meaningful analyses. We settled on county, as it produced the most reliable measures of network properties, and involved relatively fewer prescribers from outside the county. Because Massachusetts has only 12 counties with enough waived prescribers for reliable measures,

---

<sup>17</sup> Hollingsworth JM, Funk RJ, Garrison SA, Owen-Smith J, Kaufman SR, Landon BE, & Birkmeyer JD. (2015). Differences between physician social networks for cardiac surgery serving communities with high versus low proportions of black residents. *Medical Care*; 53(2): 160-167.

<sup>18</sup> Ghomrawi HMK, Funk RJ, Parks ML, Owen-Smith O & Hollingsworth JM. (2018). Physician referral patterns and racial disparities in total hip replacement: A network analysis approach. *PLoS ONE*; 13(2): e0193014. Doi.org/10.1371/journal.pone.0193014.

this choice limited the statistical power of our models, for which we had data for eight years: 2011 -- 2018. Nevertheless, we were able to conduct meaningful analyses while controlling for the most important variables likely to affect the model outcomes.

## Methods

Following the approach of the Massachusetts Department of Public Health, we measured access to OUD buprenorphine treatment (which they term “practitioner capacity”) as the ratio of the actual number of patients treated to prescriber waiver capacity.<sup>19</sup> We measured prescriber waiver capacity for each county as the sum of the individual patient limits for all prescribers located in the county who were waived by the end of each year, 2011 – 2018. We measured the actual number of patients treated (concurrently) as the average, across all prescribers located in the county who were waived by the end of each year, of the median number of monthly patients for each prescriber, again for 2011 – 2018. We examined changes in treatment capacity, number of patients treated, and access to treatment across these years for each county.

To assess associations between access to treatment and the race/ethnicity of county residents, we pooled data across the 12 counties used and the years 2011 – 2018, and conducted tobit regressions with access to treatment as the dependent variable. We used tobit regressions because the dependent variable is a fraction between 0 and 1. The following were independent variables:

- The number of waived prescribers per 10,000 population.
- The county opioid-related overdose death rate (deaths per 100,000 population), lagged one year. Publicly available from the Massachusetts Department of Public Health.
- The number of methadone clinics in the county, which provide an alternative OUD treatment, also per 100,000 population. Available from the Massachusetts Department of Public Health.
- Separately, percent of county residents living below the federal poverty line, or median household income. Both are available from estimates, based on US Census data, by the University of Massachusetts Donohue Center. Because the poverty rate tended to be correlated with percent of black or percent of Hispanic residents, we used median household income (which tended to be less correlated with these measures) as an alternative way to control for relative wealth in a county.
- Also separately, percent of county residents who were black (non-Hispanic), and percent who were Hispanic (non-white, non-black). Available from UMass Donohue.

Because values of the dependent and independent variables are likely correlated across years, the regressions controlled for clustering of these variables by county and year.

## Results

Figure II.1 below displays changes in county OUD buprenorphine treatment capacity from 2011 through 2018. In all counties, treatment capacity increased across those years, with an accelerating increase in the later years. We note also that, although there was a greater range of capacity across the counties in 2018 than in 2011, the relative ranking of counties, based on capacity, remained unchanged. We further

---

<sup>19</sup> Medication Assisted Treatment Commission Report, October 1, 2019. Available at: <https://www.mass.gov/lists/medication-assisted-treatment-mat-commission-documents>. Accessed November 15, 2020.

observe that each county trajectory has an inflection point in 2015, where the rate of capacity expansion itself increases. This is presumably attributable to the increased patient limit to 275, available beginning in September of 2016. Prescribers waived for 100 patients would need to have had that status for at least one year prior to applying for the 275-patient limit. As a result, there was a sharp increase in prescribers becoming waived for 100 patients in 2015, many of whom went on to obtain the 275-patient waiver the following year.

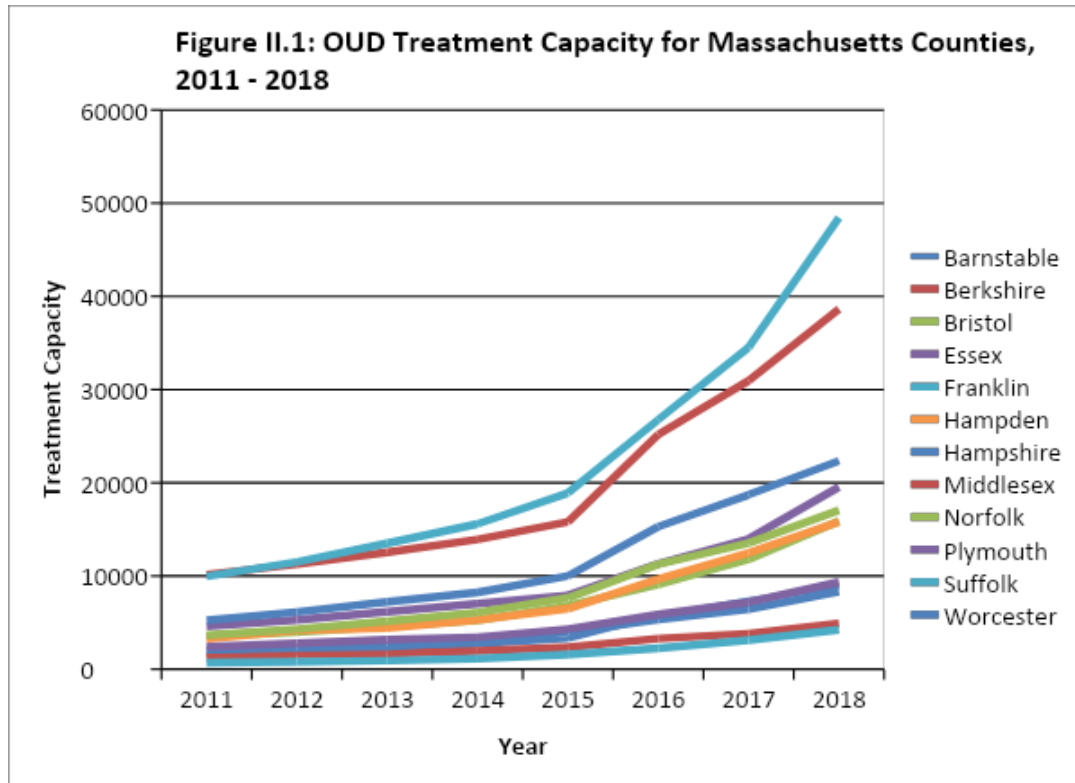
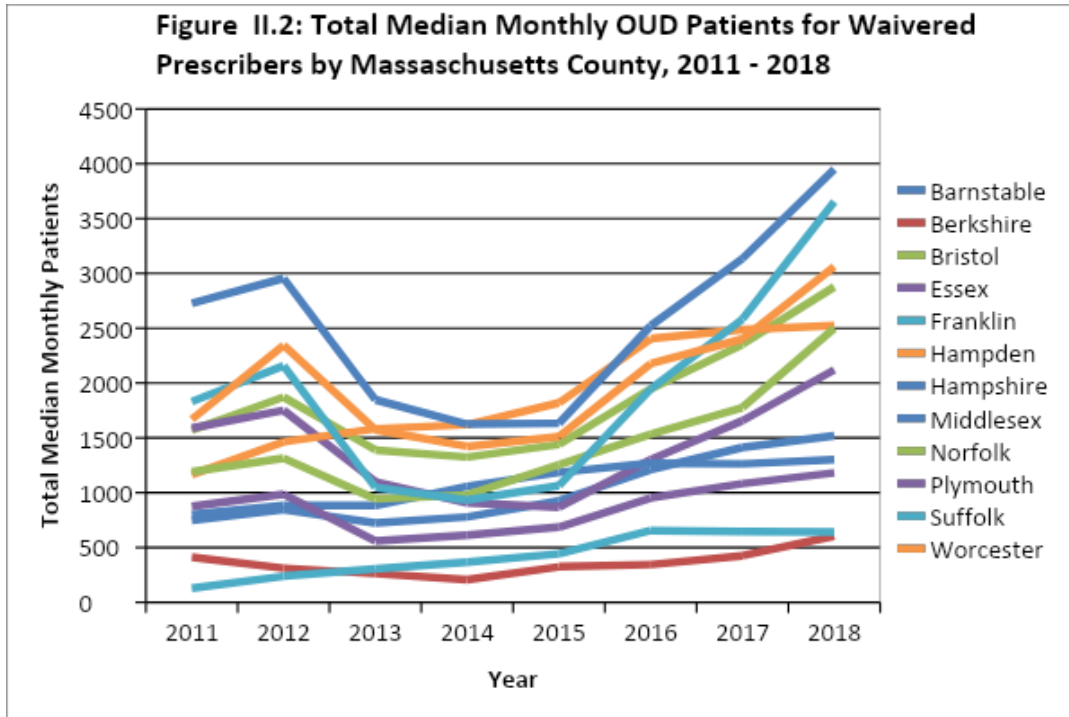
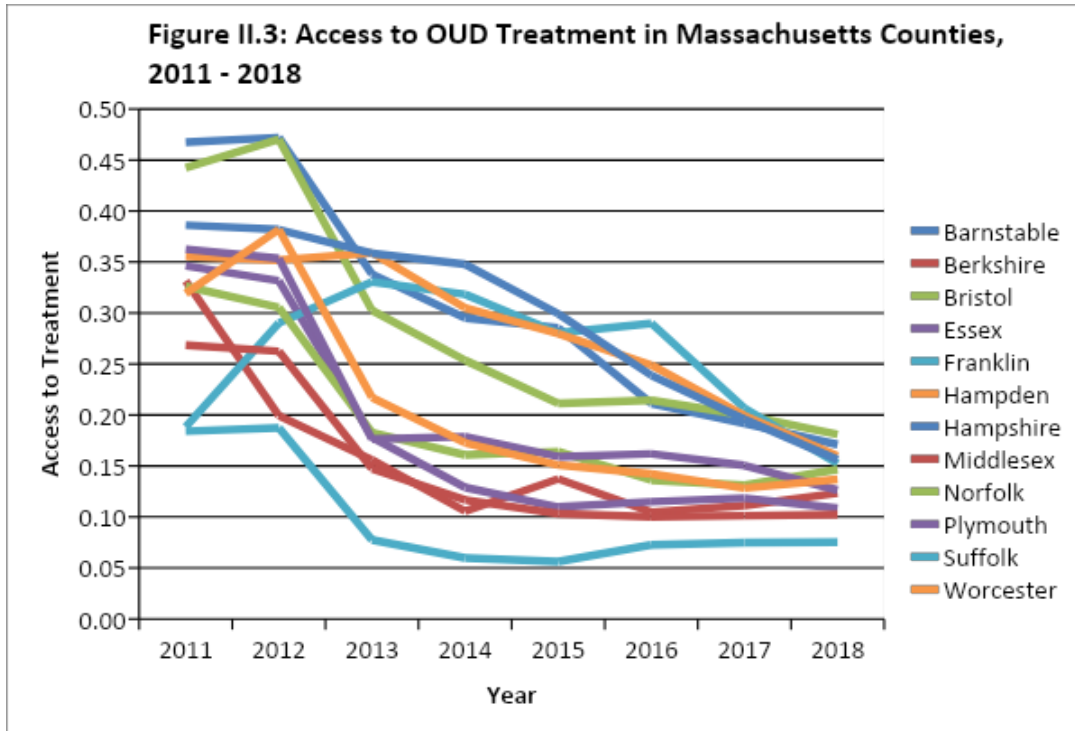


Figure II.2 displays changes in the actual number of (concurrent) patients treated in each county, 2011 – 2018. The picture here is somewhat more complex. Except for Franklin, Hampshire, and Hampden (adjoining counties in the western part of the state), counties exhibit a rough “U”-shaped pattern over time – decreases in patients from 2011/2012 to 2013 – 2015, then an upward tail from 2016 through 2018. Franklin, Hampshire, and Hampden counties exhibit a steadily increasing trend from 2011 through 2018. Although the relative county rankings do change from 2011 to 2018, they do not change a great deal: counties ranking relatively high in actual numbers of patients treated remained relatively high, and counties ranking relatively low remained relatively low. There is a somewhat greater dispersion of values in 2018 than in 2011.

As in Figure II.1, 2015 represents an inflection point for most of the county trajectories in number of patients treated. We found that the average number of patients treated increases for each increase in the patient limit waivers, so that as prescribers became waived for 275 patients, in particular, their average number of patients treated would increase noticeably.



Changes in access to treatment – the ratio of actual number of patients to treatment capacity – are shown in Figure II.3. In contrast to treatment capacity and the actual number of patients, the range of values across counties decreased from 2011 to 2018; that is, county-level access to treatment tended to converge over time, rather than diverge. As with the actual number of patients, the county rankings in access to treatment remained relatively unchanged from 2011 to 2018. An exception was Franklin County, which rose from well below the median in 2011 to above the median in 2018.



Because county-level rank in access to treatment remained relatively unchanged across these years, pooling the data to achieve greater statistical power seems warranted. Table II.1 below provides the results of tobit regressions of access to treatment, in relation to the variables listed above, including county race and ethnicity measures. Controlling for the other variables, we found that the percent of black residents was significantly negatively associated with access to treatment in both models, i.e., controlling for the percent of residents in poverty or for median household income. That is, across all eight years, counties with a higher proportion of black residents tended to have lower access to treatment. The percent of Hispanic residents was also significantly negatively associated with access to treatment in the model using the percent of residents in poverty, but only marginally significantly associated in the model using median household income.

In addition, the opioid-related overdose death rate was significantly negatively associated with access to treatment in both models. Access to treatment was also associated with poorer counties, in that it was positively associated with the percent of residents in poverty and negatively associated with median household income.



