Appendix

Dean, Adam and Kimmel, Simeon (2019). Free Trade and Opioid Overdose Death. *Social Science & Medicine - Population Health*, 8, 100409.

This Appendix further describes and presents the results from numerous robustness tests. Table 1A estimates the main model using four different proxy measures of fentanyl. Model 1 replicates the main findings from the paper; Model 2 uses a binary measure of fentanyl that takes the value of 1 for all counties in New England and Appalachia from 2013-2015; Model 3 uses a similar binary measure but only for the subset of New England and Appalachian counties that reported overdose deaths caused by synthetic opioids; Model 4 uses a continuous measure of fentanyl based on the percentage of opioid-overdose deaths caused by synthetic opioids. The results are consistent across all four models: the coefficient on *Trade Layoffs* and the interaction between *Trade Layoffs* and *Fentanyl* are both positive and statistically significant.

Table 2A displays the results after using propensity score matching to reduce possible selection bias generated by the suppression of CDC data for county-years with less than 10 deaths. In the matching phase of the analysis, we defined the treatment as all county-years with trade-related job losses above the mean trade shock of 235 jobs. We then matched each treatment observation, using nearest neighbor matching, with one control observation based on three variables that may predict trade-related job loss as well as opioid-related overdose death: county-year population, income per capita, and the unemployment rate. The resulting matched data set contains 1,148 treatment observations and 1,148 control observations. Table 2B shows that the small remaining differences in the mean levels of population, income per capita, and unemployment rates between the treatment and control groups are statistically insignificant.

We then estimated the full OLS model using this matched, subset of the data. Model 1 displays the main results from the paper using the full data (non-suppressed) and Model 2 displays the results when using the matched data. The results are similar, with the coefficient on the interaction term in Model 2 being positive and statistically significant at the $p > 0.057$ level, despite the much reduced number of observations available after propensity score matching.

Table 3A displays the results of the main model when estimated using imputed data for the suppressed county-year observations of opioid-related overdose deaths. In order to impute these observations, we obtained additional CDC data on opioid-related overdose deaths at the state-year level. We then compared the number of deaths in this data to the number of deaths included in the non-suppressed county-year. For example, the state-year CDC data reports 325 opioid-related overdose deaths in Florida in 1999, while the non-suppressed county-year CDC data only includes 227 deaths. Since the non-suppressed county-year data therefore undercounts by 98 deaths (325 - 227 = 98), we distribute these deaths into the counties in Florida in 1999 for which the CDC suppressed data, based upon their populations. This method allows us to accurately vary the number of deaths we impute at the state-year level and also captures the tendency of opioid-overdose deaths to increase over the period of our study. Model 1 replicates the main model using the imputed data, and for comparison, Model 2 displays the results from the main model using only the non-suppressed county-years. The main results are consistent across the two data sets, with the coefficient on *Trade Layoffs* and the interaction between *Trade Layoffs* and *Fentanyl* both being positive, of similar magnitudes, and statistically significant.

Table 4A further addresses concerns about selection bias by estimating the main OLS model using an enlarged data set that substitutes values for the county-year observations suppressed by the CDC. Model 1 substitutes 0 deaths for each CDC-suppressed county-year and estimates the main model without the interaction term. Model 2 substitutes 9 deaths

for each CDC-suppressed county-year and estimates the same model without the interaction term. Model 3 and Model 4 use the same substitution approach for CDC-suppressed data and estimate a model that includes the interaction term. Model 1 and Model 2 both suggest that trade-related job losses are associated with an increase in opioid-related overdose deaths. Model 3 and Model 4 both find that this relationship grows stronger when fentanyl is present, although the result is not statistically significant in Model 3.

Table 5A estimates the main model with additional controls for the number of buprenorphine providers and opioid prescription rates. Model 1 replicates the main model from the paper for the sake of comparison. Model 2 adds a control for state-year-level buprenorphine providers, which is only available starting in 2002. This model drops our measure of fentanyl and the interaction between trade-related job loss and fentanyl in order to demonstrate clearly that the main result is robust to controlling for access to treatment for opioid use disorder. The coefficient for *Trade Layoffs* is positive and statistically significant. Model 3 re-introduces the interaction term and demonstrate that the relationship between trade-related job loss and opioid-related overdose death is stronger when fentanyl is present. Model 4 replaces our county-level measure of opioid prescription rates based on the year 2013 with a county-year level measure of opioid prescription rates. Since this data is only available starting in 2006, including this variable in the model requires us to drop all observations from 1999 through 2005. The coefficient on *Trade Layoffs* is positive and of a similar magnitude to previous models, but the reduction in the number of observations renders the finding statistically insignificant ($p>0.16$). Model 5 adds buprenorphine as well as the interaction between trade-related job loss and fentanyl. The results are similar across all five models: trade-related job losses are positively associate with opioid-related overdose deaths and this relationship is significantly stronger when fentanyl is present.

