# Empirical Strategy

To estimate the effect vertical integration has on opioid prescribing rates, we use Medicare Part D prescribing rates and map in group practice information from Physician Compare, using the broadest definition of group practice by provider*[[1]](#footnote-1)*. To parse out vertically integrated practices from horizontally integrated practices, we divided all group practices into either horizontally or vertically integrated groups. We define vertically integrated group practices as a practice that contains at least two varied specialties, with or without the presence of nurse practitioners, which we call multi-specialty practices. Our specialties of interest are an inclusive set that are classified as either primary care, pain management, specialist[[2]](#footnote-2), or nurse practitioner. We define horizontally integrated groups as practices with one or more of the same specialties, again with or without the presence of nurse practitioners. We separate the horizontally integrated group practices into three subcategories: primary care, pain management, and specialist practice. Finally, we use a series of two regressions, first looking only at specialty, to establish a baseline of opioid prescribing rates, and second looking at both specialty and integration type, to measure the impact integration has on prescribing rates. To validate the robustness of our results, we use a reduced sample of only nurse practitioners. Through our series of specialty and group practice classifications, we are able to syphon out the impact of vertical integration and then compare the effect vertical integration has on specialty prescribing rates.

Our data has two complications inherent to our sample. First, we have a percentage dependent variable, and second, we face a selection problem with our sample as not all specialties who can prescribe do prescribe opioids (e.g. allergist), with the latter complication resulting in nearly 30% of the dependent datapoints having a zero value. To correct the sample selection problem while simultaneously adjusting the model for the bounded dependent variable, we use a two-part model that is commonly used for datasets with similar characteristics (Borislava Mihaylova, Andrew Briggs, Anthony O’Hagan 2011; Belotti et al. 2015; Leung and Yu 1996; Duan et al. 1984). We estimate separate models using a binary outcome for any opioid prescriptions (extensive margin) and use a continuous outcome variable for opioid prescribing rates among the positive values in the sample (intensive margin.) To transform the coefficients back into the original units, we apply a Duan Smearing technique*[[3]](#footnote-3)*, which also removes any distributional assumptions of the conditional error term (Duan et al. 1984).

The motivation to use the two-part model over other similar models, such as the Heckman selection model or a two-part model using a GLM with logit link, is that the two-part model has less assumptions and outperforms the Heckman selection model (Belotti et al. 2015; Koné et al. 2019; Duan et al. 1984; Leung and Yu 1996), and the two-part model with a logged dependent variable has demonstrated precision accuracy and efficiency over using GLM with a logit link (Manning and Mullahy 2001). Due to these shortcomings of other options, we selected the two-part model with OLS on a logged dependent variable for its reliability and flexibility.

### General Framework of model

We apply a two-part model for each of our regressions, all regressions have the same general framework but have varied data samples and explanatory variables. The first part of the model captures the extensive margin using a dummy variable indicating that a provider has given at least one opioid prescription. The second part captures the intensive margin using the log of the percentage of opioid prescriptions. The first part of the model is specified as logit:

#### First Part

*(2.1)*

*(2.2)*

) *(2.3)*

#### Second Part

The second part of the model is an OLS regression with a logged dependent variable

*(3.1)*

*(3.2)*

*(3.3)*

#### Complete Model

The full two-part model is calculated using the predicted probability from the first part and used to estimate the conditional mean to the second part:

*(4)*

When calculating the margins of the output, we transform the regressors from the log to raw value, using a Duan smearing transformation (Duan, 1984)

## Description of Model

Before we can estimate the impact vertical integration has on specialty prescribing rates, we first need to develop a baseline equation that modeled the effect specialty without controlling for any type of integration. We use this baseline equation to compare changes in coefficients by specialty groups for all subsequent equations:

where our dependent variable, *Y*, is a percentage of opioid prescriptions by provider. For our specialties, we use primary care as the reference category and compare the prescribing rates of pain management specialists (M), specialists (S), and nurse practitioners (N). All other control variables, including state indicator variables and county level characteristics are designed as Z. Lastly our error term is designated as

We find with high significance that primary care specialties have the lowest likelihood of prescribing an opioid followed by nurse practitioners, specialists, and then pain management specialists, these findings match those of previous literature **(Mark et al. 2019; Pletcher et al. 2008)** and unsurprisingly show that provider specialty has an impact on prescribing rates.

Now that we established our baseline impact specialty has on prescribing rates and rank order of specialties, our next question is how prescribing rates change when specialties work together. We hypothesize that through spillover effects of specialties with higher baselines working with specialties of lower baselines, an individual provider prescribing rate will actually be a weighted average of the types of specialties they work with. This leads us to our second equation, which builds on equation one by adding various forms of integration:

We add an inclusive set of group practices containing varied specialties to estimate the impact integration has on prescribing rates. In order to parse out vertical integration from horizontal integration, we divided group practices into either horizontally or vertically integrated classifications. Horizontally integrated group practices consist of single-specialty practices that may or may not have a nurse practitioner, these are represented by coefficients Mpractice and Spractice. Where M is single-specialty pain management practices and S is specialist practices, with single-specialty primary care practices as our reference group. Our vertically integrated group is Xpractice, which are any group practices that are some combination of M, S, and single-specialty primary care groups. Group X may or may not have nurse practitioners included

By incorporating types of group practice in the regression, we find that the magnitude of all specialties, in comparison to primary care, decrease. The ranked order of specialty remains the same, except for nurse practitioners whose prescribing rates become slightly negative. We find that providers who are in specialist group practices are the least likely to prescribe opioids, followed by primary care practices (reference category), vertically integrated practices (Group X), and pain specialist practices

The vertically integrated practices reside between our specialist, primary care, and pain management practices. This supports our hypothesis that prescribing rates are a weighted average of specialties that comprise the group practice.

To validate the robustness of our results from equation two, we wanted to test the impact vertical integration has on one specialty type. In selecting a specialty type, it is necessary for the specialty to commonly work in a variety of settings, as selecting a specialty that works heavily in one type of integrated group practice could skew the results. In this case, nurse practitioners[[4]](#footnote-4) were the logical choice as they operate in independent practices, under supervision of medical doctors, and a flexible specialty that can work with all other specialties. For equation three, we limit the sample to only nurse practitioners and keep all the control variables the same (by reducing the sample to nurse practitioner removes any other specialty):

We find that when nurse practitioners working only with other nurse practitioners prescribe the least amount of opioid prescriptions followed by, in increasing order, nurse practitioners who work in vertically integrated systems, primary care practices (reference category), specialist practices, and pain management practices.

By incorporating nurse practitioner practices, this slightly changes the ranking of the remaining group practices from regression two, switching the vertically integrated practices with the specialist practices.

This supports the results that were found in equation two – vertically integrated groups are a weighted average of the various specialties they interact with

1. For example, if a provider is listed in a primary care group practice and then again in a group practice of mixed specialties, they are indicated as a mixed specialty group practice [↑](#footnote-ref-1)
2. Specialist here is defined as any medical specialty that is not primary care, pain management, or nurse practitioner [↑](#footnote-ref-2)
3. The Duan Smearing technique is a nonparametric method of retransforming the data to the original values **(duan 1983)** [↑](#footnote-ref-3)
4. Nurse practitioners are able to practice independently with full scope of practice in certain states, work under physician supervision in other states, and most commonly specialize in primary care (CITE). These characteristics make them similar in specialty to primary care physicians but add a layer of complexity as they work with many other specialties [↑](#footnote-ref-4)