**Table II.1: Racial/Ethnic Disparities in Access to Buprenorphine Treatment by Massachusetts County, 2011 - 2018**

**II.1a. Dependent variable: Access to Treatment**

Ind. variables	Coefficient	Std. error	P-value	Coefficient	Std. error	P-value
Number of waived prescribers per 10,000 population	<b>-.0179</b>	<b>.0051</b>	<b>&lt; .001</b>	<b>-.0242</b>	<b>.0052</b>	<b>&lt; .001</b>
OD death rate, lagged 1 year	<b>-.0036</b>	<b>.0010</b>	<b>&lt; .001</b>	<b>-.0034</b>	<b>.0011</b>	<b>.002</b>
Methadone clinics per 100,000 pop.	.0213	.0283	.451	.0556	.0286	.052
Percent of population in poverty	<b>.0060</b>	<b>.0030</b>	<b>.046</b>	<b>.0069</b>	<b>.0035</b>	<b>.048</b>
Percent black	<b>-.7645</b>	<b>.1912</b>	<b>&lt; .001</b>	-	-	-
Percent Hispanic	-	-	-	<b>-.5079</b>	<b>.1613</b>	<b>.002</b>
Constant	<b>.2977</b>	<b>.0345</b>	<b>&gt;.001</b>	<b>.2843</b>	<b>.0381</b>	<b>&lt; .001</b>

**II.1b. Dependent variable: Access to Treatment**

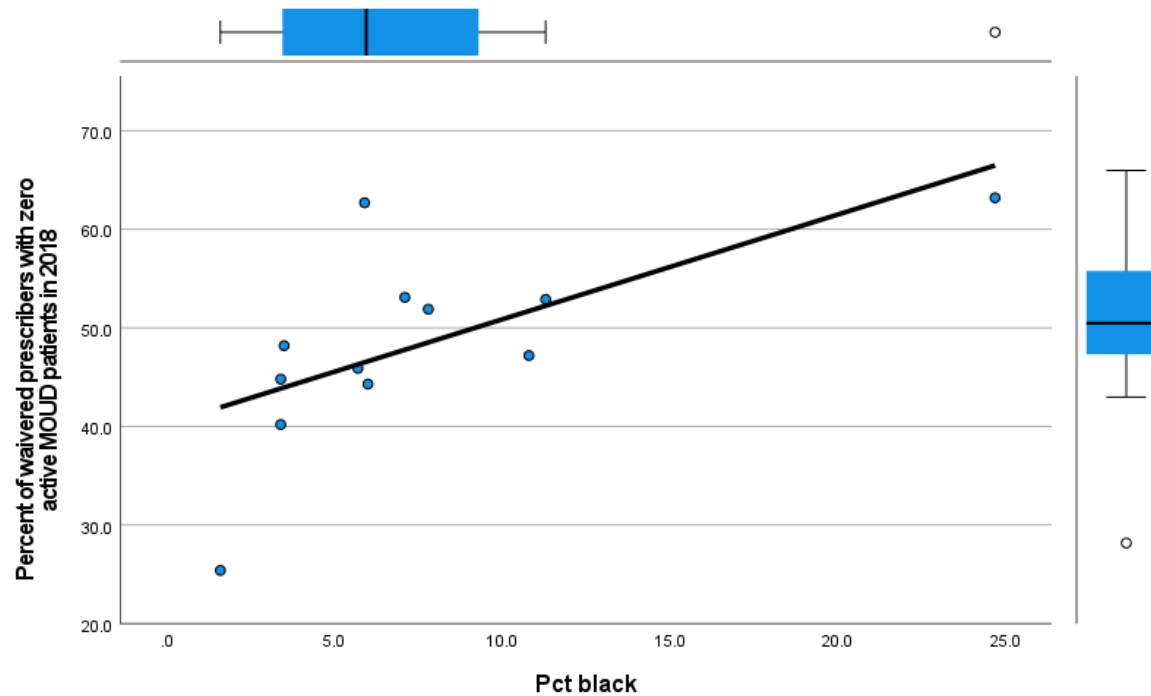
Ind. variables	Coefficient	Std. error	P-value	Coefficient	Std. error	P-value
Number of waived prescribers per 10,000 population	<b>-.0178</b>	<b>.0048</b>	<b>&lt; .001</b>	-.0074	.0063	.239
OD death rate, lagged 1 year	<b>-.0028</b>	<b>.0010</b>	<b>.004</b>	<b>-.0039</b>	<b>.0010</b>	<b>&lt; .001</b>
Methadone clinics per 100,000 pop.	-.0050	.0271	.853	-.0090	.0281	.749
Median household income	<b>-2.58e-06</b>	<b>6.67e-07</b>	<b>&lt; .001</b>	<b>-3.27e-06</b>	<b>1.13e-06</b>	<b>.004</b>
Percent black	<b>-.4864</b>	<b>.1557</b>	<b>.002</b>	-	-	-
Percent Hispanic	-	-	-	-.4138	.2282	.070
Constant	<b>.5220</b>	<b>.0473</b>	<b>&lt; .001</b>	<b>.5727</b>	<b>.0762</b>	<b>&lt; .001</b>

Note: Tobit regression controlling for clustering of values by county and year. N = 96. Parameters significant at the .05 level are in **bold**.

Two phenomena appear to underlie these observed disparities in access to treatment. First, a higher proportion of prescribers waived for 30 patients are not prescribing buprenorphine at all in counties with a higher proportion of black or Hispanic residents. Figure II.4 below, for example, depicts the correlation in 2018 between the proportion of 30-patient waived prescribers with no patients and the percent of black residents.



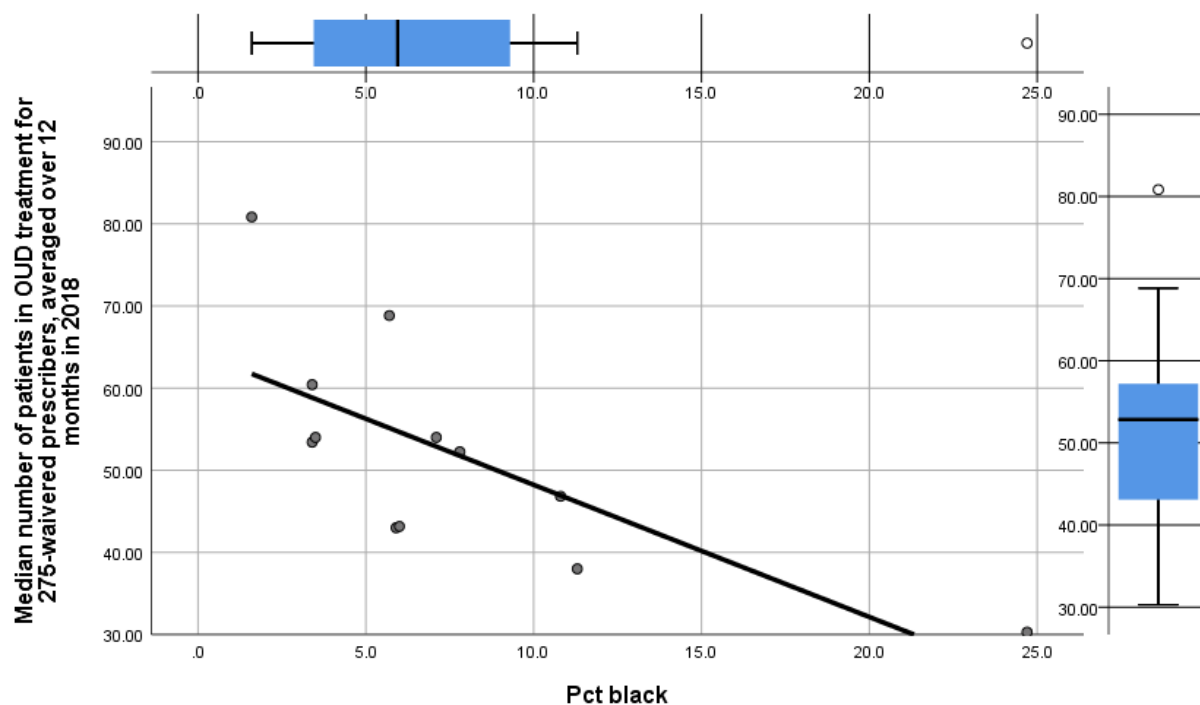
**Figure II.4: Scatterplot of percent of percent of prescribers waived for 30 patients in each county with zero MOUD patients in 2018, and percent of county residents who are black**



Note: The correlation coefficient,  $r = .648$  ( $p = .023$ ). (Without Boston, point at the farthest right,  $r = .563$ ,  $p = .071$ .)

Second, both the proportion of waived prescribers who are waived for 275 patients, and the median number of patients of those 275-patient waived prescribers, are lower in counties with a higher proportion of black or Hispanic residents. For example, Figure II.5 below shows the association in 2018 between the median number of patients of prescribers waived for 275 patients and the percent of county residents who are black.

**Figure II.5: Scatterplot of median number of patients in OUD treatment by physicians waived for 275 patients, averaged over the 12 months of 2018, and percent of county residents who are black**



Note: The correlation coefficient,  $r = -.723$  ( $p = .008$ ). Note, excluding Boston (point at far right),  $r = -.680$  ( $p = .021$ ).

An alternative way to assess both disparities in access to treatment and the role of prescribers waived for 275 patients in maintaining those disparities is to examine the county-wide averages of the median number of patients for prescribers in each waiver patient limit. In Table II.2 below are displayed the correlations, for each year 2011 – 2018, between the county-wide average of the median number of patients for prescribers waived for (i) 100 patients, and (ii) 275 patients (the latter starting in 2016), and the percent of black or Hispanic residents in the county.

**Table II.2: Correlations between numbers of patients for 100-patient and 275-patient waived prescribers, and percent black or percent Hispanic, by Massachusetts counties, 2011 - 2018**

Correlations between:	2011	2012	2013	2014	2015	2016	2017	2018
100-waiver prescribers number of patients and percent black	-.385	-.360	<b>-.610</b>	-.498	<b>-.594</b>	-.510	-.226	.023
100-waiver prescribers number of patients and percent Hispanic	-.262	-.209	-.227	-.228	-.412	-.331	-.056	-.029
275-waiver prescribers number of patients and percent black	-	-	-	-	-	-.380	-.554	<b>-.665</b>
275-waiver prescribers number of patients and percent Hispanic	-	-	-	-	-	-.100	-.331	-.351

Note: Correlations significant at the .05 level are in **bold**.

Instead of looking at the overall measure of access to treatment – the ratio of the county-wide average median number of patients for all waived prescribers, to the county-wide total waiver capacity – we are focusing on the numbers of patients per prescriber for each of the two higher waiver categories. We observe that for correlations of the 100-waiver prescribers’ number of patients with both the percent of black residents and the percent of Hispanic residents, these correlations are negative and relatively consistent from 2011 through 2016. In 2017 and, especially, 2018, however, they decrease substantially in magnitude, becoming essentially zero in 2018. Concurrently, beginning in 2016, correlations of the 275-waiver prescribers’ number of patients with the percent of black and of Hispanic residents steadily increase in (negative) magnitude, reaching statistical significance in 2018 with percent of black residents (the number of observations in each table cell is 12; statistical power is limited). In other words, apparent racial/ethnic disparities in access to treatment that were associated with the presence of prescribers waived for 100 patients for 2011 – 2016, have shifted to become associated with prescribers waived for 275 patients in the two full years in which that patient limit has existed.

We hypothesize that these phenomena are driven by provider access to peer information, support, and resources (or the lack thereof). We describe below properties of prescriber patient-sharing networks – a proxy for prescriber communication networks – likely to reflect such access, and how these properties vary in relation to county demographics.

### III. How do properties of waived prescriber patient-sharing networks, thought to reflect prescriber access to peer information, support, and resources, vary in relation to community race and ethnicity?

A growing body of research has demonstrated that physician shared-patient network ties can both reflect and influence physician behavior. Using Medicare claims data, Barnett and colleagues found that physicians who shared at least 9 patients within a year had a greater than 80% chance of self-reporting professional communication with each other.<sup>20</sup> Physician patient-sharing networks have been found to vary geographically,<sup>21</sup> across payers,<sup>22</sup> and across provider communities,<sup>23</sup> while physicians who share relatively many patients tend to exhibit similar prescribing patterns<sup>18</sup> and engage in similar cancer treatment protocols.<sup>24</sup> Additional validation of the use of shared-patient networks as proxies for physician communication networks is found in research linking properties of such networks with hospital costs and readmission rates,<sup>25,26,27</sup> care-sensitive hospital admissions,<sup>28</sup> and overall costs of health care and rates of hospitalization.<sup>29</sup> Further, providers with many shared patients are less likely to co-prescribe overlapping benzodiazepines compared with providers who share few patients.<sup>30</sup>

#### Methods

Following Barnett and colleagues, we constructed patient-sharing networks in each county for each year 2011 – 2018, where only ties of at least 10 shared patients in a year were counted. A patient was defined

---

<sup>20</sup> Barnett ML, Landon BE, O'Malley AJ, Keating NL, & Christakis NA. (2011). Mapping physician networks with self-reported and administrative data. *Health Services Research*; 46: 1592-1609.

<sup>21</sup> Landon BE, Keating NL, Barnett ML, Onnela J-P, Paul S, O'Malley AJ, Keegan T, & Christakis NA. (2012). Variation in patient-sharing networks of physicians across the United States. *JAMA*; 308(3): 265-273.

<sup>22</sup> Trogon JG, Weir WH, Shai S, Mucha PJ, Kuo TM, Meyer AM, & Stitzenber KB. (2019). Comparing shared patient networks across payers. *Journal of General Internal Medicine*; published online April 3, 2019.

<https://doi.org/10.1007/s11606-019-04978-9>.

<sup>23</sup> Stein BD, Mendelsohn J, Gordon AJ, Dick AW, Burns RM, Sorbero M, Shih RA & Pacula RL. (2017). Opioid analgesic and benzodiazepine prescribing among Medicaid-enrollees with opioid use disorders: The influence of provider communities. *Journal of Addictive Diseases*; 36(1): 14-22. Doi: 10.1080/10550887.2016.1211784.

<sup>24</sup> Pollack CE, Weissman G, Bekelman J, Liao K, & Armstrong K. (2012). Physician social networks and variation in prostate cancer treatment in three cities. *Health Services Research*; 47(1), Part II: 380-403. Doi: 10.1111/j.1475-6773.2011.01331.x.

<sup>25</sup> Barnett ML, Christakis NA, O'Malley J, Onnela J-P, Keating NL, & Landon BE. (2012). Physician patient-sharing networks and the cost and intensity of care in US hospitals. *Medical Care*; 50(2): 152-160.

<sup>26</sup> Uddin S, Hossain L, & Kelaher M. (2011). Effect of physician collaboration network on hospitalization cost and readmission rate. *European Journal of Public Health*; 22(5): 629-633. Doi: 10.1093/eurpub/ckr153.