Table 6A estimates the main model using Poisson and negative binomial regression, two modeling approaches that treat opioid-related overdose deaths as a count variable and

estimate coefficients for the independent variables that have a similar log-linear interpretation. Although these models do not include lagged dependent variables, they control for the temporal increase in opioid-related overdose deaths with year fixed effects and address cross-sectional heteroskedasticity by including state fixed-effects and estimating robust standard errors. The negative binomial regression model addresses the possibility that overdispersion in opioid-related overdose deaths may bias the standard errors in the Poisson regressions. The results from Model 1 (Poisson) and Model 2 (negative binomial) are both consistent with the main findings from the paper: trade-related job losses are positively associated with opioid-related overdose deaths and the relationship grows stronger when fentanyl is present.

As discussed in the paper, the CDC suppresses all county-year observations below 10 deaths. For counties that never cross this threshold, it is difficult to know how many deaths occur each year. However, some counties cross the threshold of 10 or more deaths during our period of study. For these counties, we can reasonably assume that the number of deaths in the year before crossing this threshold was close to 10. For this reason, we imputed 9 deaths for all such county-year observations in the main model. This imputation helped minimize the number of observations dropped when including a temporal lag of the dependent variable to address serial autocorrelation in opioid-related overdose deaths. Table 7A demonstrates that the main results are largely robust to simply dropping these observations. Model 1 finds that trade-related job loss has a positive and statistically significant association with opioid-related overdose death. Models 2 through Model 5 test our four different measures of fentanyl. Due to the drop in the number of observations, one of the interaction terms (Model 2) is positive but statistically insignificant. The interaction terms in Model 3 and and Model 4 are positive and statistically significant at the $p<0.01$ level, while the interaction term in Model 5 is positive and statistically significant at the $p<0.10$ level. Table 8A demonstrates

that our main findings are robust, and of an even larger magnitude, when we impute smaller numbers of deaths for these county-years.

Table 1A: OLS Regression Results. DV = log(Opioid-Related Overdose Deaths)
Robustness Check - Alternative Fentanyl Measures

	Model 1	Model 2	Model 3	Model 4
LagDV	0.671^{***}	0.670^{***}	0.670^{***}	0.671^{***}
	(0.015)	(0.014)	(0.014)	(0.015)
Population	0.211^{***}	0.215^{***}	0.215^{***}	0.214^{***}
	(0.014)	(0.014)	(0.014)	(0.014)
IncomePC	-0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Unemployment	0.012^{***}	0.010^{**}	0.010^{**}	0.012^{***}
	(0.003)	(0.003)	(0.003)	(0.003)
Trade Layoffs	0.022^{*}	0.025^{**}	0.025^{**}	0.022^{*}
	(0.009)	(0.009)	(0.009)	(0.009)
CMSPrescribeRate	0.013^{**}	0.014^{**}	0.014^{**}	0.013^{**}
	(0.005)	(0.005)	(0.005)	(0.005)
Pop. Density	0.004^{*}	0.003^{*}	0.003^{*}	0.004^{*}
	(0.002)	(0.002)	(0.002)	(0.002)
Percent White	0.002^{**}	0.002^{*}	0.002^{*}	0.002^{**}
	(0.001)	(0.001)	(0.001)	(0.001)
Union	-0.002	-0.004	-0.004	-0.002
	(0.005)	(0.005)	(0.005)	(0.005)
Fentanyl_1	0.085^{**}			
	(0.028)			
Trade Layoffs:Fentanyl_1	0.073^{**}			
	(0.025)			
Fentanyl_2		0.082^{***}		
		(0.022)		
Trade Layoffs:Fentanyl_2		0.276^{***}		
		(0.083)		
Fentanyl_3			0.086^{***}	
			(0.022)	
Trade Layoffs:Fentanyl_3			0.269^{**}	
			(0.084)	
Fentanyl_4				0.005^{***}
				(0.001)
Trade Layoffs:Fentanyl_4				0.005^{**}
				(0.002)
State Fixed Effects	*yes*	*yes*	*yes*	*yes*
Year Fixed Effects	*yes*	*yes*	*yes*	*yes*
N	5312	5312	5312	5312
R^2	0.857	0.858	0.858	0.858
adj. R^2	0.855	0.856	0.856	0.856
Resid. sd	0.299	0.299	0.299	0.299