<sup>27</sup> Uddin S, Hossain L, Hamra J, & Alam A. (2013). A study of physician collaborations through social network and exponential random graph. *BMC Health Services Research*; 13: 234. Doi: 10.1186/1472-6963-13-234.

<sup>28</sup> Casalino LP, Pesko MF, Ryan AM, Nyweide DJ, Iwashyna TJ, Sun X, Mendelsohn J, & Moody, J. (2015). Physician networks and ambulatory care-sensitive admissions. *Medical Care*; 53(6): 534-541.

<sup>29</sup> Pollack CE, Weissman GE, Lemke KW, Hussey PS, & Weiner JP. (2012). Patient sharing among physicians and costs of care: A network analytic approach to care coordination using claims data. *Journal of General Internal Medicine*; 28(3): 459-465. Doi: 10.1007/s11606-012-2104-7.

<sup>30</sup> Ong M-S, Olson KL, Carni A, Liu C, Tian F, Selvam N, & Mandl KD. (2015). Provider patient-sharing networks and multiple-provider prescribing of benzodiazepines. *Journal of General Internal Medicine*; 31(2): 164-171. Doi: 10.1007/s11606-015-3470-8.

as an individual who received one or more prescriptions of the buprenorphine formulations intended for OUD treatment, following a period of at least 30 days in which no buprenorphine prescriptions had been dispensed to that patient.<sup>31</sup> The waived prescriber who initially prescribed buprenorphine to the patient was deemed the primary prescriber; other prescribers of buprenorphine to that patient during the year were considered to have shared that patient. The primary prescribers were grouped by county; other prescribers sharing patients with them might be located within or outside the county.

We identified several network properties thought to reflect greater provider access to peer information, resources, and support:

- **Largest connected component.** This is the largest network component in which each member has at least one shared-patient tie with other members. The larger the percent of prescribers in the network who are part of this component, the greater the likelihood that a prescriber has a communication link with most other prescribers in the network.<sup>32</sup>
- **Small World Index.** A network's small world-ness has to do with the number of steps (ties) it takes to reach any individual from any other individual in the network. A smaller number reflects greater prescriber access to the other prescribers in the network. The measure is a combination of the clustering coefficient – the extent to which prescribers are tightly connected with one another in subgroups – and the presence of ties between the subgroups, which allows for efficient sharing of information between the groups.<sup>33</sup>
- **Centralization.** This is the extent to which the network is shaped around relatively few prescribers each of whom has many ties. Such prescribers can act as network “hubs,” in effect tying the network together and helping to reduce the presence of outlier subgroups. Values range between 0 and 1.<sup>34</sup>

To illustrate these measures, we have diagrammed below the shared-patient networks for buprenorphine prescribers in two different counties in 2018. In Berkshire County, all of the prescribers in the network (i.e., who shared at least 10 patients during the year with at least one other prescriber) are part of a single connected component. Although there are distinct subgroups, or clusters, in the network, these subgroups are connected with one another, so that the Small World Index (SMI) is relatively low at 4.13. The network tends to be organized around several “hubs,” each of whom has many ties; its centralization is moderately high at .384.

In contrast, the corresponding network for Bristol County in 2018 consists of several clusters which are not connected with each other. Slightly more than one quarter of prescribers in the network are part of the largest connected component. Because the clusters are not connected, the SMI is relatively high at 26.16. Centralization is relatively low at .124.

---

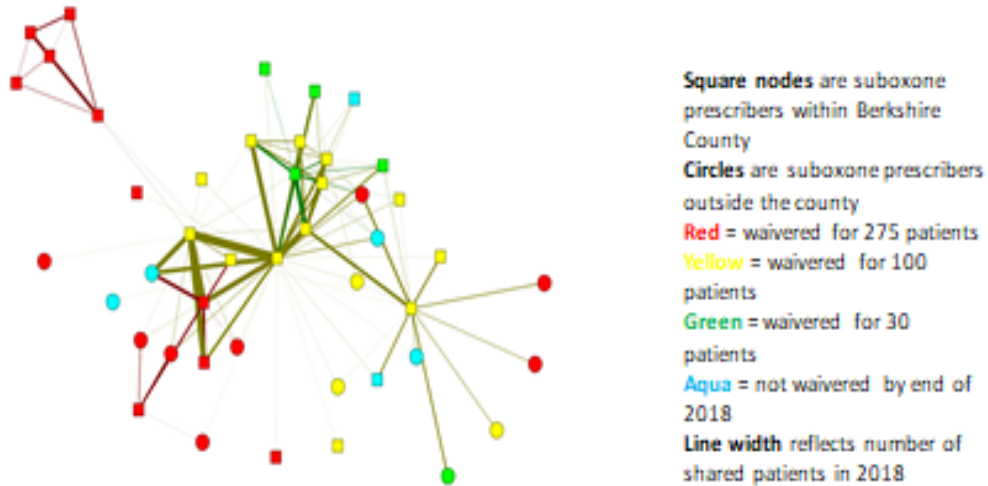
<sup>31</sup> Thomas, CP, Doyle, E, Kreiner, P, Jones, CM, Dubenitz, J, Horan, A, and Stein, BD. (2017). Prescribing patterns of buprenorphine waived physicians. *Drug and Alcohol Dependence*; 181: 213-218. [dx.doi.org/10.1016/j.drugalcdep.2017.10.002](https://doi.org/10.1016/j.drugalcdep.2017.10.002).

<sup>32</sup> Wasserman S & Faust K. (1994). *Social Network Analysis: Methods and Applications*. Cambridge, UK: Cambridge University Press. P. 109.

<sup>33</sup> Neal ZP, (2017). How small is it? Comparing indices of small worldliness. *Network Science*; 5(1): 30-44.

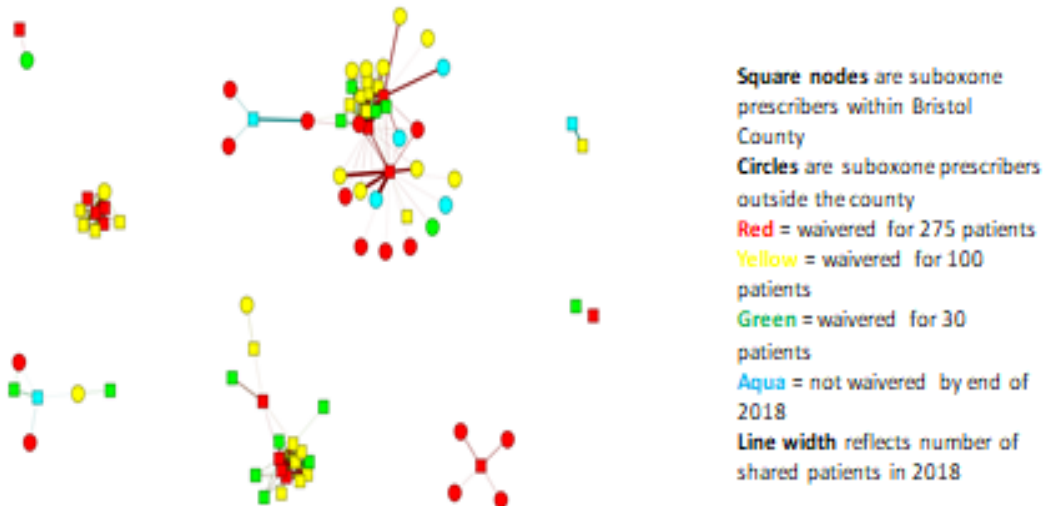
<sup>34</sup> Wasserman S & Faust K. *Op.cit.* Pp. 175-177.

## Buprenorphine prescriber patient-sharing network: Berkshire County, 2018



For Berkshire County in 2018, 100% of buprenorphine prescribers in the network are in the largest connected component. Small World Index (SMI) is 4.13, and centralization is .384.

## Buprenorphine prescriber patient-sharing network: Bristol County, 2018



In contrast, for Bristol County in 2018, 28.8% of prescribers in the network are in the largest connected component, SMI is 26.16, and centralization is .124.

Using pooled time series models similar to those used above for access to treatment, we conducted tobit regressions with each of these network properties as the dependent variable, in turn, and with the same independent variables as in the previous models. That is, we looked for evidence of racial/ethnic disparities in these properties of prescriber patient-sharing networks, controlling for the number of waived prescribers in the county (per 10,000 population), the lagged overdose death rate, methadone clinics per 100,000 population, and either percent of the population in poverty or the median household income. In a small number of instances, in the earlier years, there were too few waived prescribers who shared at least 10 patients with other waived prescribers to obtain measures of these properties. These instances were omitted from the analyses.

## Results

Results of these analyses are shown in Tables III.1 – III.3 below. Across the years 2011 – 2018, there is strong evidence of racial/ethnic disparities in the network properties of SMI and centralization – SMI (higher values are worse) is positively associated with percent black and percent Hispanic, and centralization is negatively associated with percent black and percent Hispanic. However, there is only slight evidence of a disparity for the percent of prescribers in the largest connected component, which is negatively associated with percent black only with the covariate of percent of residents in poverty.

Using models similar to those displayed in Table II.1 in the previous section, we assessed associations between each of the network properties and access to treatment. Across all eight years (2011 – 2018), we did not find significant associations. As observed in Figures II.1 and II.2 above, however, there appears to be an inflection point in the two measures that form our access to treatment measure. Moreover, as depicted in Table II.2, the dynamics of patients for waived prescribers with different patient limits appears to change starting in 2016 with the advent of the 275-patient limit. For these reasons, we conducted separate analyses for the years 2011 – 2014 and 2015 – 2018. For 2011 – 2014, we found no significant associations between the network properties and access to treatment. For 2015 – 2018, however, we found significant associations between each of the network properties and access to treatment, despite the relatively small number of observations (N = 45). These results are presented in Tables III.4a – III.4c below. That is, counties with a higher percent of waived prescribers in the shared-patient network largest connected component, with a smaller Small World Index, and with higher centralization, tended to have higher access to treatment. The models controlled for the number of waived prescribers in the county per 10,000 population, the opioid-related overdose death rate from the previous year, the number of methadone clinics per 100,000 population, and the percent of residents in poverty or the median household income. Because these network properties are somewhat correlated (and because of the relatively small number of observations), we examined them in separate models.





**Table III.1: Racial/Ethnic Disparities in Percent of Waivered Prescribers in Largest Connected Component by Massachusetts County, 2011 - 2018**

**III.1a. Dependent variable: Percent of Waivered Prescribers in Largest Connected Component**

Ind. variables	Coefficient	Std. error	P-value	Coefficient	Std. error	P-value
Number of waivered prescribers per 10,000 pop.	-.0007	.0147	.961	-.0019	.0149	.898
OD death rate, lagged 1 year	<b>.0048</b>	<b>.0022</b>	<b>.029</b>	<b>.0048</b>	<b>.0023</b>	<b>.035</b>
Methadone clinics per 100,000 pop.	.0600	.0690	.385	.0709	.0686	.301
Percent of population in poverty	.0219	.0127	.086	.0190	.0142	.181
Percent black	<b>-2.7765</b>	<b>1.2276</b>	<b>.024</b>	-	-	-
Percent Hispanic	-	-	-	1.2458	.9777	.203
Constant	.2450	.1601	.118	.2383	.1716	.165

**III.1b. Dependent variable: Percent of Waivered Prescribers in Largest Connected Component**

Ind. variables	Coefficient	Std. error	P-value	Coefficient	Std. error	P-value
Number of waivered prescribers per 10,000 pop.	-.0045	.0154	.769	-.0044	.155	.776
OD death rate, lagged 1 year	.0044	.0025	.078	.0046	.0026	.078
Methadone clinics per 100,000 pop.	.0688	.0704	.328	.0710	.0701	.311
Median household income	-2.19e-06	3.57e-06	.540	-2.63e-06	3.85e-06	.494
Percent black	-1.7853	1.1358	.116	-	-	-
Percent Hispanic	-	-	-	-.7055	.8574	.411
Constant	<b>.6054</b>	<b>.2267</b>	<b>.008</b>	<b>.5921</b>	<b>.2608</b>	<b>.023</b>

Note: Tobit regression controlling for clustering of values by county and year. N = 93. Parameters significant at the .05 level are in **bold**.

**Table III.2: Racial/Ethnic Disparities in Small World Index by Massachusetts County, 2011 - 2018**

**III.2a. Dependent variable: Small World Index**

Ind. variables	Coefficient	Std. error	P-value	Coefficient	Std. error	P-value
Number of waived prescribers per 10,000 pop.	.0260	.0741	.726	.0159	.0717	.824
OD death rate, lagged 1 year	-.0087	.0126	.490	-.0124	.0130	.342
Methadone clinics per 100,000 pop.	-.2219	.4757	.641	-.3923	.4761	.410
Percent of population in poverty	-.0259	.0666	.697	-.0520	.0705	.461
Percent black	<b>11.3412</b>	<b>5.7574</b>	<b>.049</b>	-	-	-
Percent Hispanic	-	-	-	<b>9.1905</b>	<b>4.1498</b>	<b>.027</b>
Constant	<b>2.2879</b>	<b>.8151</b>	<b>.005</b>	<b>2.5806</b>	<b>.8224</b>	<b>.002</b>

**III.2b. Dependent variable: Small World Index**

Ind. variables	Coefficient	Std. error	P-value	Coefficient	Std. error	P-value
Number of waived prescribers per 10,000 pop.	.0344	.0781	.660	.0140	.0744	.851
OD death rate, lagged 1 year	-.0063	.0135	.644	-.0121	.0137	.377
Methadone clinics per 100,000 pop.	-.2790	.4830	.564	-.3807	.4844	.432
Median household income	1.21e-06	1.83e-05	.947	1.03e-05	1.79e-05	.564
Percent black	<b>10.1682</b>	<b>5.0110</b>	<b>.042</b>	-	-	-
Percent Hispanic	-	-	-	<b>7.8646</b>	<b>3.2988</b>	<b>.017</b>
Constant	2.1006	1.1982	.080	1.4119	1.2275	.250

Note: Tobit regression controlling for clustering of values by county and year. N = 79. Parameters significant at the .05 level are in **bold**.

**Table III.3: Racial/Ethnic Disparities in Network Centrality by Massachusetts County, 2011 - 2018**

**III.3a. Dependent variable: Network Centrality**

Ind. variables	Coefficient	Std. error	P-value	Coefficient	Std. error	P-value
Number of waived prescribers per 10,000 pop.	.0169	.0093	.070	-.0076	.0111	.490
OD death rate, lagged 1 year	-.0018	.0019	.336	.0020	.0018	.264
Methadone clinics per 100,000 pop.	.0167	.0567	.768	.0677	.0525	.197
Percent of population in poverty	.0059	.0058	.307	.0112	.0090	.216
Percent black	<b>-1.4153</b>	<b>.3654</b>	<b>&lt; .001</b>	-	-	-
Percent Hispanic	-	-	-	<b>-1.1932</b>	<b>.5088</b>	<b>.019</b>
Constant	<b>.2205</b>	<b>.0628</b>	<b>&lt; .001</b>	.1633	.1014	.107

**III.3b. Dependent variable: Network Centrality**

Ind. variables	Coefficient	Std. error	P-value	Coefficient	Std. error	P-value
Number of waived prescribers per 10,000 pop.	.0175	.0092	.057	-.0053	.0113	.638
OD death rate, lagged 1 year	-.0010	.0018	.598	.0025	.0019	.177
Methadone clinics per 100,000 pop.	-.0195	.0579	.737	.0507	.0543	.350
Median household income	<b>-2.69e-06</b>	<b>1.38e-06</b>	<b>.050</b>	-3.40e-06	1.98e-06	.086
Percent black	<b>-1.1597</b>	<b>.2953</b>	<b>&lt; .001</b>	-	-	-
Percent Hispanic	-	-	-	<b>-.9467</b>	<b>.3785</b>	<b>.012</b>
Constant	<b>.4589</b>	<b>.1033</b>	<b>&lt; .001</b>	<b>.4883</b>	<b>.1354</b>	<b>&lt; .001</b>

Note: Tobit regression controlling for clustering of values by county and year. N = 92. Parameters significant at the .05 level are in **bold**.

**Table III.4: Association of Access to Treatment with Prescriber Shared-patient Network Properties, by Massachusetts County, 2015 – 2018**

**III.4a. Dependent variable: Access to treatment**

Ind. variables	Coefficient	Std. error	P-value	Coefficient	Std. error	P-value
Number of waived prescribers per 10,000 pop.	<b>-.0092</b>	<b>.0033</b>	<b>.006</b>	<b>-.0070</b>	<b>.0031</b>	<b>.024</b>
OD death rate, lagged 1 year	.0003	.0008	.718	.0010	.0009	.260
Methadone clinics per 100,000 pop.	-.0165	.0193	.392	<b>-.0758</b>	<b>.0237</b>	<b>.001</b>
Percent of population in poverty	.0019	.0027	.492	-	-	-
MHI	-	-	-	<b>-2.42e-06</b>	<b>6.13e-07</b>	<b>&lt; .001</b>
Percent of prescribers in LCC	<b>.0011</b>	<b>.0003</b>	<b>&lt; .001</b>	<b>.0010</b>	<b>.0003</b>	<b>.001</b>
Constant	<b>.1238</b>	<b>.0476</b>	<b>.009</b>	<b>.3336</b>	<b>.0685</b>	<b>&lt; .001</b>

**III.4b. Dependent variable: Access to treatment**

Ind. variables	Coefficient	Std. error	P-value	Coefficient	Std. error	P-value
Number of waived prescribers per 10,000 pop.	-.0052	.0040	.194	-.0043	.0034	.206
OD death rate, lagged 1 year	.0001	.0010	.898	.0001	.0008	.922
Methadone clinics per 100,000 pop.	-.0322	.0244	.188	<b>-.0798</b>	<b>.0239</b>	<b>.001</b>
Percent of population in poverty	<b>-.0052</b>	<b>.0025</b>	<b>.036</b>	-	-	-
MHI	-	-	-	<b>-2.76e-06</b>	<b>5.84e-07</b>	<b>&lt; .001</b>
SMI	<b>-.0020</b>	<b>.0004</b>	<b>&lt; .001</b>	<b>-.0013</b>	<b>.0004</b>	<b>.001</b>
Constant	<b>.1769</b>	<b>.0375</b>	<b>&lt; .001</b>	<b>.4467</b>	<b>.0525</b>	<b>&lt; .001</b>

Note: Tobit regression controlling for clustering of values by county and year. N = 45. Parameters significant at the .05 level are in **bold**.

**III.4c. Dependent variable: Access to treatment**

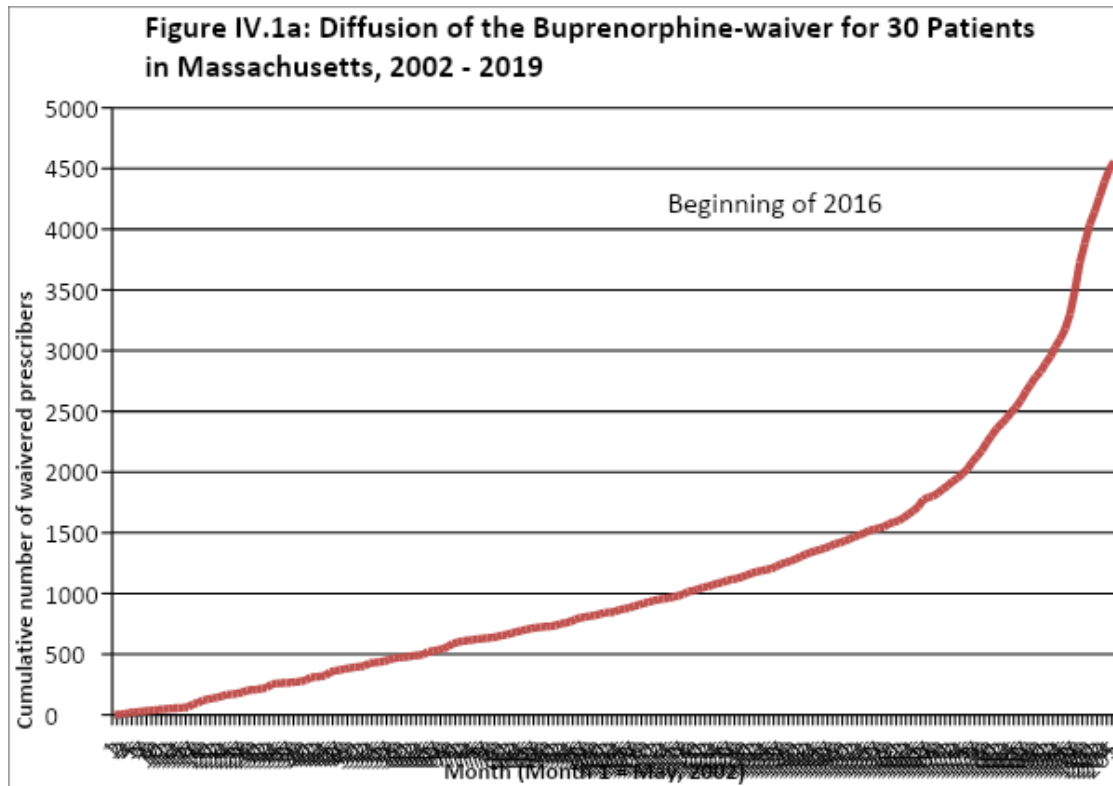
<b>Ind. variables</b>	<b>Coefficient</b>	<b>Std. error</b>	<b>P-value</b>	<b>Coefficient</b>	<b>Std. error</b>	<b>P-value</b>
Number of waived prescribers per 10,000 pop.	<b>-.0071</b>	<b>.0035</b>	<b>.045</b>	<b>-.0067</b>	<b>.0033</b>	<b>.046</b>
OD death rate, lagged 1 year	.0002	.0009	.821	.0002	.0009	.827
Methadone clinics per 100,000 pop.	-.0265	.0180	.141	<b>-.0823</b>	<b>.0229</b>	<b>&lt; .001</b>
Percent of population in poverty	.0031	.0029	.294	-	-	-
MHI	-	-	-	<b>-2.81e-06</b>	<b>6.11e-07</b>	<b>&lt; .001</b>
Centralization	<b>.1144</b>	<b>.0422</b>	<b>.007</b>	.0925	.0496	.062
Constant	<b>.1386</b>	<b>.0505</b>	<b>.006</b>	<b>.4132</b>	<b>.0638</b>	<b>&lt; .001</b>

Note: Tobit regression controlling for clustering of values by county and year. N = 45. Parameters significant at the .05 level are in **bold**.

**IV. Do patient-sharing network ties among buprenorphine prescribers facilitate prescribers becoming waived initially, increasing their patient limits, and/or their provision of buprenorphine treatment (i.e., treatment duration, number of active patients)?**

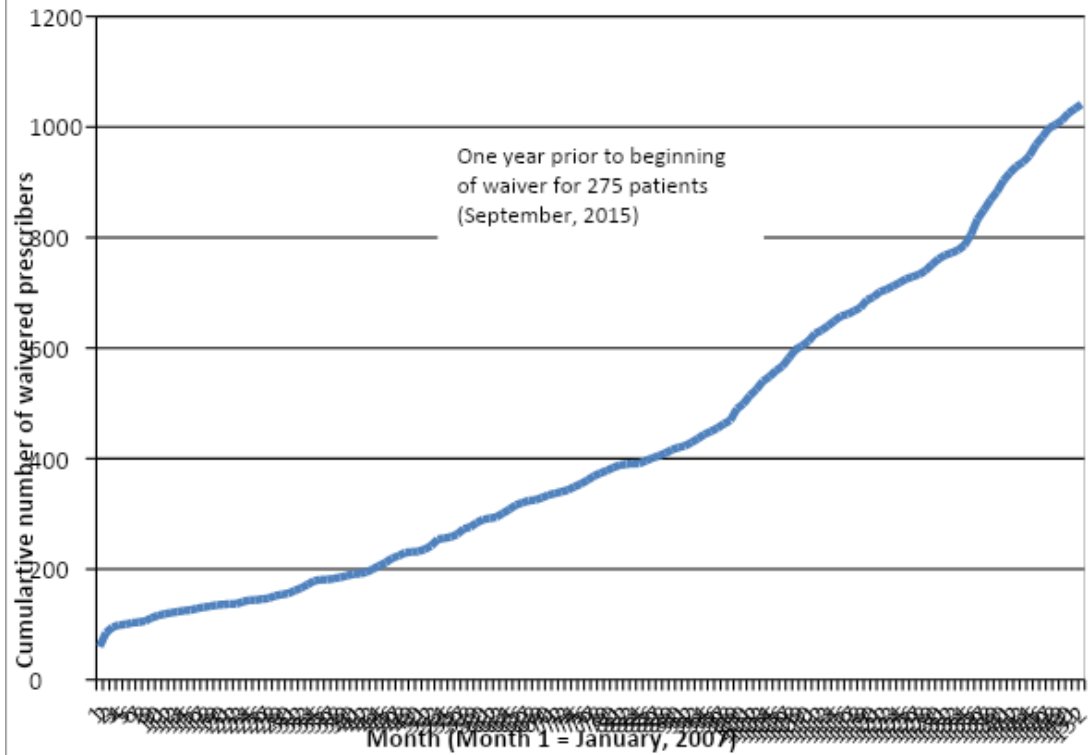
Diffusion curves depicting cumulative adoption of initially becoming buprenorphine-waivered (to treat up to 30 patients concurrently), becoming waived to treat 100 patients, and becoming waived to treat 275 patients, are shown in Figures IV.1a – IV.1c below. The waiver process began in 2002, with the increase to 100 patients beginning in 2007, and the increase to 275 patients beginning in 2016.

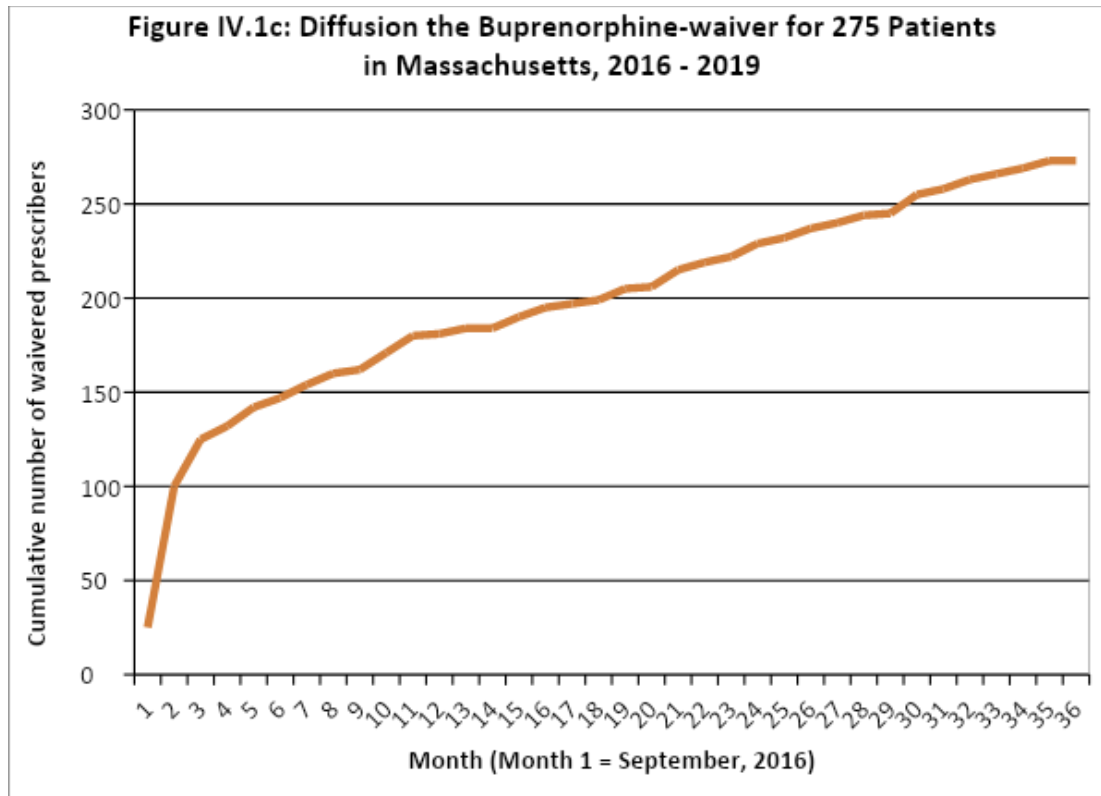
We note the different shapes of the three diffusion curves. In the diffusion of innovations literature, a distinction is made between diffusion processes that are internally driven – propelled by interactions among the individuals that are part of the system, such as the sharing of information by early adopters with those who have not (yet) adopted, or the observation of benefits achieved by early adopters, by potential adopters – and diffusion processes that are externally driven – propelled by forces outside the system, so that many individuals may adopt early because of external pressure to do so.<sup>35</sup> Internally-driven diffusions, which depend on peer interaction or peer communication, take on the traditional “S”-shaped diffusion curve; the diffusion of the buprenorphine-waiver for 30 patients has the appearance of the lower and middle portions of such a curve, including the inflection point at which adoption increases rapidly, and a bit beyond.