Robust standard errors, clustered at county-level, in parentheses

† significant at $p < .10$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

Table 2A: OLS Regression Results. DV = log(Opioid-Related Overdose Deaths)
Robustness Check - Propensity Score Matching

	Model 1	Model 2
	All Data	Matched Data
LagDV	0.671^{***}	0.700^{***}
	(0.015)	(0.021)
Population	0.211^{***}	0.251^{***}
	(0.014)	(0.025)
IncomePC	-0.001	-0.000
	(0.001)	(0.001)
Unemployment	0.012^{***}	0.013^{*}
	(0.003)	(0.006)
Trade Layoffs	0.022^{*}	0.011
	(0.009)	(0.008)
Fentanyl_1	0.085^{**}	0.134
	(0.028)	(0.097)
$\text{CMSPrescribeRate}_1$	0.013^{**}	0.031^{***}
	(0.005)	(0.009)
Pop. Density	0.004^{*}	0.001
	(0.002)	(0.002)
Percent White	0.002^{**}	0.002^{*}
	(0.001)	(0.001)
Union	-0.002	-0.002
	(0.005)	(0.007)
Trade Layoffs:Fentanyl_1	0.073^{**}	$0.052^{\dagger}$
	(0.025)	(0.027)
State Fixed Effects	*yes*	*yes*
Year Fixed Effects	*yes*	*yes*
N	5312	2296
R^2	0.857	0.887
adj. R^2	0.855	0.883
Resid. sd	0.299	0.307

Robust standard errors, clustered at county-level, in parentheses
† significant at $p < .10$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

Table 2B: Summary of balance for matched data

	Means Treated	Means Control	SD Control
distance	0.3221	0.2993	0.1521
Population	13.2883	13.1845	0.8670
IncomePC	41.4295	41.0095	10.5263
Unemployment	5.8699	5.8727	2.3014

Table 3A: OLS Regression Results. DV = log(Opioid-Related Overdose Deaths)
Robustness Check - Imputed Data for Suppressed CDC Observations

	Model 1	Model 2
	Imputed Data	Non-Suppressed Data
LagDV	0.916^{***}	0.671^{***}
	(0.005)	(0.015)
Population	0.022^{***}	0.211^{***}
	(0.002)	(0.014)
IncomePC	0.001^{***}	-0.001
	(0.000)	(0.001)
Unemployment	0.000	0.012^{***}
	(0.001)	(0.003)
Trade Layoffs	0.059^{**}	0.022^{*}
	(0.020)	(0.009)
Fentanyl_1	0.082^{***}	0.085^{**}
	(0.016)	(0.028)
CMSPrescribeRate	-0.003^{**}	0.013^{**}
	(0.001)	(0.005)
Pop. Density	0.009^{*}	0.004^{*}
	(0.004)	(0.002)
Percent White	-0.001^{***}	0.002^{**}
	(0.000)	(0.001)
Union	-0.005^{**}	-0.002
	(0.002)	(0.005)
Trade Layoffs:Fentanyl_1	0.138^{**}	0.073^{**}
	(0.052)	(0.025)
State Fixed Effects	*yes*	*yes*
Year Fixed Effects	*yes*	*yes*
N	41094	5312
R^2	0.903	0.857
adj. R^2	0.903	0.855
Resid. sd	0.364	0.299

Robust standard errors, clustered at county-level, in parentheses

† significant at $p < .10$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

Table 4A: OLS Regression Results. DV = log(Opioid-Related Overdose Deaths)
Robustness Check - Alternative CDC Codings