<sup>35</sup> See, for example, Jackson MO. (2008). *Social and Economic Networks*. Princeton: Princeton University Press, pp. 185-188.

**Figure IV.1b: Diffusion of the Buprenorphine-waiver for 100 Patients in Massachusetts, 2007 - 2019**





In contrast, the diffusion curve for the waiver for 275 patients has the appearance of an externally-driven diffusion curve – with a high early adoption followed by a leveling-off.<sup>36</sup> The diffusion of the waiver for 100 patients mostly resembles an internally-driven process, but has a slight early uptick in adoptions. The graph for the 100-patient waiver shows when prescribers would need to have been so waived to be eligible to apply for the 275-patient waiver when it first became available, in September, 2016 (there was a one-year waiting period after becoming waived for 100 patients). An increase in adoption of the 100-patient waiver began slightly before that point. For reference, we also note, in the graph for diffusion of the 30-patient waiver, the beginning of 2016; a steep increase in adoption of this waiver began around that time (presumably also driven, at least in part, by the advent of the 275-patient waiver).

**A. Initially becoming waived**

Because our PMP data only went as far back as 2011, we were unable to analyze adoption patterns for the 30-patient and 100-patient waivers from their beginnings. In both cases, our data begin when these diffusion processes had been underway for several years. As noted above, in processes characterized by an S-shaped diffusion curve, we would expect adopters after the initial adopters to have communication ties with prior adopters. In our data, shared-patient ties provide a proxy for communication ties.

**Methods**

<sup>36</sup> We note that the pool of potential adopters expanded in 2018, when nurse practitioners and physician assistants became able to obtain the waiver for 275 patients, a number of whom did then obtain these waivers.



Unlike adoption of the 100- and 275-patient waivers, where a pool of potential adopters can be readily identified (i.e., previous adopters of 30- and 100-patient waivers, respectively), initial adopters of the 30-patient waiver could be any Massachusetts prescriber licensed to prescribe controlled substances. To analyze the role that shared-patient ties with waived prescribers might have in facilitating their initial waiver adoption, we analyzed non-buprenorphine shared patient ties among Massachusetts prescribers in 2011 and in 2014, and identified which of those ties were with waived prescribers (providing non-MOUD patient care). We examined these years for two reasons. First, 2011 was the earliest year for which we have PMP data matched with waived prescriber data. Second, because analyzing prescriber ties for all prescribers who appear in the MA PMP is computationally intensive, we conducted this analysis on two years only.

Although we did not have specialty data on these prescribers, or data on their numbers of patients, we did have their county practice location. We used logistic regression to analyze the effect of having at least one non-buprenorphine shared-patient tie with a waived prescriber in 2011 on the likelihood of becoming waived in 2012, 2013, or 2014, controlling (via dichotomous variables for each county) for county location. We conducted a similar analysis for the effect of ties in 2014 on the likelihood of initially becoming waived in each of the subsequent three years.

## Results

A total of 31,522 non-waivered Massachusetts prescribers appeared in the MA PMP data for 2011. Of that total, 74 became waived for 30 patients in 2012. Also of the total of 31,522, 369 had at least one non-buprenorphine shared-patient tie of at least 10 patients with a prescriber waived as of the end of 2011. The association of having at least one such tie and becoming waived in 2012 was significant ( $p = .031$ ), as shown in Table IV.1 below. The proportion of Massachusetts prescribers active in the PMP who initially became waived in 2012 was 0.23%; as indicated in the odds ratio below, this proportion increased by 363%, to 0.81%, for those prescribers who had at least one non-buprenorphine shared-patient tie with a waived prescriber in 2011.

We also examined the effect of having one or more non-buprenorphine shared-patient ties with a waived prescriber in 2011 on becoming waived in 2013, 2014, or in any of the three years 2012-2014. In each of these cases, the effect was significant at the .001 level (Table IV.1) below, with the largest effect in 2014, representing a two-year lag, of more than 1,000% on the likelihood of initially becoming waived. Table IV.1 also shows, for each regression, the Nagelkerke  $R^2$ , a kind of pseudo- $R^2$  for logistic regressions, and the Hosmer and Lemeshow goodness-of-fit test of model to data. Although no definitive goodness-of-fit test exists for logistic regressions, the Hosmer-Lemeshow test is thought to be suggestive though not conclusive, where non-statistical significance reflects relative goodness of fit.

**Table IV.1: Logistic regressions on becoming waived for 30 patients in Massachusetts, 2012, 2013, or 2014**

**Dependent variable: Becoming waived  
for 30 patients in:**

	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2012-2014</b>
<b>Predictors:</b>	<b>OR (95% CI)</b>	<b>OR (95% CI)</b>	<b>OR (95% CI)</b>	<b>OR (95% CI)</b>
<b>Having at least one shared-patient tie with a waived prescriber in 2011</b>	<b>3.630 (1.125, 11.711)</b>	<b>10.711 (5.191, 22.101)</b>	<b>5.340 (2.405, 11.856)</b>	<b>6.533 (3.998, 10.678)</b>
<b>Constant</b>	<b>.002</b>	<b>.001</b>	<b>.003</b>	
<b>N</b>	31,522	31,370	31,278	31,522
<b>Nagelkerke R<sup>2</sup></b>	.017	.039	.032	.027
<b>Hosmer and Lemeshow Test</b>	.990	.996	.990	.990

- Notes: 1. The regressions control for county variations in prescriber location via a dichotomous variable for each county (results not shown).  
2. Odds ratios significant at the .05 level are shown in **bold**.

We also examined the effects of shared-patient ties, based on buprenorphine prescriptions, of non-waivered prescribers with waived prescribers in 2011. Of the 583 non-waivered Massachusetts prescribers who wrote a buprenorphine prescription in 2011, only 7 became initially waived in 2012. This number was too small to reliably analyze associations with shared-patient ties. When combined with the non-buprenorphine shared-patient ties, the addition of the buprenorphine shared-patient ties did not alter the association with becoming waived shown in Table IV.1 above.

We conducted analyses for non-buprenorphine shared-patient ties in 2014, similar to those shown above for 2011. Specifically, we used logistic regression to test the effect, for non-waivered prescribers, of having one or more non-buprenorphine shared-patient ties (of at least 10 patients) with a waived prescriber in 2014, on the likelihood of initially becoming waived in 2015, 2016, or 2017, and on the likelihood of initially becoming waived in any of the three years 2015-2017. As shown in Table IV.2a below, the effects on initially becoming waived in all three years were significant ( $p < .001$ ); having at least one non-buprenorphine shared-patient tie with a waived prescriber in 2014 increased the likelihood of becoming waived by more than 400% in each case, versus having no non-buprenorphine shared-patient ties with a waived prescriber.

**Table IV.2a and IV.2b: Logistic regressions on becoming waived for 30 patients in Massachusetts, 2015, 2016, or 2017**

**IV.2a. Dependent variable: Becoming waived  
for 30 patients in:**

	<b>2015</b>	<b>2016</b>	<b>2017</b>	<b>2015-2017</b>
<b>Predictors:</b>	<b>OR (95% CI)</b>	<b>OR (95% CI)</b>	<b>OR (95% CI)</b>	<b>OR (95% CI)</b>
<b>Having at least one shared-patient tie with a waived prescriber in 2014</b>	<b>6.333 (3.223, 12.443)</b>	<b>4.311 (2.456, 7.566)</b>	<b>4.324 (2.679, 6.981)</b>	<b>4.784 (3.439, 6.654)</b>
<b>Constant</b>	<b>.004</b>	<b>.006</b>	<b>.006</b>	<b>.012</b>

<b>N</b>	33,454	33,345	33,131	33,454
<b>Nagelkerke R<sup>2</sup></b>	.028	.018	.034	.027
<b>Hosmer and Lemeshow Test</b>	.955	.999	.975	.989

Notes: 1. The regressions control for county variations in prescriber location via a dichotomous variable for each county (results not shown).  
2. Odds ratios significant at the .05 level are shown in **bold**.

We further tested the effects of the number of non-buprenorphine shared-patient ties in 2014 (as opposed to having one or more such ties or not) on becoming waived in each of the next three years. As shown in Table IV.2b below, these effects were also significant ( $p < .001$  except for 2016, where  $p = .012$ ). For example, each additional non-buprenorphine shared-patient tie with a waived prescriber in 2014 increased the likelihood of initially becoming waived in any of the next three years (2015-2017) by about 48%. In contrast, for non-buprenorphine shared-patient ties in 2011, the number of such ties was not a significant predictor of initially becoming waived in 2012, 2013, or 2014. That is, having ties beyond one did not increase the likelihood of initially becoming waived in subsequent years.

**IV.2b. Dependent variable: Becoming waived for 30 patients in:**

	<b>2015</b>	<b>2016</b>	<b>2017</b>	<b>2015-2017</b>
<b>Predictors:</b>	<b>OR (95% CI)</b>	<b>OR (95% CI)</b>	<b>OR (95% CI)</b>	<b>OR (95% CI)</b>
<b>Number of shared-patient ties with a waived prescriber in 2014</b>	<b>1.562 (1.287, 1.896)</b>	<b>1.282 (1.056, 1.556)</b>	<b>1.442 (1.267, 1.641)</b>	<b>1.476 (1.318, 1.652)</b>
<b>Constant</b>	<b>.005</b>	<b>.006</b>	<b>.006</b>	<b>.013</b>
<b>N</b>	33,454	33,345	33,131	33,454
<b>Nagelkerke R<sup>2</sup></b>	.023	.012	.032	.022
<b>Hosmer and Lemeshow Test</b>	.967	.995	.215	.942

Notes: 1. The regressions control for county variations in prescriber location via a dichotomous variable for each county (results not shown).  
2. Odds ratios significant at the .05 level are shown in **bold**.

The apparently sustained effect of these non-buprenorphine shared-patient ties over several years led us to examine the stability of these ties from 2011 to 2014. Of the 26,284 non-waivered prescribers who were in both the 2011 and 2014 samples, 328 had one or more non-buprenorphine shared-patient ties in 2011. All 328 (100%) also had one or more non-buprenorphine shared-patient ties in 2014. Of the 25,802 prescribers with no non-buprenorphine shared-patient ties in 2011, 154 (0.6%) had such a tie in 2014. It is unknown how many of those ties may have been with non-waivered prescribers who became waived in 2012-2014 (that is, represented existing non-buprenorphine shared-patient ties). These

numbers suggest that non-waivered prescribers' non-buprenorphine shared-patient ties with waived prescribers tend to be very stable from year to year, and our findings of predictive effects of these ties across several years may simply reflect that.

## **B. Becoming waived for 100 patients**

### **Methods**

Using the same shared-patient networks described in Section III above, we measured the number of shared-patient ties of at least 10 patients for each waived prescriber. We modeled becoming waived for 100 patients as a diffusion process, where the pool of prescribers “at risk” for becoming 100-waivered in each year was all prescribers waived for 30 patients by the end of the prior year. Because the pool of potential adopters changed each year, we conducted separate logistic regressions on becoming 100-waivered for each year 2012 – 2019 (data available for the first 8 months of 2019 only). Predictor variables, each measured for the prior year, included: median number of monthly active MOUD patients, degree – number of shared-patient ties, percent of patients who paid for at least one buprenorphine prescription with Medicaid (data only available in 2016 and later), number of years the prescriber was waived for 30 patients, and medical specialty (broadly categorized as physician – general, physician – psychiatry and neurology, physician – other, and physician – specialty missing. Beginning in 2017, when nurse practitioners and physician assistants were allowed to obtain a waiver, we added a category for NP/PA.) For example, becoming 100-waivered in 2012 was logistically regressed on these variables measured in 2011. Each regression controlled for county differences in prescriber location by means of a dichotomous variable for each county (county control results not shown in the tables below).

Because the diffusion process had been underway for several years, we hypothesized that shared-patient ties with waived prescribers would predict adoption of the 100-patient waiver for 2012 and later years. That is, prescribers more central to the shared-patient networks (i.e., having more ties) would be more likely to adopt this waiver than prescribers less central (having fewer ties).

### **Results**

Tables IV.2a and IV.2b below show the results of the logistic regressions for each year 2012 – 2019. As hypothesized, the number of shared-patient ties was a significant predictor of adoption of the 100-patient waiver for 2012 – 2014 and 2018 and 2019. It was not significant for 2015 – 2017. Other significant predictors included a prescriber's median number of MOUD patients in the previous year (except for 2019), the number of years the prescriber had been waived for 30 patients (fewer years was predictive), and (beginning in the 2016 adoptions) the percent of patients who paid for at least one buprenorphine prescription with Medicaid. We also note that in 2015 general physicians were associated with a higher likelihood of adoption, in 2018 NP/PAs were associated with a higher likelihood of adoption at the expense (statistically) of general physicians and psychiatrists/neurologists, and in 2019 physicians – other were associated with a lower likelihood of adoption.

One explanation for the apparent disruption, in 2015-2017, in the predictive power of shared-patient ties for adoption of the 100-patient waiver, is the availability of the 275-patient waiver beginning in

September 2016. Eligibility for this latter waiver included having been waived for 100 patients for at least one year. This requirement appears to have accelerated adoption of the 100-patient waiver in 2015, altering the factors previously associated with adoption. For example, the effect of years having been waived for 30 patients on adoption of the 100-patient waiver was strongest for 2015 and 2016 compared with the other years studied. Similarly for the effect of median number of MOUD patients. These shifts appear to reflect a surge in adoption of the 100-patient waiver by prescribers newly waived for 30 patients and by prescribers already treating higher numbers of patient who now (beginning in 2016) had the possibility of increasing their practice further. In Figure IV.1b above, we note an increase in the slope of the diffusion curve for the 100-patient waiver at about the beginning of 2015.

Table IV.2a and IV.2b: Logistic regressions on becoming waived for 100 patients in Massachusetts, for each year 2012 – 2018

IV.2a: Dependent variable:

Becoming waived for 100 patients in:

	2012	2013	2014	2015
Predictors <sup>1,2</sup> :	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Median monthly active patients	<b>1.034 (1.016, 1.053)</b>	<b>1.038 (1.019, 1.058)</b>	<b>1.061 (1.017, 1.108)</b>	<b>1.123 (1.067, 1.183)</b>
Degree (no. of shared-patient ties of at least 10 patients)	<b>1.777 (1.095, 2.883)</b>	<b>1.941 (1.304, 2.890)</b>	<b>1.552 (1.015, 2.374)</b>	1.308 (.842, 2.031)
Percent of patients on Medicaid	-. <sup>4</sup>	-	-	-
Years waived for 30 patients	<b>.842 (.735, .964)</b>	<b>.775 (.680, .883)</b>	<b>.790 (.709, .879)</b>	<b>.768 (.710, .831)</b>
Medical specialty <sup>5</sup> :				
Physician - general	1.155 (.521, 2.558)	.466 (.187, 1.166)	.989 (.472, 2.071)	<b>1.705 (1.011, 2.876)</b>
Physician – psychiatry & neurology	.873 (.400, 1.904)	.622 (.289, 1.337)	1.040 (.505, 2.142)	1.111 (.645, 1.912)
Physician - other	1.573 (.672, 3.986)	1.421 (.415, 4.859)	2.805 (.972, 8.101)	.716 (.238, 2.149)
NP/PA	-	-	-	-
Constant	.397	<b>.042</b>	1.151	1.998
N	649	732	832	942
Nagelkerke R <sup>2</sup>	.187	.208	.164	.280
Hosmer and Lemeshow Test	.920	.105	.216	.060

Notes: 1. The pool of prescribers who are potential adopters of the 100-patient waiver is all prescribers waived for 30 patients in the year prior to the column year. Independent variables are for the year prior to the column year.

2. The regressions control for county variations in prescriber location via a dichotomous variable for each county (results not shown).

3. Odds ratios significant at the .05 level are shown in **bold**.

4. Medicaid data were not available prior to 2016.

5. The reference category is specialty missing.

IV.2b: Dependent variable:

Becoming waived for 100 patients in:	2016	2017	2018	2019 (1 <sup>st</sup> 8 months)
Predictors <sup>1,2</sup> :	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Median monthly active patients	<b>1.317 (1.202, 1.443)</b>	<b>1.088 (1.017, 1.164)</b>	<b>1.078 (1.010, 1.151)</b>	.990 (.915, 1.070)
Degree (no. of shared-patient ties of at least 10 patients)	.801 (.461, 1.389)	1.314 (.945, 1.827)	<b>1.431 (1.003, 2.040)</b>	<b>1.649 (1.221, 2.227)</b>
Percent of patients on Medicaid	-. <sup>4</sup>	<b>1.020 (1.012, 1.028)</b>	<b>1.015 (1.008, 1.021)</b>	<b>1.021 (1.014, 1.028)</b>
Years waived for 30 patients	<b>.639 (.563, .724)</b>	<b>.833 (.764, .907)</b>	<b>.810 (.742, .885)</b>	<b>.899 (.819, .987)</b>
Medical specialty <sup>5</sup> :				
Physician - general	1.676 (.894, 3.144)	1.264 (.622, 2.568)	<b>.354 (.200, .626)</b>	.567 (.285, 1.129)
Physician – psychiatry & neurology	.779 (.389, 1.557)	.803 (.359, 1.798)	<b>.266 (.123, .573)</b>	.494 (.192, 1.273)
Physician - other	1.710 (.657, 4.446)	1.059 (.448, 2.504)	.812 (.480, 1.372)	<b>.238 (.102, .558)</b>
NP/PA	-	-	<b>2.367 (1.417, 3.954)</b>	1.291 (.664, 2.511)
Constant	1.205	<b>.056</b>	<b>.190</b>	<b>.030</b>
N	982	1238	1748	2533
Nagelkerke R <sup>2</sup>	.329	.226	.264	.256
Hosmer and Lemeshow Test	.185	.777	.087	.725

- Notes: 1. The pool of prescribers who are potential adopters of the 100-patient waiver is all prescribers waived for 30 patients in the year prior to the column year. Independent variables are for the year prior to the column year.
2. The regressions control for county variations in prescriber location via a dichotomous variable for each county (results not shown).
3. Odds ratios significant at the .05 level are shown in **bold**.
4. Medicaid data were not available prior to 2016.
5. The reference category is specialty missing.

### C. Becoming waived for 275 patients

Diffusion theory predicts that the first adopters of an innovation are those motivated primarily by their own perceived benefit from or need for the innovation. This theory also predicts that first adopters will tend to be outliers in a communication network (i.e., those having fewest ties). We hypothesized that the first adopters of becoming 275-waivered would be those 100-waivered prescribers with the highest numbers of active MOUD patients, and with relatively few shared-patient ties.

Diffusion theory further predicts that, once the innovation starts to become more widely adopted, “opinion leaders” – those more central to communication networks (i.e., having more shared-patient ties<sup>37</sup>) – will be the primary adopters.<sup>38</sup> They will be motivated by having learned from their peers about the benefits of the innovation and will seek these benefits for themselves by adopting the innovation. We hypothesize that, after the first couple of years of adoption of becoming 275-waivered, prescribers becoming 275-waivered will tend to be more central to the shared-patient networks, and that numbers of active MOUD patients will become less important as a motivator. We separately analyzed the effects of numbers of ties to previous adopters of the 275-patient waiver. In typical, S-shaped diffusion processes, these latter ties would predict adoption. However, because the diffusion of the 275-patient waiver appears to be more externally driven, we hypothesized that the overall number of ties to waived prescribers (i.e., a prescriber’s centrality in the statewide network) would predict adoption of the 275-patient waiver, while the number of ties specifically to previous 275-patient adopters would not.

### Methods

As with the analysis of prescribers adopting the waiver for 100 patients above, we conducted separate logistic regressions of becoming waived for 275 patients for each year 2016 – 2019, because the pool of potential adopters changed each year. The models included the same set of variables as in the prior models: median number of monthly active MOUD patients, degree – number of shared-patient ties, percent of patients who paid for at least one buprenorphine prescription with Medicaid (data only available in 2016 and later), number of years the prescriber was waived for 100 patients, and medical specialty (broadly categorized as physician – general, physician – psychiatry and neurology, physician – other, and physician – specialty missing. Beginning in 2017, when nurse practitioners and physician assistants were allowed to obtain a waiver, we added a category for NP/PA.) Each regression controlled for county differences in prescriber location by means of a dichotomous variable for each county (county control results not shown in the tables below). As noted above, we also ran a set of logistic regressions replacing total number of shared-patient ties with ties to previous adopters of the 275-patient waiver only.

The logistic regressions presented below have one important difference from those used for the 100-patient waiver analyses. For the 100-patient waiver analyses, we included all Massachusetts

---

<sup>37</sup> Because the county-level networks overlap, they in effect form a large state-wide network. We computed prescriber ties such that they reflect centrality in this overall network, so that the degree measure could be applied across all waived prescribers.

<sup>38</sup> Dearing JW & Cox JG. (2018). Diffusion of innovations theory, principles, and practice. *Health Affairs*; 37(2): 183-190. Doi: 10.1377/hlthaff.2017.1104.



prescribers waived for 30 patients through the previous year, whether or not they had any MOUD patients in that year. We found that a large proportion of prescribers who adopted the 100-patient waiver had no patients in the prior year, the percentage ranging from 44% to 73%. In contrast, no prescribers waived for 100 patients, who had no patients in the prior year, adopted the 275-patient waiver in a given year. For this reason, to avoid biasing our results toward a positive association between prescriber degree and adoption of the 275-patient waiver (since both variables would have the value 0 for prescribers with no patients), we limited the pool of potential adopters to those 100-patient waived prescribers who had at least one patient in the prior year.<sup>39</sup>

## Results

In Table IV.3 we display the means and standard variations for the variables used in the analyses of adoption of the 275-patient waiver. We note a steady decrease in the percent of 100-patient waived prescribers (with at least one MOUD patient in the prior year) who adopted the 275-patient waiver from 2016 through 2019, and a similarly steady decrease in their average median numbers of patients. In contrast, the average number of shared-patient ties with other waived prescribers increased across these years, as did the average number of ties specifically with previous 275-patient waiver adopters.

As hypothesized, the number of shared-patient ties was a negative predictor of adoption of the 275-patient waiver in 2016, then became a positive predictor of adoption in 2018 and 2019 (Table IV.4a). That is, prescribers near the edges of the statewide shared-patient network were significant early adopters; by 2018, prescribers more central to this network were significant adopters. The median number of MOUD patients was also a significant predictor of adoption for 2016 – 2018, and the years a prescriber had been waived for 100 patients was a significant negative predictor of adoption. That is, prescribers waived for 100 patients for fewer years tended to be more likely to adopt the 275-patient waiver than prescribers 100-patient waived for longer periods.

Further, we found in analyses of ties to previous adopters of the 275-patient waiver that this variable was not a significant predictor of the 275-patient waiver (Table IV.4b). This finding is in line with the relatively externally-driven shape of the 275-patient waiver diffusion curve noted above. In both sets of analyses (Tables IV.4a and IV.4b), none of the provider specialty variables was a significant predictor.

In Figure IV.4, we display the proportion of (100-patient waived) prescribers who adopted the 275-patient waiver in 2019, for the different numbers of shared-patient ties they had in 2018, ranging from 0 to 8 plus (for ease of display, we capped degrees greater than 8 as 8). As shown in the figure, the association between number of ties and percent who adopted the 275-patient waiver is nearly monotonic, ranging from 4.7% for prescribers with 0 ties to 28.6% for prescribers with 8 or more ties.

---

<sup>39</sup> We ran the same logistic regressions for the whole sample of 100-patient waived prescribers in each year, and the significant predictors of adoption of the 275-patient waiver did not change.

**Table IV.3: Variable Means and Standard Deviations for each Year**

	2016		2017		2018		2019	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
<b>Percent who adopted 275-patient waiver<sup>1</sup></b>	.26	.44	.11	.32	.10	.30	.09	.29
<b>Median monthly active patients<sup>2</sup></b>	24.88	23.91	23.97	22.09	22.36	19.37	19.34	17.35
<b>Degree (no. of shared-patient ties of at least 10 patients)<sup>2</sup></b>	.97	1.87	1.38	2.41	1.41	2.17	1.50	2.24
<b>Percent of patients on Medicaid<sup>2</sup></b>	-. <sup>3</sup>		30.12	18.95	39.11	23.11	43.31	23.99
<b>Number of shared-patient ties which are to prior adopters of the 275-patient waiver<sup>2</sup></b>	-	-	.37	.78	.47	.90	.52	1.01
<b>Years waived for 100 patients<sup>2</sup></b>	3.69	2.97	3.80	3.22	4.22	3.44	4.11	3.74
<b>Medical specialty<sup>2,4</sup>:</b>								
<b>Physician - general</b>	.35	.48	.41	.49	.41	.49	.35	.48
<b>Physician – psychiatry &amp; neurology</b>	.42	.49	.37	.48	.34	.47	.28	.45
<b>Physician - other</b>	.16	.37	.15	.36	.14	.35	.10	.30
<b>Physician – specialty missing</b>	.07	.25	.07	.26	.11	.32	.11	.31
<b>NP/PA</b>	-	-	-	-	-	-	.16	.37
<b>N</b>	499		465		468		560	

- Notes: 1. The pool of prescribers who are potential adopters of the 275-patient waiver is all prescribers waived for 100 patients in the year prior to the column year who had at least one MOUD patient in that year.
2. Values are for the year prior to the column year.
3. Medicaid data were not available for 2015.
4. Indicator (0, 1) variables.

Table IV.4a and IV.4b: Logistic regressions on becoming waived for 275 patients in Massachusetts, for each year 2016 – 2019

IV.4a: Dependent variable:

Becoming waived for 275 patients in:

	2016	2017	2018	2019 (1 <sup>st</sup> 8 months)
Predictors <sup>1,2</sup> :	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Median monthly active patients	<b>1.044 (1.031, 1.058)<sup>3</sup></b>	<b>1.045 (1.027, 1.063)</b>	<b>1.042 (1.020, 1.064)</b>	1.018 (.996, 1.040)
Degree (no. of shared-patient ties of at least 10 patients)	<b>.717 (.595, .864)</b>	.901 (.767, 1.058)	<b>1.203 (1.010, 1.432)</b>	<b>1.214 (1.038, 1.421)</b>
Percent of patients on Medicaid	- <sup>4</sup>	1.017 (.997, 1.036)	1.002 (.981, 1.023)	1.008 (.989, 1.026)
Years waived for 100 patients	.923 (.852, 1.000)	<b>.829 (.738, .932)</b>	<b>.786 (.678, .911)</b>	<b>.840 (.732, .963)</b>
Medical specialty <sup>5</sup> :				
Physician - general	.458 (.182, 1.149)	1.255 (.310, 5.081)	.821 (.269, 2.507)	3.716 (.753, 18.331)
Physician – psychiatry & neurology	.760 (.311, 1.857)	1.345 (.322, 5.621)	.838 (.245, 2.869)	3.496 (.635, 19.252)
Physician - other	.480 (.172, 1.341)	.896 (.173, 4.648)	1.145 (.313, 4.189)	4.077 (.679, 24.492)
NP/PA	-	-	-	3.684 (.685, 19.815)
Constant	.150	.009	.013	.002
N	499	465	468	560
Nagelkerke R <sup>2</sup>	.232	.212	.283	.231
Hosmer and Lemeshow Test	.259	.591	.354	.122

Notes: 1. The pool of prescribers who are potential adopters of the 275-patient waiver is all prescribers waived for 100 patients in the year prior to the column year who had at least one MOUD patient in that year. Independent variables are for the year prior to the column year.

2. The regressions control for county variations in prescriber location via a dichotomous variable for each county (results not shown).