	Model 1	Model 2	Model 3	Model 4
	Suppressed = 0	Suppressed = 9	Suppressed = 0	Suppressed = 9
LagDV	0.761***	0.937***	0.747***	0.930***
	(0.009)	(0.005)	(0.009)	(0.005)
Population	0.143***	0.024***	0.134***	0.021***
	(0.006)	(0.001)	(0.006)	(0.001)
IncomePC	0.003***	0.001***	0.004***	0.001***
	(0.001)	(0.000)	(0.001)	(0.000)
Unemployment	0.002	0.000	0.003	0.001
	(0.002)	(0.000)	(0.002)	(0.000)
Trade Layoffs	0.115***	0.026***	0.127***	0.027***
	(0.024)	(0.008)	(0.026)	(0.008)
$\text{CMSPrescribeRate}_1$	0.004*	0.000†	0.003†	0.000
	(0.002)	(0.000)	(0.001)	(0.000)
Pop. Density	0.018*	0.002	0.020*	0.002
	(0.009)	(0.002)	(0.009)	(0.002)
Percent White	−0.001**	−0.000***	−0.001***	−0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Union	−0.008**	−0.002*	−0.005*	−0.001†
	(0.003)	(0.001)	(0.002)	(0.001)
Fentanyl_1			0.299***	0.066***
			(0.022)	(0.006)
$\text{Trade Layoffs:Fentanyl}_1$			0.059	0.053*
			(0.065)	(0.023)
State Fixed Effects	*yes*	*yes*	*yes*	*yes*
Year Fixed Effects	*yes*	*yes*	*yes*	*yes*
N	40419	40419	40419	40419
R^2	0.784	0.909	0.786	0.909
adj. R^2	0.783	0.908	0.786	0.909
Resid. sd	0.547	0.141	0.544	0.141

Robust standard errors, clustered at county-level, in parentheses.

In Models 1 and 3, 1 is added to DV before logarithmic transformation.

† significant at $p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$

Table 5A: OLS Regression Results. DV = log(Opioid-Related Overdose Deaths)
Robustness Check - Opioid and Buprenorphine Prescriptions

	Model 1	Model 2	Model 3	Model 4	Model 5
	1999 - 2015	2002 - 2015	2002 - 2015	2006 - 2015	2006 - 2015
LagDV	0.671***	0.670***	0.668***	0.669***	0.668***
	(0.015)	(0.015)	(0.015)	(0.016)	(0.016)
Population	0.211***	0.222***	0.219***	0.230***	0.227***
	(0.014)	(0.014)	(0.014)	(0.017)	(0.017)
IncomePC	−0.001	−0.001†	−0.001†	−0.000	−0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Unemployment	0.012***	0.007†	0.008†	0.003	0.003
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)
Trade Layoffs	0.022*	0.025*	0.018	0.023	0.009
	(0.009)	(0.012)	(0.013)	(0.016)	(0.017)
Fentanyl_1	0.085**		0.085**		0.058*
	(0.028)		(0.030)		(0.029)
$\text{CMSPrescribeRate}_1$	0.013**	0.012*	0.011*		
	(0.005)	(0.005)	(0.005)		
$\text{CMSPrescribeRate}_2$				0.001***	0.001***
				(0.000)	(0.000)
Pop. Density	0.004*	0.003*	0.004*	0.000	0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Percent White	0.002**	0.002***	0.002***	0.001†	0.001†
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Union	−0.002	−0.008	−0.007	−0.007	−0.008
	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)
$\text{Trade Layoffs:Fentanyl}_1$	0.073**		0.074**		0.078**
	(0.025)		(0.028)		(0.028)
Buprenorphine		0.000	0.000		0.000
		(0.000)	(0.000)		(0.000)
State Fixed Effects	*yes*	*yes*	*yes*	*yes*	*yes*
Year Fixed Effects	*yes*	*yes*	*yes*	*yes*	*yes*
N	5312	4417	4417	3596	3596
R^2	0.857	0.862	0.863	0.870	0.870
adj. R^2	0.855	0.860	0.861	0.867	0.868
Resid. sd	0.299	0.296	0.295	0.291	0.290

Robust standard errors, clustered at county-level, in parentheses

† significant at $p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$

Table 6A: Poisson and Negative Binomial Regression Results.
DV = Opioid-Related Overdose Deaths