3. Odds ratios significant at the .05 level are shown in **bold**.

4. Medicaid data were not available for 2015.

5. The reference category is specialty missing.

IV.4b: Dependent variable:

Becoming waived for 275 patients in:

	2016	2017	2018	2019 (1 <sup>st</sup> 8 months)
Predictors <sup>1,2:</sup>	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Median monthly active patients	-	<b>1.034 (1.017, 1.051)</b>	<b>1.047 (1.026, 1.067)</b>	<b>1.026 (1.005, 1.047)</b>
Degree <sup>275</sup> (no. of shared-patient ties of at least 10 patients with prior adopters of the waiver for 275 patients)	-	1.377 (.923, 2.054)	1.379 (.949, 2.003)	1.228 (.912, 1.654)
Percent of patients on Medicaid	-	1.017 (.998, 1.037)	1.001 (.981, 1.022)	1.009 (.991, 1.027)
Years waived for 100 patients	-	<b>.858 (.764, .964)</b>	<b>.787 (.680, .910)</b>	<b>.834 (.727, .955)</b>
Medical specialty <sup>5:</sup>				
Physician - general	-	1.330 (.313, 5.653)	.723 (.245, 2.139)	4.042 (.834, 19.601)
Physician – psychiatry & neurology	-	1.593 (.364, 6.984)	.649 (.200, 2.104)	3.316 (.610, 18.021)
Physician - other	-	1.138 (.213, 6.088)	.874 (.246, 3.099)	4.222 (.714, 24.973)
NP/PA	-	-	-	3.458 (.663, 18.019)
Constant	-	.004	.017	.001
N		465	468	560
Nagelkerke R <sup>2</sup>		.214	.277	.216
Hosmer and Lemeshow Test		.697	.438	.143

Notes: 1. The pool of prescribers who are potential adopters of the 275-patient waiver is all prescribers waived for 100 patients in the year prior to the column year who had at least one MOUD patient in that year. Independent variables are for the year prior to the column year.

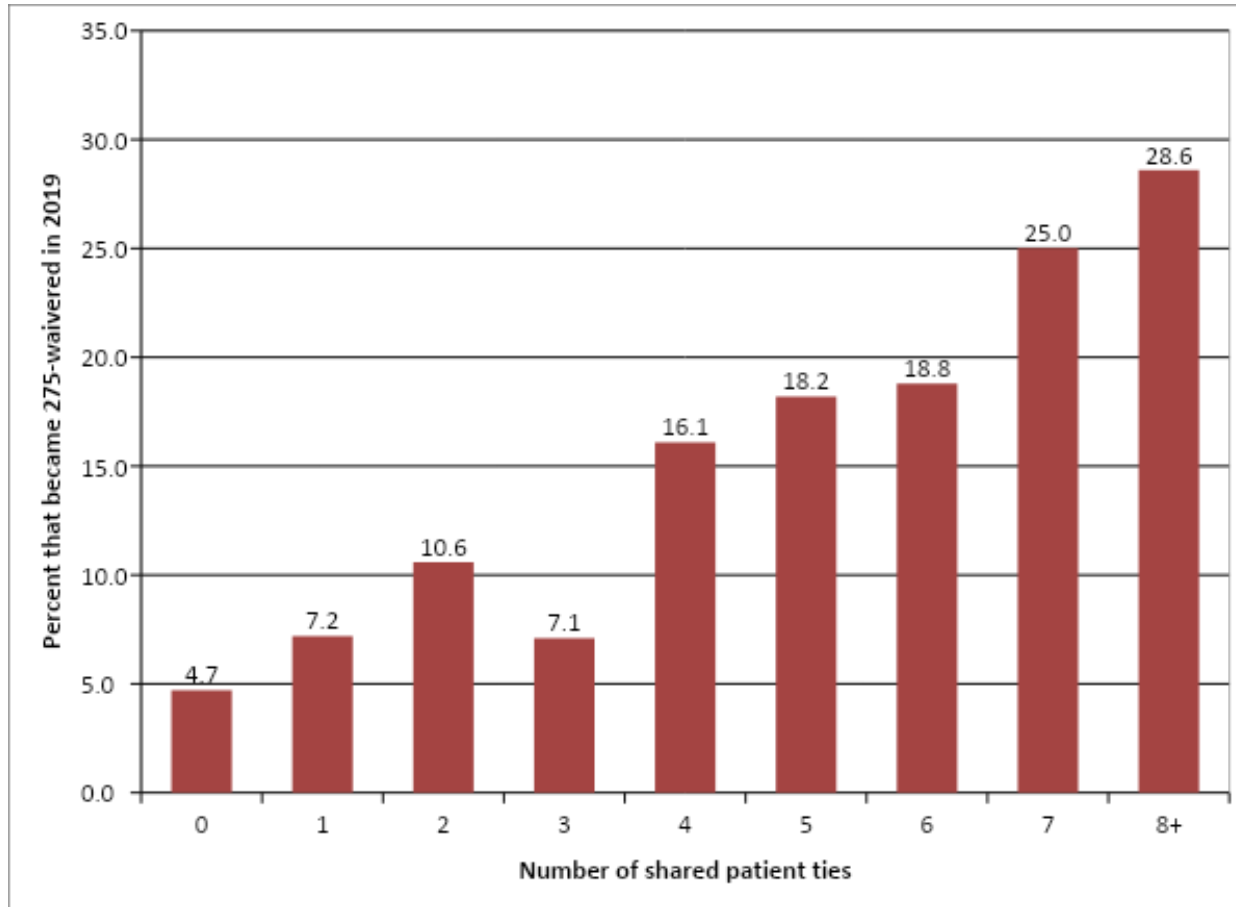
2. The regressions control for county variations in prescriber location via a dichotomous variable for each county (results not shown).

3. Odds ratios significant at the .05 level are shown in **bold**.

4. Medicaid data were not available for 2015.

5. The reference category is specialty missing.

**Figure IV.4: Prescribers waived for 100 patients through 2018: Number of shared-patient ties of at least 10 patients and percent of each group that became waived for 275 patients in the first 8 months of 2019**



#### **D. Treatment duration**

Our goal was to assess how patient, county and prescriber characteristics were associated with duration of Buprenorphine treatment. In particular, to examine whether there were racial/ethnic disparities in MOUD treatment duration. Patients who remain in treatment longer tend to have better outcomes.<sup>40</sup>

#### **Methods**

The original sample consisted of 99,155 patients of buprenorphine-waivered Massachusetts prescribers with a Buprenorphine Naïve prescription between April 1, 2011 and December 31, 2018. A Buprenorphine naïve prescription is one which occurs after 30 days without a buprenorphine prescription. Excluded were 181 patients missing demographic data, 206 under 18 years old and 2,560 over 60, 4844 from Nantucket and Dukes County (which each had too few waivered prescribers to be included in the county-level analyses), 21,612 who were prescribed by smaller providers with fewer than 10 patients, 1,229 with missing count of prescriber ties or waiver number and 1,272 missing prescriber specialty data. This yielded a sample of 67,251 people.

Our goal was to analyze the association of patient, county and prescriber characteristics with duration of buprenorphine treatment. We used the following patient variables: (1) gender recorded at buprenorphine prescription, (2) age recorded at buprenorphine prescription, and (3) number of providers per patient in a year. County variables included: (1) percentage of blacks in county of patient residence, and (2) percentage of Hispanics in county of patient residence. Provider variables included: (1) provider specialty, (2) number of patients waivered for (30, 100, 275), and (3) number of prescriber shared-ties (of 10 or more patients in a year) for each prescriber. The following variables were time varying covariates: number of providers per patient in a year, number of patients waivered for, number of prescriber ties for each prescriber. These variables varied over time if a patient was in treatment for more than one calendar year.

In related models, continuous independent variables were replaced by categorical variables to elucidate some interpretations. Age was divided into four clinically meaningful categories: 18-29, 30-39, 40-49, 50-60. Other variables were split into three categories (low, medium and high) based on terciles as follows: percent Hispanic (< 4.2%, 4.2%-8.6%, >8.6%), percent Black (< 3.1%, 3.1%-5.3%, > 5.3%), number of prescribers (1,2,3+), and shared prescriber ties (0, 1-2, 3+). Because there was a large gap between 11% and 20% for the percent Black variable, we created an additional three-category variable for percent Black (< 3.1%, 3.1%-11%, >11%).

The outcome of interest was time to end of buprenorphine treatment, or days between date of first buprenorphine naïve prescription and end of buprenorphine treatment for that episode. We used Cox Proportional Hazards regression to examine the relationship between the independent variables and time to end of buprenorphine treatment. A conventional logistic model predicting any buprenorphine cessation during the period does not make maximum use of available information; that is, it does not consider time from baseline until end of treatment. The dependent variable in a Cox regression consists of two parts: an event indicator (end of buprenorphine treatment in our study) and time until

---

<sup>40</sup> XXX

occurrence of the event. Censoring occurs when a person does not end treatment by the end of the study. In this analysis, anyone who did not end treatment by December 31, 2019 was censored because they did not have an outcome by the end of the study. They were marked as censored and given a time equal to the number of days between entry and December 31, 2019.

Hazard rates measure the risk of ending treatment within a time interval given that the person survived up until the beginning of that interval. The hazard rate for end of buprenorphine treatment after a particular period of time, say thirty days, is the number of people ending treatment in those thirty days divided by the number of people still in treatment after 30 days. We are interested in the hazard ratio for each variable (e.g., female), which is the hazard rate of that variable divided by the hazard rate of the controls (e.g. males). A hazard ratio of one indicates that the risk of ending treatment is the same for both groups. A hazard ratio of more than one indicates that the risk of ending treatment for females is higher. A hazard ratio of less than one indicates the risk of ending treatment for females is lower, that is, being female would be associated with longer duration.

The data were structured to incorporate the time varying nature of variables. For example, a patient who was in treatment from 2012-2016 would have five different values for number of prescribers, one for each year in treatment. However, that patient is only counted as one observation just as if they had only one year of treatment. Additionally, since patients with the same prescriber likely have correlated durations of treatment, the analysis clustered on prescribers resulting in a robust estimate of variance for coefficients.

Cox regression is a semi-parametric model which assumes non-informative censoring, that is, censoring is random. It also assumes proportional hazards, which implies that the hazard rates for males and females, for example, remains relatively constant at every time point after baseline.

## **Results**

In the initial model (Table IV.5a), the following variables were associated with longer treatment duration: female, being older, having more prescribers, and having a primary prescriber who is waived for 100 patients or for 275 patients. Living in a county with a higher percentage of black or of Hispanic residents was associated with shorter treatment duration, as was having a primary prescriber with more shared-patient ties (of at least 10 patients in a year), and having a primary prescriber who is a nurse practitioner or physician assistant. None of the medical specialties for primary prescriber was associated with higher or lower duration.

We examined these associations further in the second model (Table IV.5b), in which the predictor variables with multiple values were broken out into categories (with a dichotomous variable for each category). Longer treatment duration was associated with older age groups: 50 – 60 year-olds had longer duration than 40 – 49 year-olds, who in turn had longer duration than 30 – 39 year-olds, who in turn had longer duration than 20 – 29 year-olds (reference category). Patients with three or more prescribers had longer duration than patients with two prescribers, who in turn had longer duration than patients with one prescriber. Patients whose primary prescriber had three or more shared-patient ties had shorter treatment duration than patients whose primary prescriber had one or two shared-patient ties, and the latter had shorter duration than patients whose primary prescriber had no shared-patient ties. We

further found that patients living in counties in the highest tercile of percent Hispanic residents had shorter duration than patients living in counties with a mid-level percent of Hispanic residents, who in turn had shorter duration than patients living in the lowest tercile of percent Hispanic residents. However, this pattern did not hold for percent of black residents. Patients living in the highest and mid-level county terciles of percent black residents did not have significantly shorter treatment duration than patients living in the lowest county tercile of percent black residents. Because this finding seemed to contradict the finding in Table IV.5a, we examined the distribution of percent of black residents across counties. Suffolk County (primarily Boston) is an outlier, with more than 20% of residents self-reporting as black, non-Hispanic; the next highest county had 11% of residents as black. When we treated Suffolk County as its own category, contrasted with revised mid-level and low categories of percent black residents, we found that patients in Suffolk County had significantly shorter treatment duration than patients in either of the other two county categories, and patients in the mid-level category did not have shorter duration than patients in the lowest percent black residents category.

Because being waived for 100 or for 275 patients was associated with longer treatment duration, with the reference category being prescribers waived for 30 patients, the finding that prescribers with more shared-patient ties were associated with shorter treatment duration probably applies mostly to prescribers waived for 30 patients, since prescribers waived for the higher patient limits tend to have more shared-patient ties. However, it's not clear why prescribers waived for 30 patients who have more shared-patient ties would be associated with shorter treatment duration.



**Tables IV.5a and IV.5b: Hazard Rate Analysis of Ending OUD Buprenorphine Treatment**

**IV.5a: Patient age grouping, number of prescribers, percent black/Hispanic, and prescriber number of shared-patient ties collapsed into single variables**

**Dependent variable: Time to end of treatment**

<b>Ind. variables</b>	<b>Hazard ratio</b>	<b>Robust Std. error</b>	<b>P-value</b>	<b>Hazard ratio</b>	<b>Robust Std. error</b>	<b>P-value</b>
Gender (Female)	<b>.9448</b>	<b>.0095</b>	<b>&lt; .001</b>	<b>.9464</b>	<b>.0095</b>	<b>&lt; .001</b>
Age grouping	<b>.9879</b>	<b>.0006</b>	<b>&lt; .001</b>	<b>.9877</b>	<b>.0006</b>	<b>&lt; .001</b>
Number of prescribers	<b>.6515</b>	<b>.0066</b>	<b>&lt; .001</b>	<b>.6503</b>	<b>.0066</b>	<b>&lt; .001</b>
Percent black in patient county	<b>2.5934</b>	<b>.5163</b>	<b>&lt; .001</b>	-	-	-
Percent Hispanic in patient county	-	-	-	<b>2.5221</b>	<b>.4464</b>	<b>&lt; .001</b>
Primary prescriber has waiver for 100 patients	<b>.8439</b>	<b>.0420</b>	<b>.001</b>	<b>.8386</b>	<b>.0409</b>	<b>.015</b>
Primary prescriber has waiver for 275 patients	<b>.8551</b>	<b>.0472</b>	<b>.005</b>	<b>.8545</b>	<b>.0465</b>	<b>.004</b>
Primary prescriber number of shared-patient ties	<b>1.0472</b>	<b>.0049</b>	<b>&lt; .001</b>	<b>1.0448</b>	<b>.0051</b>	<b>&lt; .001</b>
General physician	1.0147	.0456	.746	1.0024	.0458	.958
Psychiatrist or neurologist	.9681	.0488	.520	.9588	.0489	.410
Physician – other	1.0509	.0672	.438	1.0359	.0686	.595
NP/PA	<b>1.5295</b>	<b>.1062</b>	<b>&lt; .001</b>	<b>1.4917</b>	<b>.1037</b>	<b>&lt; .001</b>

Note: 67,251 patients for the period April 1, 2011 – December 31, 2018. Higher hazard ratios represent shorter treatment duration.

**IV.5b: Patient age grouping, number of prescribers, percent black/Hispanic, and prescriber number of shared-patient ties disaggregated**

**Dependent variable: Time to end of treatment**

<b>Ind. variables</b>	<b>Hazard ratio</b>	<b>Robust Std. error</b>	<b>P-value</b>	<b>Hazard ratio</b>	<b>Robust Std. error</b>	<b>P-value</b>
Gender (Female)	<b>.9426</b>	<b>.0098</b>	<b>&lt; .001</b>	<b>.9439</b>	<b>.0098</b>	<b>&lt; .001</b>
Age 30 - 39	<b>.8447</b>	<b>.0105</b>	<b>&lt; .001</b>	<b>.8402</b>	<b>.0106</b>	<b>&lt; .001</b>
40 – 49	<b>.7930</b>	<b>.0118</b>	<b>&lt; .001</b>	<b>.7879</b>	<b>.0119</b>	<b>&lt; .001</b>
50 - 60	<b>.7166</b>	<b>.0120</b>	<b>&lt; .001</b>	<b>.7116</b>	<b>.0123</b>	<b>&lt; .001</b>
# prescribers = 2	<b>.4667</b>	<b>.0088</b>	<b>&lt; .001</b>	<b>.4649</b>	<b>.0085</b>	<b>&lt; .001</b>
# prescribers >= 3	<b>.2822</b>	<b>.0077</b>	<b>&lt; .001</b>	<b>.2800</b>	<b>.0075</b>	<b>&lt; .001</b>
County: medium percent black	1.0330	.0458	.464	-	-	-
County: high percent black	1.0771	.0499	.109	-	-	-
County: medium percent Hispanic	-	-	-	<b>1.0980</b>	<b>.0317</b>	<b>.001</b>
County: high percent Hispanic	-	-	-	<b>1.1817</b>	<b>.0417</b>	<b>&lt; .001</b>
Primary prescriber has waiver for 100 patients	<b>.7910</b>	<b>.0411</b>	<b>&lt; .001</b>	<b>.7936</b>	<b>.0400</b>	<b>&lt; .001</b>
Primary prescriber has waiver for 275 patients	<b>.7860</b>	<b>.0460</b>	<b>&lt; .001</b>	<b>.7901</b>	<b>.0456</b>	<b>&lt; .001</b>
Primary prescriber # of shared-patient ties = 1 or 2	<b>1.2684</b>	<b>.0393</b>	<b>&lt; .001</b>	<b>1.2691</b>	<b>.0388</b>	<b>&lt; .001</b>
Primary prescriber # of shared-patient ties = 3 or more	<b>1.8252</b>	<b>.0728</b>	<b>&lt; .001</b>	<b>1.8150</b>	<b>.0743</b>	<b>&lt; .001</b>
General physician	1.0023	.0461	.959	.9858	.0469	.763
Psychiatrist or neurologist	1.0323	.0527	.534	1.0199	.0535	.708
Physician – other	1.0372	.0728	.603	1.0267	.0748	.718
NP/PA	<b>1.5046</b>	<b>.1041</b>	<b>&lt; .001</b>	<b>1.4770</b>	<b>.1032</b>	<b>&lt; .001</b>

Note: 67,251 patients for the period April 1, 2011 – December 31, 2018. Higher hazard ratios represent shorter treatment duration.

## V. Implications and recommendations

Implications. A number of our findings appear to converge as follows. The availability of the 275-patient waiver, starting in September, 2016, led to a surge in adoption of that waiver and also had a powerful upstream influence on the adoption of waivers for 100 and 30 patients. Adoptions of the 100- and, especially, the 275-patient waiver helped to stabilize prescriber shared-patient networks beginning in 2015: on average, prescribers with the 100-patient waiver had about three times as many shared-patient ties (of 10 or more patients in a year) as prescribers with the 30-patients waiver, and prescribers with the 275-patient waiver had, in turn, almost three times as many shared patient ties as prescribers with the 100-patient waiver.<sup>41</sup> That is, prescribers with waivers for the higher patient limits tended to be “hubs” in the shared-patient networks, linking many other prescribers and providing a kind of glue for the network as a whole. The presence of network hubs facilitates a network’s having small-world properties,<sup>42</sup> whereby any network member is reachable in a few steps (i.e., prescriber ties) from any other member, and where the distribution of shared-patient ties among network members tends to follow a power law – a few highly-connected prescribers and many other prescribers with relatively few connections. Small world-ness is also associated with network stability and robustness in the face of external changes: patterns of shared-patient ties tend to persist, even as the individual patients change, especially in networks with small-world properties.

Proportionally to the number of waived prescribers in a county, prescribers with the 275-patient waiver tended to be located in counties with lower percentages of black or Hispanic residents. In addition, prescribers with the 275-patient waiver located in counties with fewer black or Hispanic residents tended to treat higher numbers of MOUD patients. Both effects combine to imply that the location of 275-patient waived prescribers tends to support racial/ethnic disparities in access to treatment. Because 275-waivered prescribers also have the most shared-patient ties, they tend to provide a scaffold for more robust shared-patient prescriber networks, whose small-world properties facilitate prescriber access to peer information, resource, and support. The 275-patient waiver thus also supports racial/ethnic disparities in the properties of these networks that support prescribers in treating more patients. This consequence of the advent of the 275-patient waiver appears to continue (and perhaps strengthen) a trend already present prior to 2016 in the location of prescribers waived for 100 patients.

Our premise that shared-patient ties (of at least 10 patients in a year) among prescribers could serve as a proxy for communication ties appears to have been upheld in the findings of the adoption of the 30-, 100-, and 275-patient waivers. By 2018, adoption of the 275-patient waiver by prescribers already waived for 100 patients was driven by shared-patient ties as well as by the number of patients these prescribers were already treating, and by 2019, adoption was driven mainly by shared-patient ties. Similarly, by 2018 adoption of the 100-patient waiver was driven by shared-patient ties, as it had been

---

<sup>41</sup> It is also true that the median number of MOUD patients increased substantially with waivers for the higher patient limits, and having more patients would increase the likelihood of having more shared-patient ties. However, median number of patients and number of shared-patient ties were only modestly correlated (correlation coefficient of about .3).

<sup>42</sup> The presence of hubs also facilitates the other two network properties we measured – the percent of network prescribers in the largest connected component and network centrality.

prior to 2015. Further, in our analysis of initially becoming waived in 2012-2017, we found that having non-buprenorphine shared-patient ties with waived prescribers was associated with becoming waived for 30 patients (and thus providing a pool of potential adopters of the 100-patient waiver). Because shared-patient ties are less prevalent, on average, in counties with higher proportions of black or Hispanic residents, these waiver adoption findings support the earlier findings of racial and ethnic disparities in access to treatment and in provider network properties that support access to treatment.

Finally, our findings on treatment duration reinforce these conclusions about disparities. We found evidence of shorter treatment duration in counties with a higher proportion of Hispanic residents and in Suffolk County, which has the highest proportion of black residents (though not in counties with medium proportions of black residents, compared with counties with the fewest black residents). We also found that patients whose primary prescriber was waived for 100 or for 275 patients had longer treatment duration.

*Strengths.* The study had several strengths. To our knowledge, it broke new ground in the following areas:

- We used prescription monitoring program data to construct prescriber shared-patient networks. Previous studies have all used insurance claims data for this purpose (e.g., Medicare claims data). We thus ensured that all buprenorphine prescriptions for OUD treatment (i.e., Suboxone) would be included.
- We found direct evidence of racial and ethnic disparities in access to MOUD treatment in Massachusetts counties over eight years.
- Using rigorous models, we examined properties of buprenorphine shared-patient networks thought to be associated with provider access to peer information, resources, and support in relation to county demographics in Massachusetts. We also found effects of these networks properties on access to treatment.
- We identified factors associated with the adoption of the 30-, 100-, and 275-patient buprenorphine waivers. In particular, we found significant effects of shared-patient ties with waived prescribers on the likelihood of adoption, both non-buprenorphine shared-patient ties (in the case of initially becoming waived) and buprenorphine shared-patient ties (in the cases of adoption of the waivers for 100 and 275 patient limits).

*Limitations.* The study also had several limitations. Because the PMP data does not include patient race or ethnicity, we relied on the race and ethnicity of geographic areas to analyze disparities in MOUD treatment. We settled on county as the most viable such area because it yielded the most reliable measures of prescriber networks over time. However, Massachusetts has only 12 counties with enough waived prescribers to analyze. Even eight years of data produces a total of 96 observations. Although we found significant effects of race and ethnicity on access to treatment and on network properties, this is a relatively small number of observations from which to generalize.

Although we found highly significant effects of both non-buprenorphine and buprenorphine shared-patient ties on adoption of the different waiver categories, we were not in every year able to control for prescriber factors that might influence adoption, such as total number of patients (for initial waiver adoption) or percent of patients who paid for their prescription with Medicaid (for years prior to

2016). When we were able to control for such factors, however, we still found significant effects of shared-patient ties on waiver adoption.

Based on the foregoing implications, we offer the following recommendations.

Recommendations. (1) Existing shared-patient networks can be used to identify prescribers in the role of network broker, or “structural hole,” who serve to connect different subgroups of a network. To increase the small world properties of a network in which they are embedded, or to which their network is adjacent, these prescribers might be provided incentives to form new shared-patient connections with prescribers in network subgroups with which they currently do not share patients. Because such prescribers have experience in linking different subgroups, and presumably benefit by being able to access different sources of information and resources associated with these subgroups, they are more likely than other prescribers to be willing and able to make new connections. An educational or training event might bring them together with prescribers to newly connect with. However, maintaining ongoing connections requires an ongoing benefit, which might eventually take the form of information and resources different from those received elsewhere, but which probably needs an additional incentive to become established.

(2) Shared-patient networks can also be used to identify prescribers who are “influencers.” We computed total shared-patient ties for potential adopters of each waiver status. However, ties with specific individuals could also be computed, as well as the number of potential adopters tied to each individual who went on to adopt a higher patient limit. Prescribers with high numbers of ties to potential adopters who later adopted higher patient limits might have greater influence in facilitating such adoptions. These individuals could be recruited to serve as mentors (see (3) below).

(3) In counties with lower access to treatment, and where prescriber networks are characterized by weaker small world properties, a mentorship program might be set up encourage prescribers currently waived for 30 or 100 patients to become waived for 275 patients, and to support them in providing treatment to more patients. Specifically, they might be paired with a prescriber currently waived for 275 patients (whether in the same or an adjacent county), whom they could observe and from whom they could receive coaching and support to build their own treatment practice. At least some prospective mentors may need an incentive to participate in such a program; for others, the possibility of assisting a peer to help address disparities in access to treatment may be enough. In addition to being waived for 275 patients, prospective mentors might be selected based on continuing growth in the number of patients they treat and their centrality (i.e., number of shared-patient ties) in their prescriber network.

(4) Further study is needed on the following topics to help tailor efforts to address racial/ethnic disparities in access to treatment.

a) Hampden County appears to be an outlier in our data, in that it ranked third among counties in percent of residents who are black and first in percent of residents who are Hispanic, yet it ranked in the upper half of counties in access to treatment. It also ranked high (better) in the percent of network prescribers in the largest connected component, the Small World Index, and network centralization. Understanding how Hampden County achieved this level of access to treatment and

prescriber network properties could give clues to how other counties with relatively high percentages of black and Hispanic residents can increase access to treatment. For example, Hampden County is known for its intensive efforts in recent years to provide MOUD treatment to incarcerated individuals, and to link these individuals with ongoing treatment once they leave incarceration. Such efforts may involve a number of waived providers in coordinating and maintaining treatment for these individuals, thus involving them in expanded shared-patient networks.

- b) Many prescribers waived for 30 patients stopped prescribing buprenorphine altogether. This was especially pronounced in counties with higher percentages of black or Hispanic residents. Understanding the reasons for their stopping (or never starting) and what would have helped them develop or maintain treatment of MOUD patients would inform efforts to prevent their stopping. For example, having non-buprenorphine ties with waived prescribers increased the likelihood of a provider's initially becoming waived. And shared buprenorphine-patient ties for 30-patient waived prescribers were associated with a higher likelihood of their becoming waived for 100 patients. It was beyond the scope of this study to examine the role that shared-patient ties might play in maintaining or increasing the number of MOUD patients. But because of the role these ties play in facilitating adoption of increasing waiver patient limits, it seems reasonable to hypothesize that their presence would support the provision of MOUD treatment to consistent or increasing numbers of patients.
- c) To help counties facilitate their prescribers' adoption of the 275-patient waiver as well as increase shared-patient ties among prescribers, a more detailed understanding of these ties is needed. In particular,
  - I. To what extent does belonging to the same group practice account for shared-patient ties? Do shared-patient ties among members of the same practice have the same effects (e.g., in driving adoption of waivers for higher patient limits) as ties between prescribers in different practices? (Answering these questions requires access to data on membership in group practices, which we currently do not have.)
  - II. How do a prescriber's shared-patient ties change/increase as the prescriber becomes waived for higher patient limits? Which other prescribers do they connect with (i.e., medical specialty, waiver patient limits)? What factors facilitate growth in shared-patient ties and in number of MOUD patients? How do these factors differ in communities with higher proportions of non-white residents?
- d) Based on the data we have, we can only infer MOUD patient status. It would be helpful to link our data with, e.g., the Massachusetts All-payer Claims data to obtain clinical information about the patient. This data source also contains patient race (albeit missing for many patients), which would allow a more direct assessment of racial/ethnic disparities in treatment.
- e) Interviews with waived prescribers would be helpful to understand how and to what extent shared-patient ties increase prescriber access to peer information, resources, and support for providing MOUD treatment, as is true in other healthcare settings. Do these ties operate differently for different medical specialties? Does their utility change over time? How do these ties come into being, especially between prescribers not in the same practice?