	Model 1	Model 2
	Poisson	Negative Binomial
Population	0.889^{***}	0.789^{***}
	(0.014)	(0.012)
IncomePC	-0.003^{***}	-0.004^{***}
	(0.001)	(0.001)
Unemployment	0.046^{***}	0.050^{***}
	(0.006)	(0.004)
Trade Layoffs	0.038^{**}	0.065^{***}
	(0.013)	(0.013)
Fentanyl_4	0.018^{***}	0.010^{***}
	(0.002)	(0.002)
$\text{CMSPrescribeRate}_1$	0.078^{***}	0.058^{***}
	(0.008)	(0.006)
Pop. Density	0.012^{***}	0.021^{***}
	(0.002)	(0.002)
Percent White	0.005^{***}	0.005^{***}
	(0.001)	(0.001)
Union	-0.022^{**}	-0.025^{***}
	(0.008)	(0.007)
Trade Layoffs:Fentanyl_4	0.005^{*}	0.008^{**}
	(0.002)	(0.003)
θ		6.500^{***}
		(0.144)
State Fixed Effects	*yes*	*yes*
Year Fixed Effects	*yes*	*yes*
N	5832	5832
AIC	71579.674	45152.132
BIC	73607.693	47206.835
$\log L$	−35485.837	−22268.066

Robust standard errors in parentheses

† significant at $p < .10$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

Table 7A: OLS Regression Results. DV = log(Opioid-Related Overdose Deaths)
Robustness Check - No Substitution for LagDV when DV > 9

	Model 1	Model 2	Model 3	Model 4	Model 5
LagDV	0.725***	0.723***	0.720***	0.720***	0.722***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Population	0.225***	0.223***	0.229***	0.229***	0.228***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
IncomePC	−0.000	−0.000	−0.000	−0.000	−0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Unemployment	0.012***	0.013***	0.010**	0.010**	0.013***
	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)
Trade Layoffs	0.018*	0.016†	0.016*	0.016*	0.014†
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
$\text{CMSPrescribeRate}_1$	0.023***	0.022***	0.023***	0.023***	0.021***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
Pop. Density	0.002	0.002	0.001	0.001	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Percent White	0.002**	0.002**	0.002*	0.002*	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Union	−0.005	−0.004	−0.006	−0.006	−0.005
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Fentanyl_1		0.172**			
		(0.059)			
Trade Layoffs:Fentanyl_1		0.041			
		(0.026)			
Fentanyl_2			0.121***		
			(0.024)		
Trade Layoffs:Fentanyl_2			0.222**		
			(0.070)		
Fentanyl_3				0.125***	
				(0.024)	
Trade Layoffs:Fentanyl_3				0.214**	
				(0.069)	
Fentanyl_4					0.007***
					(0.001)
Trade Layoffs:Fentanyl_4					0.003†
					(0.002)
State Fixed Effects	*yes*	*yes*	*yes*	*yes*	*yes*
Year Fixed Effects	*yes*	*yes*	*yes*	*yes*	*yes*
N	4191	4191	4191	4191	4191
R^2	0.852	0.853	0.854	0.854	0.853
adj. R^2	0.850	0.850	0.851	0.851	0.851
Resid. sd	0.301	0.301	0.300	0.300	0.300

Robust standard errors, clustered at county-level, in parentheses
† significant at $p < .10$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

Table 8A: OLS Regression Results. DV = log(Opioid-Related Overdose Deaths)
Robustness Check - Alternative Substitutions for LagDV when DV > 9

	Model 1	Model 2
	Substitute 5	Substitute 1
LagDV	0.486^{***}	0.181^{***}
	(0.016)	(0.010)
Population	0.300^{***}	0.517^{***}
	(0.019)	(0.026)
IncomePC	-0.002^{*}	-0.004^{**}
	(0.001)	(0.002)
Unemployment	0.016^{***}	0.029^{***}
	(0.005)	(0.007)
Trade Layoffs	0.039^{**}	0.058^{**}
	(0.013)	(0.018)
Fentanyl_1	0.026	0.037
	(0.040)	(0.054)
$\text{CMSPrescribeRate}_1$	$0.013^{\dagger}$	0.025^{*}
	(0.007)	(0.011)
Pop. Density	0.009^{***}	0.017^{***}
	(0.003)	(0.004)
Percent White	0.003^{*}	0.005^{**}
	(0.001)	(0.002)
Union	−0.003	−0.011
	(0.006)	(0.008)
Trade Layoffs:Fentanyl_1	0.123^{***}	0.174^{***}
	(0.032)	(0.044)
State Fixed Effects	*yes*	*yes*
Year Fixed Effects	*yes*	*yes*
N	5312	5312
R^2	0.821	0.752
adj. R^2	0.818	0.749
Resid. sd	0.335	0.394

Robust standard errors, clustered at county-level, in parentheses
† significant at $p < .10$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$